EusLisp

version 8.25

Reference Manual

Featuring Multithread and XToolKit

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1 Introduction

EusLisp is an integrated programming system for the research on intelligent robots based on Common Lisp and Object-Oriented programming. The principal subjects in the field of robotics research are sensory data processing, visual environment recognition, collision avoiding motion planning, and task planning. In either problem, three dimensional shape models of robots and environment play crucial roles. A motivation to the development of EusLisp was a demand for an extensible solid modeler that can easily be made use of from higher level symbolic processing system. Investigations into traditional solid modelers proved that the vital requirement for their implementation language was the list processing capability to represent and manage topology among model components. Numerical computation power was also important, but locality of geometric computation suggested the provision of vector/matrix functions as built-ins would greatly ease programming.

Thus the primary decision to build a solid modeler in a Lisp equipped with a geometric computation package was obtained. Although a solid modeler provides facilities to define shapes of 3D objects, to simulate their behaviors, and to display them graphically, its applications are limited until it is incorporated in robot modules mentioned above. These modules also need to be tightly interconnected to achieve fully integrated robot systems. EusLisp sought for the framework of this integration in object-oriented programming (OOP). While OOP promotes modular programming, it facilitates incremental extension of existing functions by using inheritance of classes. In fact, components in the solid modeler, such as bodies, faces, and edges, can orderly be inplemented by extending one of the most basic class *coordinates*. These components may have further subclasses to provide individual functions for particular robot applications.

Based upon these considerations, EusLisp has been developped as an object-oriented Lisp which implements an extensible solid modeler[8]. Other features include intertask communication needed for the cooperative task coordination, graphics facilities on X-window for visual user interface, and foreign language interface to support mixed language programming.

In the implementation of the language, two performance-effective techniques were invented in type discrimination and memory management [9, 5, 7]. The new type discrimination method guarantees constant-time discrimination between types in tree structured hiearchy without regard to the depth of trees. Heap memory is managed in Fibonacci buddy method, which improves memory efficiency without sacrificing runtime or garbage-collection performance.

This reference manual describes EusLisp version 7.27 in two parts, *EusLisp Basics and EusLisp Extensions*. The first part describes Common Lisp features and object-oriented programming. Since a number of literatures are available on both topics, the first part is rather indifferent except EusLisp's specific features as described in *Interprocess Communication and Network*, *Toplevel Interaction*, *Disk Save*, etc. Beginners of EusLisp are advised to get familiar with Common Lisp and object oriented programming in other ways [2, 4]. The second part deals with features more related with robot applications, such as *Geometric Modelling*, *Image Processing*, *Manipulator Model* and so on. Unfortunately, the descriptions in this part may become incomplete or inaccurate because of EusLisp's rapid evolution. The update information is available via euslisp mailing list as mentioned in section 1.6.

1.1 EusLisp's Object-Oriented Programming

Unlike other Lisp-based object-oriented programming languages like CLOS [4], EusLisp is a Lisp system built on the basis of object-orientation. In the former approach, Lisp is used as an implementation language for the object-oriented programming, and there is apparent distinction between system defined objects and user defined objects, since system data types do not have corresponding classes. On the other hand, every data structure in EusLisp except number is represented by an object, and there is no inherent difference between built-in data types, such as `cons` and `symbols`, and user defined classes. This implies that even the system built-in data types can be extended (inherited) by user-defined classes. Also, when a user defines his own class as a subclass of a built-in class, he can use built-in methods and functions for the new class, and the amount of description for a new program can be reduced. For example, you may extend the `cons` class to have extra field other than `car` and `cdr` to define queues, trees, stacks, etc. Even for these instances, built-in functions for built-in cons are also applicable without any loss of efficiency, since those functions recognize type hierarchy in a constant time. Thus, EusLisp makes all the system built-in facilities open to programmers in the form of extensible data types. This uniformity is also beneficial to the implementation of EusLisp, because, after defining a few kernel functions such as **defclass**, **send**, and **instantiate**, in the implementation language, most of house-keeping functions to access the internal structure of built-in data types can be coded in EusLisp itself. This has much improved the reliability and maintainability of EusLisp.

1.2 Features

object-oriented programming EusLisp provides single-inheritance Object-Oriented programming. All data types except numbers are represented by objects whose behaviors are defined in their classes.

Common Lisp EusLisp follows the specifications of Common Lisp described in [2] and [3] as long as they are consistent with EusLisp's goal and object-orientation. See next subsection for incompatibilities.

compiler EusLisp's compiler can boost the execution 5 to 30 times as fast as the interpreted execution. The compiler keeps the same semantics as the interpreter.

memory management Fibonacci buddy method, which is memory efficient, GC efficient, and robust, is used for the memory management. EusLisp can run on machines with relatively modest amount of memory. Users are free from the optimization of page allocation for each type of data.

geometric primitives Since numbers are always represented as immediate data, no garbage is generated by numeric computation. A number of geometric functions for arbitrary-sized vectors and matrices are provided as built-in functions.

geometric modeler Solid models can be defined from primitive bodies using CSG set operations. Mass properties, interference checking, contact detection, and so on, are available.

graphics Hidden-line eliminated drawing and hidden-surface eliminated rendering are available. Postscript output to idraw can be generated.

image processing Edge based image processing facility is provided.

manipulator model 6 D.O.F.s robot manipulator can easily be modeled.

Xwindow interface Three levels of Xwindow interface, the Xlib foreign functions, the Xlib classes and the original XToolKit classes are provided.

foreign-language interface Functions written in C or other languages can be linked into EusLisp. Bidirectional call between EusLisp and other language are supported. Functions in libraries like LINPACK become available through this interface. Call-back functions in X toolkits can be defined in Lisp.

unix binding Most of unix system calls and unix library functions are assorted as Lisp functions. Signal handling and asynchronous I/O are also possible.

multithread multithread programming, which enables multiple contexts sharing global data, is available on Solaris 2 operating system. Multithread facilitates asynchronous programming and improves real-time response[6, 10]. If EusLisp runs on multi-processor machines, it can utilize parallel processors' higher computating power.

1.3 Compatibility with Common Lisp

Common Lisp has become the well-documented and widely-available standard Lisp [2, 3]. Although EusLisp has introduced lots of Common Lisp features such as variable scoping rules, packages, sequences, generalized variables, blocks, structures, keyword parameters, etc., incompatibilities still remain. Here is a list of missing features:

1. multiple values: multiple-value-call,multiple-value-prog1, etc.

2. some of data types: complex number, bignum, ratio, character and deftype

3. some of special forms: progv, compiler-let,macrolet

Following features are incomplete:

4. closure – only valid for dynamic extent
5. declare,proclaim – inline and ignore are unrecognized

1.4 Revision History

1986 The first version of EusLisp ran on Unix-System5/Ustation-E20. Fibonacci buddy memory management, simple compiler generating M68020 assembly code, and vector/matrix functions were tested.

1987 The new fast type checking method is implemented. The foreign language interface and the SunView interface were incorporated.

1988 The compiler was changed to generate C programs as intermediate code. Since the compiler became processor independent, EusLisp was ported on Ultrix/VAX8800 and on SunOS3.5/Sun3 and /Sun4 . IPC facility using socket streams was added. The solid modeler was implemented. Lots of Common Lisp features such as keyword parameters, labeled print format to handle recursive data objects, generic sequence functions, readtables, tagbody, go, flet, and labels special forms, etc., were added.

1989 The Xlib interface was introduced. % read macro to read C-like mathematical expressions was made. manipulator class is defined.

1990 The XView interface was written by M.Inaba. Ray tracer was written. Solid modeler was modified to keep CSG operation history. Asynchronous I/O was added.

1991 The motion constraint program was written by H.Hirukawa. Ported to DEC station. Coordinates class changed to handle both 2D and 3D coordinate systems. Body composition functions were enhanced to handle contacting objects. CSG operation for contacting objects. The package system became compatible with Common Lisp.

1992 **Face+** and **face*** for union and intersection of two coplanar faces were added. Image processing facility was added. The first completed reference manual was printed and delivered.

1993 EusLisp was stable.

1994 Ported to Solaris 2. Multi-context implementation using Solaris's multithread facility. XToolKit is built. Multi robot simulator, MARS was written by Dr. Kuniyoshi. EusLisp organized session at RSJ 94, in Fukuoka.

1995 The second version of the reference manual is published.

1.5 Installation

The installation procedure is described in `README`. The installation directory, which is assumed to be `"/usr/local/eus/"`, should be set to the global variable `*eusdir*`, since this location is referenced by **load** and the compiler.

Subdirectories in `*eusdir*` are described in table 1. Among these, `c/, l/, comp/, geo/, clib/,` and `xwindow` contain essential files to make eus and eusx. Others are optional libraries, demonstration programs and contributions from users.

1.6 License

EusLisp can be obtained with its source code via ftp from etlport.etl.go.jp (192.31.197.99). Those who use EusLisp must observe following articles and submit a copy of license agreement (doc/LICENCE) to the author.

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FILES	this document
README	a brief guide to lisence, installation and sample run
VERSION	EUSLisp version number
bin	executables (eus, euscomp and eusx)
c/	EusLisp kernel written in C
l/	kernel functions written in EusLisp
comp/	EusLisp compiler written in EusLisp
clib/	library functions written in C
doc/	documentation (latex and jlatex sources and memos)
geo/	geometric and graphic programs
lib/	shared libraries (.so) and start-up files
llib/	Lisp library
llib2/	secondary Lisp library developed at UTYO
xwindow/	X11 interface
makefile@	symbolic link to one of makefile.sun[34]os[34],.vax, etc.
pprolog/	tiny prolog interpreter
xview/	xview tool kit interface
tool/	
vxworks/	interface with VxWorks real-time OS
robot/	robot models and simulators
vision/	image processing programs
contact/	motion constraint solver by H.Hirukawa [12, 1, 11]
demo/	demonstrative programs
bench/	benchmark programs

Table 1: Directories in `*eusdir*`

Users are registered in the euslisp mailing list (euslisp@etl.go.jp), where information for Q&A, bug fix, and upgrade information is circulated. This information has been accumulated in `*eusdir*/doc/mails`.

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7. The copyright of programs developped in EusLisp belongs to the developper. However, he cannot extend his copyright over the main body of EusLisp.
8. Neither the author nor ETL provides warranty.

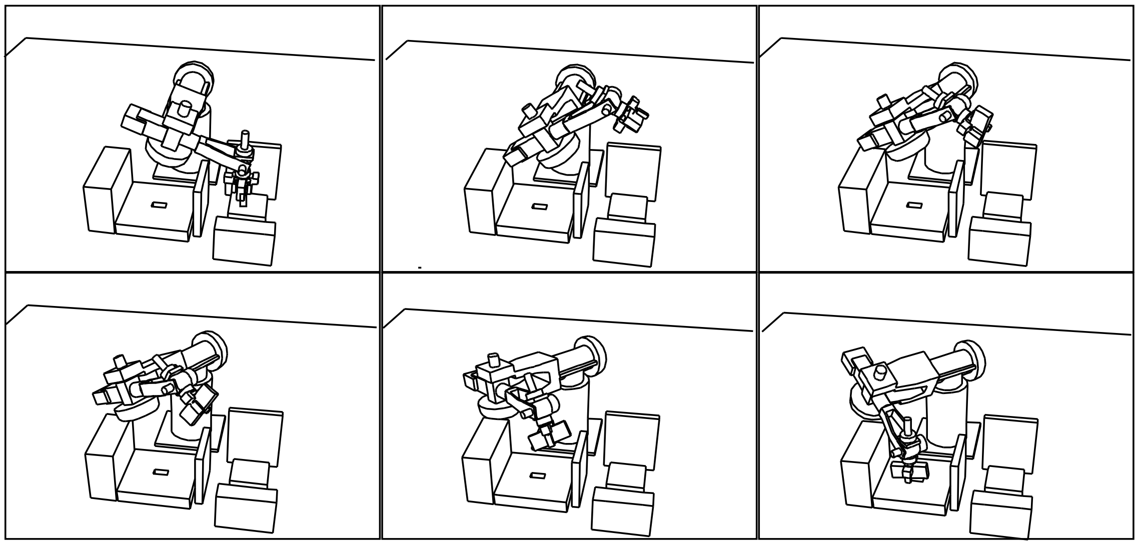
1.7 Demonstrations

Demonstration programs are found in `demo` subdirectory. `cd` to `*eusdir*` and run eusx.

Robot Animation Load `demo/animdemo.l` from eusx. Smooth animation of eta3 manipulator will be shown after a precomputation of approximately 20 minutes.

Ray-Tracing If you have 8-bit pseudo color display, a ray-tracing image can be generated by loading `demo/renderdemo.l`. Make sure `geo/render.l` has already been compiled.

Edge Vision Loading `demo/edgedemo.l`, a sample gray-scale image is displayed. You give parameters for choosing the gradient operator and edge thresholds. Edges are found in a few second and overlayed on the original image.



drawn by ONDA

Figure 1: Animation of Collision Avoidance Path Planning

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2 Data Types

Like other Lisps, it is data objects that are typed, not variables. Any variable can have any object as its value. Although it is possible to declare the type of object which is bound to a variable, but usually it is only advisory information to the compiler to generate faster code. Numbers are represented as immediate values in pointers and all the others are represented by objects referenced by pointers.

In the implementation of Sun4, a pointer or a number is represented by a long word as depicted in fig.2. Two bits at LSB of a pointer are used as tag bits to discriminate between a pointer, an integer, and a float. Since a pointer's tags are all zero and it can use all 32 bits for addressing an object, EusLisp can utilize up to 4GB of process address space.

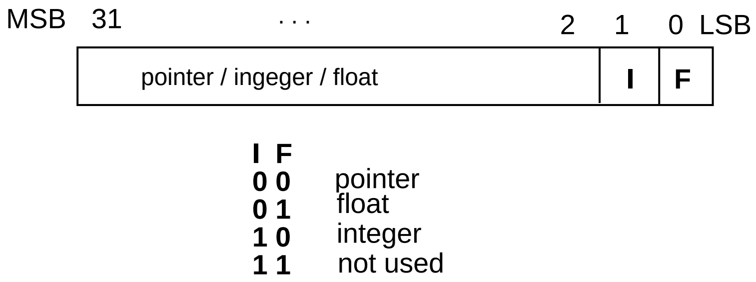

Figure 2: Pointer and Immediate Value

2.1 Numbers

There are two kinds of numbers, integer and float (floating-point number), both are represented with 29 bits value and 1 bit sign. Thus, integers range from -536,870,912 to 536,870,911. Floats can represent plus/minus from 4.8E-38 to 3.8E38 with the approximate accuracy of 6 digits in decimal, i.e., floating-point epsilon is approximately 1/1,000,000.

Numbers are always represented by immediate data, and not by objects. This is the only exception of EusLisp's object orientation. However, since numbers never waste heap memory, number crunching applications run efficiently without causing garbage collection.

EusLisp does not have the character type, and characters are represented by integers. In order to write a program independent of character code sets, `#\` reader dispatch macro is used. However, when the character is read, it is converted to numerical representation, and the printer does not know how to reconvert it to `#\` notation.

A number has two tag bits in a long word Figure 2, which must be stripped off by shifting or masking when used in arithmetic computation. Note that an integer should ignore two MSB bits by arithmetic shifting, while a float should ignore two LSB bits by masking. Byte swap is also necessary for an architecture like VAX which does not use the rightmost byte as the least-significant mantissa byte.

2.2 Objects

Every data other than number is represented by an object which is allocated in heap. Each memory cell of an object has the object header and fixed number of slots for object variables. Since vectors may consist of arbitrary number of elements, they have 'size' slot immediately after the header. Fig. 3 depicts the structures of object and vector, and their header word. Only the words indicated as *slot* and *element* are accessible from users.

A header is composed of six fields. Two MSB bits, m and b, are used to indicate the side of the neighbor cell in Fibonacci-buddy memory management. There are three mark bits in the *mark* field, each of which is used by the garbage collector to identify accessible cells, by the printer to recognize circular objects in printing in `#n=` and `#n#` notations, and by **copy-object** to copy shared objects. The *elmt* field discriminates one of seven possible data types of vector elements, *pointer, bit, character, byte, integer, float* and *foreign-string*. Although *elmt* can be available in the class, it is provided in the header to make the

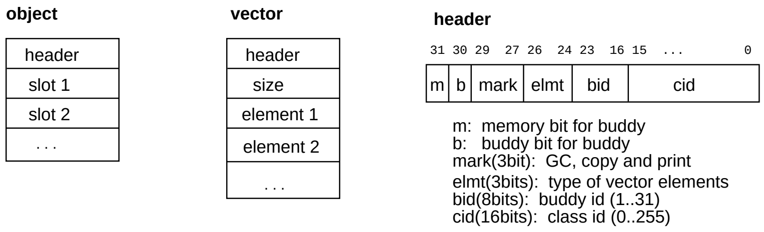

Figure 3: Structures of object, vector, and object header

memory manager independent of the structure of a class and to make the element accessing faster. The *bid* field represents the physical size of a memory cell. 31 different sizes up to 16 MB are represented by the five bits in this field. The lower short word (16 bits) is used for the class id. This is used to retrieve the class of an object via the system's class table. This class id can be regarded as the type tag of traditional Lisps. Currently only the lower 8 bits of the cid are used and the upper 8 bits are ignored. Therefore, the maximum number of classes is limited to 256, though this limit can be raised up to 65536 by reconfiguring the EusLisp to allocate more memory to the system's class table.

2.3 Class Hierarchy

The data structure of objects are defined by classes, and their behaviors are defined by methods in the classes. In EusLisp, a few dozens of classes have already been defined in tree structured hierarchy as depicted in fig. 4. You can browse the real inheritance structure by the **class-hierarchy** function. The class 'object' at the leftmost is the ultimate super-class of all the classes in EusLisp. User-defined classes can inherit any of these built-in classes.

A class is defined the **defclass** macro or by the **defstruct** macro.

```
(defclass class-name &key :super          class
                          :slots          ()
                          :metaclass      metaclass
                          :element-type   t
                          :size -1
)
(defstruct struct-name slots...)
(defstruct (struct-name [struct-options ...])
              (slot-name1 [slot-option...])
              (slot-name2 [slot-option...])
              ...)
```

Methods are defined by the **defmethod** special form. **Defmethod** can appear any times for a particular class.

```
(defmethod class-name
(:method-name1 (parameter...)  .  body1)
(:method-name2 (parameter...)  .  body2)
...)
```

Field definitions for most of built-in classes are found in `*eusdir*/c/eus.h` header file. `(describe` *class*) gives the description of all the slots in *class*, namely, super class, slot names, slot types, method list, and so on. Definitions of built-in classes follow. Note that the superclass of class **object** is NIL since it has no super class.

(defclass **object** :super **NIL** :slots ())

(defclass **cons** :super **object** :slots (car cdr))

```
object
     cons
     propertied-object
          symbol   -----  foreign-pod
          package
          stream
               file-stream
               broadcast-stream
          io-stream ---- socket-stream
          metaclass
               vectorclass
                    cstructclass
          read-table
          array
          thread
          barrier-synch
          synch-memory-port
          coordinates
               cascaded-coords
                    body
                    sphere
                    viewing
                         projection
                              viewing2d
                              parallel-viewing
                              perspective-viewing
                    coordinates-axes
               viewport
          line --- edge --- winged-edge
          plane
               polygon
                    face
                    hole
               semi-space
          viewer
          viewsurface  ----- tektro-viewsurface
     compiled-code
          foreign-code
          closure
          load-module
     label-reference
     vector
          float-vector
          integer-vector
          string
               socket-address
               cstruct
          bit-vector
          foreign-string
     socket-port
     pathname
     hash-table
     surrounding-box
     stereo-viewing
```

Figure 4: Hierarchy of Predefined Classes

```
(defclass propertied-object :super object
          :slots (plist))       ;property list


(defclass symbol :super propertied-object
          :slots (value          ;specially bound value
                  vtype          ;const(0),var(1),special(2)
                  function       ;global func def
                  pname          ;print name string
                  homepkg))      ;home package


(defclass foreign-pod :super symbol
          :slots (podcode          ;entry code
                  paramtypes       ;type of arguments
                  resulttype))


(defclass package :super propertied-object
          :slots (names          ;list of package name and nicknames
                  uses           ;spread use-package list
                  symvector      ;hashed obvector
                  symcount       ;number of interned symbols
                  intsymvector   ;hashed obvector of internal symbols
                  intsymcount    ;number of interned internal symbols
                  shadows        ;shadowed symbols
                  used-by))      ;packages using this package


(defclass stream :super propertied-object
          :slots (direction   ;:input or :output, nil if closed
                  buffer      ;buffer string
                  count       ;current character index
                  tail))      ;last character index


(defclass file-stream :super stream
          :slots (fd       ;file descriptor (integer)
                  fname))  ;file name str; qid for msgq


(defclass broadcast-stream :super stream
          :slots (destinations))       ;streams to which output is delivered

(defclass io-stream :super propertied-object
                  :slots (instream outstream))

(defclass socket-stream :super io-stream
                      :slots (address))            ; socket address

(defclass read-table :super propertied-object
          :slots (syntax       ; byte vector representing character types
                               ; 0:illegal, 1:white, 2:comment, 3:macro
                               ; 4:constituent, 5:single_escape
                               ; 6:multi_escape, 7:term_macro, 8:nonterm_macro
                  macro        ;character macro expansion function
                  dispatch-macro))
```

```
(defclass array :super propertied-object
          :slots (entity       ;simple vector storing array entity
                  rank         ;number of dimensions:  0-7
                  fillpointer  ;pointer to push next element
                  offset       ;offset for displaced array
                  dim0,dim1,dim2,dim3,dim4,dim5,dim6)) ;dimensions


(defclass metaclass :super propertied-object
          :slots (name      ;class name symbol
                  super     ;super class
                  cix       ;class id
                  vars      ;var name vector including inherited vars
                  types     ;type vector of object variables
                  forwards  ;components to which messages are forwarded
                  methods)) ;method list


(defclass vectorclass :super metaclass
          :slots (element-type    ;vector element type 0-7
                  size))          ;vector size; 0 if unspecified


(defclass cstructclass :super vectorclass
          :slots (slotlist))    ;cstruct slot descriptors


(defclass vector :super object :slots (size))

(defclass float-vector :super vector :element-type :float)

(defclass string :super vector :element-type :char)

(defclass hash-table :super propertied-object
          :slots (lisp::key           ;hashed key vector
                  value               ; value vector
                  size                ; the size of the hash table
                  count               ; number of elements entered in the table
                  lisp::hash-function
                  lisp::test-function
                  lisp::rehash-size
                  lisp::empty lisp::deleted


(defclass pathname :super propertied-object
          :slots (lisp::host device           ; not used
                  directory                   ; list of directories
                  name                        ; file name before the last "."
                  type                        ; type field after the last "."
                  lisp::version)              ; not used


(defclass label-reference      ;for reading #n=, #n# objects
          :super object
          :slots (label value unsolved next))
```

```
(defclass compiled-code :super object
          :slots (codevector
                  quotevector
                  type         ;0=func, 1=macro, 2=special
                  entry))      ;entry offset

(defclass closure :super compiled-code
                :slots (env1 env2));environment

(defclass foreign-code :super compiled-code
          :slots (paramtypes       ;list of parameter types
                  resulttype))     ;function result type

(defclass load-module :super compiled-code
       :slots (symbol-table   ;hashtable of symbols defined
               object-file    ;name of the object file loaded, needed for unloading
               handle         ;file handle returned by ''dlopen''
```

2.4 Type Specifier

Though EusLisp does not have the **d**eftype special form, type names are used in declarations and functions requesting to specify the type of results or contents, as in **coerce, map, concatenate, make-array**, etc. Usually, class names can be used as type specifiers, as in `(concatenate cons "ab" "cd") = (97 98 99 100)`, where Common Lisp uses `(quote list)` instead of `cons`.

As EusLisp does not have classes to represent numbers, types for numbers need to be given by keywords. **:**integer, **i**nteger, **:**int, **f**ixnum, or **:**fixnum is used to represent the integer type, **:**float or **f**loat, the floating point number type. As the *e*lement-type argument of **m**ake-array, **:**character, **c**haracter, **:**byte, and **b**yte are recognized to make strings. Low level functions such as **d**efcstruct, **s**ys:peek, and **s**ys:poke, also recognize **:**character, **c**haracter, **:**byte, or **b**yte for the byte access, and **:**short or **s**hort for short word access. In any cases, keywords are preferable to lisp package symbols with the same pname.

3 Forms and Evaluation

3.1 Atoms

A data object other than a cons is always an atom, no matter what complex structure it may have. Note that NIL, which is sometimes noted as () to represent an empty list, is also an atom. Every atom except a symbol is always evaluated to itself, although quoting is required in some other Common Lisp implementations.

3.2 Scoping

Every symbol may have associated value. A symbol is evaluated to its value determined in the current binding context. There are two kinds of variable bindings; the lexical or static binding and the special or dynamic binding. Lexically bound variables are introduced by **lambda** form or **let** and **let*** special forms unless they are declared special. Lexical binding can be nested and the only one binding which is introduced innermost level is visible, hiding outer lexical bindings and the special binding. Special variables are used in two ways: one is for global variables, and the other is for dynamically scoped local variables which are visible even at the outside of the lexical scope as long as the binding is in effect. In the latter case, special variables are needed to be declared special. The declaration is recognized not only by the compiler, but also by the interpreter. According to the Common Lisp's terms, special variables are said to have indefinite scope and dynamic extent.

Even if there exists a lexical variable in a certain scope, the same variable name can be redeclared to be special in inner scope. Function **symbol-value** can be used to retrieve the special values regardless to the lexical scopes. Note that **set** function works only for special variable, i.e. it cannot be used to change the value of lambda or let variables unless they are declared special.

```
(let ((x 1))
   (declare (special x))
   (let* ((x (+ x x)) (y x))
      (let* ((y (+ y y)) (z (+ x x)))
         (declare (special x))
         (format t "x=~S y=~s z=~s~%" x y z) ) ) )
--> x=1 y=4 z=2
```

A symbol can be declared to be a constant by **defconstant** macro. Once declared, an attempt to change the value signals an error thereafter. Moreover, such a constant symbol is inhibited to be used as the name of a variable even for a local variable. NIL and T are examples of such constants. Symbols in the keyword package are always declared to be constants when they are created. In contrast, **defvar** and **defparameter** macro declare symbols to be special variables. **defvar** initializes the value only if the symbol is unbound, and does nothing when it already has a value assigned, while **defparameter** always resets the value.

When a symbol is referenced and there is no lexical binding for the symbol, its special value is retrieved. However, if no value has been assigned to its special value yet, unbound variable error is signaled.

3.3 Generalized Variables

Generally, any values or attributes are represented in slots of objects (or in stack frames). To retrieve and alter the value of a slot, two primitive operations, *access* and *update*, must be provided. Instead of defining two distinct primitives for every slot of objects, EusLisp, like Common Lisp, provides uniform update operations based on the generalized variable concept. In this concept, a common form is recognized either as a value access form or as a slot location specifier. Thus, you only need to remember accessing form for each slot and update is achieved by **setf** macro used in conjunction with the access form. For example, `(car x)` can be used to replace the value in the car slot of `x` when used with **setf** as in `(setf (car '(a b) 'c)`, as well as to take the car value out of the list.

This method is also applicable to all the user defined objects. When a class or a structure is defined, the access and update forms for each slot are automatically defined. Each of those forms is defined as a macro whose name is the concatenation of the class name and slot name. For example, car of a cons can be addressed by `(cons-car '(a b c))`.

and	flet	quote
block	function	return-from
catch	go	setq
cond	if	tagbody
declare	labels	the
defmacro	let	throw
defmethod	let*	unwind-protect
defun	progn	while
eval-when	or	

Table 2: EusLisp's special forms

```
(defclass person :super object :slots (name age))
(defclass programmer :super person :slots (language machine))
(setq x (instantiate programmer))
(setf (programmer-name x) "MATSUI"
      (person-age x) 30)
(incf (programmer-age x))
(programmer-age x)   --> 31
(setf (programmer-language x) 'EUSLISP
      (programmer-machine x) 'SUN4)
```

Array elements can be accessed in the same manner.

```
(setq a (make-array '(3 3) :element-type :float))
(setf (aref a 0 0) 1.0 (aref a 1 1) 1.0 (aref a 2 2) 1.0)
a --> #2f((1.0 0.0 0.0) (0.0 1.0 0.0) (0.0 0.0 1.0))

(setq b (instantiate bit-vector 10))  --> #*0000000000
(setf (bit b 5) 1)
b --> #*0000010000
```

In order to define special setf methods for particular objects, **defsetf** macro is provided.

```
(defsetf symbol-value set)
(defsetf get (sym prop) (val) `(putprop ,sym ,val ,prop))
```

3.4 Special Forms

All the special forms are listed in Table 2. **macrolet, compiler-let,** and **progv** have not been implemented. Special forms are essential language constructs for the management of evaluation contexts and control flows. The interpreter and compiler have special knowledge to process each of these constructs properly, while the application method is uniform for all functions. Users cannot add their own special form definition.

3.5 Macros

Macro is a convenient method to expand language constructs. When a macro is called, arguments are passed to the macro body, which is a macro expansion function, without being evaluated. Then, the macro expansion function expands the arguments, and returns the new form. The resulted form is then evaluated again outside the macro. It is an error to apply a macro or special form to a list of arguments. **Macroexpand** function can be used for the explicit macro expansion.

Though macro runs slowly when interpreted, it speeds up compiled code execution, because macro expansion is taken at compile-time only once and no overhead is left to run-time. Note that explicit call to eval or apply in the macro function may produce different results between interpreted execution and the compiled execution.

3.6 Functions

A function is expressed by a lambda form which is merely a list whose first element is **lambda**. If a lambda form is defined for a symbol using **defun**, it can be referred as a global function name. Lambda form takes following syntax.

```
(lambda ({var}*
         [&optional {var | (var [initform])}*]
         [&rest form]
         [&key {var | (var [initform]) | ((keyword var) [initform])}*
               [&allow-other-keys]]
         [&aux {var | (var [initform])}*])
     {declaration}*
     {form}*)
```

There is no function type such as EXPR, LEXPR, FEXPR, etc.: arguments to a function are always evaluated before its application, and the number of acceptable arguments is determined by lambda-list. Lambda-list specifies the sequence of parameters to the lambda form. Each of **&optional, &rest, &key** and **&aux** has special meaning in lambda-lists, and these symbols cannot be used as variable names. Supplied-p variables for &optional or &key parameters are not supported.

Since a lambda form is indistinguishable from normal list data, **function** special form must be used to inform the interpreter and compiler the form is intended to be a function. [1] **Function** is also important to freeze the environment onto the function, so that all the lexical variables can be accessible in the function even the function is passed to another function of different lexical scope. The following program does not work either interpretedly nor after compiled, since `sum` from the `let` is invisible inside lambda form.

```
(let ((x '(1 2 3)) (sum 0))
  (mapc '(lambda (x) (setq sum (+ sum x))) x))
```

To get the expected result, it should be written as follows:

```
(let ((x '(1 2 3)) (sum 0))
   (mapc #'(lambda (x) (setq sum (+ sum x))) x ))
```

#' is the abbreviated notation of **function**, i.e. `#'(lambda (x) x)` is equivalent to `(function (lambda (x) x))`. Here is another example of what is called a funarg problem:

```
(defun mapvector (f v)
    (do ((i 0 (1+ i)))
       ((>= i (length v)))
       (funcall f (aref v i))))
(defun vector-sum (v)
    (let ((i 0))
       (mapvector #'(lambda (x) (setq i (+ i x))) v)
       i))
(vector-sum #(1 2 3 4)) --> 10
```

EusLisp's closure cannot have indefinite extent: i.e. a closure can only survive as long as its outer extent is in effect. This means that a closure cannot be used for programming of "generators". The following program does not work.

```
(proclaim '(special gen))
(let ((index 0))
   (setq gen #'(lambda () (setq index (1+ index)))))
(funcall gen)
```

[1] In CLtL-2 a quoted lambda form is no longer a function. Application of such a form is an error.

However, the same purpose is accomplished by object oriented programming, because an object can hold its own static variables:

```
(defclass generator object (index))
(defmethod generator
 (:next () (setq index (1+ index)))
 (:init (&optional (start 0)) (setq index start) self))
(defvar gen (instance generator :init 0))
(send gen :next)
```

4 Control Structures

4.1 Conditionals

Although **and, or** and **cond** are advised to be macros by Common Lisp, they are implemented as special forms in EusLisp to improve the interpreting performance.

and {*form*}* [special]
Forms are evaluated from left to right until NIL appears. If all forms are evaluated to non-NIL, the last value is returned.

or {*form*}* [special]
Forms are evaluated from left to right until non-NIL appears, and the value is returned. If all forms are evaluated to NIL, NIL is returned.

if *test then [else]* [special]
if can only have single *then* and *else* forms. To allow multiple *then* or *else* forms, they must be grouped by **progn**.

when *test forms* [macro]
Unlike **if**, **when** and **unless** allow you to write multiple *forms* which are executed when *test* holds (**when**) or does not *unless*. On the other hand, these macros cannot have the *else* forms.

unless *test forms* [macro]
is equivalent to `(when (not` *test*`) .` *forms*`)`.

cond *(test {form}*)** [special]
Arbitrary number of cond-clauses can follow **cond**. In each clause, the first form, that is *test*, is evaluated. If it is non-nil, the rest of the forms in that clause are evaluated sequentially, and the last value is returned. If no forms are given after the *test*, the value of the *test* is returned. When the *test* fails, next clause is tried until a *test* which is evaluated to non-nil is found or all clauses are exhausted. In the latter case, **cond** returns NIL.

case *key {({label | ({lab}*) {form}*)}** [macro]
For the clause whose *label* matches with *key*, *form*s are evaluated and the last value is returned. Equality between *key* and *label* is tested with **eq** or **memq**, not with **equal**.

4.2 Sequencing and Lets

prog1 *form1 &rest forms* [function]
form1 and *forms* are evaluated sequentially, and the value returned by *form1* is returned as the value of **prog1**.

progn {*form*}* [special]
Forms are evaluated sequentially, and the value of the rightmost form is returned. **Progn** is a special form because it has a special meaning when it appeared at top level in a file. When such a form is compiled, all inner forms are regarded as they appear at top level. This is useful for a macro which expands to a series of **defun**s or **defmethod**s, which must appear at top level.

setf {*access-form value*}* [macro]
assigns *value* to a generalized-variable *access-form*.

let *({var | (var [value])}*) {declare}* {form}** [special]
introduces local variables. All *value*s are evaluated and assigned to *var*s in parallel, i.e., `(let ((a 1)) (let ((a (1+ a)) (b a)) (list a b)))` produces (2 1).

let* *({var | (var [value])}*) {declare}* {form}** [special]
introduces local variables. All *value*s are evaluated sequentially, and assigned to *var*s i.e., `(let ((a 1)) (let* ((a (1+ a)) (b a)) (list a b)))` produces (2 2).

4.3 Local Functions

flet *({(fname lambda-list . body)}*) {form}** [special]
defines local functions.

labels *({(fname lambda-list . body)}*) {form}** [special]
defines locally scoped functions. The difference between *flet* and *labels* is, the local functions defined by *flet* cannot reference each other or recursively, whereas *labels* allows such mutual references.

4.4 Blocks and Exits

block *tag {form}** [special]
makes a lexical block from which you can exit by **return-from**. *Tag* is lexically scoped and is not evaluated.

return-from *tag value* [special]
exits the block labeled by *tag*. **return-from** can be used to exit from a function or a method which automatically establishes block labeled by its function or method name surrounding the entire body.

return *value* [macro]
`(return x)` is equivalent to `(return-from nil x)`. This is convenient to use in conjunction with **loop, while, do, dolist,** and **dotimes** which implicitly establish blocks labeled NIL.

catch *tag {form}** [special]
establishes a dynamic block from which you can exit and return a value by **throw**. *Tag* is evaluated. The list of all visible catch tags can be obtained by `sys:list-all-catchers`.

throw *tag value* [special]
exits and returns *value* from a catch block. *tag* and *value* are evaluated.

unwind-protect *protected-form {cleanup-form}** [special]
After the evaluation of *protected-form* finishes, *cleanup-form* is evaluated. You may make a block or a catch block outside the `unwind-protect`. Even **return-from** or **throw** is executed in *protected-form* to escape from such blocks, *cleanup-form* is assured to be evaluated. Also, if you had an error while executing *protected-form*, *cleanup-form* would always be executed by *reset*.

4.5 Iteration

while *test {form}** [special]
While *test* is evaluated to non-nil, *form*s are evaluated repeatedly. **While** special form automatically establishes a block by name of nil around *form*s, and **return** can be used to exit from the loop.

tagbody *{tag | statement}** [special]
*tag*s are labels for **go**. You can use **go** only in **tagbody**.

go *tag* [special]
transfers control to the form just after *tag* which appears in a lexically scoped **tagbody**. **Go** to the tag in a different **tagbody** across the lexical scope is inhibited.

prog *({var | (var [init])}*) {tag | statement}** [macro]
prog is a macro, which expands as follows:

```
(block nil (let var (tagbody tag | statement)))
```

do *({(var init [next])}*) (endtest [result]){declare} {form} ** [macro] *var*s are local variables. To each *var*, *init* is evaluated in parallel and assigned. Next, *endtest* is evaluated and if it is true, **do** returns *result* (defaulted to NIL). If *endtest* returns NIL, each *form* is evaluated sequentially. After the evaluation of forms, *next* is evaluated and the value is reassigned to each *var*, and the next iteration starts.

do* *({var init [next]}*) (endtest [result]){declare} {form}** [macro]

do* is same as **do** except that the evaluation of *init* and *next*, and their assignment to *var* occur sequentially.

dotimes *(var count [result]) {forms}** [macro]

evaluates *forms count* times. *count* is evaluated only once. In each evaluation, *var* increments from integer zero to *count* minus one.

dolist *(var list [result]) {forms}** [macro]

Each element of *list* is sequentially bound to *var*, and *forms* are evaluated for each binding. **Dolist** runs faster than other iteration constructs such as **mapcar** and recursive functions, since **dolist** does not have to create a function closure or to apply it, and no new parameter binding is needed.

until *condition {forms}** [macro]

evaluates forms until *condition* holds.

loop *{forms}** [macro]

evaluates *forms* forever. To terminate execution, **return-from, throw** or **go** needed to be evaluated in *forms*.

4.6 Predicates

Typep and **subtypep** of Common Lisp are not provided, and should be simulated by **subclassp** and **derivedp**.

eq *obj1 obj2* [function]

returns T, if *obj1* and *obj2* are pointers to the same object, or the same numbers. Examples: `(eq 'a 'a)` is T, `(eq 1 1)` is T, `(eq 1. 1.0)` is nil, `(eq "a" "a")` is nil.

eql *obj1 obj2* [function]

Eq and **eql** are identical since all the numbers in EusLisp are represented as immediate values.

equal *obj1 obj2* [function]

Checks the equality of any structured objects, such as strings, vectors or matrices, as long as they do not have recursive references. If there is recursive reference in *obj1* or *obj2*, **equal** loops infinitely.

superequal *obj1 obj2* [function]

Slow but robust **equal**, since **superequal** checks circular reference.

null *object* [function]

T if *object* is nil. Equivalent to (eq *object* nil).

not *object* [function]

not is identical to **null**.

atom *object* [function]

returns NIL only if object is a cons. `(atom nil) = (atom '()) = T)`. Note that **atom** returns T for vectors, strings, read-table, hash-table, etc., no matter what complex objects they are.

every *pred &rest args* [function]

returns T if all *args* return T for *pred*. **Every** is used to test whether *pred* holds for every *args*.

some *pred &rest args* [function]

returns T if at least one of *args* return T for *pred*. **Some** is used to test whether *pred* holds for any of *args*.

functionp *object* [function]

T if *object* is a function object that can be given to **apply** and **funcall**. Note that macros cannot be *apply*'ed or *funcall*'ed. **Functionp** returns T, if *object* is either a compiled-code with type=0, a symbol that has function definition, a lambda-form, or a lambda-closure. Examples: (functionp 'car) = T, (functionp 'do) = NIL

compiled-function-p *object* [function]

T if *object* is an instance of compiled-code. In order to know the compiled-code is a function or a macro, send `:type` message to the object, and `function` or `macro` is returned.

5 Object Oriented Programming

The structures and behaviors of objects are described in classes, which are defined by **defclass** macro and **defmethod** special form. **defclass** defines the name of the class, its super class, and slot variable names, optionally with their types and message forwarding. **defmethod** defines methods which will invoked when corresponding messages are sent. Class definition is assigned to the symbol's special value. You may think of **class** as the counter part of Common Lisp's **structure**. Slot accessing functions and **setf** methods are automatically defined for each slot by **defclass**.

Most classes are instantiated from the built-in class **metaclass**. Class **vector-class**, which is a subclass of **metaclass**, is a metaclass for vectors. If you need to use class-variables and class-methods, you may make your own metaclass by subclassing **metaclass**, and the metaclass name should be given to **defclass** with `:metaclass` keyword.

Vectors are different from other record-like objects because an instance of the vector can have arbitrary number of elements, while record-like objects have fixed number of slots. EusLisp's object is either a record-like object or a vector, not both at the same time.

Vectors whose elements are typed or the number of elements are unchangeable can also be defined by **defclass**. In the following example, class `intvec5` which has five integer elements is defined. Automatic type check and conversion are performed when the elements are accessed by the interpreter. When compiled with proper declaration, faster accessing code is produced.

```
(defclass intvec5 :super vector :element-type :integer :size 5)
(setq x (instantiate intvec5))  --> #i(0 0 0 0 0)
```

When a message is sent to an object, the corresponding method is searched for, first in its class, and next in its superclasses toward **object**, until all superclasses are exhausted. If the method is undefined, forward list is searched. This forwarding mechanism is introduced to simulate multiple inheritance. If the search fails again, a method named `:nomethod` is searched, and the method is invoked with a list of all the arguments. In the following example, the messages `:telephone` and `:mail` are sent to `secretary` slot object which is typed `person`, and `:go-home` message is sent to `chauffeur` slot.

```
(defclass president :super object
                    :slots ((name :type string)
                            (age  :type :integer)
                            (secretary  :type person
                                        :forward (:telephone :mail))
                            (chauffeur  :forward (:go-home))))
```

In a method, two more local variables, **class** and **self**, become accessible. You should not change either of these variables. If you do that, the ones supplied by the system are hidden, and **send-super** and **send self** are confused.

5.1 Classes and Methods

defclass *classname &key* *:super object* [macro]
:slots ({var | (var [:type type] [:forward selectors])})*
:metaclass metaclass
:element-type t
:size -1

creates or redefine a class. When a class is redefined to have different superclass or slot variables, old objects instantiated from the previous class definition will behave unexpectedly, since method definitions assume the new slots disposition.

defmethod *classname {(selector lambda-list . body)}** [special]
defines one or more methods of *classname*. Each *selector* must be a keyword symbol.

defclassmethod *classname {(selector lambda-list . body)}** [macro]

classp *object* [function]
T if *object* is a class object, that is, an instance of class **metaclass** or its subclasses.

subclassp *class super* [function]
Checks *class* is a subclass of *super*.

vector-class-p *x* [function]
T if *x* is an instance of **vector-class**.

delete-method *class method-name* [function]
The method definition is removed from the specified class.

class-hierarchy *class* [function]
prints inheritance hierarchy below *class*.

system:list-all-classes [function]
lists up all the classes defined so far.

system:find-method *object selector* [function]
tries to find a method specified by *selector* in the class of *object* and in its superclass. This is used to know whether *object* can respond to *selector*.

system:method-cache *[flag]* [function]
Interrogates the hit ratio of the method cache, and returns a list of two numbers, hit and miss. If *flag* is NIL, method caching is disabled. If non-nil flag is given, method cache is purged and caching is enabled.

5.2 Message Sending

send *object selector* {*arg*}* [function]
send a message consisting of *selector* and *arg* to *object*. *object* can be anything but number. *selector* must be evaluated to be a keyword.

send-message *target search selector* {*arg*}* [function]
Low level primitive to implement **send-super**.

send* *object selector &rest msg-list* [macro]
send* applies **send-message** to a list of arguments. The relation between **send** and **send*** is like the one between **funcall** and **apply**, or **list** and **list***.

send-all *receivers selector &rest mesg* [function]
sends the same message to all the receivers, and collects the result in a list.

send-super *selector &rest msgs* [macro]
sends *msgs* to self, but begins method searching at the superclass of the class where the method currently being executed is defined. It is an error to *send-super* outside a method (i.e. in a function).

send-super* *selector &rest msg-list* [macro]
send-super* is apply version of send-super.

5.3 Instance Management

instantiate *class &optional size* [function]
the lowest primitive to create a new object from a class. If the class is a vector-class, *size* should be supplied.

instance *class &rest message* [macro]

An instance is created, and the message is sent to it.

make-instance *class &rest var-val-pairs* [function]

creates an instance of *class* and sets its slot variables according to *var-val-pairs*. For example, `(make-instance cons :car 1 :cdr 2)` is equivalent to `(cons 1 2)`.

copy-object *object* [function]

copy-object function is used to copy objects keeping the referencing topologies even they have recursive references. **Copy-object** copies any objects accessible from *object* except symbols and packages, which are untouched to keep the uniqueness of symbols. **copy-object** traverses all the references in an object twice: once to create new objects and to mark original objects that they have already copied, and again to remove marks. This two-step process makes copy-object work slower than copy-seq. If what you wish to copy is definitely a sequence, use of **copy-seq** or **copy-tree** is recommended.

become *object class* [function]

changes the class of *object* to *class*. The slot structure of both the old class and the new class must be consistent. Usually, this can be safely used only for changing class between binary vectors, for example from an integer-vector to a bit-vector.

replace-object *dest src* [function]

dest must be an instance of the subclass of src.

class *object* [function]

returns the class object of *object*. To get the name of the class, send :name message to the class object.

derivedp *object class* [function]

derivedp checks if an object is instantiated from *class* or *class*'s subclasses. **subclassp** and **derivedp** functions do not search in class hierarchy: type check always finishes within a constant time.

slot *object class (index | slot-name)* [function]

Returns the named or indexed slot value.

setslot *object class (index | slot-name) value* [function]

Setslot is a internal function and users should not use it. Use, instead, combination of **setf** and **slot**.

5.4 Basic Classes

object [class]

:super

:slots

Object is the most basic class that is located at the top of class hierarchy. Since it defines no slot variables, it is no use to make an instance of **object**.

:prin1 *&optional stream &rest mesg* [method]

prints the object in the standard re-readable object format, that is, the class name and the address, enclosed by angle brackets and preceded by a pound sign. Any subclasses of **object** can use this method to print itself with more comprehensive information by using **send-super** macro specifying *mesg* string. An object is re-readable if it begins with #<, followed by its class name, correct address, any lisp-readable information, and >. Since every data object except numbers inherits **object**, you can get print forms in this notation, even for symbols or strings. Specifying this notation, you can catch data objects that you forgot to **setq** to a symbol, as long as there happened no garbage collection after it is printed.

:slots [method]

returns the list of variable-name and value pair of all the slots of the object. You can get the value of a specific slot by applying **assoc** to this list, although you cannot alter them.

propertied-object [class]

:super	**object**
:slots	plist

defines objects that have property list. Unlike other Common Lisp, EusLisp allows any objects that inherit propertied-object to have property lists, even if they are not symbols.

:plist *&optional plist* [method]

if *plist* is specified, it is set to the plist slot of this object. Previous plist, if there had been one, is lost. Legal plist should be of the form of `((indicator1 . value1) (indicator2 . value2) ...)`. Each `indicator` can be any lisp form that are tested its equality with the **eq** function. When a symbol is used for an indicator, use of keyword is recommended to ensure the equality check will be performed interpacakge-widely. **:plist** returns the current plist.

:get *indicator* [method]

returns the value associated with *indicator* in the property list. `(send x :get :y) == (cdr (assoc :y (send x :plist)))`.

:put *indicator value* [method]

associates *value* to *indicator* in the plist.

:remprop *indicator* [method]

removes *indicator* and value pair from the plist. Further attempt to *:get* the value returns nil.

:name *&optional name* [method]

defines and retrieves the `:name` property in the plist. This property is used for printing.

:prin1 *&optional stream &rest mesg* [method]

prints the object in the re-readable form. If the object has **:name** property, it is printed after the address of the object.

:slots [method]

returns a list of variable and value pairs of this object.

:methods [method]

returns a list of all method names defined for this object. In other words, this object can accept method calls listed by :methods.

:get-val *variable-name* [method]

returns the value of the slot designated by *variable-name*. If the object does not have the variable-name slot, an error is reported.

:set-val *variable-name value* [method]

sets *value* in the variable-name slot of this object. If the object does not have the variable-name slot, an error is reported.

metaclass [class]

:super	**propertied-object**
:slots	name super cix vars types forwards methods

Metaclass defines classes. Classes that have own class variables should be defined with **metaclass** as their superclass.

:new [method]

creates an instance of this class and returns it after filling all the slots with NIL.

:super [method]

returns the super class object of this class. You cannot alter superclass once defclassed.

:methods [method]

returns a list of all the methods defined in this class. The list is composed of lists each of which describes the name of the method, parameters, and body.

:method *name* [method]
returns the method definition associated with *name*. If not found, NIL is returned.

:method-names *subname* [method]
returns a list of all the method names each of which contains *subname* in its method name. Methods are searched only in this class.

:all-methods [method]
returns a list of all methods that are defined in this class and its all the super classes. In other words, an instance of this class can execute each of these methods.

:all-method-names *subname* [method]
returns a list of all the method names each of which matches with *subname*. The search is made from this class up to **object**.

:slots [method]
returns the slot-name vector.

:name [method]
returns the name symbol of this class.

:cid [method]
returns an integer that is assigned to every instance of this class to identify its class. This is an index to the system-internal class table, and is changed when a new subclass is defined under this class.

:subclasses [method]
returns a list of the direct subclass of this class.

:hierarchy [method]
returns a list of all the subclasses defined under this class. You can also call the **class-hierarchy** function to get a comprehensive listing of all the class hierarchy.

find-method *object selector* [function]
searches for the method identified by *selector* in *object*'s class and its super classes. This function is useful when object's class is uncertain and you want to know whether the object can handle the message without causing nomethod error.

6 Arithmetic Functions

6.1 Arithmetic Constants

most-positive-fixnum [constant]
#x1fffffff=536,870,911

most-negative-fixnum [constant]
-#x20000000= -536,870,912

short-float-epsilon [constant]
A floating point number on machines with IEEE floating-point format is represented by 21 bit mantissa with 1 bit sign and 7 bit exponent with 1 bit sign. Therefore, floating point epsilon is $2^{-21} = 4.768368 \times 10^{-7}$.

single-float-epsilon [constant]
same as **short-float-epsilon**, 2^{-21}.

long-float-epsilon [constant]
same as **short-float-epsilon** since there is no double or long float. 2^{-21}.

pi [constant]
π, actually 3.14159203, not 3.14159265.

2pi [constant]
$2 \times \pi$

pi/2 [constant]
$\pi/2$

-pi [constant]
-3.14159203

-2pi [constant]
$-2 \times \pi$

-pi/2 [constant]
$\pi/2$

6.2 Arithmetic Predicates

numberp *object* [function]
T if *object* is number, namely integer or float. Note that characters are also represented by numbers.

integerp *object* [function]
T if *object* is an integer number. A float can be converted to an integer by **round, trunc** and **ceiling** functions.

floatp *object* [function]
T if *object* is a floating-point number. An integer can be converted to a float by the **float** function.

zerop *number* [function]
T if the number is integer zero or float 0.0.

plusp *number* [function]
equivalent to (> number 0).

minusp *number* [function]
equivalent to (< number 0).

oddp *integer* [function]

The argument must be an integer. T if *integer* is odd.

evenp *integer* [function]

The argument must be an integer. T if *integer* is an even number.

/= *n1 n2* [function]

Both *n1* and *n2* must be numbers. T if *n1* is not equal to *n2*.

= *num1 num2 &rest more-numbers* [function]

Both *n1* and *n2* must be numbers. T if *n1* is equal to *n2*.

> *num1 num2 &rest more-numbers* [function]

< *num1 num2 &rest more-numbers* [function]

>= *num1 num2 &rest more-numbers* [function]

<= *num1 num2 &rest more-numbers* [function]

These comparisons can only be applicable to numbers. For numerical comparisons with tolerance, use functions prefixed by **eps** as described in the section 16.

6.3 Integer and Bit-Wise Operations

Following functions request arguments to be integers.

mod *dividend divisor* [function]

returns remainder when *dividend* is divided by *divisor*. `(mod 6 5)=1`, `(mod -6 5)=-1`, `(mod 6 -5)=1`, `(mod -6 -5)=-1`.

1- *integer* [function]

The compiler assumes the argument to be an integer. $integer - 1$ is returned.

1+ *integer* [function]

Arguments to 1+ and 1- must be an integer. $integer + 1$ is returned.

logand *&rest integers* [function]

bitwise-and of *integers*.

logior *&rest integers* [function]

bitwise-inclusive-or of *integers*.

logxor *&rest integers* [function]

bitwise-exclusive-or of *integers*.

logeqv *&rest integers* [function]

logeqv is equivalent to (lognot (logxor ...)).

lognand *&rest integers* [function]

bitwise-nand of *integers*.

lognor *&rest integers* [function]

bitwise-nor of *integers*.

lognot *integer* [function]

bit reverse of *integer*.

logtest *integer1 integer2* [function]

T if (logand *integer1 integer2*) is not zero.

logbitp *index integer* [function]
T if *index*th bit of *integer* (counted from the LSB) is 1, otherwise NIL.

ash *integer count* [function]
Arithmetic Shift Left. If *count* is positive, shift direction is left, and if *count* is negative, *integer* is shifted to right by abs(*count*) bits.

ldb *target position width* [function]
LoaD Byte. Byte specifier for **ldb** and **dpb** does not exist in EusLisp. Use a pair of integers instead. The field of *width* bits at *position* within *target* is extracted. For example, `(ldb #x1234 4 4)` is 3.

dpb *value integer position width* [function]
DePosit byte. *Width* bits of *value* is put in *integer* at *position*th bits from LSB.

6.4 Generic Number Functions

+ *&rest numbers* [function]
returns the sum of *numbers*.

- *num &rest more-numbers* [function]
If *more-numbers* are given, they are subtracted from *num*. Otherwise, *num* is negated.

***** *&rest numbers* [function]
returns the product of *numbers*.

/ *num1 num2 &rest more-numbers* [function]
num1 is divided by *num2* and *more-numbers*. The result is an integer if all the arguments are integers, and an float if at least one of the arguments is a float.

abs *number* [function]
returns absolute number.

round *number* [function]
rounds to the nearest integer. `(round 1.5)=2, (round -1.5)=2`.

floor *number* [function]
rounds to the nearest smaller integer. `(floor 1.5)=1, (floor -1.5)=-2`.

ceiling *number* [function]
rounds to the nearest larger integer. `(ceiling 1.5)=2, (ceiling -1.5)=-1`.

truncate *number* [function]
rounds to the absolutely smaller and nearest integer. `(truncate 1.5)=1, (truncate -1.5)=-1`.

float *number* [function]
returns floating-point representation of *number*.

max *&rest numbers* [function]
finds the maximum value among *numbers*.

min *&rest numbers* [function]
finds the minimum number in *numbers*.

random *range &optional (randstate *random-state*)* [function]
Returns a random number between 0 or 0.0 and *range*. If *range* is an integer, the result is truncated to an integer. Otherwise, a floating value is returned. Optional *randstate* can be specified to get predictable random number sequence. There is no special data type for random-state, and it is represented with an integer vector of two elements.

incf *variable &optional (increment 1)* [macro]
variable is a generalized variable. The value of *variable* is incremented by *increment*, and it is set back

to *variable*.

decf *variable &optional decrement* [macro]
variable is a generalized variable. The value of *variable* is decremented by *decrement*, and it is set back to *variable*.

reduce *func seq* [function]
combines all the elements in *seq* using the binary operator *func*. For an example, `(reduce #'expt '(2 3 4)) = (expt (expt 2 3) 4)=4096`.

rad2deg *radian* [function]
Radian value is converted to degree notation. #R does the same thing at read time. Note that the official representation of angle in EusLisp is radian and every EusLisp function that accepts angle argument requests it to be represented by radian.

deg2rad *degree* [function]
Conversion from degree to radian. Also accomplished by #D reader's dispatch macros.

6.5 Trigonometric and Related Functions

sin *theta* [function]
theta is a float representing angle by radian. returns $sin(theta)$.

cos *theta* [function]
theta is a float representing angle by radian. returns $cos(theta)$.

tan *theta* [function]
theta is a float representing angle by radian. returns $tan(theta)$.

sinh *x* [function]
hyperbolic sine, that is, $\frac{e^x - e^{-x}}{2}$.

cosh *x* [function]
hyperbolic cosine, that is, $\frac{e^x + e^{-x}}{2}$.

tanh *x* [function]
hyperbolic tangent, that is, $\frac{e^x + e^{-x}}{e^x - e^{-x}}$.

asin *number* [function]
arc sine of *number*.

acos *number* [function]
arc cosine of *number*.

atan *y &optional x* [function]
When **atan** is called with one argument, its arctangent is calculated. When called with two arguments, $atan(y/x)$ is returned.

asinh *x* [function]
hyperbolic arc sine.

acosh *x* [function]
hyperbolic arc cosine.

atanh *x* [function]
hyperbolic arc tangent.

sqrt *number* [function]
returns square root of *number*.

log *number* [function]

returns natural logarithm of *number*.

exp x [function]

returns exponential, e^x.

expt a x [function]

returns xth power to a.

7 Symbols and Packages

7.1 Symbols

A symbols is assured to be unique if it is interned in a package. The uniqueness is tested by symbol's print-names. There are no duplicated symbols in a package which have the same print-name as other symbols in the package. When EusLisp is running, there always is a special package called the current package, which is referred by **lisp:*package***. When a symbol without a package name is read by the reader, the current package is searched for to locate the symbol with the same print-name. If no such symbol is found, search is continued in the packages listed in the package use list of the current package. If still no such symbol is found, a new symbol object with the designated print-name is created and is interned in the current package. The package can be specified by prefixing the package name followd by a colon(:). If a symbol name is preceeded by a package name, the search begins in the designated package.

Every symbol may have at most one home package. If a symbol has no such home package, it is said to be an uninterned symbol. Uninterned symbols can be created by the **gensym** or **make-symbol** function, and they are prefixed by "#:" when printed. Since these symbols are not interned, two such symbols with the same print-name are not guaranteed to be equal.

Usually, when the lisp reader encounters a symbol, the reader converts the print-name string of the symbol to uppper case. Thus, for example, if you input `(symbol-name 'car)`, EusLisp responds `"CAR"` instead of `"car"`. Note that `(make-symbol "car")` returns |`car`| instead of `car` or `CAR`. If you want the reader to make symbols constituted by lower case letters, use reader's escapes, \ and |...|.

symbolp *object* [function]

returns T if *object* is an instance of CLASS symbol or its subclasses.

symbol-value *symbol* [function]

gets *symbol*'s special value. Lexical (local) variables' values cannot be retrieved by this function.

symbol-function *symbol* [function]

gets *symbol*'s global function definition. Lexical (local) function cannot be taken by this function.

symbol-package *sym* [function]

returns the package where *sym* is interned.

symbol-name *sym* [function]

returns *sym*'s print-name. Note that **symbol-name** does not copy the pname string, whereas **string** does. Thus, if you change the string returned by **symbol-name**, the symbol becomes inaccessible through normal intern procedure.

symbol-plist *sym* [function]

Returns *sym*'s property list (plist). EusLisp's plist takes the same form as an association list, which consists of dotted pairs of an attribute name and its value. This is incompatible with Common Lisp definition which requests a plist to have linear lists of attribute name and value. In EusLisp, plist is not the unique facility of symbols. Any objects instantiated from a class that inherits **propertied-object** can have property lists. To set and retrieve these plists in propertied-objects, **propertied-object-plist** macro should be used instead of **symbol-plist**. However, **get** and **putprop** work for either object.

boundp *symbol* [function]

Checks if *symbol* has a globally bound value. Note that symbols used for local and object variables always have bound value and **boundp** cannot test the bound state of these local variables.

fboundp *symbol* [function]

Checks if *symbol* has a globally bound function definition.

makunbound *symbol* [function]

symbol is forced to be unbound (to have no special value). Note that lexical (local) variables always have values assigned and cannot be *makunbound*ed.

get *sym attribute* [function]

retrieves *sym*'s value associated with *attribute* in its plist. `= (cdr (assoc` *attribute* `(symbol-plist` *sym*`)))`

putprop *sym val attribute* [function]
Putprop should be replaced with the combination of **setf** and **get**.

remprop *sym attr* [function]
removes attribute-value pair from *sym*'s property list.

setq {*var value*}* [special]
assigns *value* to *var* which is either a symbol or a dotted-pair. *Var* is searched for in the name spaces of local variables, object variables, and special variables in this order unless explicitly declared special.

set *sym val* [function]
assigns *val* to the special value of *sym*. **Set** cannot assign values to local or object variables.

defun *symbol [documentation] lambda-list . body* [special]
defines a global function to *symbol*. Use *flet* or *labels* for defining local functions. If no *documentation* is given, a default documentation string describing the lambda-list is entered.

defmacro *symbol [documentation] lambda-list . body* [special]
defines a global macro. EusLisp does not have facilities for defining locally scoped macros.

defvar *var &optional (init nil) doc* [macro]
If *var* symbol has any special value, **defvar** does nothing. If *var* is unbound, it is declared to be special and *init* is set to its value.

defparameter *var init &optional doc* [macro]
defparameter declares *var* to be special and *init* is set to its value, even if *var* already has value.

defconstant *sym val &optional doc* [macro]
defconstant sets *val* as *sym*'s special value. Unlike *defvar, defparameter* and *setq*, the value set by *defconstant* cannot be altered by these forms. If the value of a constant symbol is tried to be changed, an error is reported. However, another *defconstant* can override the previous constant value, issuing a warning message.

keywordp *obj* [function]
T if *obj* is a symbol and its home package is **KEYWORD**.

constantp *symbol* [function]
T if the symbol is declared to be constant with defconstant macro.

documentation *sym &optional type* [function]
retrieves documentation string of *sym*.

gensym *&optional x* [function]
creates a new uninterned symbol composed of a prefix string and a suffix number like `g001`. Uninterned symbols are denoted by the #: package prefix indicating no package is associated with the symbols. Symbols with #: prefix are unreadable symbols and the reader cannot create references to these uninterned symbols. *X* can either be a string or an integer, which is used as the prefix or the suffix.

gentemp *&optional (prefix "T") (pkg *package*)* [function]
creates a new symbol interned in *pkg*. In most applications, **gensym** is preferable to **gentemp**, because creation of uninterned symbols is faster and uninterned symbols are garbage collect-able.

7.2 Packages

Packages provide separate name spaces for groups of symbols. Common Lisp introduced the package system in order to reduce the symbol (function and variable name) conflict problems in the course of developing huge software systems which require more than one programmer to work together. Each package may have internal symbols and external symbols. When a symbol is created in a package, it is always internal, and it becomes external by **export**. External symbols in different packages are referenced by prefixing the package name and a single colon, as `x:*display*`, while referencing internal symbols in other packages requires double colons, as `sys::free-threads`. In order to omit this package prefixing, a package may **i**mport symbols from other packages. Moreover, **u**se-package allows importing all external symbols from another package at once. When symbols are exported or imported, symbol name conflicts can be detected, since every symbol in any packages must have the unique print name. **S**hadow allows creating a symbol with the same print name as the existing symbol in a package by virtually removing the old symbol from the package.

EusLisp defines following eight packages;

lisp: All the lisp functions, macros, constants, etc.

keyword: keyword symbols

unix: unix system calls and library functions

system: system management or dangerous functions; nicknames=sys,si

compiler: EusLisp compiler; nicknames=comp

user: User's work space

geometry: geometric classes and functions

xwindow: X-window interface; nickname=x

These packages and user-defined packages are linked in the system's package list, which can be obtained by **list-all-packages**. Each package manages two hash tables to find and locate internal and external symbols. Also, a package records its name (string or symbol) and a list of nick names, and a list of other packages that the package is using. ***Package*** is a special variable that holds the current package for read and print. If *package* is not `user:`, top-level prompt changes to indicate the current package, like `mypkg:eus$`.

lisp-package [constant]
  Lisp package.

user-package [constant]
  User package.

unix-package [constant]
  Unix package.

system-package [constant]
  System Package.

keyword-package [constant]
  Keyword Package.

find-symbol *string &optional (package *package*)* [function]
  finds and locates the symbol which has *string* as its print name in *pacakge*. If found, the symbol is returned, NIL otherwise.

make-symbol *string* [function]
  makes a new uninterned symbol by the print name of *string*.

intern *string &optional (package *package*) (klass symbol)* [function]
  tries to find a symbol whose print-name is same with *string*. If the search succeeds, the symbol is returned. If fails, a symbol whose print-name is *string* is newly made, and is located in *package*.

list-all-packages [function]
  returns the list of all packages ever made.

find-package *name* [function]
  find the package whose name or nickname is equal to the *name* string.

make-package *name &key nicknames (use '(lisp))* [function]
makes a new package by the name of *name*. *Name* can either be a string or a symbol. If the package already exists, error is reported.

in-package *pkg &key nicknames (uses '(lisp))* [function]
changes the current pacakge (the value of ***pacakge***) to *pkg*.

package-name *pkg* [function]
returns the string name of the *pkg* package.

package-nicknames *pkg* [function]
returns a list of nicknames of *pkg*.

rename-package *pkg new-name &optional new-nicknames* [function]
changes the name of *pkg* to *new-name* and its nicknames to *new-nicknames*, which can either be a symbol, a string, or a list of symbols or strings.

package-use-list *pkg* [function]
returns the list of packages which are used by *pkg*.

packagep *pkg* [function]
T if *pkg* is a package.

use-package *pkg &optional (curpkg *package*)* [function]
adds *pkg* to *curpkg*'s use-list. Once added, symbols in *pkg* become visible from *curpkg* without package prefix.

unuse-package *pkg &optional (curpkg *package*)* [function]
removes *pkg* from *curpkg*'s use-list.

shadow *sym &optional(pkg *package*)* [function]
makes a symbol interned in *pkg*, by hiding existing *sym*.

export *sym &optional (pkg *package*)* [function]
sym is a symbol or a list of symbols. **export** makes *sym* accessible from other packages as external symbol(s). Actually, *sym* is registered as an external symbol in *pkg*. If a symbol is exported, it becomes accessible using a single colon ":" as package marker, whereas unexported symbols require double colons. In addition, exported symbols do not need colons when they are used by **use-package** or they are imported into the package. Whether a symbol is exported or not is attributed to packages where it is interned, not to each symbol. So, a symbol can be internal in a package and external in another. **Export** checks *sym* to have name conflict with symbols in other packages using *pkg*. If there is a symbol having the same print name with *sym*, "symbol conflict" error is reported.

unexport *sym &optional pkg* [function]
If *sym* is an external symbol in *pkg*, it is unexported and becomes an internal symbol.

import *sym &optional (pkg *package*)* [function]
sym is a symbol or a list of symbols. **import** makes symbols defined in other packages visible in *pkg* as an internal symbol without package prefix. If there is already a symbol that has the same print name as *sym*, then an "name conflict" error is reported.

do-symbols *(var pkg) &rest forms* [macro]
repeats evaluatiing forms for each binding of *var* to symbols (internal or external) in *pkg*.

do-external-symbols *(var pkg) &rest forms* [macro]
repeats evaluating forms for each binding of *var* to external symbols in *pkg*.

do-all-symbols *(var [result]) &rest forms* [macro]
repeats evaluating forms for each binding of *var* to symbols in all packages. Note that forms may be evaluated more than once to a symbol if it appears more than one package.

8 Sequences, Arrays and Tables

8.1 General Sequences

Vectors (one dimensional arrays) and lists are generic sequences. A string is a sequence, since it is a vector of characters.

For the specification of result type in **map, concatenate** and **coerce**, use class name symbol, such as `cons, string, integer-vector, float-vector`, etc. without quotes, since the class object is bound to the symbol.

elt *sequence pos* [function]
elt is the most general function to get and put (in conjunction with **setf**) value at the specific position *pos* in *sequence*. *Sequence* may be a list, or a vector of arbitrary object, bit, char, integer, or float. **Elt** cannot be applied to a multi-dimensional array.

length *sequence* [function]
returns the length of *sequence*. For vectors, **length** finishes in constant time, but time proportional to the length is required for a list. **Length** never terminates if *sequence* is a circular list. Use list-length, instead. If *sequence* is an array with a fill-pointer, **length** returns the fill-pointer, not the entire size of the array entity. Use **array-total-size** to know the entire size of those arrays.

subseq *sequence start [end]* [function]
makes a copy of the subsequence from *start*th through (*end*-1)th inclusively out of *sequence*. *end* is defaulted to the length of *sequence*.

copy-seq *sequence* [function]
does shallow-copying of *sequence*, that is, only the top-level references in *sequence* are copied. Use **copy-tree** to copy a nested list, or **copy-object** for deep-copying of a sequence containing recursive references.

reverse *sequence* [function]
reverse the order of *sequence* and returns a new sequence of the same type as *sequence*.

nreverse *sequence* [function]
Nreverse is the destructive version of **reverse**. **Nreverse** does not allocate memory, while **reverse** does.

concatenate *result-type sequence** [function]
concatenates all *sequences*. Each *sequence* may be of any sequence type. Unlike **append**, all the sequences including the last one are copied. *Result-type* should be a class such as cons, string, vector, float-vector etc.

coerce *sequence result-type* [function]
changes the type of *sequence*. For examples, `(coerce '(a b c) vector) = #(a b c)` and `(coerce "ABC" cons) = (a b c)`. A new sequence of type *result-type* is created, and each element of *sequence* is copied to it. *result-type* should be one of vector, integer-vector, float-vector, bit-vector, string, cons or other user-defined classes inheriting one of these. Note that *sequence* is copied even if its type equals to *result-type*.

map *result-type function seq &rest more-seqs* [function]
function is applied to a list of arguments taken from *seq* and *more-seqs* orderly, and the result is accumulated in a sequence of type *result-type*.

fill *sequence item &key (:start 0) (:end (length sequence))* [function]
fills *item* from *start*th through (*end*-1)th in *sequence*.

replace *dest source &key :start1 :end1 :start2 :end2* [function]
elements in *dest* sequence indexed between *start1* and *end1* are replaced with elements in *source* indexed between *start2* and *end2*. *start1* and *start2* are defaulted to zero, and *end1* and *end2* to the length of each sequence. If the one of subsequences is longer than the other, its end is truncated to

match with the shorter subsequence.

sort *sequence compare &optional key* [function]
sequence is destructively sorted using Unix's quick-sort subroutine. *key* is not a keyword parameter. Be careful with the sorting of a sequence which have same elements. For example, `(sort '(1 1) #'>)` fails because comparisons between 1 and 1 in both direction fail. To avoid this problem, use functions like #'>= or #'<= for comparison.

merge *result-type seq1 seq2 pred &key (key #'identity)* [function]
two sequences *seq1* and *seq2* are merged to form a single sequence of *result-type* whose elements satisfy the comparison specified by *pred*.

merge-list *list1 list2 pred key* [function]
merges two lists. Unlike **merge** no general sequences are allowed for the arguments, but **merge-list** runs faster than **merge**.

Following functions consist of one basic function and its variants suffixed by -if and -if-not. The basic form takes at least the item and sequence arguments, and compares item with each element in the sequence, and do some processing, such as finding the index, counting the number of appearances, removing the item, etc. Variant forms take predicate and sequence arguments, applies the predicate to each element of sequence, and do something if the predicate returns non-nil (-if version), or nil (-if-not version).

position *item seq &key :start :end :test :test-not :key (:count 1)* [function]
finds *count*th appearance of *item* in *seq* and returns its index. The search begins from the *start*th element, ignoring elements before it. By default, the search is performed by **eql**, which can be altered by the *test* or *test-not* parameter.

position-if *predicate seq &key :start :end :key* [function]

position-if-not *predicate seq &key :start :end :key* [function]

find *item seq &key :start :end :test :test-not :key (:count 1)* [function]
finds *count*th element between the *start*th element and the *end*th element in *seq*. The element found, which is eql to *item* if no *test* or *test-not* other than #'eql is specified, is returned.

find-if *predicate seq &key :start :end :key (:count 1)* [function]
finds *count*th element in *seq* for which *pred* returns non nil.

find-if-not *predicate seq &key :start :end :key* [function]

count *item seq &key :start :end :test :test-not :key* [function]
counts the number of *item*s which appear between the *start*th element and the *end*th element in *seq*.

count-if *predicate seq &key :start :end :key* [function]
count the number of elements in *seq* for which *pred* returns non nil.

count-if-not *predicate seq &key :start :end :key* [function]

remove *item seq &key :start :end :test :test-not :key :count* [function]
creates a new sequence which has eliminated *count* (defaulted to infinity) occurrences of of *item*(s) between the *start*th element and the *end*th element in *seq*. If you are sure that there is only one occurrence of *item*, *count=1* should be specified to avoid meaningless scan over the whole sequence.

remove-if *predicate seq &key :start :end :key :count* [function]

remove-if-not *predicate seq &key :start :end :key :count* [function]

remove-duplicates *seq &key :start :end :key :test :test-not :count* [function]

removes duplicated items in *seq* and creates a new sequence.

delete *item seq &key :start :end :test :test-not :key :count* [function]

is same with **remove** except that **delete** modifies *seq* destructively and does not create a new sequence. If you are sure that there is only one occurrence of *item*, *count=1* should be specified to avoid meaningless scan over the whole sequence.

delete-if *predicate seq &key :start :end :key :count* [function]

delete-if-not *predicate seq &key :start :end :key :count* [function]

count for *remove*s and *delete*s is defaulted to 1,000,000. If you have a long sequence and you want to delete an element which appears only once, :count should be specified as 1.

substitute *newitem olditem seq &key :start :end :test :test-not :key :count* [function]

returns a new sequence which has substituted the *count* occurrence(s) of *olditem* in *seq* with *newitem*. By default, all the *olditems* are substituted.

substitute-if *newitem predicate seq &key :start :end :key :count* [function]

substitute-if-not *newitem predicate seq &key :start :end :key :count* [function]

nsubstitute *newitem olditem seq &key :start :end :test :test-not :key :count* [function]

substitute the *count* occurrences of *olditem* in *seq* with *newitem* destructively. By default, all the *olditem*s are substituted.

nsubstitute-if *newitem predicate seq &key :start :end :key :count* [function]

nsubstitute-if-not *newitem predicate seq &key :start :end :key :count* [function]

8.2 Lists

listp *object* [function]
returns T if object is an instance of cons or NIL.

consp *object* [function]
equivalent to (not (atom object)). (consp '()) is nil.

car *list* [function]
returns the first element in *list*. **car** of NIL is NIL. **car** of atom is error.

cdr *list* [function]
returns the list which removed the first element of *list*. **cdr** of NIL is NIL. **cdr** of atom is error.

cadr *list* [function]

cddr *list* [function]

cdar *list* [function]

caar *list* [function]

caddr *list* [function]

caadr *list* [function]

caaar *list* [function]

cdadr *list* [function]

cdadr *list* [function]

cdaar *list* [function]

cdddr *list* [function]

cdddr *list* [function]

cddar *list* [function]

first *list* [function]
retrieves the first element in *list*. **s**econd, third, fourth, fifth, sixth, seventh, eighth are also available.

nth *count list* [function]
returns the *count*-th element in *list*. Note that `(nth 1 list)` is equivalent to `(second list)`, and to `(elt list 1)`.

nthcdr *count list* [function]
applies **cdr** *count* times to *list*.

last *list* [function]
the last cons is returned, not the last element.

butlast *list &optional (n 1)* [function]
returns a list which does not contain the last *n* elements.

cons *car cdr* [function]
makes a new cons whose car is *car* and cdr is *cdr*.

list {*element*}* [function]
makes a list of *element*s.

list* {*element*}* [function]
makes a list of *element*s, but the last element is consed in cdr: for example, `(list* 1 2 3 '(4 5)) = (1 2 3 4 5)`.

list-length *list* [function]
returns the length of the *list*. *List* can be circular.

make-list *size &key (initial-element nil)* [function]
makes a list whose length is *size* and elements are *initial-element*.

rplaca *cons a* [function]
replace the car of *cons* with a. Use of **setf** to **car** is recommended.

rplacd *cons d* [function]
replace the cdr of *cons* with d. Use of **setf** to **cdr** is recommended.

memq *item list* [function]
resembles **member**, but test is always done by **eq**.

member *item list &key :key (:test #'eq) :test-not* [function]
The *list* is searched for an element that satisfies the *test*. If none is found, NIL is returned; otherwise, the tail of *list* beginning with the first element that satisfied the test is returned. The *list* is searched on the top level only.

assq *item alist* [function]

assoc *item alist &key :key (:test #'eq) :test-not* [function]
searches the association list *alist*. The value returned is the first pair in the *alist* such that the *car* of the pair satisfies the *test*, or NIL if there is no such pair in the *alist*.

rassoc *item alist* [function]
returns the first pair in *alist* whose cdr is equal to *item*.

pairlis *l1 l2 &optional alist* [function]
makes a list of pairs consing corresponding elements in *l1* and *l2*. If *alist* is given, it is concatenated at the tail of the pair list made from *l1* and *l2*.

acons *key val alist* [function]
add the *key val* pair to *alist*, that is, `(cons (cons key val) alist)`.

append {*list*}* [function]
appends *list* to form a new list. All the elements in *list*, except the last list, are copied.

nconc {*list*}* [function]
concatenates *list* destructively by replacing the last cdr of each *list*.

subst *new old tree* [function]
substitutes every *old* in *tree* with *new*.

flatten *complex-list* [function]

Complex-list composed of atoms and lists of any depth is transformed into a single level linear list which have all the elements in *complex-list* at the top level. For example, `(flatten '(a (b (c d) e))) = (a b c d e)`

push *item place* [macro]
pushes item into a stack (list) bound to *place*.

pop *stack* [macro]
removes the first item from *stack* and returns it. If *stack* is empty (nil), nil is returned.

pushnew *item place &key test test-not key* [macro]
pushes *item* in the *place* list if *item* is not a member of *place*. The *test*, *test-not* and *key* arguments are passed to the member function.

adjoin *item list* [function]
The item is added at the head of the list if it is not included in the list.

union *list1 list2 &key (test #'eq) (test-not) (key #'identity)* [function]
returns union set of two lists.

subsetp *list1 list2 &key (test #'eq) (test-not) (key #'identity)* [function]
tests if *list1* is a subset of *list2*, i.e. if each element of *list1* is a member of *list2*.

intersection *list1 list2 &key (test #'eq) (test-not) (key #'identity)* [function]
returns the intersection of two sets, *list1* and *list2*.

set-difference *list1 list2 &key (test #'eq) (test-not) (key #'identity)* [function]
returns the list whose elements are only contained in *list1* and not in *list2*.

set-exclusive-or *list1 list2 &key (test #'eq) (test-not) (key #'identity)* [function]
returns the list of elements that appear only either in *list1* or *list2*.

list-insert *item pos list* [function]
Insert *item* as the *pos*'th element in *list* destructively. If *pos* is bigger than the length of *list*, *item* is nconc'ed at the tail. For example, `(list-insert 'x 2 '(a b c d)) = (a b x c d)`

copy-tree *tree* [function]
returns the copy of *tree* which may be a nested list but cannot have circular reference. Circular lists can be copied by **copy-object**. Actually, **copy-tree** is simply coded as `(subst t t tree)`.

mapc *func arg-list &rest more-arg-lists* [function]
applies *func* to a list of N-th elements in *arg-list* and each of *more-arg-lists*. The results of application are ignored and *arg-list* is returned.

mapcar *func &rest arg-list* [function]
maps *func* to each element of *arg-list*, and makes a list from all the results. Before using **mapcar**, try **dolist**.

mapcan *func arg-list &rest more-arg-lists* [function]
maps *func* to each element of *arg-list*, and makes a list from all the results by **nconc**. **Mapcan** is suitable for filtering (selecting) elements in *arg-list*, since nconc does nothing with NIL.

8.3 Vectors and Arrays

Up to seven dimensional arrays are allowed. A one-dimensional array is called vector. Vectors and lists are grouped as sequence. If the elements of an array is of any type, the array is said to be general. If an array does not have fill-pointer, is not displaced to another array, or is adjustable, the array is said to be simple.

Every array element can be recalled by **aref** and set by **setf** in conjunction with aref. But for simple vectors, there are simpler and faster access functions: **svref** for simple general vectors, **char** and **schar** for simple character vectors (string), **bit** and **sbit** for simple bit vectors. When these functions are compiled, the access is expanded in-line and no type check and boundary check are performed.

Since a vector is also an object, it can be made by instantiating some vector-class. There are five kinds of built-in vector-classes; vector, string, float-vector, integer-vector and bit-vector. In order to ease instantiation of vectors, the function make-array is provided. Element-type should be one of **:integer, :bit, :character, :float, :foreign** or user-defined vector class. **:initial-element** and **:initial-contents** key word arguments are available to set initial values of the array you make.

array-rank-limit [constant]
7

array-dimension-limit [constant]
#x1fffffff, logically, but stricter limit is imposed by the physical or virtual memory size of the system.

vectorp *object* [function]
An array is not a vector even if it is one dimensional. T is returned for vectors, integer-vectors, float-vectors, strings, bit-vectors or other user-defined vectors.

vector *&rest elements* [function]
makes a simple vector from *elements*.

make-array *dims &key (element-type vector)*
(initial-contents nil)
(initial-element nil)
(fill-pointer nil)
(displaced-to nil)
(displaced-index-offset 0)
(adjustable nil) [function]

makes a vector or array. *dims* is either an integer or a list. If *dims* is an integer, a simple-vector is created.

svref *vector pos* [function]
returns *pos*th element of *vector*. *Vector* must be a simple general vector.

aref *vector &rest (indices)* [function]
returns the element indexed by *indices*. **Aref** is not very efficient because it needs to dispatch according to the type of *vector*. Type declarations should be given to improve the speed of compiled code whenever possible.

vector-push *val array* [function]
store *val* at the *fill-pointer*th slot in *array*. *array* must have a *fill-pointer*. After val is stored, the fill-pointer is advanced by one to point to the next location. If it exceeds the array boundary, an error is reported.

vector-push-extend *val array* [function]
Similar to **vector-push** except that the size of the array is automatically extended when *array*'s fill-pointer reaches the end.

arrayp *obj* [function]
T if *obj* is an instance of array or vector.

array-total-size *array* [function]
returns the total number of elements of *array*.

fill-pointer *array* [function]

array-rank *array* [function]

array-dimensions *array* [function]
returns a list of array-dimensions.

array-dimension *array axis* [function]
Axis starts from 0. **array-dimension** returns the *axis*th dimension of *array*.

bit *bitvec index* [function]
returns the *index*th element of *bitvec*. Use **setf** and **bit** to change an element of a bit-vector.

bit-and *bits1 bits2 &optional result* [function]

bit-ior *bits1 bits2 &optional result* [function]

bit-xor *bits1 bits2 &optional result* [function]

bit-eqv *bits1 bits2 &optional result* [function]

bit-nand *bits1 bits2 &optional result* [function]

bit-nor *bits1 bits2 &optional result* [function]

bit-not *bits1 &optional result* [function]
For bit vectors *bits1* and *bits2* of the same length, their boolean and, inclusive-or, exclusive-or, equivalence, not-and, not-or and not are returned, respectively.

8.4 Characters and Strings

There is no character type in EusLisp; a character is represented by an integer. In order to handle strings representing file names, use **pathname**s described in 11.6.

digit-char-p *ch* [function]
T if *ch* is #\0 through #\9.

alpha-char-p *ch* [function]
T if *ch* is #\A through #\Z or #\a through #\z.

upper-case-p *ch* [function]
T if *ch* is #\A through #\Z.

lower-case-p *ch* [function]
T if *ch* is #\a through #\z.

alphanumeric-p *ch* [function]
T if *ch* is #\0 through #\9, #\A through #\Z or #\a through #\z.

char-upcase *ch* [function]
convert the case of *ch* to upper.

char-downcase *ch* [function]
convert the case of *ch* to lower.

char *string index* [function]
returns *index*th character in *string*.

schar *string index* [function]
extracts a character from *string*. Use **schar** only if the type of *string* is definitely known and no type check is required.

stringp *object* [function]
string is a vector of bytes (integers less than 256).

string-upcase *str &key start end* [function]
converts *str* to upper case string and returns a new string.

string-downcase *str &key start end* [function]
converts *str* to lower case string and returns a new string.

nstring-upcase *str* [function]
converts *str* to upper case string destructively.

nstring-downcase *str &key start end* [function]
converts *str* to lower case string destructively.

string= *str1 str2 &key start1 end1 start2 end2* [function]
T if *str1* is equal to *str2*. *string=* is case sensitive.

string-equal *str1 str2 &key start1 end1 start2 end2* [function]
tests equality of *str1* and *str2*. **string-equal** is not case sensitive.

string *object* [function]
gets string notation of *object*. If *object* is a string, the *object* is returned. If *object* is a symbol, its pname is copied and returned. Note that (equal (string 'a) (symbol-pname 'a))==T, but (eq (string 'a) (symbol-pname 'a))==NIL. If object is number its string representation is returned (this is incompatible with Common Lisp). In order to get string representation for more complex objects, use **format** with NIL in the first argument.

string< *str1 str2* [function]

string<= *str1 str2* [function]

string> *str1 str2* [function]

string>= *str1 str2* [function]

string-left-trim *bag str* [function]

string-right-trim *bag str* [function]

str is scanned from the left(or right), and its elements are removed if it is included in the *bag* list. Once a character other than the ones in the *bag* is found, further scan is aborted and the rest of *str* is returned.

string-trim *bag str* [function]

Bag is a sequence of character codes. A new copy of *str* which does not contain characters specified in *bag* in its both end is made and returned.

substringp *sub string* [function]

T if string *sub* is contained in *string* as a substring. Not case sensitive.

8.5 Foreign Strings

A foreign-string is a kind of byte-vector whose entity is held somewhere outside EusLisp's heap. While a normal string is represented by a sequence of bytes and its length, a foreign-string holds the length and the address of the string entity. Although foreign-string is a string, some string and sequence functions cannot be applicable. Only **length**, **aref**, **replace**, **subseq** and **copy-seq** recognize the foreign-string, and application of other functions may cause a crash.

A foreign-string may refer to a part of I/O space usually taken in /dev/a??d?? special file where ?? is either 32 or 16. In case the device attached in one of these I/O space only responds to byte access, **replace** always copies element byte by byte, which is relatively slow when a large chunk of memory is accessed consecutively.

make-foreign-string *address length* [function]

makes an instance of foreign-string located at *address* and spanning for *length* bytes. For example, `(make-foreign-string (unix:malloc 32) 32)` makes a reference to a 32-byte memory located outside EusLisp's heap.

8.6 Hash Tables

Hash-table is a class to search for the value associated with a key, as accomplished by **assoc**. For a relatively large problem, hash-table performs better than assoc, since time required for searching remains constant even the number of key-value pairs increases. Roughly speaking, hash-table should be used in search spaces with more than 100 elements, and assoc in smaller spaces.

Hash-tables automatically expands if the number of elements in the table exceeds rehash-size. By default, expansion occurs when a half of the table is filled. **sxhash** function returns a hash value which is independent of memory address of an object, and hash values for **equal** objects are always the same. So, hash tables can be re-loadable since they use sxhash as their default hashing functions. While sxhash is robust and safe, it is relatively slow because it scans all the elements in a sequence or a tree. For faster hashing, you may choose another hash function appropriate for your application. To change the hash function, send `:hash-function` message to the hash-table. In simple cases, it is useful to change hash function from #'**sxhash** to #'**sys:address**. This is possible because the addresses of any objects never change in a EusLisp process.

sxhash *obj* [function]

calculates the hash value for *obj*. Two objects which are **equal** are guaranteed to yield the same hash value. For a symbol, hash value for its pname is returned. For numbers, their integer representations are returned. For a list, sum of hash values for all its elements is returned. For a string, shifted sum of each character code is returned. For any other objects, **sxhash** is recursively called to calculate the hash value of each slot, and the sum of them is returned.

make-hash-table *&key (size 30) (test #'eq) (rehash-size 2.0)* [function]

creates a hash table and returns it.

gethash *key htab* [function]

gets the value that corresponds to *key* in *htab*. **Gethash** is also used to set a value to key by combining with **setf**. When a new entry is entered in a hash table, and the number of filled slots in the table exceeds 1/rehash-size, then the hash table is automatically expanded to twice larger size.

remhash *key htab* [function]

removes a hash entry designated by *key* in *htab*.

maphash *function htab* [function]

maps *function* to all the elements of *htab*.

hash-table-p *x* [function]

T if *x* is an instance of class hash-table.

hash-table [class]

:super	**object**
:slots	(key value count hash-function test-function rehash-size empty deleted)

defines hash table. *Key* and *value* are simple-vectors of the same *size*. *Count* is the number of filled slots in *key* and *value*. *Hash-function* is defaulted to **sxhash** and *test-function* to **eq**. *Empty* and *deleted* are uninterned symbols to indicate slots are empty or deleted in the *key* vector.

:hash-function *newhash* [method]

changes the hash function of this hash table to *newhash*. *Newhash* must be a function with one argument and returns an integer. One of candidates for *newhash* is **system:address**.

8.7 Queue

A queue is a data structure that allows insertion and retrieval of data in the FIFO manner, i.e. the first-in first-out order. Since the queue class is defined by extending the cons class, ordinary list functions can be applied to a queue. For example, caar retrieves the next element to be dequeued, and cadr gets the element that is queued most recently.

queue [class]

:super	**cons**
:slots	(car cdr)

defines queue (FIFO) objects.

:init [method]

initializes the queue to have no elements.

:enqueue *val* [method]

puts val in the queue as the most recent element.

:dequeue *&optional (error-p nil)* [method]

retrieves the oldest value in the queue, and removes it of the queue. If the queue is empty, it reports an error when error-p is non-nil, or returns NIL otherwise.

:empty? [method]

returns T if the queue is empty.

:length [method]

returns the length of the queue.

9 Text Processing

9.1 Japanese Text

Japanese characters are encoded in 16-bit, i.e. two bytes. Inside EusLisp, there is no provision to handle Japanese 16-bit character as a representation of Japanese. They are just regarded as a series of byte-encoded characters. The following code will print a Japanese character "AI" that means *love* in English, if you are using a terminal that can display EUC kanji, like kterm.

```
(setq AI-str
      (let ((jstr (make-string 2)))
          (setf (aref jstr 0) #xb0
        (aref jstr 1) #xa6)
  jstr))
(print AI-str)
```

In a similar manner, (intern AI-str) will create a symbol with its printname "AI".

```
(set (intern AI-str) "love")
```

Conversion functions for different character codes and Roman-ji representation are provided.

romkan *romanji-str* [function]
Roman-ji representation is converted into EUC coded Japanese. Numbers are converted into pronunciation in hiragana.

romanji *kana-str* [function]
kana-str which represents Japanese in hiragana or in katakana coded in EUC is converted into a roman-ji representation. English alphabets and numbers are unchanged.

sjis2euc *kana-str* [function]
kana-str coded in shift-jis is converted into EUC.

euc2sjis *kana-str* [function]
kana-str coded in EUC is converted into shift-JIS.

jis2euc *kana-str* [function]
kana-str coded in EUC is converted into JIS coding, which enters kana mode by `ESC$B` and exits by `ESC(J`. Note that there is no euc2jis function is provided yet.

kana-date *time* [function]
time is converted a Japanese date pronunciation represented in roman-ji. The default time is the current time.

kana-date *time* [function]
time is converted a Japanese time pronunciation represented in roman-ji. The default time is the current time.

hira2kata *hiragana-str* [function]
hiragana-str is converted into katakana representation.

kata2hira *katakana-str* [function]
katakana-str is converted into hiragana representation.

9.2 Regular Expression

regmatch *regpat string* [function]
searches for an occurence of a regular expression, *regpat* in *string*. If found, a list of the starting index and the ending index of the found pattern is returned. example; (regmatch "ca[ad]+r" "any string ...") will look for cadr, caar, cadadr ... in the second argument.

9.3 Base64 encoding

Base64 is an encoding scheme to represent binary data using only printable graphic characters. The scheme is applied to uuencode/uudecode. The following functions are defined in lib/llib/base64.l.

base64encode *binstr* [function]

A binary string, *binstr* is converted to an ASCII string consisting only of

$$A - Za - z0 - 9 + / =$$

letters according to the base-64 encoding rule. The resulted string is 33% longer than the original. A newline is inserted every 76 characters. One or two '=' characters are padded at the end to adjust the length of the result to be a multiple of four.

base64decode *ascstr* [function]

An ASCII string, *ascstr*, is converted to a binary string according to the base-64 encodeing. Error is reported if ascstr includes an invalid character.

9.4 DES cryptography

Linux and other UNIX employs the DES (Data Encryption Standard) to encrypt password strings. The function is provided in the libcrypt.so library. lib/llib/crypt.l links this library and provides the following functions for string encryption. Note that the $2^5 6$ key space of DES is not large enough to reject challenges by current powerful computers. Note also that only the encrypting functions are provided and no rational decrypting is possible.

crypt *str salt* [function]

The raw function provided by libcrypt.so. *Str* is encrypted by using the *salt* string. *Salt* is a string of two characters, and used to randamize the output of encryption in 4096 ways. The output string is always 13 characters regardless to the length of *str*. In other words, only the first eight characters from *str* are taken for encryption, and the rest are ignored. The same string encrypted with the same salt is the same. The same string yields different encryption result with different salts. The salt becomes the first two characters of the resulted encrypted string.

rcrypt *str &optional (salt (random-string 2))* [function]

The plain string, *str*, is converted into its encrypted representation. The *salt* is randomly generated if not given.

random-string *len &optional random-string* [function]

This is a utility function to generate a random string which constitutes of elements in the *random-string*. By default, "A-Za-z0-9/." is taken for the *random-string*. In order not to make mistakes between i, I, l, 1, O, 0, and o, you can specify *safe-salt-string* for the *random-string*.

compcrypt *input cryption* [function]

Input is a plain string and *cryption* is a encrypted string. *Input* is encrypted with the salt found in the *cryption* and the result is compared with it. If both are the same, T is returnd, NIL, otherwise.

10 Date and Time

The time class defines both calendar time and time period.

time [class]

:super	**propertied-object**
:slots	(micro second minute hour day month weekday year timezone dst seconds)

defines time objects.

:now [method]
`(instance time :now)` creates a time object for the current time.

:init *&optional sec micro dst tzone* [method]
creates a time object which represents *sec* second after January 1, 1970.

:make *&key (year 1970) (month 0) (day 1) (weekday 4) (hour 0) (minute 0) (second 0) (micro 0) (timezone (* -9 3600)))* [method]
creates a time object which is represented by a calendar notation. The timezone is defaulted to JST.

:year [method]
returns the year component of the time object. Note that the year is represented in a full (four) digit notation, not the least two digits.

:month [method]
returns the month component of the time object. Note that the month begins from 0 for January.

:day [method]
returns the day component of the time object. Note that the day begins from 1 for the first of a month.

:weekday [method]
returns the weekday component of the time object. Note that the weekday begins from 0 for Sunday.

:hour [method]
returns the hour component of the time object in 24-hour representation. Note that the hour ranges from 0 to 23.

:minute [method]
returns the minute component of the time object. Note that the hour ranges from 0 to 59.

:second [method]
returns the second component of the time object. Note that the hour ranges from 0 to 59.

:seconds [method]
returns the seconds component of the time object. Seconds represents time after the origin of the unix time, i.e., the midnight of January 1, 1970.

:year-day [method]
returns the number of days after the beginning of the year. For example, year-day of a time object representing February 2nd is 32.

:difference *atime* [method]
returns a new time object representing the time difference of self from atime.

:add *atime* [method]
returns a new time object representing the added time of self and atime.

11 Streams and Input/Output

11.1 Streams

Echo-streams and concatenated-streams are not available. Predefined streams are following:

standard-input stdin fd=0

standard-output stdout fd=1

error-output stderr fd=2 bufsize=1

terminal-io two-way stream made of ***standard-input*** and ***standard-output***

streamp *object* [function]

Any object created from **s**tream, **i**o-stream, or their subclasses returns T.

input-stream-p *object* [function]

T if *object* is a stream and capable of reading.

output-stream-p *object* [function]

T if *object* is a stream and capable of writing.

io-stream-p *object* [function]

T if *object* is a two-way stream.

open *path &key :direction :input* [function]
:if-exists :new-version
:if-does-not-exist
:permission #o644
:buffer-size 512

Open makes a stream associated with a file designated by *path*. *path* may either be a string or a pathname. Direction should be one of **:input, :output** or **:io**. Several open options, **:append, :new-version, :overwrite, :error** and nil are allowed for **:if-exists** parameter. However, this parameter is ignored when *direction* is **:input**. Alternatives for **:if-does-not-exist** are **:error, :create** and nil. **:new-version**, **:rename** and **:supersede** are not recognized. By default, the file is overwritten if *direction* is either **:output** or **:io** when the file exists. For :input files, an error is reported when the file does not exist. To know the existence of a file, **probe-file** can be used. Default value for **buffer-size** is 512 bytes, and #O644 for **:permission**. SunOS4 allows to open as many as sixty files at the same time.

with-open-file *(svar path . open-options) &rest forms* [macro]

A file named *path* is opened with *open-options* and the stream is bound to *svar*. Then *forms* are evaluated. The stream is automatically closed when evaluation of *forms* finishes or exits with **throw**, **return-from** or error. **With-open-file** is a macro defined by **unwind-protect** with **close** in its clean-up forms.

close *stream* [function]

closes the *stream*, and returns T if successful. The stream may have already been closed, in which case nil is returned. Streams are automatically closed by GC if there is no reference to that stream object.

make-string-input-stream *string* [function]

makes an input stream from a string.

make-string-output-stream *size* [function]

makes an output stream to a string of *size* length. Actually, the length is automatically expanded, so *size* is only advisory information to allocate string at initialization.

get-output-stream-string *string-stream* [function]

gets a string out of a *string-stream*.

make-broadcast-stream *&rest output-streams* [function]

makes a broad-cast stream which forwards all the messages written to this stream to each of *output-streams*.

11.2 Reader

Reader's global variables:

read-base number base to be read; default is decimal ten

readtable current readtable which determines reader syntax

Reader's default macro characters:

(	read list
”	read string
’	read quoted expression
#	dispatch macro
;	comment until end of line
‘	back-quote
,	list-time eval
@	append
%	read C-like mathematical forms

Escape characters:

\	single character escape
|...|	multiple character escape

When an unescaped symbol is read, all the constituent characters are converted to upcase by default, and upcase-character symbol is stored internally. For example, 'abc and 'ABC are regarded as the same symbol. Escape is necessary to distinguish between them. '|ABC|, 'ABC and 'abc are identical, while '|abc| and 'abc are different symbols. By default, even if you enter a symbol with upcase letters, When symbols are printed, EusLisp's printer converts them into lowercase from internal upcase representation. This conversion is suppressed by setting ***print-case*** to **:UPCASE**.

Note that 10. is read as integer 10, not floating 10.0. Since ':' is reserved for package marker, it must be escaped when used as a constituent of a symbol, like '$|g:pcube|$. This restriction is imposed not by the syntax of the character ':', but by the attribute which determines the alphabetical order and the meaning of the letter. The attributes of characters are hardwired in the reader. Thus, although you may change the syntax of a certain character by creating a new readtable by **copy-readtable** and resetting the syntactic meaning for the character by **set-syntax-from-char**, you cannot change its attribute anyway. In other words, digits are always digits, alphabets are alphabets, and we cannot use letters like '#$%@' to represent numbers.

String is denoted by two double quotes '"' at the beginning and at the end. No case conversion is taken inside the quotes. A back-slash ’́is used as an escape to include a double quote. Therefore, ”He said, Ï like Lisp.̈” is read as a string including two double quotes. To enter a back-slash, two back-slashes are needed. Note that shift-JIS encoding of Japanese text is inadequate for this read-string convention, since some characters happen to have the code of a back-slash (`#x5c`) as their second byte. Use of EUC coding is preferrable.

% is an extended read-macro character specific to EusLisp. Preceding % to a mathematical formula written in infix notation, the formula is converted to lisp's prefix form. For an instance, `%(1 + 2 * 3 / 4.0)` is transformed to `(+ 1 (/ (* 2 3) 4.0))` and `2.5` is resulted. C-like function calls and array references are converted to lisp forms, too, thus, `%(sin(x) + a[1])` is evaluated to `(+ (sin x) (aref a 1))`. Functions having more than one arguments and arrays of more than two dimeisions are notated as `func(a b c ...)` and `ary[1 2 3 ...]`, not `func(a,b,c)` nor `ary[1][2][3]`. Relative expressions and assignments are also properly handled, so, `%(a < b)` is converted to `(< a b)`, and `%(a[0] = b[0] * c[0])` is to `(setf (aref b 0) (* (aref b 0) (aref c 0)))`. A simple optimization is performed to reduce duplicated function calls and array references. `%(sin(x) + cos(x) / sin(x))` is converted into `(let* ((temp (sin x))) (+ temp (/ (cos x) temp)))`.

Dispatch macros are preceeded by the `#` character. A number (integer) argument can be given between `#` and a dispatch macro character. This means that any digits (0 .. 9) cannot be defined as dispatch macro characters. Reader's standard dispatch macro characters follow:

`#nA(..)` array

`#B` binary number

`#D` degree to radian conversion; #D180 = 3.14

`#F(...)` floatvector

`#nF((..))` float array; #2F((..) (..)) is matrix

`#I(...)` integer-vector

`#nI((...))` integer array

`#J(...)` general object #J(myclass ....); obsolete

`#O` octal number

`#P` pathname

`#R` radian to degree conversion; #R3.14 = 180.0

`#S(classname slotname1 val1 slotname2 val2 ...)` structure (any object)

`#V(...)` vector #V(vectorclass ...)

`#X` hexadecimal number

`#(...)` vector

`#n#` label reference

`#n=` label definition

`#'` FUNCTION; compiled-code or lambda-closure

`#\` character

`#,` read-time evaluation

`#+` conditional read (positive)

`#-` conditional read (negative)

`#*` bit vector

`#:` uninterned symbol

`#|...|#` comment; can be nested

Some reader functions have *eof-error-p, eof-value* and *recursive-p* parameters. The first two parameters control the behavior when the reader encounters with end-of-file. The default of *eof-error-p* is t, which causes an error at eof. If you want to know the occurrence of eof and don't want the system's error-handler to snatch control, specify nil to *eof-error-p*. Thus, when an eof appears during reading, the reader returns the *eof-value* instead of entering an error loop. *Eof-value* is defaulted to nil. So, you cannot know if nil is actually read, or eof appears. To distinguish them, give a value which can never appear in the stream. Use **cons** or **gensym** to make such unique data object.

Recursive-p is often used in read-macro functions, which call reader recursively. Non-nil value of *recursive-p* tells the reader that the read operation has been started somewhere else and it should not reset the internal table for reading forms labeled by `#n=` and `#n#`.

read *&optional stream (eof-error-p t) (eof-value nil) recursive-p* [function]
reads one S-expression.

read-delimited-list *delim-char &optional stream recursive-p* [function]
reads s-expression which is delimited by *delim-char*. This is useful to read comma-separated list, or to read a sequence terminated by a special character like `#\]`.

read-line *&optional stream (eof-error-p t) (eof-value nil)* [function]
reads a line which is terminated by a `#\newline`. The string returned does not contain the last newline character.

read-char *&optional stream (eof-error-p t) (eof-value nil)* [function]
reads one character and returns its integer representation.

read-from-string *string &optional (eof-error-p t) (eof-value nil)* [function]
reads one s-expression from *string*. Only the first s-expression can be read. If successive read operations need to be performed on a string containing more than one expression, use string-stream made by **m**ake-string-input-stream.

unread-char *char &optional stream* [function]
puts the *char* back to the *stream*. More than one characters cannot be put back successively.

peek-char *&optional stream (eof-error-p t) (eof-value nil)* [function]
reads a character from the *stream* without removing it from the buffer of the *stream*. This is equivalent to a *read-char* followed by a *unread-char*.

y-or-n-p *&optional format-string &rest args* [function]
prints *format-string* and *args* on your terminal, and asks "y-or-n". Repeat query until your response begins with either of "y" or "n", and returns T or NIL. Case does not matter.

yes-or-no-p *&optional stream* [function]
prints *format-string* and *args* on your terminal, and asks "yes-or-no". Repeat query until your response is either of "yes" or "no", and returns T or NIL. Case does not matter.

In the readtable manipulating functions, the default value of readtable is the value of the global variable ***readtable***.

readtable-p *x* [function]
T if *x* is an readtable.

copy-readtable *&optional from-readtable to-readtable* [function]
If no *to-readtable* is specified, a new one is created. All the information in *from-readtable* is transferd to *to-readtable*. The information included is, syntax table, read-macro table and dispatch-macro table, each of which has 256 elements.

set-syntax-from-char *to-char to-char [to-readtable from-readtable]* [function]
copies syntax and read-macro definition of *from-char* in *from-readtable* to that of *to-char* in *to-readtable*.

set-macro-character *char func [non-teminating-p readtable]* [function]
defines *func* as the read-macro function for *char*.

get-macro-character *char [readtable]* [function]
returns the read-macro function for *char*.

set-dispatch-macro-character *dispchar char func [readtable]* [function]
defines *func* as the dispatch read-macro function for the combination of *dispchar* and *char*.

get-dispatch-macro-character *dispchar char [readtable]* [function]
returns the dispatch read-macro function for the combination of *dispchar* and *char*.

11.3 Printer

The followings are special variables controlling printer's behaviors.

print-case if this is `:downcase`, all symbols are printed in lowercase althought symbols are represented in uppercase internally unless they are escaped.

print-circle print objects preserving recursive refernce

print-object print the details of all objects

print-structure print objects using #s format.

print-level printable depth of a sequence

print-length printable length of a sequence

print-escape currently not used

print-pretty currently not used

print-base number base in printing; defaulted to decimal ten

In order to print objects containing recursive references so that they can be read back again, print the objects with both ***print-circle*** and ***print-structure*** set to T. Although most of the user defined objects can be printed in re-readable forms, classes, compiled-codes and packages cannot be dumped in that way, because classes and compiled-code include unrelocatable executable codes, and the rereading packages damages the consistency among symbols.

print *obj &optional stream* [function]
is **prin1** followed by **terpri**.

prin1 *obj &optional stream* [function]
outputs one s-expression in the format that they can be read back again by **read**. The format includes slashes (escapes) and quotation marks.

princ *obj &optional stream* [function]
same as **print** except that **princ** does not add escape or quote. Objects printed by **princ** cannot be read back. For example, the output of `(princ 'abc)` is identical with that of `(princ "abc")` and the reader cannot distinguish between them.

terpri *&optional stream* [function]
outputs #\newline and flush *stream*.

finish-output *&optional stream* [function]
flushes output stream.

princ-to-string *x &optional (l 16)* [function]

prin1-to-string *x &optional (l 16)* [function]
makes a string-output-stream, writes to it, and get-output-stream-string.

format *stream format-string &rest args* [function]
Format only recognizes ~A(ascii), ~S(S-expression), ~D(decimal), ~X(hexadicimal), ~O(octal), ~C(character), ~F(floating), ~E(exponential), ~G(general float), ~V(dynamic number parameter), ~T(tab) and ~%(newline) format specifiers.

```
(format t "~s ~s ~a ~a ~10,3f~%" "abc" 'a#b "abc" 'a#b 1.2)
--->  "abc" |A#B| abc a#b     1.200
```

pprint *obj &optional (stream *standard-output*) (tab 0) (platen 75)* [function]
pretty-prints *obj*.

print-functions *file &rest fns* [function] write the "defun" forms of function definitions of *fns* out to *file*.

write-byte *integer stream* [function]

write-word *integer stream* [function]

write-long *integer stream* [function]
write *integer* as a one-, two- or four-byte binary.

spaces *n &optional stream* [function]
outputs spaces *n* times.

pf *func &optional stream *standard-output*)* [macro]
pretty-prints a function. Compiled function cannot be printed.

pp-method *class selector &optional (stream *standard-output*)* [function]
pretty-prints the method defined in *class* by the name of *selector*.

tprint *obj tab &optional (indent 0) (platen 79) (cpos 0)* [function]
print *obj* in tabular format.

print-size *obj* [function]
returns inexact length of obj when it is printed.

11.4 InterProcess Communication and Network

EusLisp provides four kinds of IPC facilities, *shared memory, message-queue, FIFO* and *socket.* [2] Normally, efficiency decreases in this order. If you are using multithread facility, synchronization functions described in the section 14 are also used for communications. Availability of these facilities depends on the configuration and the version of Unix.

11.4.1 Shared Memory

EusLisp supports the shared memory provided by SunOS's mmap, not by System5's shmem. Shared memory is allocated by the **map-file** function. **Map-file** maps a file into the EusLisp process memory space and an instance of **foreign-string** is returned. Data can be written and retrieved using string functions on this foreign-string. Since shared memory is allocated at system-dependent page boundary, you should not specify the map address. Mapping a file with the **:share** keyparameter set to NIL or **:private** set to T means the file should be accessed privately (exclusively). Since this is not useful for the purpose of memory sharing, the default value of **:share** key is T. When a file is shared between two users, the read/write permission must be properly set for both users. Unfortunately, SunOS does not support file sharing through networks between different workstations.

Example programs to share a file of 64 byte length between two euslisp are shown below.

```
;; Create a file of 64 bytes
(with-open-file (f "afile" :direction :output)  (princ (make-string 64) f))
;; Map it
(setq shared-string1 (map-file "afile" :direction :io))
;;
;; In another process
(setq shared-string2 (map-file "afile" :direction :io))
```

Then, data written to `shared-string1` immediately appears in `shared-string2`, and vice versa. Writing to a foreign string can be made by **replace** or **setf** in conjunction with **aref**.

map-file *filename &key (direction :input) length (offset 0) (share t) (address 0)* [function]
maps the file named *filename* to memory space. *Filename* can be either of a local file, an NFS-mounted remote file, or a memory device in `/dev`. A **f**oreign-string, whose elements can be accessed by **aref**, is returned. Writing data into a foreign-string mapped by `map-file` with *direction=:input* will result a segmentation fault.

11.4.2 Message Queues and FIFOs

A message-queue is created by **make-msgq-input-stream** or **make-msgq-output-stream**. Each of these returns an instance of file-stream, which can then accept read and print operations like other streams connected to files. The `fname` slot of message-queue stream is set to the key when it is created.

To make a stream to FIFO, you first create a FIFO node with **unix:mknod** function by setting its second argument *mode*=#o10000, and you open it as a normal file. Message-queues and FIFOs are created locally on a machine and only provide communication channels within the machine.

Note that message-queues and FIFOs are not removed from the system even after the owner process terminates. Explicit use of **unix:msgctl** or **ipcrm** command is needed to delete them.

make-msgq-input-stream *key &optional (buffer-size 128)* [function]
returns an input file-stream which is connected to a message-queue identified by *key*.

make-msgq-output-stream *key &optional (buffer-size 128)* [function]
returns an output file-stream which is connected to a message-queue identified by *key*.

[2]Since the pipe, the traditional process communication mechanism in Unix, is always used in conjunction with 'fork', EusLisp provides the **piped-fork** function explained in the section 13.3.

11.4.3 Sockets

The socket is more versatile than other communication mechanisms because it can operate either host-locally (in unix domain) or network-widely (in internet domain). Connection-oriented socket (SOCK_STREAM) and unconnected socket (SOCK_DGRAM) are supported. In both cases, you must first create a socket address object by **make-socket-address** function, which returns an instance of `socket-address`. In unix domain, a socket address is specified by a path-name in the unix file system. In internet domain, the address is specified by combining the host machine name, the port number, and optionally the protocol number. If the port number is defined in `/etc/services`, it can be referred through the symbol specified by the service name. The function **unix:getservbyname** can be used to retrieve the port number from the symbolic service name. Port numbers less than 1024 are reserved for root users, and non-priviledged users are advised to use port numbers greater than 1024 for their private sockets.

Although connected streams provide bidirectional communication channels, the connection establishment operation is asymmetric. One endpoint is refered to server and other to client. The endpoint on the behalf of the server (service access point) must be first established. It is created by **make-socket-port** function which returns an instance of `socket-port`. The socket-port object is then used to accept connections from one or more clients by **make-server-socket-stream**. A call to **make-server-socket-stream** may be blocked until a connection request from a client really happens. Clients can make socket streams by **make-client-socket-stream** specifying a socket-address.

```
;;; an example of IPC through a socket stream:
;;; server side
(setq saddr  (make-socket-address :domain af_inet :host "etlic2" :port 2000))
(setq sport  (make-socket-port saddr))
(setq sstream (make-server-socket-stream sport))
;;;
;;; client side
(setq caddr (make-socket-address :domain af_inet :host "etlic2" :port 2000))
(setq cstream (make-client-socket-stream caddr))
```

In applications like a database or an environment simulator for mobile robots, *multiple connection service* between one server and many clients is required. This type of server can be programmed by the **open-server** function. From the current host name and given port number, **open-server** creates a socket port (service access point) on which connection requests are listened for. Since this port is attributed to be asynchronous, **open-server** is not blocked and returns immediately. Thereafter, each connection request interrupts EusLisp's main loop, and an socket-stream is created asynchronously. This socket-stream also works in asynchronous mode: the asynchronous input processing function which is the second argument to **open-server** is invoked whenever new data appear in this stream. Up to 30 connections can be established so that as many clients can access the server's data at the same time.

```
;; server side
(defun server-func (s)
   (case (read s) ...    ;do appropriate jobs according to inputs
(open-server 3000 #'server-func)
... do other jobs in parallel
;; client-1 through client-N
(setq s (connect-server "etlmmd" 3000))
(format s "..." ...) (finish-output s) ;issue a command to the server
(read s)                                 ;receive response
```

In contrast to the *connection-oriented* streams which provide reliable communication channels, the *connectionless* sockets are unreliable: messages may be lost, duplicated, and may arrive out-of-order. The *connectionless* sockets, however, have advantages that they do not need to assign file descriptor to each connection, and sending process is never blocked even if the receiver is not reading data and the buffer overflows.

To make connectionless sockets, use the following procedures. Messages are transferred by the **unix:sendto** and **unix:recvfrom**.

```
;;; receiver side
```

```
(setq saddr  (make-socket-address :domain af_inet :host "etlic2" :port 2001))
(setq sock   (make-dgram-socket saddr))
(unix:recvfrom sock)
;;;
;;; client side
(setq caddr (make-socket-address :domain af_inet :host "etlic2" :port 2001))
(setq sock (unix:socket (send caddr :domain) 2 0))
(unix:sendto sock caddr "this is a message")
;;;
;;; how to use echo service which is registered in /etc/services.
(setq caddr (make-socket-address :domain af_inet :host "etlic2"
                                 :port (car (unix:getservbyname "echo"))))
(setq echosock (unix:socket (send caddr :domain) 2 0))
(unix:sendto echosock caddr "this is a message")
(unix:recvfrom echosock)  --> "this is a message"
```

make-socket-address *&key domain pathname host port proto service* [function]
makes a sockaddr structure.

make-socket-port *sockaddr* [function]
makes a server-side socket port which is used to establish a connection with a client.

make-server-socket-stream *sockport &optional (size 100)* [function]
accepts a connection from a client and returns a two-way stream.

make-client-socket-stream *sockaddr &optional (size 100)* [function]
connects to a server port and returns a two-way stream.

open-server *port remote-func* [function]
prepares a socket port designated by the host name and *port* in internetnet domain, and waits for the connection requests asynchronously. Each time a connection is requested, it is accepted and a new socket-stream is opened. When a message arrives at the socket-port, *remote-func* is invoked with the socket port as the argument.

connect-server *host port* [function]
This is a shorhand of successive calls to make-socket-address and make-client-socket-stream. A socket-stream for a client to communicate with the server specified by *host* and *port* is returned. The port is made in internet domain.

11.5 Asynchronous Input/Output

select-stream *stream-list timeout* [function]
finds a list of streams which are ready for input operation, in *stream-list*. NIL is returned if *timeout* seconds have expired before any streams become ready. **Select-stream** is useful when you choose active streams out of a list of input-streams on which input operation becomes possible asynchronously. *Timeout* specifies the time when the select operation is aborted. It can be a float number. If no timeout is specified, select-stream blocks until input arrives at least one stream. If *timeout* is specified and no input appears on any streams, select-stream aborts and returns NIL.

def-async *stream function* [macro]
defines *function* to be called when data arrives at *stream*. *stream* is either a file-stream or a socket-port. When data comes to the file-stream or a connection request appears on the socket-port, *function* is invoked with the stream as its argument. This macro installs a SIGIO handler that dispatches to user supplied *function* which is expected to perform actual input operation, and uses **unix:fcntl** on *stream* to issue SIGIO asynchronously when *stream* becomes ready to be read.

11.6 Pathnames

Pathnames give the way to analyze and compose file names OS-independently. A typical path name is assumed to be consisted of following components: host:device/directory1/.../directory-n/name.type.version. Since EusLisp only runs on Unix, host, device and version fields are ignored. The **pathname** function decomposes a string into a list of directory components, name and type, and returns a pathname object, which is printed as a string prefixed by `#P`.

pathnamep *name* [function]
returns T if *name* is a pathname.

pathname *name* [function]
name is pathname or string. *name* is converted to pathname. To indicate the last name is a directory name, don't forget to suffix with "/". The inverse conversion is performed by *namestring*.

pathname-directory *path* [function]
returns a list of directory names of *path*. Root directory (/) is represented by :ROOT. *path* can be either of string or pathname.

pathname-name *path* [function]
returns the file-name portion of *path*. *path* can be either of string or pathname.

pathname-type *path* [function]
extracts the file-type portion out of *path*. *path* can be either of string or pathname.

make-pathname *&key host device directory name type version defaults* [function]
makes a new pathname from *directory*, *name* and *type*. On unix, other parameters are ignored.

merge-pathnames *name &optional (defaults *default-pathname-defaults*))* [function]

namestring *path* [function]
returns string representation of *path*.

parse-namestring *name* [function]

truename *path* [function]
tries to find the absolute pathname for the file named *path*.

11.7 URL-Pathnames

URL-Pathname is an extension of pathname to have slots for a protocol and a port. A URL is composed of six components; protocol, server, port, directories, filename, and file-type, like `http://shock2.etl.go.jp/matsui/index.htm`

url-pathname *name* [function]
name is pathname or string. *name* is converted to pathname. To indicate the last name is a directory name, don't forget to suffix with "/". The inverse conversion is performed by *namestring*.

11.8 File-name generation

digits-string *n digits &optional (base 10))* [function]
generates a string representing the integer *n* in n columns of digits. Zeros are padded before the number if n is too small to represent in digits.

sequential-file-name *head num extension &optional (digits 4))* [function]
generates a filename string with an advancing number part. This is similar to gentemp, but differs in that an extension can be specified and the result is a string.

timed-file-name *head extension &optional (dt (unix:localtime)))* [function]
generates a filename string that consists of head, hour, minute, second, and extension. For example, (timed-file-name "img" "jpg") generates "img191015.jpg" at 7:10:15 pm.

dated-file-name *head extension &optional (dt (unix:localtime)))* [function]
generates a filename string formatted as "headyymmmdd.extension", where yy is the lower two digits of the year, mmm is the abbreviated month name, and dd is the date.

11.9 File System Interface

probe-file *path* [function]
checks if a file named *path* exists.

file-size *path* [function]
returns the size of the file named *path* in bytes.

directory-p *path* [function]
returns T if *path* is a directory, NIL otherwise even *path* does not exist.

find-executable *file* [function]
returns the full pathname for the Unix command named *file*. *Find-executable* provides almost the same functionality with Unix's 'which' command that searches the executable file in your path list.

file-write-date *file* [function]
returns the integer representation of the time when the *file* was last modified. String representation can be obtained by `(unix:asctime (unix:localtime (file-write-date` *file*`)))`

file-newer *new old* [function]

returns T if the *new* file is modified more recently than the *old* file.
object-file-p *file* [function]
returns T if the *file* is an object file by looking at the file's magic number in the header.

directory *&optional (path ".")* [function]
makes a list of all the files in the *path*.

dir *&optional (dir ".")* [function]
prints file names in the specified directory.

12 Evaluation

12.1 Evaluators

In order to specify the behaviors upon an error and an interrupt(signal), set an appropriate function to each of the special variables ***error-handler*** and ***signal-handler*** in advance. There is no correctable or continue-able error. After analyzing errors you must abort the current execution by **reset** or appropriate **throw** to upper level catchers. **reset** is equivalent to `(throw 0 NIL)`, since EusLisp's top-level creates catch frame named `0`.

Error handlers should be programmed as functions with three or four arguments: *code msg1 form &optional (msg2)*. *Code* is the error code which identifies system defined errors, such as 14 for 'mismatch argument' or 13 for 'undefined function'. These mappings are described in "c/eus.h". *msg1* and *msg1* are messages displayed to the user. *form* is the S-expression which caused the error.

Signal handlers should be programmed as functions receiving two arguments: *sig* and *code*. *Sig* is the signal number ranging from 1 to 31, and *code* is the minor signal code defined in signal-number dependent manners.

^D (*end-of-file*) at the top-level terminates eus session. This is useful when eus is programmed as a filter.

Eval-dynamic is the function to find the dynamic value bound to a symbol used as a let or lambda variable. This is useful for debugging.

identity *obj* [function]
returns obj itself. Note the difference between **identity** and **quote**. **identity** is a function whereas **quote** is a special form. Therefore, `(identity 'abc)` is evaluated to `abc` and `(quote 'abc) == (quote (quote abc))` is evaluated to `'abc`. **Identity** is often used as the default value for `:key` parameters of many generic sequence functions.

eval *form [environment]* [function]
evaluates form and returns its value. Hook function can be called before entering the evaluation, if ***evalhook*** is set to some function that accept form and environment.

apply *func &rest args* [function]
func is applied to *args*. *Func* must be evaluated to be a function symbol (a symbol which has a function definition), a lambda form, or a closure. Macros and special forms cannot be applied. The last element of *args* must be a list of arguments while other args should be bare arguments. Thus, if the last *args* is NIL, then apply is almost equivalent to funcall, except that apply has one more arguments than funcall. `(apply #'max 2 5 3 '(8 2)) --> 8`.

funcall *func &rest args* [function]
applies *func* to *args*. The number of *args* must coincide to the number of arguments the *func* requests.

quote *obj* [special]
evaluates to *obj* itself.

function *func* [special]
makes a function closure. If *func* is a symbol, its function definition is retrieved.

evalhook *hookfunc form [env]* [function]
evaluates *form* once after binding *hookfunc* to ***evalhook***.

eval-dynamic *variable* [function]
finds the value of *variable* (symbol) on the stack.

macroexpand *form* [function]
expands *form* if it is a macro call. If *form* is expanded to a macro call again, expansion is repeated until non macro call results.

eval-when *situation* {*form*}* [special]
Situation is a list of `compile, load and eval`. Forms are evaluated when the current execution

mode matches with situation. **eval-when** is important to control the behavior and environment of the compiler. If `compile` is specified, *forms* are evaluated by the compiler so that the result will affect the consequent compilation. For example, *defmacro* should be evaluated by the compiler in order to let the compiler expand macro calls at compile time. If `load` is given in the *situation* list, *forms* are compiled to be loaded (evaluated) at load time, i.e., compiled functions are defined at load time. This is the normal effect that we expect to the compiler. `load` situation is used to control the compiler's environment. If `eval` is included in situation list, *forms* are evaluated when their source code is loaded.

the *type form* [special]

Declares *form* is of *type*. *type* is either a class object, :integer, :fixnum, or :float.

declare *declaration** [special]

Each *declaration* is a list of a declaration specifier and an integer or target symbols. Declarations are important to let the compiler produce faster code.

special declares special variables

type declares the type of variables; `(type integer count)`; valid type specifiers are *integer*, :integer *fixnum*, :float and *float*. The **type** keyword may be omitted if type specifier is either one listed here. So `(integer count)` is a correct declaration. Other types (classes) such as *float-vector*, *integer-vector*, etc. need to be preceded by **type**, as `(type float-vector vec1)`.

ftype declares the result type of functions

optimize set *optimize* parameter (0–3) of the compiler

safety set *safety* parameter (0–3) of the compiler

space set *space* parameter (0–3) of the compiler

inline not recognized

not-inline not recognized

proclaim *proclamation* [function]

globally declares the types of variables and compiler options. The same declarations are accepted as described for **declare** special form. However, **proclaim** is a function of one argument and proclamation is evaluated.

warn *format-string &rest args* [function]

prints warning-message given as *format-string* and *args* to *error-output*.

error *format-string &rest args* [function]

calls the current error-handler function bound to ***error-handler***. The default error-handler 'euserror' first prints arguments to ***error-output*** using **format**, then enters a new top level session. The prompt shows you the depth of your error session. **Throw**ing to the number, you can go back to the lower level error session.

In the multithread EusLisp, special variables are shared among threads and the same ***error-handler*** is referenced by different threads. To avoid this inconvenience, multithread EusLisp provides the **install-error-handler** function which installs different error handler for each thread.

install-error-handler *handler* [function]

installs the *handler* as the error handler of the current thread.

12.2 Top-level Interaction

EusLisp's standard top-level read-eval-print loop is controlled by **eustop**. When EusLisp is invoked, **eustop** tries to load the file named `".eusrc"` in your home directory or the file specified by the `EUSRC` environment variable. It also tries to load a file named `".eusrc"` in the current working directory. So, if you are in your home directory, note that .eusrc is loaded twice. Then EusLisp loads files specified in its argument list. After these loading, **eustop** enters normal interactive session.

When ***standard-input*** is connected to user's tty, **eustop** prints prompt generated by the **toplevel-prompt** function. The default toplevel-prompt prints `"eus$ "`. The effect of changing the definition of toplevel-prompt appears when eustop is invoked next time. One way to change the prompt from the first time is to define toplevel-prompt in your `.eusrc` file.

Inputs are read from ***terminal-io*** stream. If the input is parenthesized, it is taken as a lisp form and is evaluated by **eval**. Else if the first symbol of the input line has function definition, the line is automatically parenthesized and evaluated. If no function definition is found, then its special value is examined and the value is printed. If the symbol is unbound, the line is regarded as UNIX command and passed to sh (Bourn's shell). If sh cannot find corresponding unix command, "command unrecognized" message is printed. Thus, **eustop** works both as a lisp interpreter and as a unix shell. If you do not wish to execute the input as UNIX command, you may escape the form by preceeding a comma ',' at the begining of the line. This is also useful to see the dynamic value binding when an error occured in the interpretive execution. Since EusLisp adopts lexical scope, we cannot examine the value of local variables outside of the scope unless they are declared special.

If the environment variable, **USE_TOP_SELECTOR**, is defined, the toplevel input is read in an asynchronous manner using the `select` library call. The input stream (`*standard-input*`) is registered to the `*top-selector*`, which is an instance of the **port-selector** class, together with the read-eval-print function (`repsel`) Therefore arrival of key inputs invokes the evaluation of the `repsel`. This feature is particularly useful when EusLisp is to handle multiple events, i.e., key inputs, X window events, and socket connection requests, at the same time. In order to exploit this asynchronous toplevel interaction, users should never write a code that blocks at the `read` operation. Instead, the input stream should be registered to the `*top-selector*` with its handler function by using the `:add-port` method. The handler function is expected to read from the stream, which is already known ready to return the input without blocking.

Note that Xwindow event handlers are defined to use the `*top-selector*` implicitly when `USE_TOP_SELECTOR` is defined, and user programs do not have to call `x:window-main-loop` at all to catch X events.

Using the time-out of the select call, users may define a timer handler. Each time the select call times out, the function bound to `*timer-job*` is invoked with no argument. The timer interval is defined by *top-selector-interval*, which is defaulted to 10.0 second. Note that the timer function invokation is not precisely periodic when there are inputs to the *top-selector*.

In the toplevel interaction, each line input is remembered in ***history*** vector with a sequence number. You can recall a specific input by **!** function as if you were in csh. The difference from csh's history is, you need at least one white space between the exclamaition mark and the sequence number since **!** is a function, and you can edit the line interactively with control keys, as in emacs.

^D (EOF) terminates EusLisp normally. To return abnormal termination code to upper level (usually a csh), use **exit** with an appropriate condition code.

eustop sets a signal handler only for SIGINT and SIGPIPE, and other signals are not caught. Thus, signals such as SIGTERM or SIGQUIT cause EusLisp to terminate. In order to catch these signals to avoid termination, use **unix:signal** function to set user-defined signal handlers.

- [variable]

current input.

+ [variable]

previous input.

++ [variable]

old input.

+++ [variable]

ancient input.

***** [variable]
previous result.

****** [variable]
old result.

******* [variable]
ancient result.

prompt-string [variable]
prompt string used by **eustop**.

program-name [variable]
the command that invoked this EusLisp, possibly eus, eusx, eusxview or user-saved euslisp.

eustop *&rest argv* [function]
is the default toplevel loop.

eussig *sig code* [function]
is the default signal hander for SIGPIPE. **eussig** prints signal number upon its arrival and enters another toplevel loop.

sigint-handler *sig code* [function]
is the default signal handler for SIGINT (control-C). It enters a new top level session.

euserror *code message &rest arg* [function]
the default error handler that prints *message* and enters a new error session.

reset [function]
quits error loop and goes back to the outermost eustop session.

exit *&optional termination-code* [function]
terminates EusLisp process and returns *termination-code* (0..255) as the process status code (0..255).

top-selector [variable]
The port-selector object to handle asynchronous function invocation according to inputs from multiple streams.

h [function]
prints all the inputs remembered in ***history*** vector with associated sequence numbers.

! *&optional (seq 0)* [function]
recalls the input line associated with the sequence number *seq*. When *seq* is 0, the most recent command is recalled, and if *seq* is negative, the line is specified relatively to the current input. The recalled line is printed and the cursor is located at the end of the line. You can go backward by control-H (backspace) or control-B, go forward by control-F or control-K, go to the beginning of line by control-A, to the end of line by control-L. control-C cancels the line editing. control-M (carriage-return) or control-J (line-feed) finishes editing the line and starts evaluation of the edited line. If *seq* is not a number and is a symbol or a string, the history list is searched toward old input, and a command line which include the symbol or a string as a substring is returned.

new-history *depth* [function]
initializes ***history*** vector to have *depth* length. *Depth* input lines are remembered. All the input lines recorded in the current ***history*** are discarded.

12.3 Compilation

EusLisp compiler is used to speed the execution of Lisp programs. You can expect 5 to 30 times faster execution and notable reduction of garbage collection time elapsed by macro expansion.

Euscomp does optimization for arithmetic operation and vector access. Sometimes proper type declarations are needed to inform the compiler applicability of optimization.

Compile-function compiles functions one by one. **Compile-file** compiles an entire source file. During the execution of **Compile-file**, each form in a file is read and evaluated. This may change the current EusLisp environment. For examples, **defparameter** may set a new value to a symbol and **defun** may substitute the existing compiled function with its non-compiled version. To avoid these unexpected effects, use the **eval-when** special form without compile time situation, or use **euscomp** command to run the compiler as a separate process.

Euscomp is a unix command, which is usually a symbolic link to **eus**. It recognizes several options. -O flag indicates optimization of the C compiler. Each of -O1,-O2, -O3 indicates optimization level of EusLisp compiler, which is equivalent to proclaiming (optimize 1 or 2 or 3). Each of -S0, -S1, -S2, -S3 set 0,1,2 and 3 to compiler:*safety*. If *safety* is less than 2, no code for checking interrupt is emitted, and you will lose control if the program enters an infinite loop. If *safety* is zero, the number of required arguments is not checked. -V flag is used to print function names when they are compiled (verbose). -c flag prevents from forking and exec'ing cc. -D pushes next argument to the ***features*** list, which can be used for conditional compilation in conjunction with #- and #+ read-macro.

The compiler translates EusLisp source program named as "xxx.l" into the intermediate C program file named "xxx.c" and the header file named "xxx.h". Then the C compiler is run and "xxx.o" is generated. Intermediate files "xxx.c" and "xxx.h" are left for the purpose of cross compilation: usually you only need to compile "xxx.c" files by cc unix command when you wish to use the code on machines of different architecture. Compiled code is loaded to EusLisp by '(load "xxx")'.

Each intermediate file refers to the "eus.h" header file, which is supposed to be located in the `*eusdir*/c` directory. `*eusdir*` is copied from the `EUSDIR` environment variable. If none is set, `/usr/local/eus/` is taken as the default directory.

When compiled, intermediate C programs are usually much bigger than the original source code. For example, 1,161 lines of "l/common.l" lisp source expands to 8,194 lines of "l/common.c" and 544 lines of "l/common.h". Compiling 1,000 lines of lisp source is not a hard task, but optimized compililation of nearly 10,000 lines of C program not only takes long time (several minutes), but also consumes much disk space. So if you are compiling relatively big programs, be sure your machine has sufficient /var/tmp disk, otherwise CC may die. Setting the `TEMPDIR` environment variable to a bigger disk slice may help.

As the linkage is performed at load-time or at run-time, no recompilation is required even the eus kernel is updated. On the other hand, run-time linkage may impose you another inconvenience. Suppose you have two functions A and B in a file "x.l" and A calls B. After compiling "x.l", you load "x.o" and tries to call A which internally calles B. Then you find a bug in B, and probably you would redefine B. Here, you have compiled A and non-compiled B. You may call A again, but nothing will change, since A still calls old compiled B which is linked regidly when A first called B. To avoid this problem, A must be redefined again, or B must be redefined just after "x.o" is loaded and before A is called.

When a compiled-code is loaded, its top level code, which is normally a series of defun, defmethod, etc., is excuted. This top level code is defined as the entry function of the load module. The compiler names the entry function, and the loader has to know the exact name of this function. To make the situation simple, both the compiler and the loader assume the entry function name is identical to the basename of the object file. For example, if you are compile and load "fib.l", the compiler produce "fib(...)" as the entry function of "fib.c", and the loader looks for "fib" in the "fib.o" object file. Since the final object file is produced by "cc" and "ld" of unix, this entry function name has to satisfy the naming rule of C functions. Therefore, you have to avoid C's reserved keywords such as "int", "struct", "union", "register", "extern", etc., or the private identifiers defined in "c/eus.h" such as "pointer", "cons", "makeint", etc., to be used as the name of the file. If you have to use one of these reserved words as the name of the source file, you specify it for *:entry* arguments of the compiler and the loader.

A restriction exists for the usage of closure: **return-from** special form in closures and clean-up forms in unwind-protect is not always correctly compiled.

Disassemble is not implemented. In order to analyze compiled code, see the intermediate C program or use `adb`.

euscomp {*filename*}* [unix-command]

Invokes EusLisp compiler.

compile-file *srcfile &key* *(:verbose nil)* [function]

(:optimize 2) (:c-optimize 1) (:safety 1)	;optimization level
(:pic t)	;generate position independent code to build library
(:cc t)	; run c compiler
(:entry (pathname-name file))	

compiles a file. ".l" is assumed for the suffix of the *srcfile*. If *:verbose* is T, names of functions and methods being compiled are printed to make it easy to find the expressions where errors occurred. *:Optimize, :c-optimize* and *:safety* specifies the optimization levels. *:Pic* should be set T, unless the module is hard-linked in the EusLisp core during the make stage.

compile *funcname* [function]

compiles a function. **Compile** first prints the function definition into a temporary file. The file is compiled by **compile-file** and then is loaded by **load**. Temporary files are deleted.

compile-file-if-src-newer *srcfile &key compiler-options* [function]

compiles the *srcfile* if it is newer (more recently modified) than its corresponding object file. The object file is supposed to have the ".o" suffix.

optimize [variable]

controls optimization level.

verbose [variable]

When set to non-nil, the name of a function or a method being compiled, and the time required for the compilation are displayed.

safety [variable]

controls safety level.

12.4 Program Loading

load *fname &key* *:verbose* **load-verbose**
:package **package**
:entry *(pathname-name fname)*
:symbol-input *"/usr/local/bin/eus"*
:symbol-output *"a.out"*
:print *nil*
:ld-option *""*

Load is the function to read either a source file or an compiled object file into the EusLisp process. If the file specified by *fname* exists, it is loaded. Whether the file is source or binary is automatically checked by seeing its magic number. If the file does not exist but a file with the file type '.o' exists, the file is loaded as an object file. on Sun based systems. Else if a file with the '.l' suffix is found, it is loaded as a source program. Therefore, there is a case where you specified "foo.so" expecting "foo.l" is already compiled, but "foo.l" is actually loaded, since it has not yet been compiled in reality. In other words, if you just specify a base-name of a file, its compiled version is first tried to be loaded, and the source file suffixed by ".l" is tried later. If the file name is not specified in the absolute path by prefixing the name with a slash "/",

load searches for the file in the directories specified by the ***load-path*** global variable. For example, if `*load-path*` is `("/user/eus/" "/usr/lisp/")`, and `"llib/math"` is given as *fname*, **load** tries to find `"/user/eus/llib/math.o", "/usr/lisp/llib/math.o", "/user/eus/llib/math.l"` and `"/usr/lisp/llib/mat` in this order. If no appropriate file could be found, an error is reported.

:entry option specifies the entry address to initialize the load module. For example, `:entry "_myfunc"` option means that the execution begins at `_myfunc`. Default entry is the basename of the file loaded as described in the section 12.3. Library module names can be specified in **:ld-option** option string. For example, in order to link a module which uses suncore libraries, **:ld-option** `"-lsuncore -lsunwindow -lpixrect -lm -lc"` should be given. On non Solaris systems, ld runs twice when libraries are included; once to determine the size of the linked module, and again to link them actually with a proper memory allocation.

:symbol-input and **:symbol-output** options are used to solve references from one object module to another or to avoid duplicated loading of libraries. Suppose you have two object modules A and B which has reference to symbols defined in A. You first load the module A specifying `:symbol-output = "a.out"`. Symbol information generated by this linking is written to `a.out`. In order to load the module B, you have to specify `:symbol-input = "a.out"` to solve the references from B to A.

On Solaris2 OS, the loading of compiled code is done by calling *dlopen* in the dynamic loader library. Application of *dlopen* is restricted to shared objects which are compiled position independently with "-K pic" option. Also, since *dlopen* cannot open the same file twice, load first does *dlclose* on the file already loaded.
:print option decides whether load should produce output to *standard-output* for each input expression. This option is provided to find which expression (usually defun, defmethod, etc.) results error in loading.

load-files *&rest files* [function]

loads *files* successively with setting `:verbose` to T.

modules [variable]

holds a list of names of the modules that have been loaded so far.

provide *module-name* [function]

adds *module-name* in `*modules*` as the name of the module being loaded. *module-name* should be a symbol or a string. Calls to **require** should appear at the beginning of files that compose a complete modules.

require *module-name &optional file* [function]

loads *file* unless *module-name* is found in `*modules*`. **provide** and **require** control dependency among modules and are used to avoid duplicated loading of basic modules. Suppose you have one basic module named "A" and two application modules named "B" and "C" which are independent from each other but rely on "A" module. At the beginning of each file, module name is declared by **provide**. Since "A" module does not depend on any other modules it does not **require** anything. `(require "A" "a.o")` follows calls to **provide** in "B" and "C". If you load "B" (more precisely, "b.o"), "a.o" is also loaded since it is found in `*modules*` and two module names "A" and "B" are added to `*modules*`. Then if you load "C", "A" module is not loaded and "C" is added to `*modules*`.

system:binload *opath qpath &optional (entry (pathname-name opath))*
(symfile "/usr/local/bin/eus")
(symout "a.out")
(ldopt "") [function]

link-load a binary file.

system:txtload *fname* [function]

12.5 Debugging Aid

describe *obj &optional (stream *standard-output*)* [function]

Describe prints the contents of an object slot by slot.

describe-list *list &optional (stream *standard-output*)* [function]

describes each element in *list*.

inspect *obj* [macro]

Inspect is the interactive version of **describe**. It accepts subcommands to print each slot of an object, to go deeper into a slot, or set a new value to a slot, etc. Use '?' command to see the subcommand menu.

more *&rest forms* [function]

After evaluating forms with the binding of *standard-output* to a temporary file, the temporary file is output to *standard-output* with Unix's 'more' command. **More** is useful to see a long output generated by functions like **describe**.

break *&optional (prompt ":: ")* [function]

Enters a break loop. Since the current binding context is in effect, local variables can be seen by prefixing "," to an input. To end break, type control-D.

help *topic* [function]

Help prints the brief description on the topic which is usually a function symbol. The help description has been created from the reference manual (this document). The environment variable `LANG` is referrenced to determine one of two reference manuals, Japanese or English. If `LANG` is constituted either with `"ja", "JA", "jp"`, or `"JP"`, Japanese is selected. Otherwise, English. This determination is made when EusLisp start up. The actual reading of the help document is made at the first time when the 'help' is invoked to save memory if unnecessary.

apropos *key* [function]

Apropos is useful when you forget the exact name of a function or a variable and you only know its partial or ambiguous name. It prints all the symbols whose symbol-names include the *key* as a substring. Case insensitive.

apropos-list *key* [function]

is similar to **appropos** but does no printing and returns the result as a list.

constants *&optional (string "") (pkg *package*)* [function]

lists every symbol in pkg which has defined constant and matches with *string*.

variables *&optional (string "") (pkg *package*)* [function]

lists every symbol in pkg which has global value assigned and matches with *string*.

functions *&optional (string "") (pkg *package*)* [function]

lists every symbol in pkg which has global function defined and matches with *string*.

btrace *&optional (depth 10)* [function]

prints call history of *depth* levels.

step-hook *form env* [function]

step *form* [function]

Step and **trace** work correctly only for functions, and not for macro or special forms.

trace *&rest functions* [function]

begins tracing of *functions*. Each time functions are called, their arguments and results are prited.

untrace *&rest functions* [function]

stops tracing.

timing *count &rest forms* [macro]

executes *forms* count times, and calculates time required for one execution of forms.

time *function* [macro]

begins measurement of time elapsed by *function*.

sys:list-all-catchers [function]

returns a list of all **catch** tags.

sys:list-all-instances *aclass [scan-sub]* [function]

scans in the overall heap, and collects all the instances of the specified class. If *scan-sub* is NIL, then instances of exactly the *aclass* are listed, otherwise, instances of *aclass* or its subclasses are collected.

sys:list-all-bindings [function]

scans bind stack, and returns a list of all the accessible value bindings.

sys:list-all-special-bindings [function]

scans the stack and list up all value bindings.

12.6 Dump Objects

EusLisp's reader and printer are designed so that they can write any objects out to files in the forms that are rereadable. The objects may have mutual or recursive references. This feature is enabled when `*print-circle*` and `*print-object*` are set to T. Following functions set these variables to T, open a file, and print objects. The most important application of these functions is to dump the structures of 3D models that have mutual references.

dump-object *file &rest objects* [function]

dump-structure *file &rest objects* [function]

dumps objects to *file* in a format as they can be read back again.

dump-loadable-structure *file &rest symbols* [function]

dumps objects bound to symbols to *file*. The file can be read back again by simply loading it.

12.7 Process Image Saving

This process image saving is no longer supported on Solaris2 based EusLisp, since it heavily depends on Solaris's dynamic loading facility which loads shared objects position-independently above the `sbrk` point.

save *path &optional (symbol-file "") starter* [function]

Save dumps the current EusLisp process environment to a file which can be invoked as a Unix command later. If a function name is specified for *starter*, the function is evaluated when the command begins execution. Each command line argument is coerced to string in EusLisp and they are passed to *starter* as its arguments, so that it can parse the command line. Be sure that you have closed all the streams except ***standard-input*** and ***standard-output***. File open states cannot be saved. Also, be sure you have not attempted **mmap**, which unnoticeably happens when you make internetwork socket-stream. Sun's network library always memory-maps NIS information such as host-by-name table and locates them at the uppermost available location of a process that cannot be saved. When the saved image is run later, any access to the network library fails and causes core dump. Note that Xwindow also uses this library, thus you cannot save your process image once you opened connection to Xserver.

12.8 Customization of Toplevel

When EusLisp is invoked from Unix, execution is initiated by the toplevel function bound to ***toplevel***. This function is `eustop` in `eus` and `xtop` in `eusx`. You can change this toplevel function by specifying your own function to the third argument to **save**.

The toplevel function should be programmed to accept arbitrary number of arguments. Each argument on the command line is coerced to a string and transfered to the toplevel function. The program below repeatedly reads expressions from the file given by the first argument and pretty-prints them to the second argument file.

```
(defun pprint-copy (infile outfile)
  (with-open-file (in infile)
     (with-open-file (out outfile :direction :output)
        (let ((eof (cons nil nil)) (exp))
           (while (not (eq (setq exp (read in nil eof)) eof))
              (pprint exp out))))))
(defun pprint-copy-top (&rest argv)
   (when (= (length argv) 2)
      (pprint-copy (first argv) (second argv))))
```

Once you defined these functions in EusLisp, `(save "ppcopy" "" 'pprint-copy-top)` creates a unix executable command named `ppcopy`.

In Solaris based EusLisp, the toplevel evaluator cannot change in this manner, since **save** is not available. Instead, edit `lib/eusrt.l` to define the custom toplevel evaluator and set it to ***toplevel***. `lib/eusrt.l` defines initialization procedures evaluated at every invocation of the EusLisp.

12.9 Miscelaneous Functions

lisp-implementation-type [function]

returns `"EusLisp"`.

lisp-implementation-version [function]

returns the name, the version and the make-date of this EusLisp. This string is also printed at the opening of a session. `"MT-EusLisp 7.50 X 1.2 for Solaris Sat Jan 7 11:13:28 1995"`

Part II
EusLisp Extensions

13 System Functions

13.1 Memory Management

The design of memory management scheme affects much to the flexibility and efficiency of object-oriented languages. EusLisp allocates memory to any sort of objects in a unified manner based on the *Fibonacci buddy method*. In this method, each of large memory pools called chunks is split into small cells which are unequally sized but aligned at Fibonacci numbers. A memory chunk is a homogeneous data container for any types of objects such as `symbol, cons, string, float-vector`, etc. as long as their sizes fit in the chunk. A chunk has no special attributes, like static, dynamic, relocatable, alternate, etc. EusLisp's heap memory is the collection of chunks, and the heap can extend dynamically by getting new chunks from UNIX. The expansion occurs either automatically on the fly or on user's explicit demand by calling **system:alloc** function. When it is managed automatically, free memory size is kept about 25% of total heap size. This ratio can be changed by setting a value between 0.1 and 0.9 to the **sys:*gc-margin*** parameter.

When all the heap memory is exhausted, mark-and-sweep type garbage collection runs. Cells accessible from the root (packages, classes and stacks) remain at the same place where they were. Other inaccessible cells are reclaimed and linked to the free-lists. No copying or compactification occurs during GC. When a garbage cell is reclaimed, its neighbor is examined whether it is also free, and they are merged together to form a larger cell if possible. This merging, however, is sometimes meaningless, since `cons`, which is the most frequently called memory allocator, requests the merged cell to be divided to the smallest cell. Therefore, EusLisp allows to leave a particular amount of heap unmerged to speed up cons. This ratio is determined by **sys:*gc-merge*** parameter, which is set to 0.3 by default. With the larger **sys:*gc-merge***, the greater portion of heap is left unmerged. This improves the performance of consing, since buddy-cell splitting rarely occurs when conses are requested. This is also true for every allocation of relatively small cells, like three dimensional float-vectors.

SYS:GC invokes garbage collector explicitly, returning a list of two integers, numbers of free words and total words (not bytes) allocated in the heap. **SYS:*GC-HOOK*** is a variable to hold a function that is called upon the completion of a GC. The hook function should receive two arguments representing the sizes of the free heap and the total heap.

If "fatal error: stack overflow" is reported during execution, and you are convinced that the error is not caused by a infinite loop or recursion, you can expand the size of the Lisp stack by **sys:newstack**. **reset** should be performed before **sys:newstack**, since it discards everything in the current stack such as special bindings and clean-up forms of *unwind-protect*. After a new stack is allocated, execution starts over from the point of printing the opening message. The default stack size is 65Kword. The Lisp stack is different from the system stack. The former is allocated in the heap, while the latter is allocated in the stack segment by the operating system. If you get "segmentation fault" error, it might be caused by the shortage of the system stack. You can increase the system stack size by the `limit` csh command.

Sys:reclaim and **sys:reclaim-tree** function put cells occupied by objects back to the memory manager, so that they can be reused later without invoking garbage collection. You must be assured that there remains no reference to the cell.

memory-report and **room** function display statistics on memory usage sorted by cell sizes and classes respectively.

address returns the byte address of the object and is useful as a hash function when used with hash-table, since this address is unique in the process.

Peek and **poke** are the functions to read/write data directly from/to a memory location. The type of access should be either of **:char, :byte, :short, :long, :integer, :float** and **:double**. For an instance, `(SYS:PEEK (+ 2 (SYS:ADDRESS '(a b))) :short)` returns class id of a cons cell, normally 1.

There are several functions prefixed with 'list-all-'. These functions returns the list of a system resource or environment, and are useful for dynamic debugging.

sys:gc [function]

starts garbage collection, and returns a list of the numbers of free words and total words allocated.

sys:*gc-hook* [variable]
Defines a function that is called upon the completion of a GC.

sys:gctime [function]
returns a list of three integers: the count of gc invoked, the time elapsed for marking cells (in 1/60 sec. unit), and the time elapsed for reclamation (unmarking and merging).

sys:alloc *size* [function]
allocates at least *size* words of memory in the heap, and returns the number of words really allocated.

sys:newstack *size* [function]
relinquishes the current stack, and allocates a new stack of *size* words.

sys:*gc-merge* [variable]
is a memory management parameter. ***gc-merge*** is the ratio the ratio of heap memory which is left unmerged at GC. This unmerged area will soon filled with smallest cells whose size is the same as a cons. The default value is 0.3. The larger values, like 0.4, which specifies 40% of free heap should be unmerged, favors for consing but do harm to instantiating bigger cells like float-vectors, edges, faces, etc.

sys:*gc-margin* [variable]
is a memory management parameter. ***gc-margin** determines the ratio of free heap size versus the total heap. Memory is acquired from UNIX so that the free space does not go below this ratio. The default value 0.25 means that 25% of free space is maintained at every GC.

sys:reclaim *object* [function]
relinquishes *object* as a garbage. It must be guaranteed that it is no longer referenced from any other objects.

sys:reclaim-tree *object* [function]
reclaims all the objects except symbols traversable from *object*.

sys:btrace *num* [function]
prints the back-trace information of *num* depth on the Lisp stack.

sys:memory-report *&optional strm* [function]
prints a table of memory usage report sorted by cell sizes to the *strm* stream.

sys:room *output-stream* [function]
outputs memory allocation information ordered by classes.

sys:address *object* [function]
returns the address of *object* in the process memory space.

sys:peek *[vector] address type* [function]
reads data at the memory location specified by *address* and returns it as an integer. *type* is one of **:char, :byte, :short, :long, :integer, :float**, and **:double**. If no *vector* is given, the address is taken in the unix's process space. For example, since the a.out header is located at `#x2000` on SunOS4, `(sys:peek #x2000 :short)` returns the magic number (usually `#o403`). Solaris2 locates the ELF header at `#10000`, and `(sys:peek #x10000 :long)` returns `#xff454c46` whose string representation is "ELF".

If *vector*, which can be a foreign-string, is specified, address is recognized as an offset from the vector's origin. `(sys:peek "123456" 2 :short)` returns short word representation of "34", namely #x3334 (13108).

Be careful about the address alignment: reading short, integer, long, float, double word at odd address may cause bus error by most CPU architectures.

sys:poke *value [vector] address value type* [function]
writes *value* at the location specified by *address*. Special care should be taken since you can write to anywhere in the process memory space. Writing to outside the process space surely causes segmentation

fault. Writing short, integer, long, float, double word at odd address causes bus error.

sys:list-all-chunks [function]
list up all allocated heap chunks. Not useful for other than the implementor.

sys:object-size *obj* [function]
counts the number of cells and words accessible from *obj*. All the objects reference-able from obj are traversed, and a list of three numbers is returned: the number of cells, the number of words logically allocated to these objects (i.e. accessible from users), and the number of words physically allocated including headers and extra slots for memory management. Traversing stops at symbols, i.e. objects referenced from a symbol such as property-list or print-name string are not counted.

13.2 Unix System Calls

EusLisp assorts functions which directly correspond to the system calls and library functions of UNIX operating system. For further detail of these functions, consult UNIX system interface reference (2). These low-level functions defined in `*unix-package*` are sometimes dangerous. Use higher level functions defined in other packages if possible. For example, use IPC facilities described in the section 11.4 instead of `unix:socket, unix:bind, unix:connect`, and so on.

13.2.1 Times

unix:ptimes [function]
a list of five elements, elapsed time, system time, user time, subprocess's system time, subprocess's user time, is returned. Unit is always one sixtieth second. This function is obsolete and use of **unix:getrusage** is recommended.

unix:runtime [function]
Sum of the process's system and user time is returned. Unit is 1/60 second.

unix:localtime [function]
Current time and date is returned in an integer vector. Elements are second, minute, hour, day-of-a-month, year, weekday.

unix:asctime *tm_intvector* [function]
Converts localtime represented with an integer-vector into a string notation.
`(unix:asctime (unix:localtime))` returns a string representation of the current real time.

13.2.2 Process

unix:getpid [function]
returns the process id (16bit integer) of this process.

unix:getppid [function]
returns the process id of the parent process.

unix:getpgrp *integer* [function]
returns the process group id.

unix:setpgrp *integer* [function]
sets a new process group id.

unix:getuid [function]
gets user id of this process.

unix:geteuid [function]
returns the effective user id of this process.

unix:getgid [function]
returns the group id of this process.

unix:getegid [function]
returns the effective group id of this process.

unix:setuid *integer* [function]
sets effective user id of this process.

unix:setgid *integer* [function]
sets the effective group id of this process.

unix:fork [function]

creates another EusLisp. 0 is returned to the subprocess and the pid of the forked process is returned to the parent process. Use **system:piped-fork** described in section 13.3 to make a process connected via pipes.

unix:vfork [function]
forks another EusLisp, and suspends the parent process from execution until the new EusLisp process terminates.

unix:exec *path* [function]
replaces executing EusLisp with another program.

unix:wait [function]
waits for the completion of one of subprocesses.

unix:exit *code* [function]
terminates execution and returns *code* as its completion status. Zero means normal termination.

sys:*exit-hook* [variable]
Defines a function that is called just before the process is exited.

unix:getpriority *which who* [function]
returns the highest priority (nice value) enjoyed by this process. *Which* is one of 0(process), 1(process-group) or 2(user).

unix:setpriority *which who priority* [function]
sets priority of the resource determined by *which* and *who*. *which* is one of 0(process), 1(process-group) or 2(user). *who* is interpreted relative to *which* (a process identifier for *which* $= 0$, process group identifier for *which* $= 1$, and a user ID for *which* $= 2$. A zero value of who denotes the current process, process group, or user. To lower the priority (nice value) of your EusLisp process, `(unix:setpriority 0 0 10)` will sets the nice value to 10. Bigger nice value makes your process get less favored.

unix:getrusage *who* [function]
returns list of system resource usage information about *who* process. Elements are ordered as follows: More comprehensive display is obtained by **lisp:rusage**.

```
float ru_utime (sec.) /* user time used */
float ru_stime (sec.) /* system time used */
int  ru_maxrss;       /* maximum resident set size */
int  ru_ixrss;        /* currently 0 */
int  ru_idrss;        /* integral resident set size */
int  ru_isrss;        /* currently 0 */
int  ru_minflt;       /* page faults without physical I/O */
int  ru_majflt;       /* page faults with physical I/O */
int  ru_nswap;        /* number of swaps */
int  ru_inblock;      /* block input operations */
int  ru_oublock;      /* block output operations */
int  ru_msgsnd;       /* messages sent */
int  ru_msgrcv;       /* messages received */
int  ru_nsignals;     /* signals received */
int  ru_nvcsw;        /* voluntary context switches */
int  ru_nivcsw;       /* involuntary context switches */
```

unix:system *[command]* [function]
executes *command* in a sub shell. *command* must be recognizable by Bourn-shell.

unix:getenv *env-var* [function]
gets the value for the environment variable *env-var*.

unix:putenv *env* [function]
adds *env* in the process's environment variable list. *env* is a string which equates var to value like `"VARIABLE=value"`.

unix:sleep *time* [function]

suspends execution of this process for *time* seconds.

unix:usleep *time* [function]
suspends execution of this process for *time* micro-seconds (**u** represents micro). **Usleep** is not available on Solaris2 or other Sys5 based systems.

13.2.3 File Systems and I/O

unix:uread *stream [buffer] [size]* [function]
reads *size* bytes from *stream*. *stream* may either be a stream object or an integer representing fd. If *buffer* is given, the input is stored there. Otherwise, input goes to the buffer-string in *stream*. Therefore, if *stream* is fd, *buffer* must be given. **unix:uread** never allocates a new string buffer. **unix:uread** returns the byte count actually read.

unix:write *stream string &optional size* [function]
writes *size* bytes of *string* to *stream*. If *size* is omitted, the full length of *string* is output.

unix:fcntl *stream command argument* [function]

unix:ioctl *stream command buffer* [function]

unix:ioctl_ *stream command1 command2* [function]

unix:ioctl_R *stream command1 command2 buffer [size]* [function]

unix:ioctl_W *stream command1 command2 buffer [size]* [function]

unix:ioctl_WR *stream command1 command2 buffer [size]* [function]

unix:close *fd* [function]
close a file specifying its file descriptor *fd*.

unix:dup *fd* [function]
returns the duplicated file descriptor for *fd*.

unix:pipe [function]
creates a pipe. An io-stream for this pipe is returned.

unix:lseek *stream position [whence 0]* [function]
sets the file pointer for *stream* at *position* counted from *whence*.

unix:link *path1 path2* [function]
makes a hard link.

unix:unlink *path* [function]
removes a hard link to the file specified by *path*. If no reference to the file lefts, it is deleted.

unix:mknod *path mode* [function]
makes inode in a file system. *path* must be a string, not a pathname object.

unix:access *path mode* [function]
checks the access rights to *path*.

unix:stat *path* [function]
gets inode information of *path* and returns a list of integers described below.

```
st_ctime ; file last status change time
st_mtime ; file last modify time
st_atime ; file last access time
st_size ; total size of file, in bytes
st_gid ; group ID of owne
st_uid ; user ID of owner
st_nlink ; number of hard links to the file
st_rdev ; the device identifier (special files only)
st_dev ; device file resides on
st_ino ; the file serial number
st_mode ; file mode
```

unix:chdir *path* [function]
changes the current working directory to *path*.

unix:getwd [function]
gets current working directory.

unix:chmod *path integer* [function]
changes access mode (permission) for *path*.

unix:chown *path integer* [function]
changes the owner of the file *path*.

unix:isatty *(stream | fd)* [function]
returns T if *stream* is connected to a tty-type device (a serial port or a pseudo tty) .

unix:msgget *key mode* [function]
creates or allocates a message queue which is addressed by *key*.

unix:msgsnd *qid buf [mtype [flag]]* [function]

unix:msgrcv *qid buf [size [mtype [flag]]]* [function]

unix:socket *domain type &optional proto* [function]
creates a socket whose name is defined in *domain* and whose abstract type is *type*. *type* should be one of 1 (SOCK_STREAM), 2 (SOCK_DGRAM), 3 (SOCK_RAW), 4 (SOCK_RDM) and 5 (SOCK_SEQPACKET).

unix:bind *socket name* [function]
associates *name* to *socket*. *name* should be a unix path-name if the socket is defined in unix-domain.

unix:connect *socket addr* [function]
connects *socket* to another socket specified by *addr*.

unix:listen *socket &optional backlog* [function]
begins to accept connection request on *socket*. *backlog* specifies the length of the queue waiting for the establishment of connection.

unix:accept *socket* [function]
accepts the connection request on *socket* and returns a file-descriptor on which messages can be exchanged bidirectionally.

unix:recvfrom *socket &optional mesg from flag* [function]
receives a datagram message from *socket*. The socket must be assigned a name by **unix:bind**. *mesg* is a string in which the incoming message will be stored. If *mesg* is given, **recvfrom** returns the number of bytes received. If it is omitted, a new string is created for the storage of the message and returned.

unix:sendto *socket addr mesg &optional len flag* [function]
sends a datagram message to another socket specified by *addr*. *Socket* must be a datagram-type socket which has no name assigned. *Mesg* is a string to be sent and *len* is the length of the message counting from the beginning of the string. If omitted, whole string is sent.

unix:getservbyname *servicename* [function]
returns the service number (integer) for *servicename* registered in `/etc/services` or in NIS database.

unix:gethostbyname *hostname* [function]
returns the list of ip address of *hostname* and its address type (currently always AF_INET==2).

unix:syserrlist *errno* [function]
returns a string describing the error information for the error code *errno*.

13.2.4 Signals

unix:signal *signal func [option]* [function]
installs the signal handler *func* for *signal*. In BSD4.2 systems, signals caught during system call processing cause the system call to be retried. This means that if the process is issuing a read system call, signals are ignored. If *option=2* is specified, signals are handled in the system-5 manner, which causes the system call to fail.

unix:kill *pid signal* [function]
sends a signal to a process named by *pid*.

unix:pause [function]
suspends execution of this process until a signal arrives.

unix:alarm *time* [function]
sends an alarm clock signal (SIGALRM 14) after *time* seconds. Calling **unix:alarm** with *time*=0 resets the alarm clock.

unix:ualarm *time* [function]
same as **unix:alarm** except that the unit of *time* is micro seconds. **ualarm** is not available on Solaris2 or on other Sys5 based systems.

unix:getitimer *timer* [function]
One Unix process is attached with three interval timers, i.e., a real-time timer that decrements as the real time passes, a virtual-timer that decrements as the process executes in the user space, and a prof-timer that decrements as the kernel executes on behalf of the user process. *timer* is either 0 (`ITIMER_REAL`), 1 (`ITIMER_VIRTUAL`), or 2(`ITIMER_PROF`). A list of two elements is returned, the value of the timer in second and the interval. Both are floating-point numbers.

unix:setitimer *timer value interval* [function]
sets *value* and *interval* in *timer*. *timer* is eiterh 0 (`ITIMER_REAL`), 1 (`ITIMER_VIRTUAL`), or 2(`ITIMER_PROF`). `ITIMER_REAL` delivers SIGALRM when *value* expires. `ITIMER_VIRTUAL` delivers SIGVTALRM, and `ITIMER_PROF` delivers SIGPROF.

unix:select *inlist outlist exceptlist timeout* [function]
inlist, outlist and *exceptlist* are bitvectors indicating file descriptors whose I/O events should be tested. For example, if *inlist*=#b0110, *outlist*=#b100, and *exceptlist*=NIL, then whether it is possible to read on fd=1 or 2, or to write on fd=2 is tested. *Timeout* specifies seconds for which **select** is allowed to wait. Immediately after incoming data appear on one of the ports specified in *inlist*, or writing become available on one of the ports specified in *outlist*, or exceptional condition arises in one of the ports specified in *exceptlist*, **select** returns the number of ports that are available for I/O operation, setting ones for the possible port s in each of *inlist, outlist and exceptlist*.

unix:select-read-fd *read-fdset timeout* [function]
I/O selection is usually meaningful only for input operation. **unix:select-read-fd** is a short-hand for `select fdset nil nil timeout`. *Read-fdset* is not a bit-vector, but an integer that specifies the reading fd set.

13.2.5 Multithread

There is no way to create bound threads. Therefore only one signal stack and one interval timer are available in a EusLisp process. On Solaris2, the main top-level runs in a separated thread.

unix:thr-self [function]
returns the id (integer) of the thread currently running.

unix:thr-getprio *id* [function]
returns the execution priority of the thread specified by *id*.

unix:thr-setprio *id newprio* [function]
sets the execution priority of the thread specified by *id* to *newprio*. The smaller numerical value of *newprio* means the higher priority. In other words, a thread with a numerically greater *newprio* gets less access to CPU. Users cannot raise the execution priority higher than the process's nice value, which is usually 0.

unix:thr-getconcurrency [function]
returns the concurrency value (integer) which represents the number of threads that can run concurrently.

unix:thr-setconcurrency *concurrency* [function]
The concurrency value is the number of LWP in the process. If the concurrency is 1, which is the default, many threads you created are assigned to one LWP in turn even though all of them are runnable. If the program is running on a multi-processor machine and you want to utilize more than one CPU at the same time, you should set a value bigger than one to *concurrency*. Note that a big concurrency value let the operating system consume more resource. Usually *concurrency* should be smaller than or equal to the number of processors.

unix:thr-create *func arg-list &optional (size 64*1024)* [function]
creates a new thread with *size* words of Lisp stack and *size* bytes of C stack, and let it apply *func* to *arg-list*. The thread cannot return any results to the caller. Use of this function is discouraged.

13.2.6 Low-Level Memory Management

unix:malloc *integer* [function]
allocates memory outside EusLisp memory space.

unix:free *integer* [function]
deallocates a memory block allocated by *unix:malloc*.

unix:valloc *integer* [function]

unix:mmap *address length protection share stream offset* [function]

unix:munmap *address length* [function]

unix:vadvise *integer* [function]

13.2.7 IOCTL

Although Unix controls terminal device by a set of commands (second argument) to `ioctl`, EusLisp provides them in the forms of function to eliminate to reference the include files and or'ing argument with the command codes. For the detail, refer to the *termio* manual pages of Unix.

There are two sets of terminal io-controls: TIOC* and TC*. Be careful about the availability of these functions on your operating system. Basically, BSD supports TIOC* io-controls and Sys5 supports TC*.

SunOS 4.1 Both TIOC* and TC*

Solaris2 only TC*

mips, ultrix? only TIOC*

unix:tiocgetp *stream [sgttybuf]* [function]
gets parameters.

unix:tiocsetp *stream sgttybuf* [function]
sets parameters.

unix:tiocsetn *stream [sgttybuf]* [function]

unix:tiocgetd *stream [sgttybuf]* [function]

unix:tiocflush *stream* [function]
flushes output buffer

unix:tiocgpgrp *stream integer* [function]
gets process group id.

unix:tiocspgrp *stream integer* [function]
sets process group id.

unix:tiocoutq *stream integer* [function]

unix:fionread *stream integer* [function]

unix:tiocsetc *stream buf* [function]

unix:tioclbis *stream buf* [function]

unix:tioclbic *stream buf* [function]

unix:tioclset *stream buf* [function]

unix:tioclget *stream buf* [function]

unix:tcseta *stream buffer* [function]
sets terminal parameters immediately.

unix:tcsets *stream buffer* [function]
sets terminal parameters.

unix:tcsetsw *stream buffer* [function]
sets terminal parameters after all characters queued for output have been transmitted.

unix:tcsetsf *stream buffer* [function]
sets terminal parameters after all characters queued for output have been transmitted and all characters queued for input are discarded.

unix:tiocsetc *stream buffer* [function]

unix:tcsetaf *stream buffer* [function]

unix:tcsetaw *stream buffer* [function]

unix:tcgeta *stream buffer* [function]

unix:tcgets *stream buffer* [function]

unix:tcgetattr *stream buffer* [function]

unix:tcsetattr *stream buffer* [function]

13.2.8 Keyed Indexed Files

Recent Unix provides with the *dbm* or *ndbm* library for the management of keyed index files. Making use of this library, you can build a data base that is composed of many pairs of key and datum association. Following functions are defined in clib/ndbm.c. On Sun, it should be compiled by `cc -c -Dsun4 -Bstatic`, and loaded into EusLisp by `(load "clib/ndbm" :ld-option "-lc")`.

dbm-open *dbname mode flag* [function]

Dbm-open must be called first to create a data base file, and to begin read/write operations to the data base. *Dbname* is the name of the data base. Actually, ndbm manager creates two files which have suffixes `".pag"` and `".dir"`. *Mode* specifies file-open mode; 0 for read-only access, 1 for write-only, and 2 for read-write; also #x200 should be *or*ed when you create the file at the first time. *Flag* gives access permission that is changed by chmod. #o666 or #o664 is good for *flag*. **Dbm-open** returns an integer that identifies the data base in the process. This value is used by other dbm functions to identify the data base. In other words, you can open several data bases at the same time.

dbm-store *db key datum mode* [function]

stores *key-datum* association in *db*. *Db* is an integer to identify the data base. *Key and datum* are strings. *Mode* is 0 (insert) or 1 (replace).

dbm-fetch *db key* [function]

retrieves datum that is associated with *key* in *db*.

13.3 Unix Processes

In order to launch unix commands from EusLisp, use the **unix:system** function. **Piped-fork** creates a subprocess whose standard input and standard output are connected to EusLisp's bidirectional stream through pipes. **Piped-fork** returns the stream. Following is a function to count the number of lines contained in a file by using `"wc"`.

```
(defun count-lines (file) (read (piped-fork "wc" file)))
```

The next example creates eus process on another workstation identified by "etlic0" and provides a port for distributed computation.

```
(setq ic0eus (piped-fork "rsh" "etlic0" "eus"))
(format ic0eus "(list 1 2 3)~%")
(read ic0eus) --> (1 2 3)
```

For source code editing, you can call `ez` from the EusLisp. The screen editor ez communicates with EusLisp through message-queues. If you have an ez process already running in parallel with the EusLisp, **ez** restarts ez and it gains the terminal control. By issuing esc-P or esc-M commands in ez, texts are sent back and evaluated by EusLisp. This is useful for the debugging since entire file does not need to be loaded when you add a little modification to the file. Similar function is available on emacs by M-X run-lisp command.

cd *&optional (dir (unix:getenv "HOME"))* [function]
: changes the current working directory.

ez *&optional key* [function]
: enters display editor ez, and reads Lisp forms from it, and evaluates them.

piped-fork *&optional (exec) &rest args* [function]
: forks a process, and makes a two-way stream between the current EusLisp and the subprocess. Exec is the file name of a unix command and args are arguments to the command. If exec (string) includes one or more space, it is assumed a shell command, and executed by /bin/sh calling the unix:system function. If no exec is given, another euslisp is created as the subprocess.

xfork *exec &key (stdin *standard-input*) (stdout *standard-output*) (stderr *error-output*) (args nil)* [function]
: forks a process, replaces its stdin, stdout, and stderr streams to specified ones, and exec's "exec" with the args arguments. piped-fork is roughly equivalent to `(xfork exec :stdin (unix:pipe) :stdout (unix:pipe))` Though xfork returns an io-stream to stdin and stdout with their directions reversed, it is not always useful unless they are pipes. The name of this function, xfork (cross-fork), comes from this reversed io-stream, namely, the io-stream's input comes from the stdout of the subprocess and the output comes from the stdin.

rusage [function]
: prints resource usage of this process.

13.4 Adding Lisp Functions Coded in C

Programs that heavily refer to C include files or frequently access arrays perform better or are more clearly described if written in C or other languages rather than in EusLisp. EusLisp provides the way to link programs coded in C.

If you want to define EusLisp function written in C, each EusLisp-callable C-function must be coded to accept three arguments: the context pointer, the number of arguments and the pointer to the Lisp argument block. These arguments must be named as `ctx, n` and `argv`, since the macros in `c/eus.h` assume these names. The C program must include `*eusdir*/c/eus.h`. The programmer should be familiar with the types and macros described there. The entry function should be named by the basename of the source file.

A sample code for C function AVERAGE which computes the arithmetic average of arbitrary number of floats is shown below. In this example, you can see how to get float values from arguments, how to make the pointer of a float, how to set a pointer in the special variable AVERAGE, and how to define a function and a symbol in the entry function `ave`. Compile this program by `'cc -c -Dsun4 -DSolaris2 -K pic'`. `-Dsun4` and `-DSolaris2` are needed to chose proper definitions in `c/eus.h`. `-K pic` is needed to let the c compiler generate position independent code necessary for the loadable shared object. Then the resulted '.o' file can be loaded into EusLisp. More complete examples can be found in `*eusdir*/clib/*.c`, which are defined and loaded in the same manner described here.

```
/* ave.c */
/* (average &rest numbers) */
#include "/usr/local/eus/c/eus.h"
static pointer AVESYM;
pointer AVERAGE(ctx,n,argv)
context *ctx;
int n;
pointer argv[];
{ register int i;
  float sum=0.0, a, av;
  pointer result;
  numunion nu;
  for (i=0; i<n; i++) {
    a=ckfltval(argv[i]);
    sum += a;} /*get floating value from args*/
  av=sum/n;
  result=makeflt(av);
  AVESYM->c.sym.speval=result;  /*kindly set the result in symbol*/
  return(result);}

ave(ctx,n,argv)
context *ctx;
int n;
pointer argv[];
{ char *p;
  p="AVERAGE";
  defun(ctx,p,argv[0],AVERAGE);
  AVESYM=intern(ctx,p,strlen(p),userpkg); /* make a new symbol*/
  }
```

13.5 Foreign Language Interface

Functions written in C without concern about linking with EusLisp can be loaded onto EusLisp, too. These functions are called foreign functions. Such programs are loaded by **load-foreign** macro which returns an instance of **foreign-module**. External symbol definitions in the object file is registered in the module object. **Defforeign** is used to make entries to C functions to be called from EusLisp. **Defun-c-callable** defines lisp functions callable from C. C-callable functions have special code piece called *pod-code* for converting parameters and transferring control to the corresponding EusLisp function. **Pod-address** returns the address of this code piece which should be informed to C functions.

Here is an example of C program and its interface functions to EusLisp.

```
/* C program named cfunc.c*/

static int (*g)(); /* variable to store Lisp function entry */

double sync(x)
double x;
{ extern double sin();
  return(sin(x)/x);}

char *upperstring(s)
char *s;
{ char *ss=s;
  while (*s) { if (islower(*s)) *s=toupper(*s); s++;}
  return(ss);}

int setlfunc(f)      /* remember the argument in g just to see */
int (*f)();          /* how Lisp function can be called from C */
{ g=f;}

int callfunc(x)      /* apply the Lisp function saved in g to the arg.*/
int x;
{ return((*g)(x));}

;;;; Example program for EusLisp's foreign language interface
;;;; make foreign-module
(setq m (load-foreign "cfunc.o"))

;; define foreign functions so that they can be callable from lisp
(defforeign sync m "sync" (:float) :float)
(defforeign toupper m "upperstring" (:string) :string)
(defforeign setlfunc m "setlfunc" (:integer) :integer)
(defforeign callfunc m "callfunc" (:integer) :integer)

;; call them
(sync 1.0) --> 0.841471
(print (toupper "abc123"))  --> "ABC123"

;; define a test function which is callable from C.
(defun-c-callable TEST ((a :integer)) :integer
      (format t "TEST is called, arg=~s~%" a)
      (* a a))    ;; return the square of the arg
;;  call it from C
;;setlfunc remembers the entry address of Lisp TEST function.
(setlfunc (pod-address (intern "TEST")))
(callfunc 12)  --> TEST is called, arg=12  144
```

Data representations in EusLisp are converted to those of C in the following manners: EusLisp's 30-bits integer (including character) is sign-extended and passed to a C function via stack. 30-bit float is extended to double and passed via stack. As for string, integer-vector and float-vector, only the address of the first element is passed on the stack, and the entire array remains uncopied. The string can either be a normal string or a foreign-string. A string may contain null codes, though it is guaranteed that the string also has a null code at the end. EusLisp does not know how to pass arrays of more than one dimension. Every array of more than one dimension has correspoiding one dimensional vector that holds the entire elements linearly. This vector is obtained by the **array-entity** macro. Also, note that a two-dimensional matrix should be transposed if it is sent to the FORTRAN subroutines, since rows and columns are ordered oppositely in FORTRAN.

Since EusLisp's representation of floating-point numbers is always single precision, conversion is required when you pass a vector of double precision floating point numbers. For this purpose, the conversion functions, **double2float** and **float2double** are provided by `clib/double.c`. For an instance, if you have a 3x3 float-matrix and want to pass it to a C function named cfun as a matrix of double, use the following forms.

```
(setq mat (make-matrix 3 3))
(cfun (float2double (array-entity mat)))
```

Struct in C can be defined by the **defcstruct** macro. **Defcstruct** accepts struct-name followed by field definition forms.

```
(defcstruct <struct-name>
   {(<field> <type> [*] [size])}*)
```

For example, following struct definition is represented by the next defcstruct.

```
/* C definition */
struct example {
   char  a[2];
   short b;
   long  *c;
   float *d[2];};

/* equivalent EusLisp definition */
(defcstruct example
   (a :char 2)
   (b :short)
   (c :long *)
   (d :float * 2))
```

load-foreign *objfile &key symbol-input symbol-output (symbol-file objfile) ld-option)* [macro]

loads an object module written in languages other than EusLisp. In Solaris2, **load-foreign** just calls **load** with a null string as its *:entry* parameter. A compiled-code object is returned. This result is necessary to make entries to the functions in the module by **defforeign** called later on. Libraries can be specified in *ld-option*. However, the symbols defined in the libraries cannot be captured in the default symbol-output file. In order to allow EusLisp to call functions defined in the libraries, *symbol-output* and *symbol-file* must be given explicitly. (These arguments are not needed if you are not going to call the library functions directly from EusLisp, i.e. if you are referring them only from functions in *objfile*). **Load-foreign** links *objfile* with libraries specified and global symbols in EusLisp which is in core, and writes the linked object in *symbol-output*. Then, symbols in *symbol-file* are searched and listed in the foreign-module. Since *symbol-file* is defaulted to be *objfile*, only the symbols defined in *objfile* are recognized if *symbol-file* is not given. To find all the global entries both in *objfile* and libraries, the linked (merged) symbol table resulted from the first link process of load-foreign must be examined. For this reason, an identical file name must be given both to *symbol-output* and to *symbol-file*.

As shown below, the intermediate symbol file can be removed by **unix:unlink**. However, if you are loading more than one foreign modules both of which refer to the same library, and if you want to avoid loading the library duplicatedly, you have to use *symbol-input* argument. Suppose you have loaded all the functions in "linpack.a" in the above example and you are going to load another file "linapp.o" that calls functions in "linpack.a". The following call of load-foreign should be issued before you unlink "euslinpack". `(load-foreign "linapp.o" :symbol-input "euslinpack")` See `*eusdir*/llib/linpack.l` for more complete examples of **load-foreign** and **defforeign**.

```
(setq linpack-module
    (load-foreign "/usr/local/eus/clib/linpackref.o"
        :ld-option  "-L/usr/local/lib -llinpack -lF77 -lm -lc"
        :symbol-output "euslinpack"
```

```
         :symbol-file "euslinpack"
         ))
(unix:unlink "euslinpack")
```

defforeign *funcname module cname paramspec resulttype* [macro]

makes a function entry in a foreign language module. *funcname* is a symbol to be created in EusLisp. *module* is a compiled-code object returned by **load-foreign**. *cname* is the name of the C-function defined in the foreign program. It is a string like "_myfunc". *paramspec* is a list of parameter type specifications which is used for the data type conversion and coercion when arguments are passed from EusLisp to the C function. *Paramspec* can be NIL if no data conversion or type check is required. One of **:integer, :float , :string**, or *(:string n)* must be given to *resulttype*. **:Integer** means that the c function returns either char, short or int (long). **:Float** should be specified both for float and double. **:String** means the C function returns a pointer to a string, and EusLisp should add a long-word header to the string to accomodate it as a EusLisp string. The length of the string is found by *strlen*. Note that the writing a header just before the string may cause a disastrous result. On the other hand, **(:string n)** is safer but slower because a EusLisp string of length **n** is newly created and the contents of C string is copied there. `(:string 4)` should be used for a C function that returns a pointer to an integer. The resulted integer value of the result can be obtained by `(sys:peek result :long)`, where result is a variable set to the result of the C function. You may also specify `(:foreign-string [n])` for C functions that return a string or a struct. The result is a foreign-string whose content is held somewhere outside EusLisp control. If the result string is null-terminated and the length of the string is known by strlen, you don't need to specify the length [n]. However, if the result contains null codes, which is usual for structs, the length of the foreign-string should be explicitly given. Whether you should use (:string n) or (:foreign-string n) is not only the matter of speed, but the matter of structure sharing. The difference is whether the result is copied or not.

Fortran users should note that every argument to a Fortran function or a subroutine is passed by call-by-reference. Therefore, even a simple integer or float type argument must be put in a integer-vector or a float-vector before it is passed to Fortran.

defun-c-callable *funcname paramspec resulttype . body* [macro]

defines a EusLisp function that can be called from foreign language code. *funcname* is a symbol for which a EusLisp function is defined. *paramspec* is a list of type specifiers as in **defforeign**. Unlike **defforeign**'s paramspec, **defun-c-callable**'s paramspec cannot be omitted unless the function does not receive any argument. *:integer* should be used for all of int, short and char types and *:float* for both of float and double. *resulttype* is the type of the Lisp function. *resulttype* can be omitted unless you need type check or type coercion from integer to float. *body* is lisp expressions that are executed when this function is called from C. The function defined by **defun-c-callable** can be called from Lisp expressions, too. **Defun-c-callable** returns *funcname*. It looks like a symbol, but it is not, but an instance of **f**oreign-pod which is a subclass of symbol.

pod-address *funcname* [function]

returns the address of a foreign-to-EusLisp interface code of the c-callable Lisp function *funcname* defined by **defun-c-callable**. This is used to inform a foreign language program of the location of a Lisp function.

array-entity *array-of-more-than-one-dimension* [macro]

returns one-dimensional vector which holds all the elements of a multi-dimensional array. This is needed to pass a multi-dimensional or general array to a foreign function, although a simple vector can be passed directly.

float2double *float-vector [doublevector]* [function]

converts a float-vector to double precision representation. The result is of type float-vector but the length is twice as much as the first argument.

double2float *doublevector [float-vector]* [function]

A vector of double precision numbers is converted to single precision float-vector.

14 Multithread

The multithread is the concurrent and asynchronous programming facility on the Solaris operating system. Asynchronous programming is required for programs to respond to external events via multiple sensors occurring independently of the program's state. Parallel programming is effective to improve performance of computation bound processing such as image processing and interference checking in path planning.

14.1 Design of Multithread EusLisp

14.1.1 Multithread in Solaris 2 operating system

Multithread EusLisp (MT-Eus) runs on the Solaris 2 operating system with one or more processors. Solaris's threads are units for allocating CPU in a traditional UNIX process, having shared memory and different contexts. The thread library provided by the Solaris OS allocates each thread to a single LWP (light weight process), which is a kernel resource. The Unix kernel schedules the allocation of LWPs to one or more physical CPUs based on thread priorities assigned to each thread. Fig.5 depicts the relations between threads, LWPs, and CPUs. Two major changes in the design of the contexts and the memory management of EusLisp have been made to upgrade it to multithread capabilities.

14.1.2 Context Separation

MT-Eus allocates private stacks and contexts to each threads so that they can run independently of each other. Objects such as symbols and conses are allocated in the shared heap memory as in sequential EusLisp. Therefore, thread-private data such as block labels, catch tags, and local variables are protected from other threads, whereas values (objects) pointed by global variables are visible to all threads allowing information exchange among threads.

A context consists of a C-stack, a binding-stack and frame pointers that chain lexical blocks such as `lambda, block, catch, let, flet`, and so on, and is established when a new thread is created. Since more than one context can be active at the same time on a real multi-processor machine, we cannot hold a single pointer to the current context in a global variable. Rather we have to add one more argument to every internal function to transfer the context pointer from the topmost eval to the memory manager at the bottom.

14.1.3 Memory Management

EusLisp adopts a Fibonacci buddy memory management scheme in a single heap for every type of object. After running programs having different memory request characteristics, we have been convinced that Fibonacci buddy can allocate objects of various sizes equally fast, garbage-collects quickly without copying , and exhibits high memory utilization (the internal loss is 10 to 15% and the external loss is negligible). For multithreading, the second point, i.e., non-copying GC, is very important. If addresses of objects were changed by copying-GC, pointers in the stack and CPU registers of all thread contexts would have to be redirected to new locations, which is impossible or very difficult.

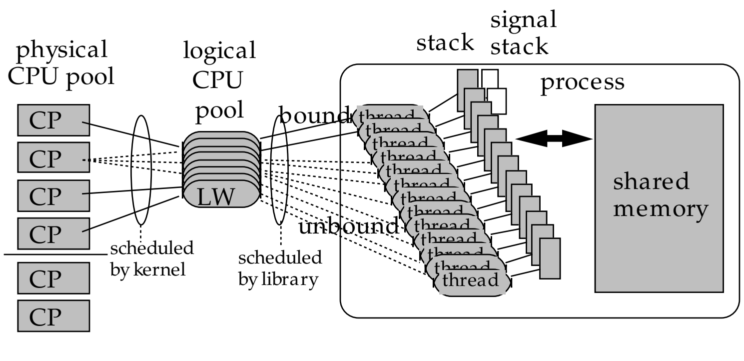

Figure 5: Solaris operating system's thread model

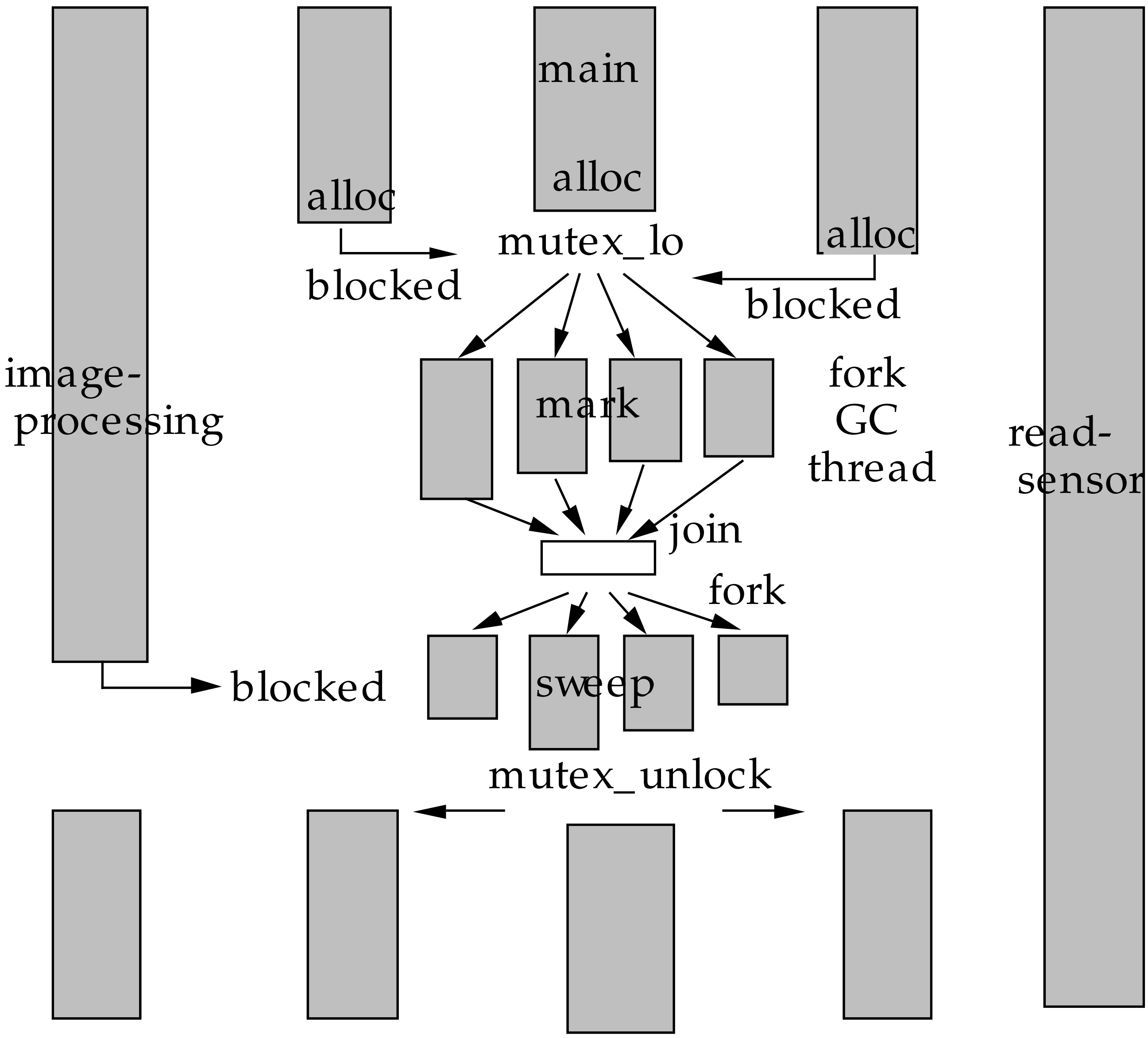

Figure 6: Parallel threads requesting memory and GC running in parallel

All memory allocation requests are handled by the `alloc` function at the lowest level. `Alloc` does mutex-locking because it manipulates the global database of free lists. Since we cannot predict when a garbage collection begins and which thread causes it, every thread must prepare for sporadic GCs. All pointers to living objects have to be arranged to be accessible by the GC anytime to prevent them from being reclaimed as garbage. This is done by storing the pointers to the most recently allocated objects in fixed slots of each context, instead of trusting they are maintained on the stacks.

Fig. 6 illustrates flow of threads requesting memory and forked inside GC to process marking and sweeping in parallel. Note that threads that do not request memory or manipulate pointers can run in parallel with the GC, improving real-time response of the low-level tasks such as signal processing and image acquisition.

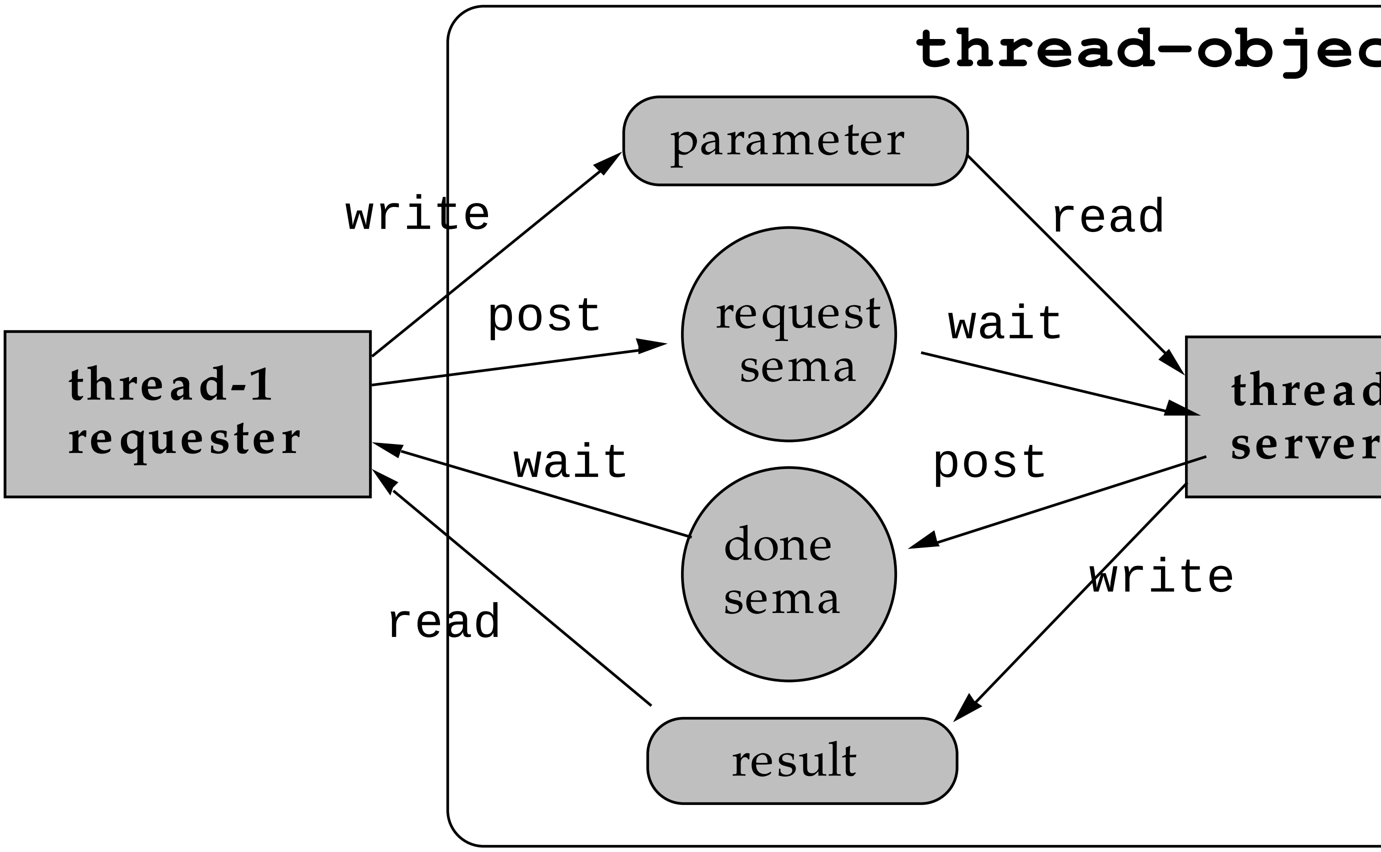

Figure 7: Thread-object for transferring control and data between threads (left) and the collection of threads put in the thread-pool.

14.2 Asynchronous and Parallel Programming Constructs

14.2.1 Thread Creation and Thread Pool

In order for Solaris to execute a program in parallel on many processors, the program needs to be written as a collection of functions, each of which is executed by a thread dynamically created in a process. Although the time required for thread creation is faster than process creation, it takes a few mili-seconds for EusLisp to start off a thread after allocating stacks and setting a page attribute for detecting stack-overflow. Since this delay, which should be compared to a function invocation, is intolerable, sufficient number of threads are created by the `make-thread` function beforehand and put in the system's thread pool, eliminating the need for system calls at evaluation time. Each thread in the thread pool is represented by a thread object, as depicted in Fig.7, consisted of thread-id, several semaphores for synchronization, and slots for argument and evaluation result transfer.

14.2.2 Parallel Execution of Threads

For the allocation of parallel computation to threads, the thread function is used. Thread takes one free thread out of the thread pool, transfers arguments via shared memory, wakes up the thread by signaling the semaphore as indicated in fig. 7, and returns a thread object to the caller without blocking. The woken-up thread begins evaluation of the argument running in parallel to the calling thread. The caller uses `wait-thread` to receive the evaluation result from the forked thread. The `plist` macro is a more convenient form to describe parallel evaluation of arguments. `Plist` attaches threads to evaluate each argument and lists up results after waiting for all threads to finish evaluation.

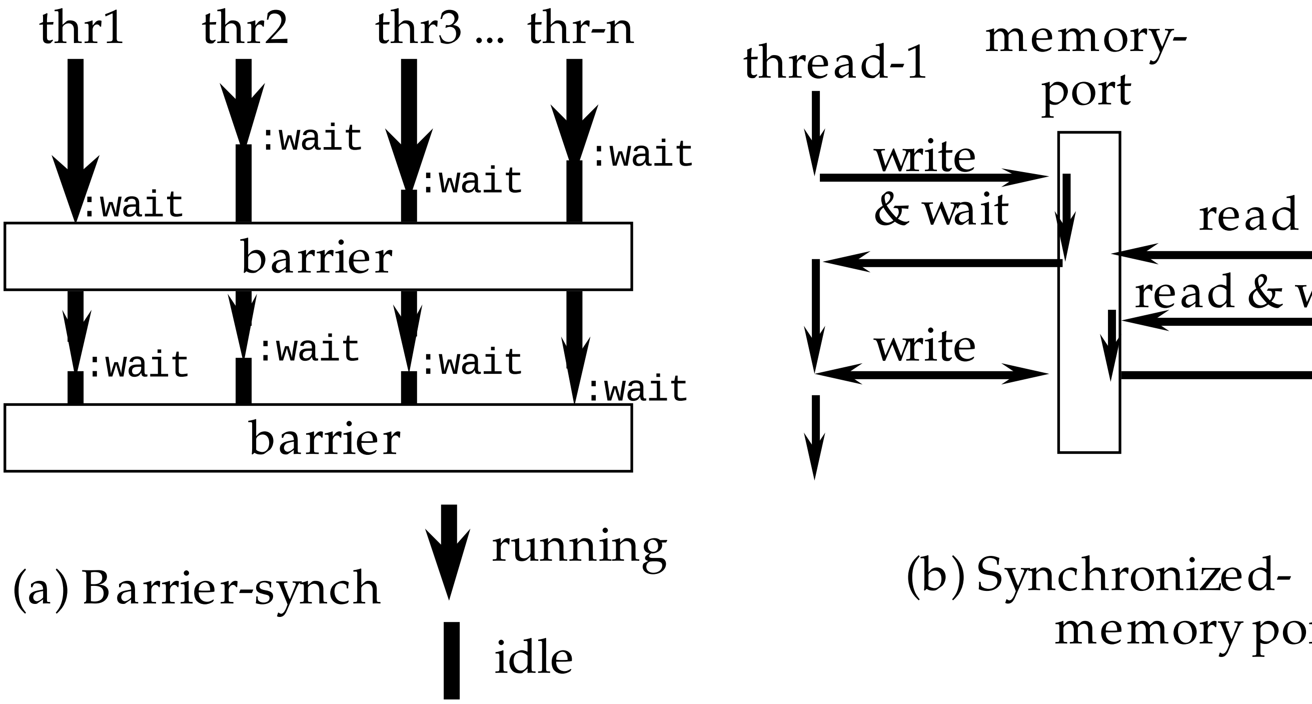

Figure 8: Barrier synchronization and synchronozed memory port

14.2.3 Synchronization primitives

MT-Eus has three kinds of synchronization primitives, namely *mutex locks, condition variables*, and *semaphores.* Mutex locks are used to serialize accesses to shared variables between threads. Condition variables allow a thread to wait for a condition to become true in a mutex-locked section by temporarily releasing and re-acquiring the lock. Semaphores are used to inform occurrences of events, or to control sharing of finite resources. These synchronization primitives cause voluntary context switching, while the Solaris kernel generates involuntary task switching on a time-sliced scheduling basis.

14.2.4 Barrier synchronization

Barrier-synch is a mechanism for more than two threads to synchronize at the same time (Fig. 8). For this purpose, an instance of the barrier class is created and threads that participate in the synchronization register themselves in the object. Then, each thread sends the `:wait` message to the barrier object, and the thread is blocked. When the last thread registered in the object sends its `:wait` message, the waits are released and all waiting threads get a return value of T. Barrier-sync plays an important role of global clocking in a multi-robot simulation.

14.2.5 Synchronized memory port

Synchronized memory port is a kind of stream to exchange data between threads (Fig. 8). Since all threads in a process share the heap memory, if one thread binds an object to a global variable, it instantly becomes visible to other threads. However, shared memory lacks capability to send events that the global data is updated. Synchronized memory port ensures this synchronization for accessing a shared object. A synchronized memory port object consists of one buffer slot and two semaphores used for synchronizing read and write.

processors	1	2	4	8	GC (ratio)
(a) compiled Fibonacci	1.0	2.0	4.0	7.8	0
(b) interpreted Fibonacci	1.0	1.7	2.7	4.4	0
(c) copy-seq	1.0	1.3	0.76	0.71	0.15
(d) make-cube	1.0	0.91	0.40	0.39	0.15
(e) interference-check	1.0	0.88	0.55	0.34	0.21

Table 3: Parallel gains of programs executed on multi-processors

14.2.6 Timers

Real-time programs often require functions to execute at predetermined timing or to repeat in particular intervals. Sequential EusLisp could run user' functions triggered by signals generated periodically by Unix's interval timers. This preemption can cause deadlock in MT-Eus, because interruption may occur within a mutex-ed block. Therefore, control must be transferred at secured points such as at the beginning of `eval`. To avoid delays caused by the above synchronization, MT-Eus also provides signal-notification via semaphores. In other words, the signal function takes either a function or a semaphore that is called or posted upon the signal arrival. Since the semaphore is posted at the lowest level, latency for synchronization is minimal.

The following a example image processing program coded by using the multithread facilities. Image input thread and filtering threads are created. samp-image takes image data periodically by waiting for samp-sem to be posted every 33msec. Two threads synchronize via read-and-write of a thread-port. Filter-image employs two more threads for parallel computation of filtering.

```
(make-threads 8)
(defun samp-image (p)
   (let ((samp-sem (make-semaphore)))
        (periodic-sema-post 0.03 samp-sem)
        (loop (sema-wait samp-sem)
              (send p :write (read-image))))
(defun filter-image (p)
  (let (img)
       (loop (setf img (send p :read))
             (plist (filter-up-half img)
                    (filter-low-half img)))))
(setf port (make-thread-port))
(setf sampler (thread #'samp-image port))
(setf filter (thread #'filter-image port))
```

14.3 Measured Parallel Gains

Table. 3 shows the parallel execution performance measured on a Cray Supserserver configured with 32 CPUs. Linear parallel gain was obtained for the compiled Fibonacci function, because there is no shared memory access and the program code is small enough to be fully loaded onto the cache memory of each processor. Contrally, when the same program was interpreted, linearly high performance could not be attained, since memory access scatters. Further, some programs that frequently refer to shared memory and request memory allocation cannot exhibit better performance than a single processor execution. This can be understood as the result of frequent cache memory purging.

14.4 Thread creation

A thread is a unit for assigning computation, usually evaluation of a lisp form. Threads in EusLisp are represented by instances of the **thread** class. This object is actually a control port of a thread to pass arguments and result, and let it start evaluation, rather than the thread's entity representing the context.

sys:make-thread *num &optional (lsize 32*1024) (csize lsize)* [function]
creates *num* threads with *lsize* words of Lisp stack and *csize* words of C stack, and put them in the system's thread pool. All the threads in the thread pool is bound to sys:*threads*, which is extended each time **make-thread** is called. By the **thread** function, a computation is assigned to one of free threads in the thread pool. Therefore it is not a good idea to change stack sizes from thread to thread, since you cannot control which thread is assigned to a specific computation.

sys:*threads* [variable]
returns the list of all the threads created by **make-threads**.

sys::free-threads [function]
returns the list of threads in the free thread pool. If the result is NIL, new commitment of a task to a thread is blocked until any currently running threads finish evaluation or new threads are created by **make-thread** in the free thread pool.

sys:thread *func &rest args* [function]
picks up one free thread from the thread pool, and assigns it for evaluation of *(func . args)*. **Sys:thread** can be regarded as asynchronous **funcall**, since **sys:thread** applies *func* to the spread list of *args* but it does not accept the result of the function application. Rather, **sys:thread** returns the thread object assigned to the funcall, so that the real result can be obtained later by **sys:wait-thread**.

```
(defun compute-pi (digits) ...)
(setq trd (sys:thread \#'compute-pi 1000)) ;assign compute-pi to a thread
...  ;; other computation
(sys:wait-thread trd) ;get the result of (compute-pi 1000)
```

sys:thread-no-wait *func &rest args* [function]
assigns computation to one of free threads. The thread is reclaimed in the free thread pool when it finishes evaluation without being **wait-thread**'ed.

sys:wait-thread *thread* [function]
waits for *thread* to finish evaluation of funcall given by the **sys:thread** function, and retrieves the result and returns it. **Sys:wait-thread** is mandatory if the thread is assigned evaluation by **sys:thread** because the thread is not returned to the free thread pool until it finishes transferring the result.

sys:plist *&rest forms* [macro]
evaluates *forms* by different threads in parallel and waits for the completion of all evaluation, and the list of results is returned. **Sys:plist** may be regarded as *parallel-list* except that each form listed must be a function call.

14.5 Synchronization

Among Solaris operating systems four synchronization primitives for multithread programs, EusLisp provides mutex locks, conditional variables, and semaphores. Reader-writer lock is not available now.

Based on these primitives, higher level synchronization mechanisms, such as synchronized memory port and barrier synchronization, are realized.

sys:make-mutex-lock [function]
makes a mutex-lock and returns it. A mutex-lock is represented by an integer-vector of six elements.

sys:mutex-lock *mlock* [function]
locks the mutex lock *mlock*. If the *mlock* is already locked by another thread, *mutex-lock* waits for the lock to be released.

sys:mutex-unlock *mlock* [function]
releases *mlock* and let one of other threads waiting for this lock resume running.

sys:mutex *mlock &rest forms* [macro]

Mutex-lock and mutex-unlock have to be used as a pair. **Mutex** is a macro that brackets a critical section. *Mlock* is locked before evaluating *forms* are evaluated, and the lock is released when the evaluation finishes. This macro expands to the following progn form. Note that **unwind-protect** is used to ensure unlocking even an error occurs during the evaluation of *forms*.

```
(progn
    (sys:mutex-lock mlock)
    (unwind-protect
        (progn . forms)
        (sys:mutex-unlock mlock)))
```

sys:make-cond [function]
makes a condition variable object which is an integer vector of four elements. The returned condition variable is in unlocked state.

sys:cond-wait *condvar mlock* [function]
waits for *condvar* to be signaled. If *condvar* has already been acquired by another thread, it releases *mlock* and waits for *condvar* to be signaled.

sys:cond-signal *condvar* [function]
signals the *condvar* condition variable.

sys:make-semaphore [function]
makes a semaphore object which is represented by an integer vector of twelve elements.

sys:sema-post *sem* [function]
signals *sem*.

sys:sema-wait *sem* [function]
waits for the *sem* semaphore to be posted.

sys:barrier-synch [class]

:super	**propertied-object**
:slots	threads n-threads count barrier-cond threads-lock count-lock

represents a structure for barrier-synchronization. Threads waiting for the synchronization are put in *threads* which is mutually excluded by *threads-lock*. When a **barrier-synch** object is created, *count* is initialized to zero. Synchronizing threads are put in the *threads* list by sending `:add` message. Sending `:wait` to this barrier-sync object causes *count* to be incremented, and the sending thread is put in the wait state. When all the threads in *threads* send the `:wait` message, the waits are unblocked and all threads resume execution. The synchronization is implemented by the combination of the *count-lock* mutex-lock and the *barrier-cond* condition-variable.

:init [method]
initializes this barrier-synch object. Two mutex-lock and one condition-variable are created.

:add *thr* [method]
adds the *thr* thread in the *threads* list.

:remove *thr* [method]
removes the *thr* thread of the *threads* list.

:wait [method]
waits for all threads in the *threads* list to issue `:wait`.

sys:synch-memory-port [class]

:super	**propertied-object**
:slots	sema-in sema-out buf empty lock

realizes the one-directional synchronized memory port, which synchronizes for two threads to transfer datum via this object. Control transfer is implemented by using semaphores.

:read [method]

reads datum buffered in this synch-memory-port. If it has not been written yet, the :read blocks.

:write *datum* [method]

writes *datum* in the buffer. Since only one word of buffer is available, if another datum has already been written and not yet read out, :write waits for the datum to be transferred by :read.

:init [method]

initializes this synch-memory-port where two semaphores are created and :write is made acceptable.

15 Geometric Functions

15.1 Float-vectors

A float-vector is a simple vector whose elements are specialized to floating point numbers. A float-vector can be of any size. When *result* is specified in an argument list, it should be a float-vector that holds the result.

float-vector *&rest numbers* [function]
makes a new float-vector whose elements are *numbers*. Note the difference between `(float-vector 1 2 3)` and `#F(1 2 3)`. While the former create a vector each time it is called, the latter does when it is read.

float-vector-p *obj* [function]
returns T if *obj* is a float-vector.

v+ *fltvec1 fltvec2 &optional result* [function]
adds two float-vectors.

v- *fltvec1 &optional fltvec2 result* [function]
subtract float-vectors. If fltvec2 is omitted, fltvec1 is negated.

v. *fltvec1 fltvec2* [function]
computes the inner product of two float-vectors.

v* *fltvec1 fltvec2 &optional result* [function]
computes the outer product of two float-vectors.

v.* *fltvec1 fltvec2 fltvec3* [function]
computes the scaler triple product [A,B,C]=(V. A (V* B C))=(V. (V* A B) C).

v< *fltvec1 fltvec2* [function]
returns T if every element of fltvec1 is smaller than the corresponding element of fltvec2.

v> *fltvec1 fltvec2* [function]
returns T if every element of fltvec1 is larger than the corresponding element of fltvec2.

vmin *&rest fltvec* [function]
finds the smallest values for each dimension in *fltvec*, and makes a float-vector from the values. **Vmin** and **vmax** are used to find the minimal bounding box from coordinates of vertices.

vmax *&rest fltvec* [function]
finds the greatest values for each dimension in *fltvec*, and makes a float-vector from the values.

minimal-box *v-list minvec maxvec [err]* [function]
computes the minimal bounding box for a given vertex-list, and stores results in *minvec* and *maxvec*. If a floating number err is specified, the minimal box is grown by the ratio, i.e. if the err is 0.01, each element of minvec is decreased by 1% of the distance between minvec and maxvec, and each element of maxvec is increased by 1%. **Minimal-box** returns the distance between minvec and maxvec.

scale *number fltvec &optional result* [function]
the scaler *number* is multiplied to the every element of fltvec.

norm *fltvec* [function]
$|fltvec|$

norm2 *fltvec* [function]
$|fltvec|^2 = (\mathbf{v}.fltvec fltvec)$

normalize-vector *fltvec [result]* [function]
normalizes *fltvec* to have the norm 1.0.

distance *fltvec1 fltvec2* [function]
returns the distance $|fltvec - fltvec2|$ between two float-vectors.

distance2 *fltvec1 fltvec2* [function]
$|fltvec - fltvec2|^2$

homo2normal *homovec &optional normalvec* [function]
A homogeneous vector *homovec* is converted to its normal representation.

homogenize *normalvec &optional homovec* [function]
A normal vector *normalvec* is converted to its homogenous representation.

midpoint *p p1 p2 &optional result* [function]
P is float, and *p1* and *p2* are float-vectors of the same dimension. A point $(1-p)p1 + pp2$, which is the point that breaks *p1-p2* by the ratio $p : (1-p)$, is returned.

rotate-vector *fltvec theta axis &optional result* [function]
rotates 2D or 3D *fltvec* by *theta* radian around *axis*. *Axis* can be one of *:x, :y, :z, 0, 1, 2* or NIL. When *axis* is NIL, *fltvec* is taken to be two dimensional. To rotate a vector around an arbitrary axis in 3D space, make a rotation matrix by the **rotation-matrix** function and multiply it to the vector.

15.2 Matrix and Transformation

A matrix is a two-dimensional array whose elements are all floats. In most functions a matrix can be of any size, but the **v*, v.***, **Euler-angle** and **rpy-angle** functions can only handle three dimensional matrices. **Transform, m*** and **transpose** do not restrict the matrices to be square, and they operate on general n*m size matrices.

Functions that can accept result parameter places the computed result there, and no heap is wasted. All matrix functions are intended for the transformation in the normal coordinate systems, and not in the homogeneous coordinates.

The **rpy-angle** function decomposes a rotation matrix into three components of rotation angles around z, y and x axes of the world coordinates. The **Euler-angle** function is similar to **rpy-angle** but decomposes into rotation angles around local z, y and again z axes. Both of these functions return two solutions since angles can be taken in the opposite directions.

```
; Mat is a 3X3 rotation matrix.
(setq rots (rpy-angle mat))
(setq r (unit-matrix 3))
(rotate-matrix r (car rots) :x t r)
(rotate-matrix r (cadr rots) :y t r)
(rotate-matrix r (caddr rots) :z t r)
;--> resulted r is equivalent to mat
```

To keep track of pairs of a position and a orientation in 3D space, use the **coordinates** and **cascaded-coords** classes detailed in the section 15.4.

matrix *&rest elements* [function]
makes a new matrix from *elements*. Row x Col = (number of elements) x (length of the 1st element). Each of *elements* can be of any type of sequence. Each sequence is lined up as a row vector in the matrix.

make-matrix *rowsize columnsize &optional init* [function]
makes a matrix of $rowsize \times columnsize$.

matrixp *obj* [function]
T if *obj* is a matrix, i.e. *obj* is a two dimensional array and its elements are floats.

matrix-row *mat row-index* [function] extracts a row vector out of matrix *mat*. **matrix-row** is also used to set a vector in a particular row of a matrix using in conjunction with **setf**.

matrix-column *mat column-index* [function]
extracts a column vector out of *mat*. **matrix-column** is also used to set a vector in a particular column of a matrix using in conjunction with **setf**.

m* *matrix1 matrix2 &optional result* [function]
concatenates *matrix1* and *matrix2*.

transpose *matrix &optional result* [function]
transposes *matrix*, i.e. columns of *matrix* are exchanged with *rows*.

unit-matrix *dim* [function]
makes an identity matrix of $dim \times dim$.

replace-matrix *dest src* [function]
replaces all the elements of dest matrix with ones of src matrix.

scale-matrix *scalar mat* [function]
multiplies *scaler* to all the elements of *mat*.

copy-matrix *matrix* [function]
makes a copy of *matrix*.

transform *matrix fltvector &optional result* [function]
multiplies *matrix* to *fltvector* from the left.

transform *fltvector matrix &optional result* [function]
multiplies *matrix* to *fltvector* from the right.

rotate-matrix *matrix theta axis &optional world-p result* [function]
multiplies a rotation matrix from the left (when world-p is non-nil) or from the right (when world-p is nil). When a matrix is rotated by **rotate-matrix**, the rotation axis **:x, :y, :z** or 0,1,2 may be taken either in the world coordinates or in the local coordinates. If *world-p* is specified nil, it means rotation along the axis in the local coordinate system and the rotation matrix is multiplied from the right. Else if worldp is non-nil, the rotation is made in the world coordinates and the rotation matrix is multiplied from the left. If NIL is given to *axis*, *matrix* should be two dimensional and the rotation is taken in 2D space where *world-p* does not make sense.

rotation-matrix *theta axis &optional result* [function]
makes a 2D or 3D rotation matrix around *axis* which can be any of :x, :y, :z, 0, 1, 2, a 3D float-vector or NIL. When you make a 2D rotation matrix, axis should be NIL.

rotation-angle *rotation-matrix* [function]
extracts a equivalent rotation axis and angle from *rotation-matrix* and a list of float and float-vector is returned. NIL is returned when *rotation-matrix* is a unit-matrix. Also if the rotation angle is too small, the result may have errors. When *rotation-matrix* is 2D, the single angle value is returned.

rpy-matrix *ang-z ang-y ang-x* [function]
makes a rotation matrix defined by roll-pitch-yaw angles. First, a unit-matrix is rotated by ang-x radian along X-axis. Next, ang-y around Y-axis and finally ang-z around Z-axis. All the rotation axes are taken in the world coordinates.

rpy-angle *matrix* [function]
extracts two triplets of roll-pitch-yaw angles of *matrix*.

Euler-matrix *ang-z ang-y ang2-z* [function]
makes a rotation matrix defined by three Euler angles. First, a unit-matrix is rotated *ang-z* around Z-axis, next, *ang-y* around Y-axis and finally *ang2-z* again around Z-axis. All the rotation axes are taken in the local coordinates.

Euler-angle *matrix* [function]

extracts two tuples of Euler angles.

15.3 LU decomposition

lu-decompose and **lu-solve** are provided to solve simultaneous linear equations. First, **lu-decompose** decomposes a matrix into a lower triangle matrix and an upper triable matrix. If the given matrix is singular, **LU-decompose** returns NIL, otherwise it returns the permutation vector which should be supplied to **LU-solve**. **Lu-solve** computes the solution for a LU matrix with a given constant vector. This method is efficient if solutions for many combinations of different constant vectors and the same factor matrix are required. **Simultaneous-equation** would be more handy when you wish to get only one solution. **Lu-determinant** computes a determinant of a lu-decomposed matrix. **Inverse-matrix** function computes an inverse matrix using **lu-decompose** once, and **lu-solve** n times. Computation time for a 3*3 matrix is estimated to be 4 milli-sec.

lu-decompose *matrix &optional result* [function]

performs lu-decomposition of *matrix*.

lu-solve *lu-mat perm-vector bvector [result]* [function]

solves a linear simultaneous equations which has already been lu-decomposed. *perm-vector* should be the result returned by **lu-decompose**.

lu-determinant *lu-mat perm-vector* [function]

computes the determinant value for a matrix which has already been lu-decomposed.

simultaneous-equation *mat vec* [function]

solves a linear simultaneous equations whose coefficients are described in *mat* and constant values in *vec*.

inverse-matrix *mat* [function]

makes the inverse matrix of the square matrix, *mat*.

pseudo-inverse *mat* [function]

computes the pseudo inverse matrix using the singular value decomposition.

15.4 Coordinates

Coordinate systems and their transformations are represented by the **coordinates** class. Instead of 4*4 (homogeneous) matrix representation, coordinate system in EusLisp is represented by a combination of a 3*3 rotation matrix and a 3D position vector mainly for speed and generality.

coordinates [class]

:super **propertied-object**
:slots (pos :type float-vector
rot :type array)

defines a coordinate system with a pair of a position vector and a 3x3 rotation matrix.

coordinates-p *obj* [function]
returns T when obj is an instance of coordinates class or its subclasses.

:rot [method]
returns the 3X3 rotation matrix of this coords.

:pos [method]
returns the 3-D position vector of this coords.

:newcoords *newrot newpos* [method]
updates the coords with newrot and newpos. Whenever a condition that changes the state of this coords occurs, this method should be called with the new rotation matrix and the position vector. This message may invoke another :update method to propagate the event.

:replace-coords *newrot newpos* [method]
changes the rot and pos slots to be updated without calling newcoords method.

:coords [method]

:copy-coords *&optional dest* [method]
If dest is not given, :copy-coords makes another coordinates object which has the same rot and pos slots. If dest is given, rot and pos of this coordinates is copied to the dest coordinates.

:reset-coords [method]
forces the rotation matrix of this coords to be identity matrix, and pos vector to be all zero.

:worldpos [method]

:worldrot [method]

:worldcoords [method]
Computes the position vector, the rotation matrix and the coordinates of this object represented in the world coordinates. The coordinates class is always assumed to be represented in world, these method can simply return pos, rot and self. These methods are provided for the compatibility with cascaded-coords class which cannot be assumed to be represented in world.

:copy-worldcoords *&optional dest* [method]
First, worldcoords is computed, and it is copied to dest. If no dest is specified, a coordinates object to store the result is newly created.

:rotate-vector *vec* [method]
A vector is rotated by the rotation of this coords, i.e., an orientation vector represented in this coords is converted to the representation in the world. The position of this coords does not affect rotation.

:transform-vector *vec* [method]
A vector in this local coords is transformed to the representation in the world.

:inverse-transform-vector *vec* [method]
A vector in the world is inversely transformed to the representation in this local coordinate system.

:transform *trans &optional (wrt :local)* [method]
Transform this coords by the trans represented in wrt coords. Trans must be of type coordinates, and wrt must be one of keywords `:local, :parent, :world` or an instance of coordinates. If wrt is `:local`, the trans is applied from the right to this coords, and if wrt is `:world` or `:parent`, the trans is multiplied from the left. Else, if wrt is of type coordinates, the trans represented in the wrt coords is first transformed to the representation in the world, and it is applied from the left.

:move-to *trans &optional (wrt :local)* [method]
Replaces the rot and pos of the coords with trans represented in wrt.

:translate *p &optional (wrt :local)* [method]
changes the position of this object relatively with respective to wrt coords.

:locate *p &optional (wrt :local)* [method]
Changes the location of this coords with the parameter represented in wrt. If wrt is `:local`, then the effect is identical to **:translate** with *wrt*=`:local`.

:rotate *theta axis &optional (wrt :local)* [method]
Rotates this coords relatively by *theta* radian around the *axis*. *Axis* is one of axis-keywords (`:x, :y` and `:z`) or an arbitrary float-vector. *Axis* is considered to be represented in the *wrt* coords. Thus, if *wrt*=`:local` and *axis*=`:z`, the coordinates is rotated around the z axis of this local coords, and *wrt*=`:world` or `:parent`, the coords is rotated around the z axis of world coords. In other words, if *wrt*=`:local`, a rotation matrix is multiplied from the right of this coords, and if *wrt*=`:world` or `:parent`, a rotation matrix is multiplied from the left. Note that even *wrt* is either `:world` or `:parent`, the *pos* vector of this coordinates does not change. For the true rotation around the world axis, an instance of coordinates class representing the rotation should be given to **:transform** method.

:orient *theta axis &optional (wrt :local)* [method]
forces setting rot. This is an absolute version of :**rotate** method.

:inverse-transformation [method]
makes a new coords that is inverse to self.

:transformation *coords (wrt :local)* [method]
makes the transformation (an instance of coordinates) between this coords and the coords given as the argument. If *wrt*=`:local`, the result is represented in local coords, i.e., if the resulted transformation is given as an argument to :transform with *wrt*=`:local`, this coords is transformed to be identical with the coords.

:Euler *az1 ay az2* [method]
sets rot with Euler angles, that are, rotation angles around z (*az1*, y (*ay*) and again z *az2* axis of this local coordinates system.

:roll-pitch-yaw *roll pitch yaw* [method]
sets rot with roll-pitch-yaw angles: rotation angles around x (*yaw*), y (*pitch*) and z (*roll*) axes of the world coordinate system.

:4x4 *&optional mat44* [method]
If a matrix of 4x4 is given as *mat44*, it is converted to coordinates representation with a 3x3 rotation matrix and a 3D position vector. If *mat44* is not given, this coordinates is converted to 4x4 matrix representation.

:init *&key* [method]

:pos	*#f(0 0 0)*
:rot	*#2f((1 0 0) (0 1 0) (0 0 1))*
:rpy	*roll pitch yaw*
:Euler	*az ay az2*
:axis	*rotation-axis*
:angle	*rotation-angle*

:4X4	*4x4 matrix*
:coords	*another coordinates*
:properties	*a list of (ind . value) pair*
:name	*name property*

initializes this coordinates object and sets rot and pos. The meaning of each keyword follows:

:dimension 2 or 3 (default is 3)

:pos specifies a position vector (defaulted to #f(0 0 0))

:rot specifies a rotation matrix (defaulted to a unit-matrix)

:Euler gives a sequence of three elements for Euler angles

:rpy gives a sequence of three elements for roll-pitch-yaw

:axis rotation axis (:x,:y,:z or an arbitrary float-vector)

:angle rotation angle (used with :axis)

:wrt where the rotation axis is taken (default is :local)

:4X4 4X4 matrix is used to specify both pos and rot

:coords copies pos and rot from coords

:name set :name property

`:Angle` can only be used in conjunction with the `:axis` that is determined in the `:wrt` coordinates. Without regard to `:wrt`, `:Euler` always specifies the Euler angles, *az1, ay* and *az2*, defined in the local coordinates, and `:rpy` specifies the angles around *z*, *y* and *x* axes of the world coordinates. Two or more of `:rot, :Euler, :rpy, :axis` and `:4X4` cannot be specified simultaneously, although no error is reported. Sequences can be supplied to the `:axis` and `:angle` parameters, which mean successive rotations around the given axes. List of pairs of an attribute and its value can be given as `:properties` argument. These pairs are copied in the plist of this coordinates.

15.5 CascadedCoords

cascaded-coords [class]

:super	**coordinates**
:slots	(parent descendants worldcoords manager changed)

defines a linked coordinates. **Cascaded-coords** is often abbreviated as **c**ascoords.

:inheritance [method]

returns the inheritance tree list describing all the descendants of the cascoords. If `a` and `b` are the direct descendants of this coords, and `c` is a descendant of `a`, `((a (c)) (b))` is returned.

:assoc *childcoords &optional relative-coords* [method]

childcoords is associated to this cascoords as a descendant. If childcoords has been already assoc'ed to some other cascoords, first childcoords is dissoc'ed since each cascoords can have only one parent. The orientation or location of childcoords in the world does not change.

:dissoc *childcoords* [method]

dissociates (removes) *childcoords* from the descendants list of this coords. The orientation or location of childcoords in the world does not change.

:changed [method]

informs this coords that the coordinates of parent has changed, and the re-computation of worldcoords is needed when it is requested later.

:update [method]

is called by the **:worldcoords** method to recompute the current worldcoord.

:worldcoords [method]

returns a coordinates object which represents this coord in the world by concatenating all the cascoords from the root to this coords. The result is held in this object and reused later. Thus, you should not modify the resulted coords.

:worldpos [method]
returns rot of this coordinates represented in the world.

:worldrot [method]
returns pos of this coordinates represented in the world.

:transform-vector *vec* [method]
Regarding *vec* represented in this local coords, transforms it to the representation in the world.

:inverse-transform-vector *vec* [method]
vec represented in the world is inversely transformed into the representation in this local coords.

:inverse-transformation [method]
makes an instance of coordinates which represents inverse transformation of this coord.

:transform *trans &optional (wrt :local)* [method]

:translate *fltvec &optional (wrt :local)* [method]

:locate *fltvec &optional (wrt :local)* [method]

:rotate *theta axis &optional (wrt :local)* [method]

:orient *theta axis &optional (wrt :local)* [method]
Refer to the descriptions in class **coordinates**.

make-coords *&key :pos :rot :rpy :Euler :angle :axis :4X4 :coords :name* [function]

make-cascoords *&key :pos :rot :rpy :Euler :angle :axis :4X4 :coords :name* [function]

coords *&key :pos :rot :rpy :Euler :angle :axis :4X4 :coords :name* [function]

cascoords *&key :pos :rot :rpy :Euler :angle :axis :4X4 :coords :name* [function]
All these functions make new coordinates or cascaded-coordinates. For the keyword parameter, see **:init** method of class coordinates.

transform-coords *coords1 coords2 &optional (coords3 (coords))* [function]
Coords1 is applied (multiplied) to the coords2 from the left. The product is stored in coords3.

transform-coords* *&rest coords* [function]
concatenates transformations listed in *coords*. An instance of coordinates that represents the concatenated transformation is returned.

wrt *coords vec* [function]
transforms *vec* into the representation in *coords*. The result is equivalent to `(send` *coords* `:transform-vector` *vec*`)`.

16 Geometric Modeling

EusLisp adopts *B*rep (Boundary Representation) as the internal representation of 3D geometric models. Components in Breps are represented by classes **edge, plane, polygon, face, hole,** and **body**. Primitive body creating functions and body composition functions create new instances of these classes. In order to use your private geometric classes having more attributes, set special variables ***edge-class*, *face-class*** and ***body-class*** to your class objects.

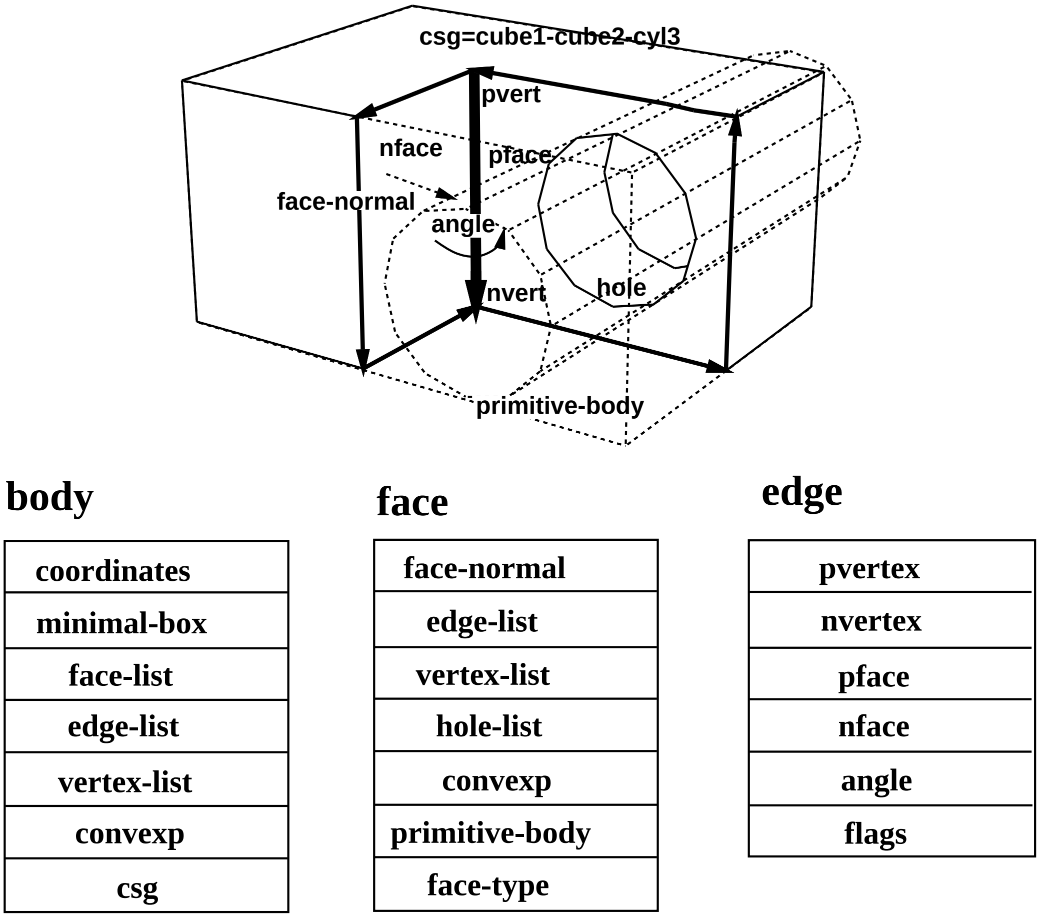

Figure 9: Arrangements of vertices, edges, and faces

16.1 Miscellaneous Geometric Functions

vplus *vector-list* [function]

returns a newly created float-vector that is the sum of all the elements of *vector-list*. The difference from **v+** is that **vplus** computes the sum of more than two arguments and no result vector can be specified.

vector-mean *vector-list* [function]

returns the mean vector of *vector-list*.

triangle *a b c &optional (normal #f(0 0 1))* [function]

a, b, c are float-vectors representing 2 or 3 dimensional points. normal is the normal vector of the plane on which *a,b*, and *c* lie. **Triangle** returns 2*area of a triangle formed by *a,b,c*. **Triangle** is positive if *a,b*, and *c* turn clockwise when you are looking in the same direction as *normal*. In other words, if **triangle** is positive, *c* locates at the left hand side of line *a*-*b*, and *b* lies at the right side of *ac*.

triangle-normal *a b c* [function]

finds a normal vector which is vertical to the triangle defined by three points *a,b,*and *c*.

vector-angle *v1 v2 &optional (normal (v* v1 v2))* [function]

Computes an angle between two vectors, denoted by $atan(normal \cdot (v1 \times v2), v1 \cdot v2)$. *v1,v2* and *normal* must be normalized vectors. When *normal* is not given, a normalized vector commonly perpendicular to *v1* and *v2* is used, in which case the result is always a positive angle in the range between 0 and π. In order to obtain a signed angle, *normal* must be specified explicitly.

face-normal-vector *vertices* [function]

Computes surface normal vector from a list of float-vectors which lie on the same plane.

farthest *p points* [function]

finds the farthest point from *p* in the list of 3D float-vectors, *points*.

farthest-pair *points* [function]

finds the farthest point pair in the list of 3D float-vectors, *points*.

maxindex *3D-floatvec* [function]

Finds the index of the absolute maximum value of three elements.

random-vector *&optional (range 1.0)* [function]

Generates a random vector which is distributed homogeneously in 3D Cartesian space.

random-normalized-vector *&optional (range 1.0)* [function]

returns a normalized-3D random vector.

random-vectors *count range* [function]

returns a list of random vectors.

line-intersection *p1 p2 p3 p4* [function]

p1, p2, p3 and *p4* are all float-vectors of more than two dimensions. *p1-p2* and *p3-p4* define two lines on a plane. **line-intersection** returns a list of two parameters of the intersection point for these two lines. When used in three dimension, *p1, p2, p3* and *p4* must be coplanar.

collinear-p *p1 p2 p3 &optional tolerance* [function]

p1, p2, p3 are all three-dimensional float-vectors representing three point locations. **Collinear-p** returns the parameter for *p2* on the line *p1-p3* if $norm((p2 - p1) \times (p3 - p1))$ is smaller than `*coplanar-threshold*`, otherwise NIL.

find-coplanar-vertices *p1 p2 p3 vlist* [function]

p1, p2, p3 are all three-dimensional float-vectors representing a plane. **Find-coplanar-vertices** looks for coplanar points in *vlist* that lie on the plane.

find-connecting-edge *vertex edgelist* [function]

finds an edge in *edgelist* that connects to *vertex*.

make-vertex-edge-htab *bodfacs* [function]

bodfacs is a body or a list of faces. **make-vertex-edge-htab** makes a hash-table which allows retrieving of edges connected to a vertex.

left-points *points p1 p2 normal* [function]

Assume *points, p1*, and *p2* lie on the plane whose normal vector is *normal*. **Left-points** searches in *points* and collects ones lying in the left hand side of the line passing on *p1, p2*.

right-points *points p1 p2 normal* [function]

Assume *points, p1*, and *p2* lie on the plane whose normal vector is *normal*. **Right-points** searches in *points* and collects ones lying in the right hand side of the line determined by *p1, p2*.

left-most-point *points p1 p2 normal* [function]

Assume *points, p1*, and *p2* lie on a plane whose normal vector is *normal*. **left-points** searches in *points* which lie in the left-hand side of the line determined by *p1, p2* and returns the farthest one.

right-most-point *points p1 p2 normal* [function]
Assume *points, p1*, and *p2* lie on a plane whose normal vector is *normal*. **right-most-point** searches in *points* which lie in the right-hand side of the line determined by *p1, p2* and returns the farthest one.

eps= *num1 num2 [(tolerance *epsilon*)]* [function]
compares two float numbers *num1* and *num2* for equality with the tolerance of ***epsilon***.

eps< *num1 num2 [(tolerance *epsilon*)]* [function]
returns T if $num1$ is apparently less than $num2$, i.e. $num1 < num2 - tolerance$.

eps<= *num1 num2 [(tolerance *epsilon*)]* [function]
returns T if $num1$ is possibly less than or equal to $num2$, i.e. $num1 < num2 + tolerance$.

eps> *num1 num2 [(tolerance *epsilon*)]* [function]
returns T if $num1$ is apparently greater than $num2$, i.e. $num1 < num2 - tolerance$.

eps>= *num1 num2 [(tolerance *epsilon*)]* [function]
returns T if $num1$ is possibly greater than or equal to $num2$, i.e. $num1 < num2 + tolerance$.

bounding-box [class]

:super	**object**
:slots	(minpoint maxpoint)

defines a minimal rectangular-parallel-piped which is bounded by the planes parallel to xy-, yz- and zx-planes. **Bounding-box** can be used in any dimension according to the dimension of vectors given at the initialization. Bounding-box had been defined by the name of surrounding-box.

:box [method]
returns this bounding-box object itself.

:volume [method]
returns the volume of this bounding box.

:grow *rate* [method]
increases or decreases the size of this box by the *rate*. When *rate* is 0.01, the box is enlarged by 1%.

:inner *point* [method]
returns T if *point* lies in this box, otherwise nil.

:intersection *box2 &optional tolerance* [method]
returns the intersectional bounding box of this box and *box2*. If *tolerance* is given, the box is enlarged by it. If there is no intersection, NIL is returned.

:union *box2* [method]
returns the union of bounding box of this box and *box2*.

:intersectionp *box2* [method]
returns T if this box has the intersection with the *box2*, NIL otherwise. This method is faster than **:intersection** because no new instance of bounding-box is created.

:extreme-point *direction* [method]
returns one of the eight corner points yielding the largest dot-product with *direction*.

:corners [method]
returns the list of all vertices of this box. If this box defines 2D bounding-box, then 4 points are returned, 3D, 8, and so on.

:below *box2 &optional (direction #(0 0 1)* [method]
returns T if this box is below *box2* in *direction*. This is used to check whether two box intersects when this box is moved toward *direction*.

:body [method]

returns a body object that represents a cube bounded by this box.

:init *vlist &optional tolerance* [method]

sets minpoint and maxpoint slots looking in *vlist*. If tolerance (float) is specified, the box is grown by the amount.

make-bounding-box *points [tolerance]* [function]

finds the minimum and maximum coordinates in the list of *points*, and make an instance of `bounding-box`.

bounding-box-union *boxes [tolerance *contact-threshold*]* [function]

makes an instance of the surrounding-box representing the union of *boxes*. The resulted box is expanded by the *tolerance*.

bounding-box-intersection *boxes [tolerance *contact-threshold*]* [function]

makes an instance of the surrounding-box representing the intersection of *boxes*. The resulted box is expanded by the *tolerance*.

16.2 Line and Edge

The direction of the vertex loop or the edge loop is defined so that the vertices or edges are arranged in the counter-clockwise order when the body is observed from outside. *Pvertex* and *nvertex*, and *pface* and *nface* are determined so that an edge is oriented from *pvertex* toward *nvertex* when *pface* is located at the left of the edge observing them from outside.

line [class]

:super **propertied-object**
:slots ((pvert :type float-vector) (nvert :type float-vector))

defines a line passing on pvert and nvert. The line is directed from *pvert* to *nvert* in the parametric representation: $t \cdot pvert + (1 - t)nvert$.

:vertices [method]
returns the list of *pvert* and *nvert*.

:point *p* [method]
returns a three dimensional float-vector that corresponds to the *p* parameter on this line. $parameter \cdot pvert + (1 - parameter)nvert$

:parameter *point* [method]
Computes the parameter for *point* on this line. This is the inverse method of `:point`.

:direction [method]
returns a normalized vector from **pvert** to **nvert**.

:end-point *v* [method]
returns the other end-point of this line, i.e. if *v* is *eq* to `pvert`, `nvert` is returned, if *v* is *eq* to `nvert`, `pvert` is returned, otherwise NIL.

:box [method]
creates and returns a **bounding-box** of this line.

:boxtest *box* [method]
checks intersection between *box* and the bounding-box of this line.

:length [method]
returns the length of this line.

:distance *point-or-line* [method]
returns the distance between the *point-or-line* and this line. If the foot of the vertical line from the *point* to this line does not lie between pvertex and nvertex, the distance to the closest end-point is returned. Using this method to calculate the distance between two lines, interference between two cylinders can be tested.

:foot *point* [method]
finds the parameter for the point which is the foot of the vertical line from *point* to this line.

:common-perpendicular *l* [method]
finds the line which is vertical both to this line and to *l* and returns a list of two 3D float-vectors.

:project *plane* [method]
returns a list of two points that are the projection of pvert of nvert onto *plane*. When two lines are in parallel and a common perpendicular line cannot be determined uniquely, `parallel` is returned.

:collinear-point *point &optional (tolerance *coplanar-threshold*)* [method]
checks whether *point* is collinear to this line with the tolerance of *tolerance* using **collinear-p**. If *point* is collinear to this line, the parameter for the point on the line is returned, otherwise NIL.

:on-line-point *point &optional (tolerance *coplanar-threshold*)* [method]
checks whether the *point* is collinear to this line, and the *point* lies on the part of the line between

pvert and *nvert*.

:collinear-line *ln &optional (tolerance *coplanar-threshold*)* [method]
checks if *ln* is collinear to this line, i.e. if the two end-points of *ln* lie on this line. T or NIL is returned.

:coplanar *ln &optional (tolerance *coplanar-threshold*)* [method]
checks if this line and *ln* are coplanar. Two end-points of this line and one end-point of *ln* defines a plane. If another end-point of *ln* is on the plane, T is returned, otherwise NIL.

:intersection *ln* [method]
ln is a line coplanar with this line. **:Intersection** returns a list of two parameters for the intersection point of these two lines. A parameter may be any float number, but a parameter between 0 and 1 means an actual intersection on the line segmented by two end-points. NIL if they are in parallel.

:intersect-line *ln* [method]
ln is a line coplanar with this line. Two parameters of the intersecting point is returned along with symbolic information such as `:parallel, :collinear,` and `:intersect`.

edge [class]

:super	**line**
:slots	(pface nface (angle :type float) (flags :type integer))

represents an edge defined as the intersection between two faces. Though *pface* and *nface* are statically defined in the slots, their interpretations are relative to the direction of this edge. For example, *pface* represents the correct pface when this edge is considered to goes from *pvert* toward *nvert*. So, pvert and nvert in your interpretation must be given to the **:pface** and **:nface** methods to select the appropriate face.

make-line *point1 point2* [function]
creates an instance of **line** whose pvert is *point1* and nvert is *point2*.

:pvertex *pf* [method]
returns pvertex when *face* is regarded as the pface of this edge.

:nvertex *face* [method]
returns nvertex regarding *face* as the pface of this edge.

:body [method]
returns the body object that defines this edge.

:pface *pv nv* [method]
returns pface when the *pv* and *nv* are interpreted as the virtual pface and nface of this edge, respectively.

:nface *pv nv* [method]
returns nface when the *pv* and *nv* are interpreted as the virtual pface and nface of this edge, respectively.

:binormal *aface* [method]
finds the direction vector which is perpendicular both to this line and to the normal of *aface*.

:angle [method]
returns the angle between two faces connected with this edge.

:set-angle [method]
computes the angle between two faces connected with this edge and stores it in the angle slot.

:invert [method]

:set-face *pv nv f* [method]
sets the *f* face as a pface regarding *pv* as the pvertex and *nv* as the nvertex. Note that this may change

either pface or nface of this edge.

:contourp *viewpoint* [method]

T if this is a contour edge, i.e., either pface or nface of this edge is visible and the other is invisible from *viewpoint*.

:approximated-p [method]

T if this edge is an approximated edge representing curved surface like the side of a cylinder. Approximated edges are needed to represent curves by segmented straight lines.

:set-approximated-flag *&optional (threshold 0.7)* [method]

In EusLisp, every curved surface is approximated with many planar faces. The LSB of `flags` is used to indicate that the faces on the both sides of this edge are curved faces. **:set-approximated-flag** sets this flag to T, if the angle between two faces is greater than *threshold*.

:init *&key :pface :nface :pvertex :nvertex* [method]

16.3 Plane and Face

A plane object is represented by the normal vector on the plane and the distance from the coordinates origin to the plane. Two pairs of such normal vectors and distances are recorded in a plane object. One represents the current status after transformations, while the other represents the original normal and distance when the plane is defined.

plane [class]

:super **propertied-object**
:slots ((normal :type float-vector)
(distance :float)

defines plane-equation. A plane is considered to have no boundaries and extend infinitely.

:normal [method]
returns this polygon's normal vector which is always normalized.

:distance *point* [method]
computes distance between this plane and *point*.

:coplanar-point *point* [method]
returns T if *point* lies on this plane.

:coplanar-line *line* [method]
returns T if *line* lies on this plane.

:intersection *point1 point2* [method]
computes the intersection point between this plane and the line determined by two end points, *point1* and *point2*, and returns the parameter for the intersection on the line. If the line and this plane are parallel, **:parallel** is returned.

:intersection-edge *edge* [method]
Returns the parameter of the intersection point for this plane and a line represented by point1 and point2, or edge.

:foot *point* [method]
Returns a 3D vector which is the orthogonally projection of *point* onto this plane.

:init *normal point* [method]
Defines a plane with the *point* on the plane and the *normal* vector. *Normal*must be a normalized vector, $|normal| = 1$.

polygon [class]

:super **plane**
:slots (convexp edges vertices
(model-normal float-vector)
(model-distance :float))

Polygon represents a loop on a plane. *Convexp* is a boolean flag representing the convexity of the loop. *Edges* is a list of edges forming the contour of this loop, and *vertices* is a list of vertices.

:box *&optional tolerance* [method]
returns a bounding-box for this polygon.

:boxtest *box2 &optional tolerance* [method]
makes a bounding-box for this polygon, and returns the intersection of the bounding-box and *box2*. If there is no intersection, NIL is returned.

:edges [method]

returns the list of edges (circuit) of this polygon. The list is ordered clockwise when the polygon is viewed along the normal vector of this plane. If you think of the normal vector as a screw, the edges are ordered in the rotation direction for the screw to screw in. When polygon or face is used for the surface representation of a solid object, the normal vector is directed to its outside region. When a polygon is viewed from the outside of the object, edges are ordered counter-clockwise.

:edge *n* [method]

returns the *n*-th element of edges.

:vertices [method]

returns the vertices of this polygon ordered in the same manner as edges. Note that the first vertex is copied duplicatedly at the end of the list and the list is always longer by one than the actual number of vertices. This is for the ease of edge traversal by using the vertices list.

:vertex *n* [method]

returns the *n*-th element of vertices.

:insidep *point &optional (tolerance *epsilon*)* [method]

returns :inside, :outside or :border according to the location of *point* relative to this region.

:intersect-point-vector *point vnorm* [method]

Computes the intersection with the semi-line defined by the *point* and the normalized direction vector, *vnorm*.

:intersect-line *p1 p2* [method]

Computes intersection point with a line specified by *p1* and *p2*. The result is nil(no intersection) or list of the parameter and the intersection position.

:intersect-edge *edge* [method]

Computes intersection point with a line specified by the *edge*. The result is nil(no intersection) or list of the parameter and intersection position.

:intersect-face *aregion* [method]

Returns T if this region intersects with aregion.

:transform-normal [method]

:reset-normal [method]

recomputes the surface normal vector of this polygon from the current *vertices* list.

:invert [method]

:area [method]

returns the area of this polygon.

:init *&key :vertices :edges :normal :distance* [method]

face [class]

:super	**polygon**
:slots	(holes mbody primitive-face id)

defines a face which may have holes. *Pbody* and *type* represent the primitive body and the type `(:top, :bottom, :side)` of the face in the body.

:all-edges [method]

:all-vertices [method]

Returns all the edges or vertices of the contour of this face and all the inner loops (holes). Note that

:edges and **:vertices** methods only return edges and vertices composing the contour.

:insidep *point* [method]

decides whether the point is inside of this face or not. If the point is inside the outer contour of this face but also inside the loop of any holes, it is classified as outside.

:area [method]

returns the area of this face, that is the area surrounded by external edges subtracted by the areas of holes.

:centroid *&optional point* [method]

returns a list of the floating-point number and the float-vector representing the center-of-gravity of this face. If *point* is not given, the first number represents the area of this polygon, and the second float-vector the location of center-of-gravity of this polygon. If *point* is given, it is taken as the top vertex of the cone whose bottom face is formed by this polygon, and the volume of this cone and its center-of-gravity are returned.

:invert [method]

flips the direction of this face. The normal vector is inverted, and the order of edge loop is reversed.

:enter-hole *hole* [method]

adds a hole in this face.

:primitive-body [method]

returns the primitive-body which has defined this face.

:id [method]

returns one of `(:bottom)`, `(:top)` and `(:side seq-no.)`.

:face-id [method]

returns a list of the type of primitive-body and the face type. For example, a side face of a cylinder returns `((:cylinder` *radius height segments*`) :side` *id*`)`.

:body-type [method]

returns primitive body which has defined this face.

:init *&key :normal :distance :edges :vertices :holes* [method]

hole [class]

:super	**polygon**
:slots	(myface)

hole is a polygon representing an inner loop of a face. A face may have a list of holes in its `holes` slot.

:face [method]

returns a face that contains this hole.

:enter-face *face* [method]

makes a link to a face which surrounds this hole. This method is only used in conjunction with the `:enter-hole` method of the face class.

:init *&key :normal :distance :edges :vertices :face* [method]

16.4 Body

body [class]

:super **cascaded-coords**
:slots (faces edges vertices model-vertices box convexp evertedp csg)

defines a three dimensional shape.

:magnify *rate* [method]
changes the size of this body by *rate*. Magnification is recorded in csg list.

:translate-vertices *vector* [method]
translates model-vertices. *Vector* should be given in the local coordinates. Translation is recorded in csg list.

:rotate-vertices *angle axis* [method]
rotates model-vertices *angle* radian around *axis*. Rotation is recorded in csg list.

:reset-model-vertices [method]

:newcoords *rot pos* [method]
changes coordinates.

:vertices [method]
returns the list of all vertices of this body.

:edges [method]
returns the list of all edges of this body.

:faces [method]
returns the list of all the faces composing this body.

:box [method]
returns the bounding-box of this body.

:Euler [method]
calculates Euler number of this body, that is $faces + vertices - edges - 2 - holes$. This should equal to $-2rings$.

:perimeter [method]
returns the sum of length of all the edges.

:volume *&optional (reference-point #f(0 0 0))* [method]
returns the volume of this body.

:centroid *&optional (point #f(0 0 0)* [method]
returns the location of center-of-gravity assuming that this body is homogeneously solid.

:possibly-interfering-faces *box* [method]

:common-box *body* [method]
Returns common minimal box for this body and another body. If there is interference between two bodies, the intersection must exist in this common-box.

:insidep *point* [method]
returns **:inside** if *point* resides in this body, **:border** if *point* lies on a surface of this body, and **:outside** otherwise.

:intersect-face *face* [method]
returns T if there is an interference between the faces of this body and *face*.

:intersectp *body* [method]
Checks intersection with another body.

:evert [method]
reverse the directions of all the faces and edges so that the inside of this body becomes outside.

:faces-intersect-with-point-vector *point direction* [method]
collects all faces that intersect with a vector casted from *point* towards em direction.

:distance *target* [method]
target may either be a float-vector or a plane object. **:distance** finds the closest face from *target* and returns a list of the face and the distance.

:csg [method]
returns csg body construction history.

:primitive-body [method]
returns a list of primitive bodies which have constructed this body.

:primitive-body-p [method]
T if this body is a primitive body created by one of functions listed in 16.5.

:creation-form [method]
returns a Lisp expression to create this body.

:body-type [method]
returns a list of creation parameters if this body is a primitive body, or an expression indicating this body is a complex (composed) body.

:primitive-groups [method]
returns a list of two elements. The first is a list of primitive bodies that is added (body+) to compose this body. The latter is a list of subtracted primitive-bodies.

:get-face *body [face [id]]* [method]
body is an instance of body that has composed this body, one of primitive-body types such as :cube, :cylinder, :prism, :cone, :solid-of-revolution, etc., or nil. If neither *face* nor *id* is given, all the faces that matches *body* is returned. If *face* is given, further filtering is performed. *face* must be one of `:top,` `:bottom` and `:side`. `(send abody :get-face :cylinder :top)` returns all the top faces of cylinders that compose `abody`. If *face* is `:side`, you can pick up faces that are numbered as *id*. `(send abody nil :side 2)` returns all the third (id begins from zero) side faces for any primitive-type bodies.

:init *&key :faces :edges :vertices* [method]
initializes this body from *:faces*. *:face* is a required argument. Since face, edge and vertex must maintain consistent relation to define a complete solid model, it is meaningless to call this method with inconsistent arguments. In order to create bodies, use the primitive body creating functions described in section 16.5 and the body composition functions in section 16.6.

16.5 Primitive Body Creation

make-plane *&key normal point distance* [function]
Makes a plane object which is oriented to *normal*, and passes *point*. Instead of giving *point*, *distance* can be specified.

xy-plane [variable]

yz-plane [variable]

zx-plane [variable]

make-cube *xsize ysize zsize &key name color* [function]
makes a cuboid whose sizes in x, y and z directions are *xsize, ysize* and *zsize*. The coordinates origin of this cuboid locates at the center of the body.

make-prism *bottom-points sweep-vector &key name color* [function]
Makes a prism by lifting the shape defined by *bottom-points* along *sweep-vector*. If the *sweep-vector* is a number, not a float-vector, it is taken as the height of the prism in the *z* direction. Bottom points must be ordered as they define the bottom face of the body. For example, (make-prism '(#f(1 1 0) #f(1 -1 0) #f(-1 -1 0) #f(-1 1 0)) 2.0) makes a cube of height 2.0.

make-cylinder *radius height &key (segments 12) name color* [function]
Makes a cylinder with specified *radius* and *height*. The bottom face is defined on xy-plane and the coordinates origin is located at the center of the bottom face.

make-cone *top bottom &key (segments 16) color name* [function]
makes a cone body whose summit is the *top* and bottom face is the *bottom*. *Top* is a 3D float-vector. *Bottom* is either a list of vertices of the bottom face or a radius (scalar). If it is the vertices list, it is order sensitive. `(make-cone #f(0 0 10) (list #f(10 0 0) #f(0 10 0) #f(-10 0 0) #f(0 -10 0)))` makes a cone of a square bottom.

make-solid-of-revolution *points &key (segments 16) name color* [function]
Points are revolted along z-axis in the clock wise direction. If two end points in the *points* list do not lie on z axis, those points make circular faces. Thus, `(make-solid-of-revolution '(#f(0 0 1) #f(1 0 0)))` makes a cone, and `(make-solid-of-revolution '(#f(1 0 1) #f(1 0 0)))` makes a cylinder. The *points* are order-sensitive, and are expected to be arranged from higher *z* coordinate to lower *z*.

make-torus *points &key (segments 16) name color* [function]
makes a torus, a donuts like object. *Points* is a list of vertices on a cross-section.

make-icosahedron *&optional (radius 1.0)* [function]
Makes a regular body of twenty faces. Each face is a regular triangle.

make-dodecahedron *&optional (radius 1.0)* [function]
Makes a regular body of twelve faces. Each face is a regular pentagon.

make-gdome *abody* [function]
By subdividing triangle faces of abody into four subfacets, makes a geodesic dome as a new body. Abody should be an icosahedron initially, and then the result of make-gdome can be given to make-gdome recursively. At each call, the number of faces of the Gdome increases by the factor of four, i.e. 20, 80, 320, 1280, 5120, etc.

```
(setq g0 (make-icosahedron 1.0)) ; 20 facets
(setq g1 (make-gdome g0)) ; 80 facets
(setq g2 (make-gdome g1)) ; 320 facets
...
```

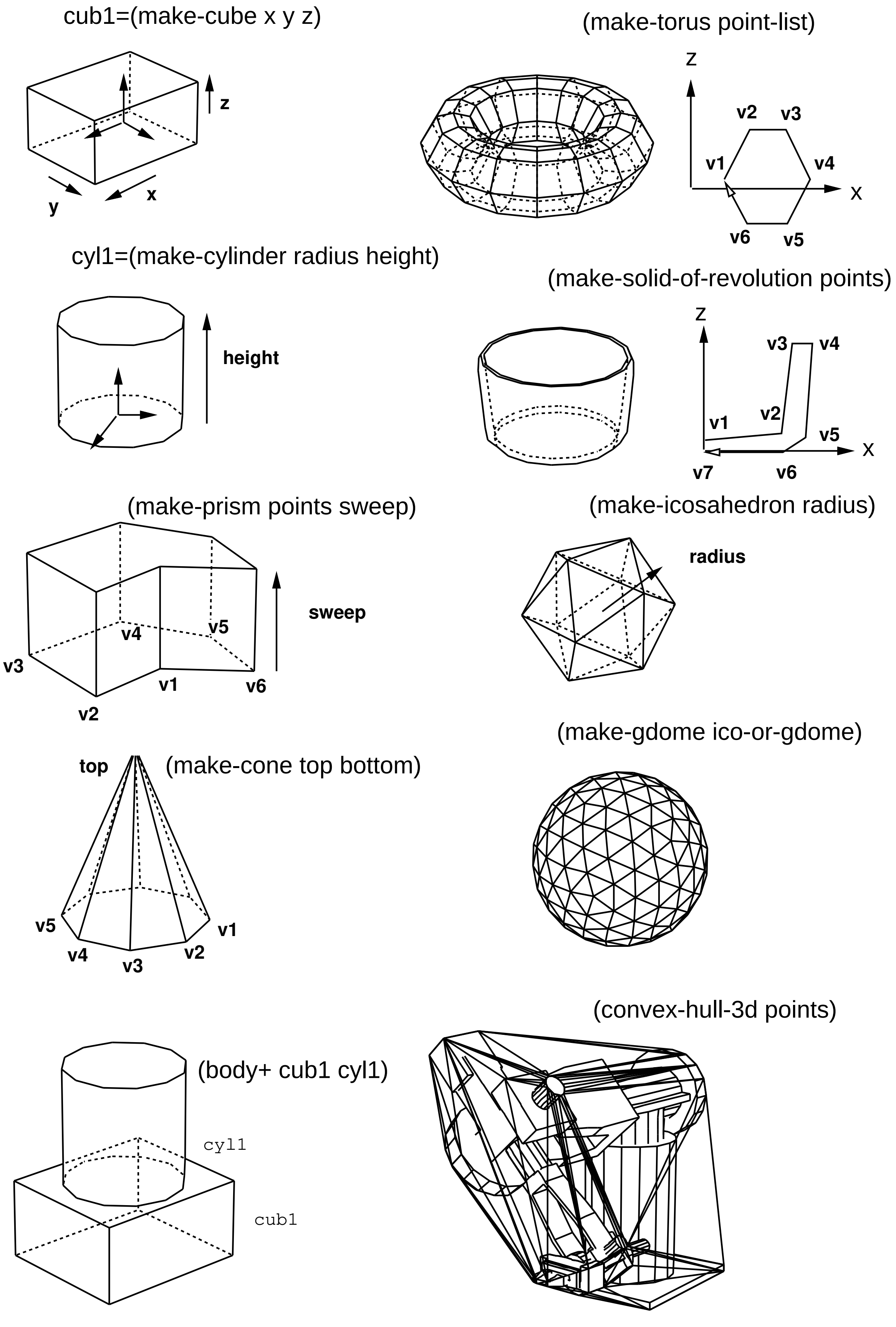

Figure 10: primitive bodies

grahamhull *vertices &optional (normal #f(0 0 1))* [function]
Computes convex-hull for 2D points by Graham's algorithm. Slower than quickhull.

quickhull *vertices &optional (normal #f(0 0 1))* [function]
Computes convex-hull for 2D points by the binary search method.

convex-hull-3d *vertices* [function]
Computes convex-hull for 3D points by gift-wrapping method.

make-body-from-vertices *vertices-list* [function]
creates a body from lists of vertices each of which define a loop of a face in the consistent order.

16.6 Body Composition

face+ *face1 face2* [function]

face* *face1 face2* [function]
face1 and *face2* are coplanar faces in 3D space. **face+** composes union of these faces and returns a face object. If there is no intersection, original two faces are returned. **face*** returns intersection of these faces. If there is no intersection, NIL is returned.

cut-body *body cutting-plane* [function]
Cuts a body by the *cutting-plane* and returns a list of faces made at the cross-section.

body+ *body1 body2 &rest more-bodies* [function]

body- *body1 body2* [function]

body* *body1 body2* [function]
Computes join, difference or intersection of two or more bodies. Each body is copied before each **body+, body-** and **body*** operation, and original bodies are unchanged. The new coordinates of the resulted body is located and oriented at the same location and orientation as the world coordinates. Even when two bodies are touching face by face, these functions are expected to work correctly if threshold parameters `*coplanar-threshold*`, `*contact-threshold*`, and `*parallel-threshold*` are properly set. However, if a vertex of a body is in contact with an edge or a face of the other body, any composition operation fails.

body/ *body plane* [function]
Cut the body by a plane which is an instance of class plane (made by **make-plane**). A newly created body is returned.

body-interference *&rest bodies* [function]
Checks interference between each one-to-one combination in *bodies*. Returns a list of two bodies that are intersecting.

16.7 Coordinates-axes

Class coordinates-axes defines 3D coordinates-axes drawable on a screen. Each axis and an arrow at the tip of z-axis are defined by line objects. Since the coordinates-axes class inherits cascaded-coords, a coordinates-axes object can be attached to another cascaded-coords originated object such as a body. This object is used to see the coordinates-axes of a body or a relative coordinates to another coordinates.

coordinates-axes [class]

:super **cascaded-coords**

:slots (size model-points points lines)

Defines drawable 3-D coordinates-axes.

16.8 Bodies in Contact

The method and functions described in this subsection require **contact/model2const.l, contact/inequalities.l, contact/drawconst.l**.

body [class]

:super **object**
:slots ()

defines a three dimensional shape.

:constraint *b* [method]
returns self's constraint when self is in contact with *b*.

constrained-motion *c* [function]
returns the possible motions which satisfy the constraint *c*.

constrained-force *m* [function]
returns the force which is applicable from the constrained body to the constraining body.

draw-constraint *c* [function]
draws the constraint *c*.

draw-motion *m a b* [function]
draws the possible motions of *a* in contact with *b*. Type the return key for drawing.

Example

```
;;
;;      peg in a hole with 6 contact points
;;
(in-package "GEOMETRY")
(load "view")
(load "../model2const.l" :package "GEOMETRY")
(load "../inequalities.l" :package "GEOMETRY")
(load "../drawconst.l" :package "GEOMETRY")

(setq x (make-prism '(#f(50 50 0) #f(50 -50 0) #f(-50 -50 0) #f(-50 50 0))
                    #f(0 0 200)))
(setq x1 (copy-object x))
(send x1 :translate #f(0 0 -100))
(send x1 :worldcoords)
(setq a1 (make-prism '(#f(100 100 -150) #f(100 -100 -150)
                       #f(-100 -100 -150) #f(-100 100 -150))
                     #f(0 0 150)))
(setq ana (body- a1 x1))
(send x :translate #f(0 -18.30127 -18.30127))
(send x :rotate -0.523599 :x)
(send x :worldcoords)

(setq c (list (send x :constraint ana)))
(setq m (constrained-motion c))
(setq f (constrained-force m))

(hidd x ana)
(draw-constraint c)
(draw-motion m)
```

The following figures shows examples of constraints. The small arrows in the figures designate the constraints for the pegs.

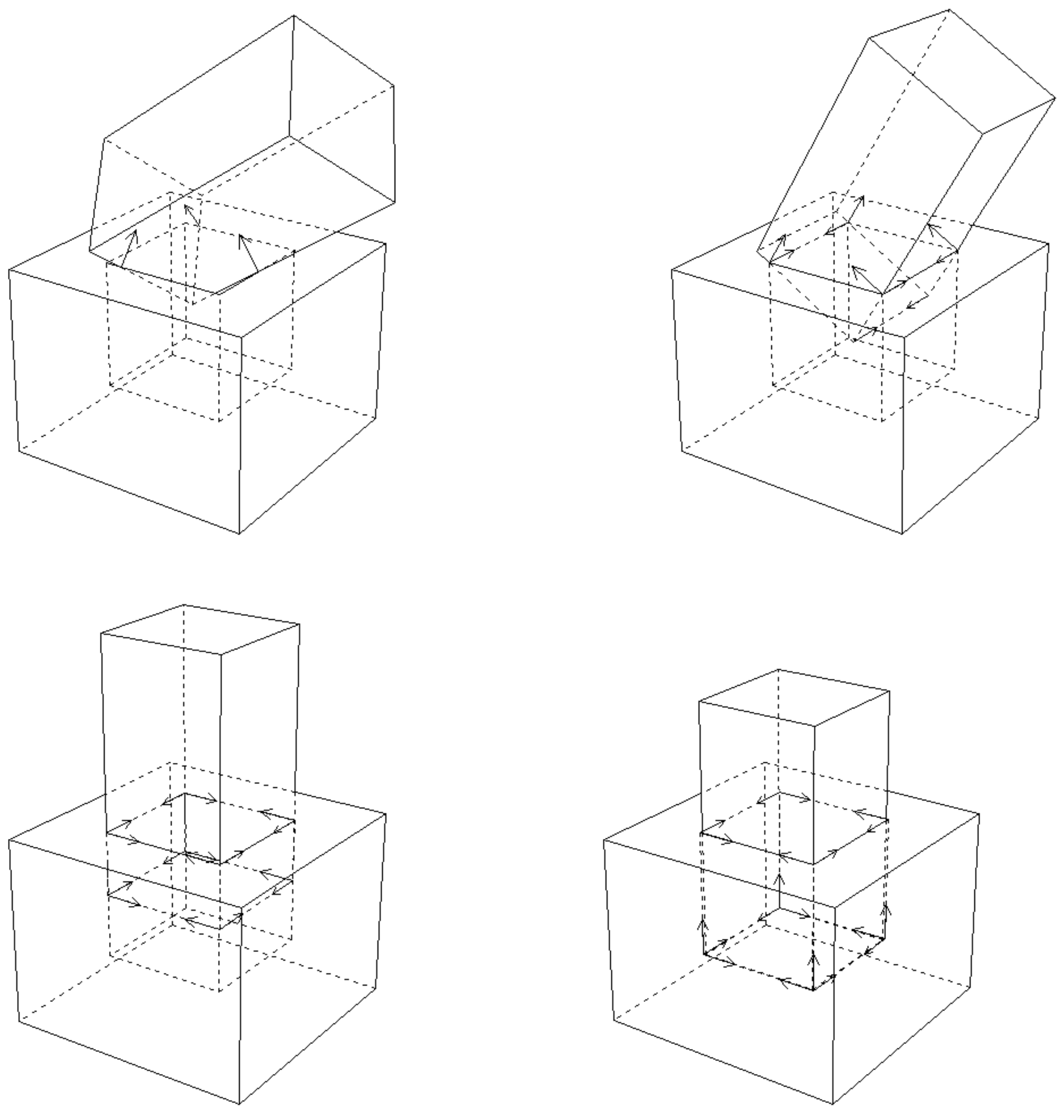

Figure 11: Constraints for a peg in a hole.

The following figures shows an example of the possible motions of a peg in a hole. The example corresponds to the above program.

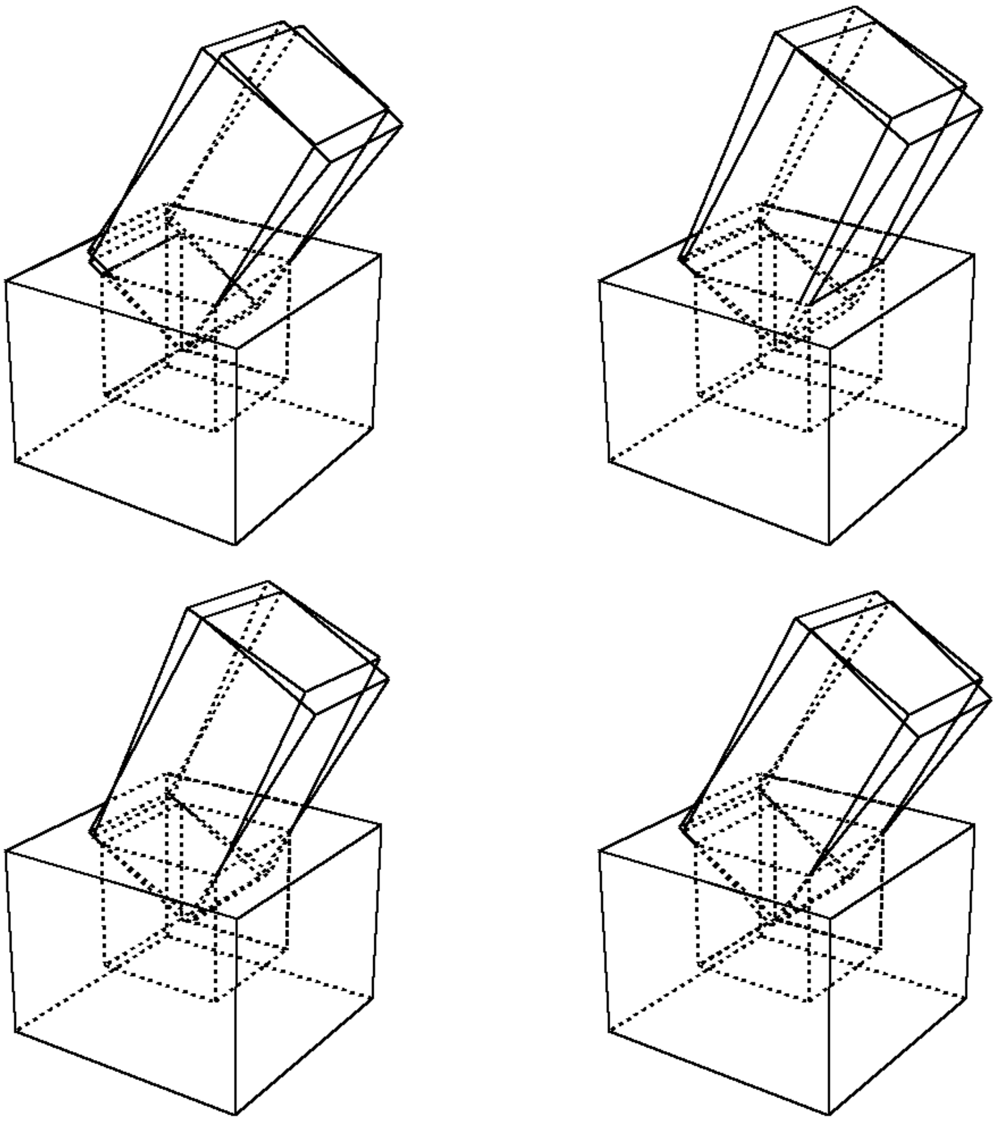

Figure 12: Possible motions of a peg in a hole

16.9 Voronoi Diagram of Polygons

Author: Philippe PIGNON, ETL Guest Researcher

The program is written in COMMON LISP. I used the method of Fortune, "A sweepline algorithm for Voronoi diagrams", in Proceedings of the 2nd Annual ACM symposium on computational geometry, 1986, 313-322. I adapted it to the polygonal case. This is a sample file with short explanations This program was written under Electrotechnical EUSLISP environment, so graphic connections are provided for it. However, you can use it with any COMMON-LISP; you'll then have to write your own display functions to replace those given in utilities.l file (see below)

PURPOSE: Computation of the voronoi diagram of a set of polygons. Please read the above quoted reference to understand the vocabulary and method used. No explanations about the program itself will be given here.

INPUT: A list of polygons coordinates plus an enclosing frame.

```
DATA= (
       (x11 y11 x12 y12 x13 y13 ...) first polygon,
                                     counterclocwise enumeration of vertices
       (x21 y21 x22 y22 x23 y23 ...) second polygon
               ...
       (xn1 yn1 xn2 yn2 xn3 yn3 ...) nth polygon

       (xf1 yf1 xf2 yf2 xf3 yf3 xf4 yf4) enclosing frame
      )
```

Enclosing frame can occur anywhere in data, and should be clockwise enumerated for outside-inside marking consistency (see below). Polygons must be simple, non intersecting. Aligned or flat edges are not accepted. Neither are isolated points or segments.

OUTPUT: *diagram*: a list of doubly connected edges list (cf utilities.l file). Each edge is a symbol, with property list including the following fields:

```
(start <pointer to a vertex>)
       (end <pointer to a vertex>)
       (pred <pointer to an edge>)
       (succ <pointer to an edge>)
       (left <pointer to a site>)
       (right <pointer to a site>)
       (type <:endpoint or :point-point or :segment-segment or :point-segment>)
       (outflag <t or nil>)
```

A *vertex* is a symbol whose property list contains the field "pos". This field itself contains a cons (xy), (real) planar coordinates of the vertex. *Pred* and *succ* field give counterclockwise predecessor and successor according to the dcel formalism (see Shamos and Preparata, Computational Geometry: An introduction, 1985, pp 15-17). A *site* is also a symbol, whose property list also contains relevant information. Sites describe original input data; they can be of type :point (a polygon vertex) or segment (a polygon edge). *Type* is the gender of the bisector, determined by the type of the sites it separates. By convention, outside is the right side of a start-end edge. The voronoi diagram computes ouside as well as inside bisectors. Sort on outflag to keep the ones you want.

pv *data* [function]

Compute the Voronoi diagram of polygons from the *data* with the above format.

SAMPLE: In order to run the program on a short sample, please perform the following steps:

0- Copy the following files in your environment:

utilities.l	Geometric utility functions, plus EUSX graphic functions
polygonalvoronoi.l	The program.
testdata.l	Demonstration data, with the above format.

1- If you do not use EUS, edit the utilities.l file and modify the "compatibility package" according to the instructions.

2- Compile and/or load the following 3 files:

utilities.l	
polygonalvoronoi.l	
testdata.l	This file contains demonstration data,with the above format

3- (pv demoworld) run the program on demonstration data. The global variable *diagram* contains the

bisectors of the voronoi diagram.
Under EUSX only (eus with XWindow interface), do the following to display the resulting diagram:

```
(make-display)          ;;Initializes the *display* window object
(dps demoworld *thick*) ;; Shows original data in thick lines
(dbs *diagram*)         ;; Shows the result
```

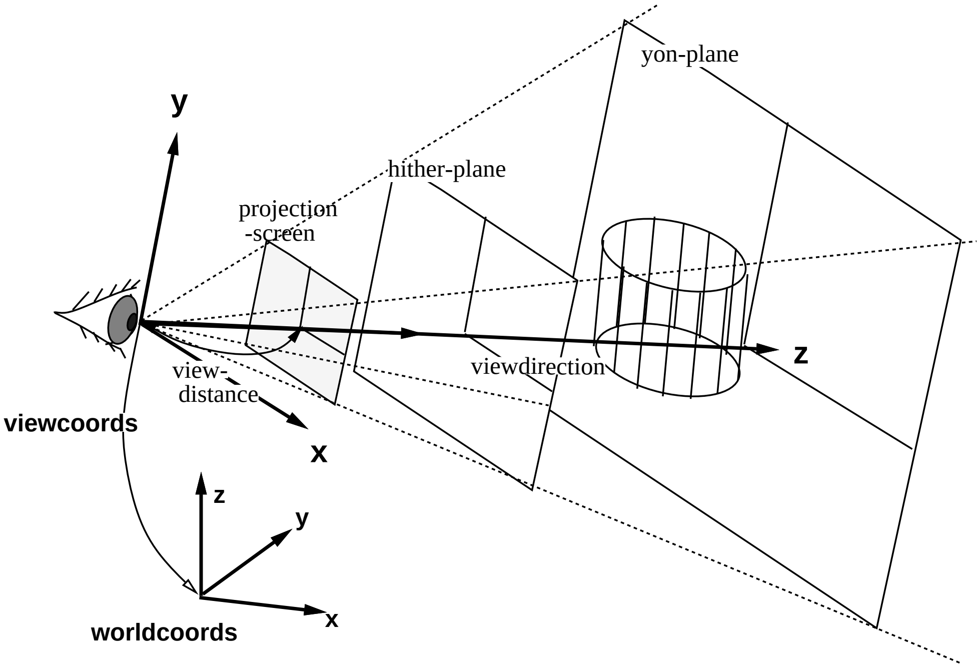

Figure 13: viewing coords and projection planes

17 Viewing and Graphics

17.1 Viewing

A viewing object manages viewing coordinate system whose origin is located at the position of a virtual camera, -*z* axis is oriented to the objects observed, and xy-plane is the projection screen. Since viewing inherits class cascaded-coords, it accepts coordinates transformation message such as **:translate, :rotate** and **:transform**. Also, it can be attached to another object derived from cascaded-coords, allowing the simulation of the camera-on-mobile-object system. The main purpose of viewing is to transform vectors represented in the world to the camera coordinates system. The transformation is taken in the opposite direction against usual coordinate transformation where vectors in the local coordinates are transformed into the representation in the world. Therefore, viewing holds the inversed left-handed transformation in the viewcoords slot, which is usually referred as the viewing coordinate system.

viewing [class]

:super **cascaded-coords**
:slots (viewcoords)

defines the viewing transformation.

:viewpoint [method]

returns the position vector of the origin of this viewing.

:view-direction [method]

returns the vector from the origin of the viewing to the center of screen. This is the z-axis direction of the viewing coordinates.

:view-up [method]

returns y-axis vector of this viewing represented in the world coords. Y-axis is the upward direction in the viewport.

:view-right [method]

returns x-axis vector of this viewing represented in the world coords. X-axis is in horizontal direction to the right in the viewport.

:look *from &optional (to #f(0 0 0))* [method]

:look conveniently sets the viewing coords as the eye is located at *from* and looking at *to* point.

:init *&key :target #f(0 0 0)* [method]
:view-direction nil
:view-up #f(0.0 0.0 1.0))
:view-right nil
&allow-other-keys

Since viewing inherits cascaded-coords, all the *:init* parameters such as *:pos*, *:rot*, *:Euler*, *:rpy*, etc. can be used to specify the location and the orientation of the viewing coordinates. However, viewing's *:init* provides easier way to determine the rotation. If only *:target* is given, view-line (-z axis) is determined to pass the viewpoint and *:target* point, and the *:view-right* vector is determined so that the x-axis is parallel to the xy-plane of the world coordinates. You may specify *:view-direction* instead of *:target* to get the same effect. If you give *:view-up* or *:view-right* parameter in addition to *:target* or *:view-direction*, you can determine all the three rotation parameters by yourself.

17.2 Projection

Class **parallel-projection and perspective-projection** process projection transformation, which is represented with a 4X4 matrix, i.e., the transformation is taken in the three dimensional homogeneous coordinates. Class **projection** is an abstract class for both of these. Since these projection classes inherit the viewing class, two coordinates transformation, world-to-viewing and projection can be performed at the same time. By sending the `:project3` message with a 3D vector to a projection object, a float-vector of four elements is returned. **Homo2normal** function is used to convert this homogeneous vector to the normal representation. The result is a vector represented in so called normalized device coordinates (NDC), in which a visible vector ranges within -1 to 1 in each of x,y, and z dimensions. For the simulation of real cameras in a robot world, the perspective projection is used more often than the parallel-projection. Perspective-projection defines a few more parameters. `Screenx` and `screeny` are the sizes of the window on the viewing plane on which observed objects are projected, and with the larger screen, the wider space is projected. `Viewdistance` which defines the distance between the viewpoint and the viewplane also concerns with the viewing angle. The larger viewdistance maps the smaller region to the window on the view plane. `Hither` and `yon` parameters determine the distance to the front and back depth clipping planes. Objects outside these two planes are clipped out. Actually, this clipping procedure is performed by the viewport object.

projection [class]

:super **viewing**
:slots (screenx screeny hither yon projection-matrix)

defines projection transformation with a 4x4 matrix.

:projection *&optional pmat* [method]

if *pmat* is given, it is set to the *projection-matrix* slot. **:projection** returns the current 4x4 projection matrix.

:project *vec* [method]

Vec is a three-dimensional homogeneous float-vector of four elements. *Vec* is transformed by projection-matrix, and the resulted homogeneous representation is returned.

:project3 *vec* [method]

Vec is a normal 3D float-vector. *Vec* is homogenized and transformed by projection-matrix, and the resulted homogeneous representation is returned.

:view *vec* [method]

applies viewing transformation and projection transformation to *vec* successively. The resulted homogeneous representation is returned.

:screen *xsize (&optional (ysize xsize))* [method]
changes the size of the viewing screen. The larger the size, the wider view you get.

:hither *depth-to-front-clip-plane* [method]
determines the distance from the viewpoint to the front-clipping plane. Objects before the front-clipping (hither) plane are clipped out.

:yon *depth-to-back-clip-plane* [method]
changes the distance between the viewpoint and the back-clipping plane. Objects behind the back-clipping (yon) plane are clipped out.

:aspect *&optional ratio* [method]
Aspect ratio is the ratio between screen-y and screen-x. If *ratio* is given, the aspect ratio is changed by setting screen-y to screen-x * *ratio*. **:aspect** returns the current aspect ratio.

:init *&key* [method]

:hither	*100.0*
:yon	*1000.0*
:aspect	*1.0*
:screen	*100.0*
:screen-x	*screen*
:screen-y	*(* screen-x aspect)*
&allow-other-keys	

initializes viewing and projection.

parallel-viewing [class]

:super	**projection**
:slots	()

defines parallel projection. **Hid** (the hidden-line elimination function) cannot handle parallel projection.

:make-projection [method]

perspective-viewing [class]

:super	**projection**
:slots	(viewdistance)

defines a perspective projection transformation.

:make-projection [method]

:ray *u v* [method]
returns the normalized direction-vector pointing (u,v) on the normalized screen from the viewpoint.

:viewdistance *&optional vd* [method]
Viewdistance is the distance between viewpoint and the screen. If *vd* is given, it is set to viewdistance. The viewdistance corresponds to the focal length of a camera. The greater the viewdistance, the more zoomed-up view you get. **:viewdistance** returns the current viewdistance.

:view-angle *&optional ang* [method]
set screen size so that the prospective angle of the diagonal of the screen becomes *ang* radian. Note that angles somewhat between 20 degree (approx. 0.4 rad.) and 50 degree (0.9 rad.) can generate a natural perspective view. Wider angle generates a skewed view, and narrower a flat view like orthogonal (parallel) viewing. **:view-angle** returns current or new view angle in radian.

:zoom *&optional scale* [method]
If *scale* is given, the screen is changed relatively to the current size by *scale* (the viewdistance is

unchanged). If you give 0.5 for *scale*, you get two times as wide view as before. **:zoom** returns new view angle in radian.

:lookaround *alfa beta* [method]
translates and rotates the viewpoint. The center of rotation is taken at the midst of the hither plane and the yon plane on the viewline. The viewing coordinates is rotated *alfa* radian around world's z-axis and *beta* radian around x-axis locally. **:lookaround** allows you to move around the object in the center of viewing.

:look-body *bodies* [method]
changes view direction, screen sizes, and hither/yon so that all the *bodies* fit in the viewport. Viewpoint does not change. View direction is chosen so that the viewing line penetrate the center of the bounding box of all bodies.

:init *&key (:viewdistance 100.0) &allow-other-keys* [method]

17.3 Viewport

Class **viewport** performs three-dimensional viewport clipping in the normalized device coordinates, and maps the result into the device dependent coordinates. The viewport is the term representing the visible rectangular area on a screen. The physical size (dots in x and y) of a viewport should be given with **:init** message as the *:width* and *:height* arguments. *:xcenter* and *:ycenter* arguments determine the physical location of the viewport. These two parameters actually decide the location where objects are drawn on the screen when you are using a primitive display device like tektronics 4014 on which every dimension must be given absolutely to the origin of the screen. If you are using more sophisticated display device like Xwindows where locations can be determined relatively to the parent window, you need not to change viewport's parameters to move the viewport. These parameters are independent of the actual display location.

Viewport class assumes the origin of the viewport at the lower-left corner of the rectangular area and y-axis extends to the upper direction. Unfortunately, in many window systems and display devices, the origin is taken at the upper-left corner and y-axis extends to the lower direction. To work around this problem, a negative value should be given to the *:height* parameter.

homo-viewport-clip *v1 v2* [function]
V1 and *v2*, which are two homogeneous vectors with four elements, represent a line in 3-D space. The line is clipped at the boundary of $x = -1, x = 1, y = -1, y = 1, z = 0, z = 1$, and a list of two vectors are returned. If the line lies completely outside the viewport, NIL is returned.

viewport [class]

:super	**coordinates**
:slots	()

viewport transformation maps the NDC (normalized device coordinates) to device specific coordinates. Inheriting the **coordinates** class, the `viewport` defines the size and the relative position of the projection screen.

:xcenter *&optional xcenter* [method]
X coordinates of the center of this viewport.

:ycenter *&optional ycenter* [method]
Y coordinates of the center of this viewport.

:size *&optional size* [method]
List of sizes in x direction and y direction.

:width *&optional width* [method]
width of this viewport.

:height *&optional height* [method]

height of this viewport.

:screen-point-to-ndc *p* [method]

p is a float-vector representing the location in the physical screen. *p* is transformed into the representation in the normalized-device coordinates.

:ndc-point-to-screen *p* [method]

NDC representation in this viewport, *p*, is transformed into the physical address on the screen.

:ndc-line-to-screen *p1 p2 &optional (do-clip t)* [method]

Two 3D float-vectors, *p1* and *p2*, define a line in NDC. These two end points are transformed to the representation in the screen space. If *do-clip* is non-nil, the line is clipped.

:init *&key (xcenter 100) (ycenter 100) (size 100) (width 100) (height 100)* [method]

makes a new viewport object.

17.4 Viewer

To get a drawing on a screen, four objects are needed: (1) objects to be drawn, (2) a viewing which defines the viewing coordinates and the projection, (3) a viewport for clipping in NDC and the transformation from NDC to physical screen coordinates, and (4) a viewsurface which performs drawing functions on a physical display device. A **viewer** object holds a viewing, a viewport and a viewsurface object, and controls successive coordinates transformation. Functions **draw** and **hid** described in section 17.5 use the instances of viewer.

viewer [class]

:super	**object**
:slots	(eye :type viewint)
	(port :type viewport)
	(surface :type viewsurface)

defines the cascaded coordinates transformation from the viewing via the viewport to the viewsurface.

:viewing *&rest msg* [method]

If *msg* is given, *msg* is sent to the viewing (eye) object, Otherwise, the viewing (eye) object is returned.

:viewport *&rest msg* [method]

If *msg* is given, *msg* is sent to the viewport (port) object, Otherwise, the viewport (port) object is returned.

:viewsurface *&rest msg* [method]

If *msg* is given, *msg* is sent to the viewsurface (surface) object, Otherwise, the viewsurface (surface) object is returned.

:adjust-viewport [method]

When the size of viewsurface has been changed, **:adjust-viewport** changes viewport transformation sending a proper message to port.

:resize *width height* [method]

changes the size of viewsurface by sending :resize message to the viewsurface and :size message to viewport.

:draw-line-ndc *p1 p2 &optional (do-clip t)* [method]

draws a line whose two end points *p1, p2* are defined in NDC.

:draw-polyline-ndc *polylines* [method]

draws polylines whose end points are defined in NDC.

:draw-star-ndc *center &optional (size 0.01)* [method]

draws a cross mark in NDC.

:draw-box-ndc *low-left up-right* [method]
draws a rectangle in NDC.

:draw-arc-ndc *point width height angle1 angle2 [color]* [method]
draws an arc in NDC. The viewsurface object bound in this viewer must accept **:arc** message.

:draw-fill-arc-ndc *point width height angle1 angle2 [color]* [method]
draws a filled-arc in NDC.

:draw-string-ndc *position string [color]* [method]
draws *string* at *position* defined in NDC.

:draw-image-string-ndc *position string [color]* [method]

:draw-rectangle-ndc *position width height [color]* [method]

:draw-fill-rectangle-ndc *point width height [color]* [method]

:draw-line *p1 p2 &optional (do-clip t)* [method]
draws a line whose two end points *p1, p2* are defined in the world coordinates.

:draw-star *position &optional (size 0.01)* [method]
draws a cross at *position* located in the world.

:draw-box *center &optional (size 0.01)* [method]
draws a rectangular at *center*in the world.

:draw-arrow *p1 p2* [method]
draws an arrow from *p1* to *p2*.

:draw-edge *edge* [method]

:draw-edge-image *edge-image* [method]

:draw-faces *face-list &optional (normal-clip nil)* [method]

:draw-body *body &optional (normal-clip nil)* [method]

:draw-axis *coordinates &optional size* [method]
draws coordinates axes whose length is *size*.

:draw *&rest things* [method]
draws 3D geometric objects. If the object is a 3D float-vector, a small cross is drawn at the position. If it is a list of 3D float-vectors, it is taken as a polyline. If *thing* accepts `:draw` message, the method is invoked with this viewer as its argument. If the object defines `:drawners` method, the **:draw** message is sent to the result of `:drawners`. `Line, edge, polygon, face`, and `body` objects are drawn by corresponding *:draw-xxx* methods defined in viewer.

:erase *&rest things* [method]
draws *things* with background color.

:init *&key :viewing :viewport :viewsurface* [method]
sets *viewing, viewport* and *viewsurface* to `eye, port`, and `surface` slots of this viewer.

view *&key (size 500) (width size) (height size)* [function]
(x 100) (y 100)

(title "eusx")
(border-width 3)
(background 0)
(viewpoint #f(300 200 100)) (target #f(0 0 0))
(viewdistance 5.0) (hither 100.0) (yon 10000.0)
(screen 1.0) (screen-x screen) (screen-y screen)
(xcenter 500) (ycenter 400)

creates a new viewer and pushes it in *viewers* list.

17.5 Drawings

draw *[viewer] &rest thing* [function]
draws *things* in *viewer*. *Thing* can be any of coordinates, body, face, edge, float-vector, list of two float-vectors. If you are running `eusx`, `(progn (view) (draw (make-cube 10 20 30)))` draws a cube in a xwindow.

draw-axis *[viewer] [size] &rest thing* [function]
draws coordinate-axes of *things* in *viewer* with *size* as the length of each coordinates-axis. *Thing* can be any object derived from coordinates.

draw-arrow *p1 p2* [function]
draws an arrow pointing from p1 to p2 in `*viewer*`.

hid *[viewer] &rest thing* [function]
draws hidden-line eliminated image in *viewer*. *Thing* can be of face or body.

hidd *[viewer] &rest thing* [function]
is same as **hid**, except that **hidd** draws hidden lines with dashed-lines.

hid2 *body-list viewing* [function]
Generate hidden-line eliminated image represented by edge-image objects. The result is bound to ***hid***.

render *&key bodies faces (viewer *viewer*) (lights *light-sources*) (colormap *render-colormap*) (y 1.0)* [function]
does ray-tracing for *bodies* and *faces* and generates hidden-surface removed images. viewing, viewport, and viewsurface are taken from *viewer*. *lights* is a list of `light-source` objects. *colormap* is xwindow's colormap object. Each of bodies and faces must have color attribute assigned. This can be done by sending `:color` message with the name of color LUT defined in the *colormap*. Currently this function works only in Xlib environment. See examples in `demo/renderdemo.l`.

make-light-source *pos &optional (intensity 1.0)* [function]
make a light-source object located at *pos*. *intensity* is magnifying ratio which multiplies default light intensity. In order to determine the intensity more precisely, use `:intensity` method of a light-source.

tektro *file &rest forms* [macro]
opens file for `*tektro-port*` stream, and evaluates forms. This is used in order to redirect the output of tektro drawings to a file.

kdraw *file &rest forms* [macro]
Kdraw is a macro to produce a [ik]draw-readable postscript file. **Kdraw** opens *file* in `:output` mode, makes a kdraw-viewsurface and a viewport with which `*viewer*` is replaced, and evaluates *forms*. Each of *forms* is a call to any of drawing functions like `draw` or `hid`. Drawing messages from these forms are redirected to a `kdraw-viewsurface`, which transforms the messages into postscript representations that `idraw` or `kdraw` can recognize, and stores them in *file*. When `idraw` or `kdraw` is invoked and *file* is opened, you see the identical figure you drew in a EusViewer window. The figure can be modified by `idraw`'s facilities, and the final drawing can be incorporated into a LaTeXdocument using the `epsfile` environment.

pictdraw *file &rest forms* [macro]
Pictdraw is a macro to produce picture files in the Macintosh PICT format.

pictdraw *file &rest forms* [macro]
Pictdraw is a macro to produce picture files for Macintosh in PICT format. **Pictdraw** opens *file* in `:output` mode makes a pictdraw-viewsurface and a viewport with which `*viewer*` is replaced, and evaluates *forms*. Each of *forms* is a call to any of drawing functions like `draw` or `hid`. Drawing messages from these forms are redirected to a `kdraw-viewsurface`, which transforms the messages into PICT format that `macdraw` or `teachtext` of Macintosh can recognize, and stores them in *file*.

hls2rgb *hue lightness saturation &optional (range 255)* [function]

Color representation in HLS (Hue, Lightness, and Saturation) is converted to RGB representation. HLS is often referred to as HSL. *Hue* represents a color around a rainbow circle (from 0 to 360). 0 for red, 45 for yellow, 120 for green, 240 for blue, 270 for magenta, and 360 again for red, etc. *Lightness* is a value between 0.0 and 1.0, representing from black to white. The color of lightness value of 0 is always black regardless to the hue and saturation, and the lightness value 1.0 is always white. *Saturation* is a value between 0.0 and 1.0, and represents the strength of the color. The greater the saturation value, the divider the color, and small saturation values generate weak, dull tone colors. *Range* limits the RGB values. If you are using a color display which can assign 8bit value to each of red, green and blue, *range* should be 255. If you use Xwindow, which virtually assigns 16bits integers to RGB, you should specify *range* to 65535. Note the difference between HSV and HLS. In HLS, vivid (rainbow) colors are defined with lightness=0.5.

rgb2hls *red green blue &optional (range 255)* [function]

RGB representation of a color is converted into the corresponding representation in HLS.

17.6 Animation

EusLisp's animation facility provides the pseudo real-time graphics on stock workstations without graphics accelerators. The basic idea is the quick playback of a series of images which have been generated after long computation. Images are retained in two ways: one is to keep a number of xwindow pixmaps each of which holds a complete pixel image, and the other is to keep line segment data obtained by hidden-line elimination. The former is faster and the only way for rendered images, but not suitable for a long animation since it requires much memory in the X server. The latter is more memory efficient and suitable for storing data in disks, but the performance is degraded when the number of line segments increases.

In either way, the user provide a function which gives new configurations to the objects to be drawn and generates drawing on `*viewer*`. **pixmap-animation** calls this function as many times as specified by the *count* argument. After each call, the content of `*viewsurface*`, which is assumed to be an xwindow, is copied to a newly created Xwindow pixmap. These pixmaps are played back by **playback-pixmaps**. Similarly, **hid-lines-animation** extracts visible line segments from the result of **hid**, and accumulates them in a list. The list is then played back by **playback-hid-lines**.

Following functions are defined in `llib/animation.l`, and `demo/animdemo.l` contains a sample animation program using **hid-lines-animation** on the ETA3 manipulator model.

pixmap-animation *count &rest forms* [macro]

forms are evaluated *count* times. After each evaluation, the content of `*viewsurface*` is copied in a new pixmap. A list of *count* pixmaps is returned.

playback-pixmaps *pixmaps &optional (surf *viewsurface*)* [function]

Each pixmap in the *pixmaps* list is copied to *surf* successively.

hid-lines-animation *count &rest forms* [macro]

forms, which are assumed to include call(s) to **hid**, are evaluated *count* times. After each evaluation, the result of **hid** held in ***hid*** is scanned and visible segments are collected in a list of point pairs. A list of length *count* is returned.

playback-hid-lines *lines &optional (view *viewer*)* [function]

lines is a list of lists of point pairs. draws lines successively on *view*. Double buffering technique allocating another pixmap is used to generate flicker-free animation.

list-visible-segments *hid-result* [function]

collects visible segments from the list of edge-images *hid-result*.

18 Image Processing

Image processing facilities are defined in `"vision/piximage"`. For the representations of image data, two classes, **pixel-image** and **color-pixel-image**, are defined. Pixel by pixel translations through look-up tables, edge-finder, and image data transfer in pbm formats are realized.

18.1 Look-Up Tables (LUT)

An LUT is a vector for the translation of pixel data.

make-equilevel-lut *levels &optional (size 256)* [function]
returns a one-dimensional integer-vector that linearly maps values between 0 and *size* into values between 0 and *levels*. For example, `(make-equilevel-lut 3 12)` returns `#i(0 0 0 0 1 1 1 1 2 2 2 2)`.

look-up *src dest lut* [function]
translates values stored in *src* vector into *dest* vector using *lut*. If *dest* is nil, a vector of the same class and size as *src* is created. For example, `(look-up #i(1 2 3) nil #(10 20 30 40 50))` returns `#i(20 30 40)`.

look-up2 *src dest lut1 lut2* [function]
Src and *dest* are integer-vector or byte-vector (string) of the same size. `:Look-up2` translates *src* into *dest* looking-up *lut1* and *lut2* successively.

look-up* *src dest luts* [function]
luts is a list of look-up tables. *src* is translated into *dest* successively looking up look-up tables given in *luts*.

concatenate-lut *lut1 lut2 &optional (size 256)* [function]
concatenates two look-up tables *lut1* and *lut2*, and returns a new look-up table which performs the same translation as *lut1* and *lut2* are looked-up successively.

x-gray32-lut [variable]
LUT to translate 32-level gray-scale into the pixel values in the default color map `x:*colormap*`. `(aref *x-gray32-lut* n)` returns the pixel value for nth gray-level out of 32 levels.

x-gray16-lut [variable]
LUT to translate 16-level gray-scale pixel into the index of x's default color map `x:*colormap*`.

x-color-lut [variable]
LUT for several vivid colors defined in `x:*color-map*`. Registered colors are "black", "red", "green", "lightblue", "yellow", "orange", "blue", "magenta", "white".

256to8 [variable]
256-entry LUT to translate integers in range of 0..255 into 0..7. The levels are linearly mapped.

256to16 [variable]
256-entry LUT to translate integers in range of 0..255 into 0..15. The levels are linearly mapped.

256to32 [variable]
256-entry LUT to translate integers in range of 0..255 into 0..31. The levels are linearly mapped.

gray32 [variable]
256-entry LUT to translate the raw gray-scale pixels into X's color map indices. This is made by concatenating two LUTs, `*256to32*` and `*x-gray32-lut*`. An Xwindow display-able pixel-image with 32 gray-levels can be obtained by translating the 256-level raw image by ***gray32***.

rainbow32 [variable]
256-entry LUT to translate 256-level hue values into into X's rainbow color map indices. This is made by concatenating two LUTs, `*256to32*` and `*x-rainbow32-lut*`.

18.2 Pixel-Image

A single plane of image data is represented by **pixel-image** object. **pixel-image** is a two-dimensional array of bytes. The interpretation of each byte is application dependent. Although it is most commonly used to represent brightness of a pixel, it may be used to represent edge intensity, gradient direction, color component intensity, bar graph, or whatever.

pixel-image [class]

:super **array**
:slots xpicture display-lut histogram
brightness-distribution0
brightness-distribution1
brightness-covariance

`Pixel-image` is the two dimensional array with displaying facility in xwindows. The pixel conversion is performed by *display-lut* and the resulted image is stored in *xpicture*. Major axis is taken vertically. The pixel of `img` at `(x, y)` should be accessed by `(aref img y x)`.

:width [method]
returns the horizontal size of a pixel-image, which is the second dimension.

:height [method]
returns the vertical size of a pixel-image.

:size [method]
is equivalent to array-total-size.

:transpose *&optional (result (instance (class self) :init dim0 dim1))* [method]
exchanges x and y coordinates.

:map-picture *lut &optional (result (send self :duplicate))* [method]
This pixel-image is translated by the *lut* and stored in *result*.

:map *fn &optional (result (send self :duplicate))* [method]
applies function *fn* to all the pixels in the image, and put the result in the *result* pixel-image.

:brightest-pixel [method]
finds the brightest pixel value in this image.

:darkest-pixel [method]
finds the darkest pixel value in this image.

:average-pixel [method]
calculates the average intensity of all the pixels in this image.

:halve *&optional simage* [method]
returns pixel-image that is shrunk into half-size image.

:subimage *x y subwidth subheight* [method]
cuts out a *subwidth* x *subheight* rectangular region with its top-left corner at *(x,y)* of this image. The origin of the image is taken at the top-left corner. `:Subimage` returns a new pixel-image object.

:xpicture *&optional lut* [method]
translates this image using the look-up table *lut* and sets translated pixel-image object to *xpicture*.

:display-lut *&optional newlut* [method]
sets look-up table *newlut* as display-lut.Then translates this image using this look-up table and sets translated pixel-image object as xpicture.

:display *(xwin geometry:*viewsurface*)* [method]
displays this pixel-image in the *xwin* xwindow by using `:putimage`. Each pixel value is referred as a index in x's color map. To get a desired appearance, this pixel-image must have been translated by

proper LUTs.

:duplicate [method]
makes an instance of the same class as this image object with the same width and height. The pixel data are not copied.

:copy-from *src* [method]
copies pixel data from another image object specified by *src*. *src* must be of the same dimension as this image.

:hex *&optional (x 0) (y 0) (w 16) (h 16) (strm t)* [method]
prints pixel data in the specified rectangular region in the hexadecimal format.

:hex1 *&optional (x 0) (y 0) (w 64) (h 16) (strm t)* [method]
prints pixel data in the specified rectangular region in the hexadecimal format.

:grin1 *strm &rest msg* [method]
prints this image-pixel object with its name and dimensions.

:init *w h &optional imgvec* [method]
initializes a pixel-image object to have *w* width and *h* height.

:amplify *rate &optional (result (send self :duplicate)* [method]
multiplies *rate* to each pixel value.

:compress-gray-scale *levels &optional result &aux pict2* [method]
translates this image into range of 0..*levels* and returns translated pixel-image object.

:lut *lut1 &optional (result (send self :duplicate))* [method]
translates this image using the look-up table *lut1* and returns translated pixel-image object.

:lut2 *lut1 lut2 &optional (result (send self :duplicate))* [method]
translates this image using a look-up table that concatenated *lut1* and *lut1*. And returns translated pixel-image object.

:histogram [method]
counts the occurrence of each pixel value in this image and returns an integer-vector representing the histogram.

:brightness-distribution [method]
returns brightness-distribution.

:optimum-threshold [method]
returns levels that is maximum of this image's brightness-distribution.

:project-x [method]
adds all pixel values of the same x coordinate and returns a vector of these values.

:project-y [method]
adds all pixel values of the same y coordinate and returns a vector of these values.

:digitize *threshold &optional (val0 0) (val1 255) result* [method]
translates this image into 2 levels image *val0* and *val1* using *threshold*.

:and *img2* [method]
bit-and operates between this image and *img2*, and returns operated pixel-image.

:plot *min max &optional color viewsurface* [method]
plots pixels having values between *min* and *max* inclusively with *color* (gc) on *viewsurface*.

:edge1 *&optional (method 1)* [method]
*(th1 *edge-intensity-threshold*) (th2 *weak-edge-threshold*)*
*(run *edge-length-threshold*) (win geometry:*viewsurface*) (edgeimg1)*

detects edge of this image. And displays this edge on this image.

18.3 Color-Pixel-Image

Color images are represented by **color-pixel-image** objects which have three **pixel-image** objects to represent red, green, and blue components in RGB representation, or hue, lightness, and saturation components in the HLS model. Conversion between RGB and HLS is supported.

color-pixel-image [class]

:super **propertied-object**
:slots width height component1 component2 component3

represents color images with three `pixel-image` objects.

:width [method]
returns the width of this image.

:height [method]
returns the height of this image.

:size [method]
returns $width \times height$ of this image.

:red [method]
returns component1.

:green [method]
returns component2.

:blue [method]
returns component3.

:hue [method]
returns component1. A hue value between 0 and 360 is represented by a byte value between 0 and 255.

:lightness [method]
returns component2. The normalized brightness values (0..1) are mapped into integers between 0 and 255.

:saturation [method]
returns component3. The normalized saturation values (0..1) are mapped into integers between 0 and 255.

:pixel *x y* [method]
returns a list of three integers each of which is taken from component1, component2 and component3 at (*x*,*y*). This triplet can be interpreted either as RGB values or HLS values.

:monochromize *&optional (NTSC nil)* [method]
computes brightness from RGB components and returns a new `pixel-image`. If *NTSC* is nil, $(R + G + B)/3$ is computed. If T, $0.299 * R + 0.587 * G + 0.114 * B$ is computed.

:HLS [method]
assuming this image is representing an RGB image, converts the image into HLS representation. **RGB2HLS** is called for the conversion of each pixel.

:RGB [method]
assuming this image is representing an HLS image, converts the image into RGB representation. **HLS2RGB** is called for the conversion of each pixel.

:halve [method]

returns color-pixel-image that is shrunk into half-size image.

:display *&optional (win *color-viewer*)* [method]
displays this color-pixel-image in a xwindow designated by *win* by using `:putimage`. Each pixel value is referred as a index in x's color map. To get a desired appearance, this pixel-image must have been translated by proper LUTs.

:display-lut *&optional (newlut1) (newlut2 newlut1) (newlut3 newlut2)* [method]
sets look-up tables *newlut1*, *newlut1* and *newlut1* as display-lut, respectively. Then translates this image using this look-up table and sets translated pixel-image object as xpicture.

:edge1 *&optional (method 1)* [method]
*(th1 *edge-intensity-threshold*) (th2 *weak-edge-threshold*)*
*(run *edge-length-threshold*) (win *color-viewer*)*
detects edge of this image. And displays this edge on this image.

:hex *&optional (x 0) (y 0) (w 16) (h 16) (strm t)* [method]
prints pixel data in the specified rectangular region in the hexadecimal format.

:hex1 *&optional (x 0) (y 0) (w 64) (h 16) (strm t)* [method]
prints pixel data in the specified rectangular region in the hexadecimal format.

:prin1 *strm &rest msg* [method]
prints this image-pixel object with its name and dimensions.

:init *width height &optional r g b* [method]
defines the size of a color image and allocates `pixel-image`s for each color component.

Provided a ppm file, you can extract color (hue) values out of the image and display it in an xwindow by the following program.

```
(setq ppmimg (read-pnm "xxx.ppm"))
(send ppmimg :hls)   ; RGB to HLS conversion
(make-ximage (send ppmimg :hue) *rainbow32*)
```

18.4 Edge Finder

Edge Finding facilities are provided by `"vision/edge/edge"`.

edge1 *img &optional (method 1)* [function]
*(th1 *edge-intensity-threshold*) (th2 *weak-edge-threshold*)*
*(run *edge-length-threshold*) result*
&aux (width (send img :width)) (height (send img :height))
finds edge pixels in this image. **edge1** first applies a gradient operator to every pixel. There are three kinds of gradient operators provided: **grad3** which takes difference between horizontally and vertically neighboring pixels, **prewitt** and **sobel**. *method*=0,1 selects **grad3**, 2 selects **prewitt** and 3 selects **sobel**. Pixels that have edge intensity greater than *th1* are identified as strong edge pixels. After thinning edges referring to edge intensities and directions of gradient, isolated edge pixels are marked. Starting from end points of these strong edges, weak edge pixels that are consistent with the strong edge's direction are searched for and linked to compose elongated lines. Weak edge pixels that have greater edge intensity than *th2* are unconditionally linked. Even very weak edge pixels that have less edge intensity than *th2* can be linked as long as they connect to another weak or strong edge within *run* length. **edge1** returns a pixel-image object each pixel of which represents either a strong edge pixel (=1), a weak and elongated edge pixel (=2), or an isolated pixel (=255).

overlay-edge *ximg edgeimg* [function]
displays *edgeimg* obtained by **edge1** on top of x-display-able pixel image *ximg*. Strong edge pixels are colored in red, weak pixels in green, and isolated pixels in blue.

edge2 *img1 edge1result &key (kvalue 8.0)* [function]

(curve-threshold 0.8) (line-error 2.8)
(curve-error 2.8) (plane-limit 0.3)

tries to fit straight lines and elliptic curves to the result obtained by **edge1**. A list of three elements, which represents regions, boundaries, and line segments is returned.

Three elements represented by **edge2** are defined as follow.

region [class]

:super **propertied-object**
:slots contour area intensity std-deviation

represents region.

boundary [class]

:super **propertied-object**
:slots parent-region hole segments intensity top-left bottom-right length

represents boundary.

edge-segment [class]

:super **propertied-object**
:slots prev next wing ; the other half-edge intensity std-deviation start end

represents edge-segment.

line-edge-segment [class]

:super **edge-segment**
:slots la lb

represents line-edge-segment.

curved-edge-segment [class]

:super **edge-segment**
:slots rotation total-rot side a b c d e

represents curved-edge-segment.

draw-ellipse-segment *elp gc &optional (vs *viewsurface*) (height (send vs :height)) (x 0) (y 0)* [function]

draws **curved-edge-segment** object *elp* on xwindow *vs*.

draw-line-segment *s &optional gc (vs *viewsurface*) (height (send vs :height)) (x 0) (y 0)* [function]

draws **line-edge-segment** object *s* on xwindow *vs*.

draw-segments *segs &key (line-gc image::*red-gc*) (ellipse-gc line-gc) (vs geometry:*viewsurface*) (height (send vs :height)) (step nil) (x 0) (y 0)* [function]

draws *s*, a list of **edge-segment** objects on xwindow *vs*.

draw-boundary *b &optional gc* [function]

draws segments of **boundary** object *b* on xwindow *vs*.

draw-boundaries *bs &optional gc (step nil)* [function]

draws segments of **boundary** objects *bs* on xwindow *vs*.

red-gc [variable]

GC whose foreground color is #ff0000

blue-gc [variable]

Figure 14: Edge Finder and Overlaid Edges

GC whose foreground color is #0000ff

green-gc [variable]
GC whose foreground color is #00ff00

yellow-gc [variable]
GC whose foreground color is #ffff00

cyan-gc [variable]
GC whose foreground color is #00ffff

18.5 Tracking

"`vision/correlation`" defines functions to find correlation between window-image and tracking-image.

tracking-window [class]

:super **pixel-image**
:slots x-pos y-pos x-vel y-vel
pattern-size window-size
x-win y-win window window-margin
update threshold half-pattern correlation

This class defines tracking window.

:correlation [method]
returns correlation between window-image and this image.

:grab *&optional (x x-pos) (y y-pos) (sampling 2)* [method]
grabs video image and returns grabbed pixel-image.

:window-rectangle *val* [method]
draws rectangle on xwindow.

:rectangle *val* [method]
draws rectangle on xwindow.

:move *newpos &aux (newx (aref newpos 0)) (newy (aref newpos 1))* [method]
moves tracking-window to *newpos* and grabs video image.

:track *display-window &optional th* [method]
tracks this image from window image.

:search *display-window &optional th* [method]
searches this image from window image.

:track-and-search *flag &optional th* [method]
tracks this image. If mistake tracking, searches this image from window image.

:pos [method]
returns up-left position of window.

:vel [method]
returns tracking velocity.

:insidep *pos &aux (x (aref pos 0)) (y (aref pos 1))* [method]
checks *pos* that is contained with tracking window.

:update *&optional (flag :get)* [method]
sets *flag* as update. if flag doesn't exist, returns update.

:prin1 *strm &rest mesg* [method]
prints this tracking-window object with its name and dimensions.

:init *x y size win-size* [method]
creates tracking-window object and sets slots.

18.6 Image File I/O

"`vision/pbmfile`" defines functions to transfer image data between EusLisp and disk files. EusLisp can read and write pgm (portable gray-scale map) and ppm (portable pixmap) format files.

read-pnm *f &optional buf0 buf1 buf2* [function]
reads a pgm or ppm file specified by file-stream *f* and returns a pixel-image or color-pixel-image object. The image file can be either in ascii (P2 and P3) or in binary (P5 and P6) format.

read-pnm-file *file &optional buf0 buf1 buf2* [function]
reads a pgm or ppm file specified by filename *file*.

write-pgm *f image &optional (depth 255)* [function]
writes a pixel-image specified by *image* into *f* file-stream in the binary ppm format.

write-ppm *f image &optional (depth 255)* [function]
writes a pixel-image specified by *image* into *f* file-stream in the binary pgm format.

write-pnm *f img* [function]
writes a pixel-image specified by *img* into *f* file-stream. If *img* is **pixel-image**, it is written in the binary pgm format. If *img* is **color-pixel-image**, written in the binary ppm format.

write-pnm-file *file img* [function]
writes the pixel-image specified by *img* into *file*.

image::read-raw-image *file &optional (x 256) (y x)* [function]
reads a raw-image file and returns a one-dimensional byte-vector (string). The dimensions of the raw-image must match with give *x* and *y*.

image::write-raw-image *file imgvec* [function]
writes pixel-values stored in a byte vector (string), *imgvec*, in *file*.

18.7 JPEG compression/decompression

EusLisp can link libjpeg.so in order to handle JPEG images. Loading "eusjpeg.l" will define JPEG-compression and -decompression functions.

19 Manipulators

documented by Hiromu Onda

Instances of **rotational-joint** class and **manipulator** class constitute a Manipulator Model. **rotational-joint** is a subclass of the **body**. **manipulator** is a subclass of the **cascaded-coords**. **rotational-joint** class defines models of manipulator joints. **manipulator** class has methods for solving a forward kinematic solution and inverse kinematic solution.

The way of the definition of a manipulator is that i) Make all the joints of the manipulator, ii) Integrate these joints into **manipulator**.

19.1 Rotational Joint

rotational-joint describes a model of a joint. **rotational-joint** has **body** as super-class. This class manages a model of shape, coordinates, rotation axis of a joint, angles of rotation, limits of joint angles, etc. **defjoint** macro below creates an instance of **rotational-joint**. This instance is bound to *joint-name*. Assign a ancestor joint to **parent**. It is not necessary to assign rotational axes to base nor fingers.

```
(defjoint joint-name
          :shape        body-object
          :color        color-id               ;0-15 for MMD
          :parent       parent-joint
          :axis         rotational-axis        ; :x, :y or :z
          :offset       trans-from-parent-joint
          :low-limit    joint-angle-limit-low
          :high-limit   joint-angle-limit-hight
          )
```

19.2 Multi-Joint Manipulators

A model of a manipulator is described by **manipulator**. **defmanipulator** macro below creates an instance of **manipulator**.

```
(defmanipulator manipulator-name
            :class            manipulator-class
            :base             base-joint
            :joints           list-of-all-joints
            :hand             handjoint
            :left-finger      left-finger
            :right-finger     right-finger
            :handcoords       trans-from-hand-to-armsolcoords
            :toolcoords       trans-from-armsolcoords-to-toolcoords
            :open-direction   finger-open-direction
            :right-handed     righty-or-lefty
            )
```

rotational-joint [class]

:super **body**
:slots (axis offset high-limit low-limit)

describes each rotational joint of a 6 D.O.Fs manipulator.

manipulator [class]

:super **cascaded-coords**

:slots (base baseinverse joint
angles right-handed hand handcoords right-finger left-finger
openvec max-span toolcoords toolinverse armsolcoords
toolinverse armsocoords approach grasp affix)

manages kinematics of a manipulator from base to hand.

:newcoords *newrot &optional newpos* [method]
updates the coords with newrot and newpos if new joint angles are within the limit.

:armsolcoords [method]
computes and makes transformation (an instance coords) between the coords of the base and those of the hand.

:tool *&rest msg* [method]
modifies or gets toolcoords.

:set-tool *newtool &optional offset copy* [method]
sets new toolcoords.

:reset-tool [method]
forces this coords to be default-toolcoords.

:worldcoords [method]
computes the position vector, the rotation matrix, and the coordinates of the toolcoords represented in the world coordinates.

:set-coords [method]
forces setting coords according to the forward kinematic solution.

:config *&optional (a newangles)* [method]
sets joint angles of the manipulator.

:park [method]
forces all the joint angles to be zero.

:hand *&optional (h nil)* [method]
sets or returns the object of its hand.

:handcoords [method]
computes the position vector, the rotation matrix, and the coordinates of the handcoords represented in the world coordinates.

:span [method]
returns the current distance between fingers.

:open-fingers *s &optional abs &aux (current (send self :span))* [method]
moves fingers relatively or absolutely.

:close-fingers [method]
closes fingers completely.

:angles *&optional flag* [method]
returns the list of current joint angles.

:get-approach [method]
returns the object to which the hand is approaching.

:set-approach *a* [method]
sets *a* as the object to which the hand will approach.

:get-grasp [method]
(:get-grasp () grasp-config)

:set-grasp *g* [method]

sets *g* as the object which the hand will grasp.

:get-affix [method]

returns the object which the hand grasps.

:affix *&optional (grasp)* [method]

sets **affixed-object grasp**. **grasp** is associated to the handcoords as a descendant.

:unfix *&optional (margin 10.0)* [method]

sets **affixed-object** nil. **grasp** is dissociated (removed) from the descendants list of the handcoords.

:create *&rest args* [method]

&key ((:name nm)) ((:hand h)) ((:joints j)) ((:left-finger lf)) ((:right-finger rf))
((:toolcoords tc) (make-coords)) ((:handcoords hc) (make-coords))
((:base bs) (make-cascoords)) (open-direction (floatvector 0 1 0))
((:max-span mspan) 100.0) ((:lefty lft) t) ((:act a) nil)
&allow-other-keys

creates and initializes a new manipulator object.

manipulator manages the linkage of the coords of **base, joints(J1. . . J6), handcoords, toolcoords**. **manipulator** has **cascaded-coords** as super-class. **manipulator** is connected with **base** which is **cascaded-coords** (or subclasses of **body**). **manipulator** manages the transformation from the base frame to the toolcoords. Messages sent to **manipulator** (i.e. **:translate, :locate, :rotate, :orient, :transform** etc.) effect the end effector of the manipulator. If WRT parameter is set one of keywords (i.e. :local, :parent, :world or an instance of coordinates) in this message, the end-effector moves with respect to the WRT parameter. In the next program **eta3** is a instance of **manipulator**.

```
(send eta3 :translate #f(0 0 -100))        ;put back the end-effector by 10cm
(send eta3 :translate #f(0 0 -100) :world) ;move down the end-effector by 10cm
(send eta3 :translate #f(0 0 -100)
             (manipulator-base eta3))  ;move down the end-effector with respect
                                       ;to the coords of the base by 10cm
```

When **manipulator** receives these messages, it calculates the arm solution and 6 joint angles are determined. Generally, more solutions than one exist. In that case, one appropriate solution is chosen of them according to the criteria (i.e. the distinction between **right-handed** and **left-handed**, and the consistency with current joint angles). If there is no solution for a given configuration or the calculated joint angles exceed its limits, **manipulator** does not move and it gives a warning.

Arm-solution method **:armsol** must be defined for respective manipulator classes which correspond to real manipulators. This method calculates the transformation between the base-coords and the hand-coords. Thus this allow us to put a manipulator wherever with respect to the world-coords. The arm solution is independent of the **base, toolcoords**.

Fig. 15 shows the relation between coordinate systems (**base, J1, J2,. . . , handcoords** and **toolcoords**). T and other transformations are calculated as follows.

$$\begin{aligned}
T &= base \cdot J1 \cdot J2 \cdot \ldots \cdot J6 \cdot handcoords \cdot toolcoords \\
&= (send\ eta3\ :worldcoords) \\
T_{Jn} &= base \cdot J1 \cdot \ldots \cdot Jn \\
&= (send\ Jn\ :worldcoords) \\
T_{arm} &= J1 \cdot J2 \cdot \ldots \cdot J6 \cdot handcoords \\
&= (send\ eta3\ :armsol-coords) \\
T_{tool} &= J1 \cdot J2 \cdot \ldots \cdot J6 \cdot handcoords \cdot toolcoords \\
&= (send\ eta3\ :copy-coords) \\
T_t &= toolcoords \\
&= (manipulator-toolcoords\ eta3) \\
T_t^{-1} &= toolcoords^{-1} \\
&= (manipulator-toolinverse\ eta3) \\
T_h &= handcoords \\
&= (manipulator-handcoords\ eta3)
\end{aligned}$$

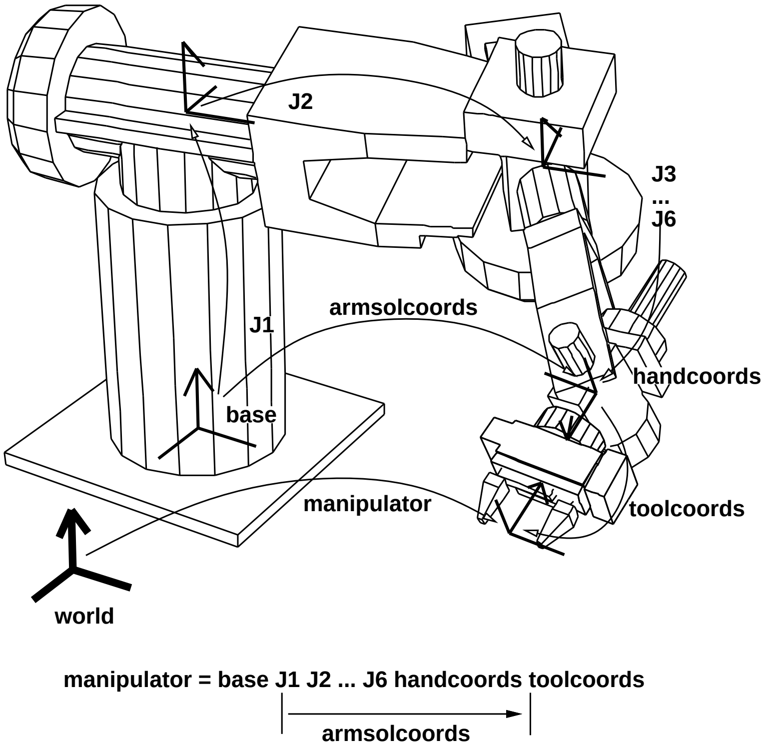

Figure 15: relation between coordinate systems in a manipulator

where T is the transformation between the world-coords and the toolcoords.

Each joint has a geometric model represented by Breps (Boundary Representation). The coordinates of the vertices and the equations of the planes are not always current ones. Messages sent to **manipulator** for translation or rotation only update the coordinate systems, these do not update the coordinates of the vertices. This is why we can reduce the calculation time when translation or rotation occurs successively. If **:worldcoords** message is sent to **manipulator**, it updates the data such as the coordinates of the vertices.

Mainly toolcoords are used for specify the motion of a manipulator in this **manipulator**. There is a method (**:config**) for specifying the configuration of the manipulator by joint angles. The arguments are a float-vector whose elements are 6.

```
  (send eta3 :config (float-vector pi/2 pi/2 0 1 0 1))
```

:config rotates joints of the manipulator if the joint angles are in the limit. As a result, the coordinates which **manipulator** manages and the current toolcoords which given joint angles determines become inconsistent. **:set-coords** message must be sent if you need consistency. **:set-coords** calculates a forward kinematic solution and calculates the arm solution using the forward kinematic solution.

Example: create the manipulator model (ETA3) and draw this on a Xwindow system.

```
;EusLisp 7.27 with Xlib created on Thu Sep 17 14:33:30 1992
(load "view.l")                                ;open a window
(load "/usr/local/eus/robot/eta3/eta3build.l") ;create the model of ETA3
(send *viewing* :look #f(2000 2000 2000))      ;change the viewpoint
(send-all (eta3arm-components eta3) :color 1)  ;change the color of lines
(send eta3 :config (float-vector 0 (/ -Pi 4.0) Pi/2 0 (/ -Pi 4.0) 0 ))
      ;set joint angles of ETA3
(send eta3 :set-coords)                        ;refer to the above explanation
(draw eta3)                                    ;draw ETA3
```

20 Xwindow Interface

The Xwindow interface on EusLisp becomes available when EusLisp is invoked by the name of `'eusx'`. [3] The "DISPLAY" environment variable should be properly set to your Xserver, since eusx tries to connect to Xserver referencing the "DISPLAY" environment variable when it starts up.

EusLisp defines three levels of xwindow interface: (1) Xlib functions, (2) Xlib classes, and (3) XToolKit classes. All the xwindow functions described in this section and the following XToolKit section are contained in the "X" package. The function names of the original Xlib are changed so that all constituent letters are converted to upcase and the first 'X' prefix is removed. For example, `XdefaultGC` is named `X:DEFAULTGC`, not `X:XDEFAULTGC`.

The Xlib functions are defined as foreign functions as the lowest level interface to Xwindow system. These Xlib functions should be used carefully, since parameter type check or parameter number check is not performed. For an instance, all the Xlib call requests `x:*display*` argument to identify the connection to Xserver, and if you forget it, Xlib reports an error and the process dies. The second level interface, Xlib classes are provided to avoid this inconvenience and to make the interface object-oriented. This section focuses on this second level interface. Even higher level xwindow library called XToolKit is explained in the next section.

Classes described in this section have the following inheritance hierarchy.

```
propertied-object
   viewsurface
      x:xobject
         x:gcontext
         x:xdrawable
             x:xpixmap
             x:xwindow
   colormap
```

20.1 Xlib global variables and misc functions

x:*display* [variable]
X's display ID (integer).

x:*root* [variable]
default root window object.

x:*screen* [variable]
default screen ID (integer).

x:*visual* [variable]
default visual ID (integer).

x:*blackpixel* [variable]
black pixel = 1

x:*whitepixel* [variable]
white pixel = 0

x:*fg-pixel* [variable]
default foreground pixel referenced at window creation, normally `*blackpixel*`.

x:*bg-pixel* [variable]
background pixel referenced at window creation, normally `*whitepixel*`

x:*color-map* [variable]
the system's default color-map

[3] Eusx is a symbolic link to eus.

x:*defaultGC* [variable]
the default gcontext referenced at pixmap creation.

x:*whitegc* [variable]
GC whose foreground color is white.

x:*blackgc* [variable]
GC whose foreground color is black.

gray-pixmap [variable]
the result of `(make-gray-pixmap 0.5)`

gray25-pixmap [variable]
16x16 pixmap, a quarter of pixels are `*fg-pixel*` and three quarters `*bg-pixel*`.

gray50-pixmap [variable]
16x16 pixmap, a half of pixels are `*fg-pixel*`.

gray75-pixmap [variable]
16x16 pixmap, three quarters of pixels are black.

gray25-gc [variable]
25% gray GC made from `*gray25-pixmap*`.

gray50-gc [variable]
50% gray GC made from `*gray50-pixmap*`.

gray75-gc [variable]
75% gray GC made from `*gray75-pixmap*`.

gray [variable]
`"#b0b0b0"`

bisque1 [variable]
`"#ffe4c4"`

bisque2 [variable]
`"#eed5b7"`

bisque3 [variable]
`"#cdb79e"`

lightblue2 [variable]
`"#b2dfee"`

lightpink1 [variable]
`"#ffaeb9"`

maroon [variable]
`"#b03060"`

max-intensity [variable]
65535

font-cour8 [variable]
`(font-id "*-courier-medium-r-*-8-*")`

font-cour10 [variable]
`(font-id "*-courier-medium-r-*-10-*")`

font-cour12 [variable]
`(font-id "*-courier-medium-r-*-12-*")`

font-cour14 [variable]

`(font-id "*-courier-medium-r-*-14-*")`

font-cour18 [variable]
`(font-id "*-courier-medium-r-*-18-*")`

font-courb12 [variable]
`(font-id "*-courier-bold-r-*-12-*")`

font-courb14 [variable]
`(font-id "*-courier-bold-r-*-14-*")`

font-courb18 [variable]
`(font-id "*-courier-bold-r-*-18-*")`

font-helvetica-12 [variable]
`(font-id "*-Helvetica-Medium-R-Normal-*-12-*")`

font-lucidasans-bold-12 [variable]
`(font-id "lucidasans-bold-12")`

font-lucidasans-bold-14 [variable]
`(font-id "lucidasans-bold-14")`

font-helvetica-bold-12 [variable]
`(font-id "*-Helvetica-Bold-R-Normal-*-12-*")`

font-a14 [variable]
`(font-id "*-fixed-medium-r-normal-*-14-*")`

x:*xwindows* [variable]
a list of all windows including subwindows created and maintained by EusLisp.

x:*xwindow-hash-tab* [variable]
a hash table to look up the xwindow object by its drawable ID. In the event structure obtained by `x:nextevent` is a window ID, and `x:window-main-loop` calls `x:event-window` to know the corresponding xwindow object using this table.

xflush [function]
sends all commands retained in the Xlib command buffer to Xserver. Since Xlib buffers output to Xserver, commands you issued commands to Xserver are not executed immediately. This is necessary to decrease network traffic and the frequency of process switching. To flush the command buffer to see the effects of the commands, use **xflush** or send **:flush** message to xwindow objects.

find-xwindow *subname* [function]
Each xwindow may have name specified at the creation time. Find-xwindow looks in the *xwindows* list and returns a list of windows that have 'subname' as a substring of its name.

20.2 Xwindow

Xobject [class]

:super **geometry:viewsurface**
:slots

The common super class for all the Xwindow related classes. Currently, no slots variables and methods are defined.

Xdrawable [class]

:super **Xobject**
:slots (drawable ; drawable ID

gcon	; this drawable's default graphic context object
bg-color	; background color
width height	; horizontal and vertical dimensions in dots

Xdrawable defines rectangular regions where graphics objects such as lines and strings can be drawn. **Xdrawable** is an abstract class to define common methods for xwindow and xpixmap, and instantiation of this class has no effect.

:init *id* [method]
Id is set to the *drawable* slot as the ID of this drawable. A new GC (graphic context) is created and set to *gcon* as the default GC of this drawable object.

:drawable [method]
returns drawable id.

:flush [method]
flushes commands retained in the Xlib's buffer.

:geometry [method]
returns the list of seven geometric attributes, *root-window-id, x-position, y-position, width, height, border-width* and *visual's depth*.

:height [method]
returns the height (dots in y direction) of this drawable.

:width [method]
returns width (dots in x direction) of this drawable.

:gc *&rest newgc* [method]
If no *newgc* is given, the current gc object is returned. If *newgc* is an instance of gcontext, it is set to the gc of this drawable. Otherwise, *newgc* is regarded as a message and sent to the current gc.

:pos [method]
returns an integer vector representing the position of this drawable. The position is always defined relative to the parent window, and windows created as direct subwindows of the root window under the intervention of the window manager return the constant coordinates in their surrounding title window regardless to their true position in the root.

:x [method]
returns the *x* coordinate of this drawable relatively to the parent window.

:y [method]
returns the *y* coordinate of this drawable relatively to the parent window.

:copy-from *drw* [method]
Drw is another drawable object (xwindow or pixmap). The contents of *drw* is copied to this drawable.

:point *x y &optional (gc gccon)* [method]
draws a point at (x, y) with optional *gc*.

:line *x1 y1 x2 y2 &optional (gc gcon)* [method]
draw a line from *(x1, y1)* to *(x2, y2)* with optional *gc. x1, y1, x2,* and*y2* must be integers.

:rectangle *x y width height &optional (gc gcon)* [method]
draws a rectangle whose center is located at *(x, y)* and size is specified by *width* and *height*.

:arc *x y width height angle1 angle2 &optional (gc gcon)* [method]
draws an elliptic arc whose center is *(x, y)* and starting angle at *angle1* and ending angle at *angle2*. Angles should be given by radian.

:fill-rectangle *x y width height &optional (gc gcon)* [method]
fills in a rectangular region.

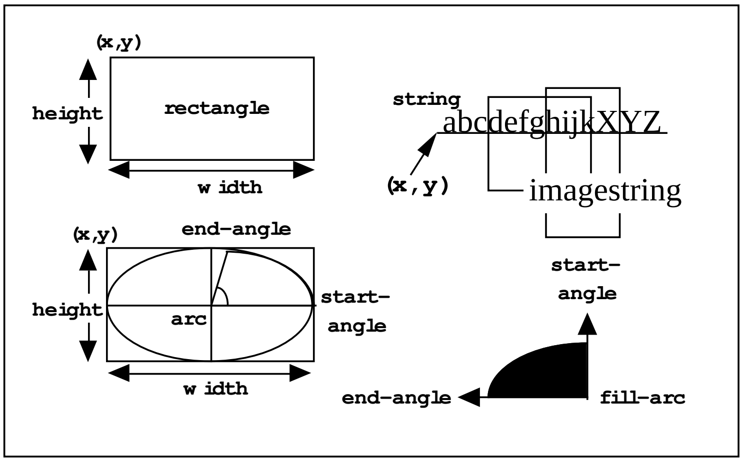

Figure 16: drawing primitives

:fill-arc *x y width height angle1 angle2 &optional (gc gcon)* [method]
fills in an arc.

:string *x y str &optional (gc gcon)* [method]
displays the string *str* starting at *(x, y)*. The background is not filled.

:image-string *x y str &optional (gc gcon)* [method]
displays an imagestring of *str*. Imagestring fills background.

:getimage *&key x y width height (mask #ffffffff) (format 2)* [method]
gets ximage from the server and returns the pixel data in a string. The pixel data sent from the server is once stored in Xlib's ximage structure, then copied to the string row by row. The ximage structure is automatically destroyed. The image string obtained by `:getimage` can be used to make a `pixel-image`, which can be written to a file in the pbm formats as described in section 18.6.

:putimage *image &key src-x src-y dst-x dst-y width height ((:gc g) gc)* [method]
puts *image* to the specified location in this drawable. *image* is a string or a address pointing to an ximage structure.

:draw-line *from to* [method]
is same as **:line** method, and provided for the compatibility with other viewsurface classes.

:line-width *&optional dots* [method]
sets line-width of this drawable's default GC. Use of the `:gc :line-width` message is recommended.

:line-style *&optional dash* [method]
sets line-style of this drawable's default GC. Use of the `:gc :line-style` is preferable.

:color *&optional c* [method]
sets color of this drawable.

:clear [method]
clears full screen. this method calls `:clear-area`

:clear-area *&key :x :y :width :height :gc* [method]
clears a rectangle using the `:fill-rectangle` method.

Xpixmap [class]

:super **Xdrawable**
:slots

Pixmap is a drawable that is often used as a picture buffer or a background pattern. Unlike xwindow, pixmap itself is not visible until it is copied to xwindow or pixmap does not generate any event.

:init *id* [method]

initializes this pixmap.

:create *&key (width 500) (height 500) (depth 1) (gc *defaultgc*)* [method]

creates a *width* x *height* pixmap with *gc* as its default GC.

:create-from-bitmap-file *fname* [method]

creates a pixmap from a bitmap file.

:write-to-bitmap-file *fname* [method]

writes the contents of this pixmap into a bitmap file, which can be read back to create a pixmap by **:create-from-bitmap-file** method.

:destroy [method]

destroys this pixmap and frees X resources.

Xwindow [class]

:super	**Xdrawable**
:slots	(parent subwindows backing-pixmap event-forward)

Xwindow defines visible rectangular regions of the screen. It is inherited not only by **t**ext-window and **canvas** where any graphics objects can be drawn, but also by many **panel-items** and **scroll-bars**, which look like graphics objects rather than windows.

:create *&key ((:parent *root*)* [method]
(x 0) (y 0) (size 256) (width size) (height size) (border-width 2)
(save-under nil) (backing-store :always) (backing-pixmap nil)
*(border *fg-pixel*) (background *bg-pixel*)*
(map T) (gravity :northwest)
(title "WINDOW") (name title)
(font)
event-mask (:key :button :enterLeave :configure :motion)

creates and initializes a xwindow. When *parent* is given, this window is created as a subwindow of *parent*, and is registered in the *subwindows* list of the *parent. X, y, size, width, height* and *border-width* determine the location and the dimensions of this window. *Save-under* and *backing-store* control the Xserver's behaviors taken upon when the window is re-mapped. *Save-under* is either T or NIL, while *backing-store* is either `:notUseful,` `:WhenMapped`, or *:Always.* When *backing-pixmap* is T, a pixmap of the same size as this window is created by EusLisp, and maintained as a backing-store in case the Xserver does not have the capability of backing-store. *Border* and *background* specify the *border_pixel* and *background_pixel* attributes, respectively. *Map* should be set NIL, if this window should not appear immediately after its creation, as is the case many small windows are created as panel-buttons in a **panel**. *Title* is the window title which appears in the title bar of the window. *Name* is the name of the window stored in the property-list of this xwindow object and printed by the printer. X's events reported to this window are determined by *Event-mask*, that is, either an integer representing a bit-coded event-mask or a list of the following symbols: `:key,` `:button,` `:enterLeave,` `:motion` and `:configure`. If more precise control is needed, the following symbols for each event can be specified: *:keyPress, :keyRelease, :ButtonPress, :ButtonRelease, :EnterWindow, :LeaveWindow, :PointerMotion, :PointerMotionHint, :ButtonMotion, :KeyMapState, :Exposure, :VisibilityChange, :StructureNotify, :ResezeRedirect, :SubstructureNotify, :SubstructureRedirect, :FocusChange, :PropertyChange, :ColormapChange* and `:OwnerGrabButton`. `:Key` enables both `:keyPress` and `:KeyRelease`, and `:button` enables both `:ButtonPress` and `:ButtonRelease`. When an event is sent from the server, **w**indow-main-loop analyzes the event structure and send the `:KeyPress,` `:KeyRelease,` `:buttonPress,` `:ButtonRelease,` `:EnterNotify,` `:LeaveNotify,` `:MotionNotify,` `:ConfigureNotify` message to the window where the event occurred.

:map [method]

makes this xwindow and all the subwindows visible.

:unmap [method]

makes this xwindow and all the subwindows invisible.

:selectinput *event-mask* [method]

Event-mask is either an integer or a list of eventmask symbols. Each event corresponding to the bit turned-on or enumerated in the *event-mask* list becomes to be reported to this window.

:destroy [method]

destroys this xwindow and frees X resource. The corresponding entries in `*xwindows*` and `*xwindow-hash-tab*` are also deleted so that this window object could be garbage-collected. All subwindows are also deleted by sending `:destroy`. This window is dissociated from the subwindow list of the parent window. The *drawable* ID is set to NIL.

:parent [method]

returns the parent window object.

:subwindows [method]

returns the list of all the subwindows. The subwindow most recently created comes first in the list. Only the direct subwindows of this window are listed and subwindows of the subwindows are not.

:associate *child* [method]

register the *child* window as a subwindow of this window.

:dissociate *child* [method]

removes the *child* window of the *subwindows* list.

:title *title* [method]

changes the title of this window. Though the title is in the Xserver, it is maintained and displayed by the window manager.

:attributes [method]

returns an integer-vector representing the attributes of this window.

:visual [method]

returns the visual resource id for this window.

:screen [method]

returns the screen resource id for this window.

:root [method]

returns the root window id.

:location [method]

returns a two dimensional integer-vector describing the x and y coordinates of this window.

:depth [method]

returns the depth (number of color planes) of this window.

:size [method]

returns the size (width and height) of this window.

:colormap [method]

returns colormap resource id for this window.

:move *newx newy* [method]

changes the location of this window to *(newx, newy).* The coordinates are given relative to the parent window.

:resize *width height* [method]

changes the size of this window. Probably because the size parameters are cached in the Xlib on the client side, `:geometry` message immediately after `:resize` may return wrong (old) result.

:raise [method]

brings this window upfront.

:lower [method]

pushes this window to the back.

:background *pixel* [method]
changes the background pixel value (the index in the color map) to *pixel*. The *pixel* value is also stored in the *bg-color* slot. `:Clear` operation is performed to fill the current background with the specified *pixel*.

:background-pixmap *pixmap* [method]
changes the background with given pixmap.

:border *pixel* [method]
sets the color of the border to *pixel*.

:set-colormap *cmap* [method]
sets colormap.

:clear [method]
clears the entire xwindow.

:clear-area *&key :x :y :width :height* [method]
clears the specified rectangular area of this xwindow.

make-xwindow *&rest args* [function]
makes x-window.

init-xwindow *&optional (display (getenv "DISPLAY"))* [function]
is the first function to call when eusx start up. `Init-xwindow` connects to the Xserver specified by *display*, and initializes default variables described in the section 20.1. `Init-xwindow` also loads default fonts and sets them to global variables, such as font-courb12, lucidasans-bold-12, etc. This font loading causes the delay at the start-up time. Reduction of the number of fonts loaded or specifying the exact font-names without using the wild-card character "*" will shorten the delay.

20.3 Graphic Context

gcontext [class]

:super **Xobject**
:slots (gcid GCValues)

defines the graphic context. In EusLisp, every xwindow has its default GC.

:create *&key (drawable defaultRootWindow)* [method]
*(foreground *fg-pixel* (background *bg-pixel*)*
function plane-mask
line-width line-style cap-style join-style
font dash

creates a gc with given attributes. *Drawable* is used by the Xserver to know the screen and depth of the screen. The resulted GC can be used in any drawables as long as they are created on the same screen.

:gc [method]
returns X's GC id.

:free [method]
frees this GC.

:copy [method]
makes a copy of this GC.

:foreground *&optional color* [method]
if *color* is given, it is set to the foreground color. *Color* is a pixel value.

:background *&optional color* [method]

if *color* is given, it is set to the background color. *Color* is a pixel value.

:foreback *fore back* [method]

sets foreground and background colors at once.

:planemask *&optional plane-mask* [method]

sets plane-mask.

:function *x* [method]

sets drawing function. *X* should either be one of the following numbers or keywords: `0=Clear, 1=And, 2=AndReverse, 3=Copy, 4=AndInverted, 5=NoOp, 6=Xor, 7=Or, 8=Nor, 9=Equiv, 10=Invert, 11=XorReverse, 12=CopyInverted, 13=OrInverted, 14=Nand, 15=Set, :clear, :and, :andReverse, :copy, :andInverted, :NoOp, :Xor, :Or, :Nor, :Equiv, :Invert, :XorReverse, :CopyInverted, :OrInverted, :Nand, :Set`.

:font *x* [method]

sets the font attribute of this GC. *X* is either a font-name or a font-ID. If *x* is a font name (string), `:font` calls `x:LoadQueryFont` to decide the font-id. If not found, `"no such font ..."` is warned. If *x* is NIL (not given), the current font-ID of this GC is returned.

:line-width *x* [method]

sets the line width in pixel.

:line-style *x* [method]

sets the line-style (solid, dashed, etc.).

:dash *&rest x* [method]

Each component of *X* is an integer. `:Dash` sets the dash pattern of the line-style.

:tile *pixmap* [method]

sets the tile of this GC to *pixmap*.

:stipple *pixmap* [method]

sets the stipple of this GC to *pixmap*.

:get-attribute *attr* [method]

gets attribute. *Attr* is one of `:function, :plane-mask, :foreground, :background, :line-width, :line-style, :cap-style, :join-style, :fill-style, :fill-rule, :font`. An integer value representing the attribute is returned.

:change-attributes *&key function plane-mask foreground background line-width line-style cap-style join-style font dash* [method]

change attributes. More than one attributes are changed at the same time.

font-id *fontname* [function]

If *fontname* is integer, it is returned regarding it as font-id. If *fontname* is string, font-structure is inquired by using `x:LoadQueryFont`, and its font-id is returned. *Fontname* can be a shorthand of exact name, such as `"*-courier-24-*"` for any 24-point courier font. If the font could not be found, `can't load font` warning is printed.

textdots *str font-id* [function]

returns a list of three integers representing (ascent descent width) of the *str* (string) in dots.

20.4 Colors and Colormaps

colormap [class]

:super **object**

:slots (cmapid planes pixels LUT-list)

defines an xwindow colormap and application oriented color look-up tables. A color is represented by RGB values from 0 through 65535. Color cells in a color map are addressed by their indices, which are between 0 and 255 on 8-bit pseudo color display.

Here we assume your display device has 8bit pseudo color capability which allows you to choose 256 colors at the same time. Basically there are two ways in the use of color maps: to share the system's default color map or to create private color maps. If you use the system's default color map, you have to be careful not to use up all the color cells in the map, since the map is shared among many processes. If you use private color maps, you can allocate all 256 color entries in the map without worrying about other processes, but the map has to be explicitly attached to your private windows. The color map is activated by the window manager when the mouse pointer is moved somewhere in the window.

The system's default color map is set up in `x:*color-map*` which is an instance of the `x:colormap` class when eusx begins execution. If you use private color maps, you create instances of `x:colormap`. These instances correspond to the colormap object defined in the x server and are identified by the `cmapid` stored in each instance.

When you use the system's default color map, you can define *read-only* colors which are shared with other processes or define *read-write* colors which are private to your EusLisp. *Read-only* means that you can define arbitrary color when you allocate the color cell, but you cannot change it after the allocation. On the other hand, *read-write* colors can be altered even after you defined them. Shared colors are *read-only* since other processes expect the colors to be unchanged. This *read-only* or *read-write* attribute is attached to each color entry (often referred to as color cell).

A colormap object defines translation from a color id to a physical representation that is a triplet of red, green and blue components. However, these logical color ids cannot be chosen arbitrarily, especially when you use the the system's default color map. The color id (often referred to as 'pixel') is an index of a particular color in a color map and Xlib chooses one of free indices for a shared color when allocation is requested. Therefore, there is no way, for example, to guarantee many levels of gray colors to be allocated contiguously or to begin from the first (zeroth) index.

From the viewpoint of applications, more logical color naming is needed. For example, a number of gray levels should be referred to with their brightness as indices. A ray trace program may wish to assign contiguous indices to a group of colors of different brightness defined in HLS model.

To cope with this problem, EusLisp's colormap provides another translation table called LUT (look-up table). For a logical group of colors, you can define a LUT and attach a symbolic name to it. More than one LUTs can be defined in a colormap. LUT is an integer vector for the translation of application specific logical color indices into physical pixel values that the Xserver can recognize.

:id [method]

returns the cmap id.

:query *pix* [method]

gets RGB values for the specific pixel number.

:alloc *r g b* [method]

this method is the same as `:store nil r g b`. A new color cell is allocated in this colormap and is assigned with the specified RGB values.

:store *pix r g b* [method]

sets RGB values to the *pix*th color cell.

:store *pix color-name* [method]

:Store is the lowest level method to set a color in a color map. In the first form, you specify the color with the red, green and blue components between 0 and 65535 inclusively. In the second form, you specify the color by name like "red" or "navy-blue". If no such color-name is found, nil is returned. Pixel is either an integer which is the index in a color map or nil. If it is integer, the color cell must be read-write-able. If it is nil, a shared read-only color cell is allocated. `:Store` returns the index of the color cell in the color map.

:store-hls *pix hue lightness saturation* [method]
stores the color specified in HLS (Hue, Lightness and Saturation) model in the *pix*th entry of this colormap. If *pix* is NIL, a shared read-only color cell is allocated. `:Store-hls` returns the index to the allocated color cell.

:destroy [method]
destroys this colormap and frees resource.

:pixel *LUT-name id* [method]
looks up in the LUT for the id'th entry and returns its pixel value. *LUT-name* is the name of the look-up-table you defined by `:define-LUT`.

:allocate-private-colors *num* [method]
allocates *num* color cells in the private color map.

:allocate-colors *rgb-list [private]* [method]
Each element of *rgb-list* is a list of red, green and blue components. Color cells are allocated for each rgb value and an integer-vector whose elements are pixel values is returned.

:define-LUT *LUT-name rgb-list [private]* [method]
Colors described in *rgb-list* are allocated, and an LUT is registered by the symbolic name of *LUT-name*. In order to define private color cells, set *private* to T.

:define-gray-scale-LUT *LUT-name levels [private]* [method]
allocates *levels* of color cells that represent linear gray scale colors and returns LUT. For example, `(send x:*color-map* :define-gray-scale-LUT 'gray8 8)` allocates eight gray colors in the system's default color map, and returns an integer vector such as `#i(29 30 31 48 49 50 51 0)`. Physical pixel values can be inquired by sending the `:pixel` message, for example, `(send x:*color-map* :pixel 'gray8 2)` returns 31.

:define-rgb-LUT *LUT-name red green blue [private]* [method]
defines an LUT for shrunk RGB representation. For example, if red=green=blue=2, totally $2^{2+2+2} = 2^6 = 64$ color cells are allocated.

:define-hls-LUT *LUT-name count hue low-brightness high-brightness saturation [private]* [method]
allocates *count* colors using the HLS model. Colors of the given *hue* (0..360), *saturation* (0..1), and different levels of brightness between *low-brightness* and *high-brightness* are stored in the color map. A LUT named LUT-name is also created.

:define-rainbow-LUT *LUT-name count (hue-start 0) (hue-end 360) (brightness 0.5) (saturation 1.0) (private nil)* [method]
allocates *count* colors using the HLS model. Colors of the given *brightness* (0..1), *saturation* (0..1), and different hues between *hue-start* and *hue-end* are stored in the color map. A LUT named *LUT-name* is also created.

:LUT-list [method]
returns all LUT list defined in this colormap. Each entry in the list is a pair of the LUT-name and an integer vector.

:LUT-names [method]
returns the name list of all LUT in this colormap.

:LUT *name* [method]
returns the integer-vector (LUT) identified by *name*.

:size *LUT-name* [method]
returns the length of *LUT*

:planes [method]
returns planes of this colormap.

:set-window *xwin* [method]

associates this colormap to the *xwin* window. This colormap is activated when the cursor enters in *xwin*.

:free *pixel — LUT* [method]

frees a specific color cell addressed by pixel, or all the entries in LUT.

:init *[cmapid]* [method]

initializes this color map with cmap id. All the LUTs registered are discarded.

:create *&key (planes 0) (colors 1) (visual *visual*) (contiguous nil)* [method]

creates a new color map object.

XColor [class]

:super	**cstruct**
:slots	((pixel :integer)
	(red :short)
	(green :short)
	(blue :short)
	(flags :byte)
	(pad :byte))

defines a color in the RGB model. Use **setf** to assign value to each slots. The RGB values are sign extended and the greatest value is represented as -1.

:red [method]

returns the red value of this XColor.

:blue [method]

returns the blue value of this XColor.

:green [method]

returns the green value of this XColor.

:rgb [method]

returns the list of red, green and blue values of this XColor.

:init *pix R G B &optional (f 7)* [method]

initializes XColor.

find-visual *type depth &optional (screen 0)* [function]

finds the visual-ID of the specified *type* and *depth*. *Type* should be either `:StaticGray`, `:GrayScale`, `:StaticColor`, `:pseudoColor`, `:TrueColor` or `:DirectColor`. Usually the *depth* should be either 1, 8 or 24.

21 XToolKit

XToolKit is the highest level X window interface to facilitate composing GUI (Graphical User Interface) by using GUI components such as buttons, pulldown menus, textWindows, etc., as building blocks. The major differences from the Xlib classes are, the XToolKit invokes user-supplied interaction routines corresponding to the Xevents sent from the Xserver, and provides consistent appearance of those interaction-oriented window parts. Classes consisting the XToolKit has the following inheritance structure.

```
xwindow
     panel
          menubar-panel
          menu-panel
          filepanel
          textviewpanel
          confirmpanel
     panel-item
          button-item
               menu-button-item
               bitmap-button-item
          text-item
          slider-item
          choice-item
          joystick-item
     canvas
     textwindow
          buffertextwindow
               scrolltextwindow
          textedit
     scroll-bar
          horizontal-scroll-bar
```

Just below the xwindow class are the five basic XToolKit classes: `panel`, `panel-item`, `canvas`, `textWindow` and `scroll-bar`. `Menubar-panel` and `menu-panel` are defined under the `panel`. A basic strategy to build a new application window and to make it run upon events is the following:

1. **define an application class** An application window class should be defined as a subclass of **panel** that has the capability to lay out XToolKit components.
2. **define event handlers** In the application class, event handlers that are called upon when buttons are pressed or menu items are selected are defined. An event handler ought to be defined as a method with panel-item specific arguments.
3. **define subpanels** If you use a `menubar-panel`, it is placed at the top of the application window, therefore it should be created first by `:create-menubar`. Similarly `menu-panel`s needs to be defined before the `menu-button-item`s to which `menu-panel`s are associated.
4. **create panel-items** Panel-items such as `button-item`, `text-item`, `slider-item`, etc., can be created by `(send-super :create-item` *class label object method*`)`. Event handlers defined above are connected to each panel-item. These initialization procedures should be defined in the `:create` method of the application window class. Do not forget to define `quit` button to make the event dispatcher terminate whenever needed. Any `textWindow` and `canvas` can also be placed in the application window via the `:locate-item` method.
5. **create the entire window** Sending the `:create` message to the application class creates the application window with its XToolKit components properly placed in the window.
6. **run the event dispatcher** In order to receive events from the Xserver and delivers them to the corresponding xwindow, run `window-main-loop`. On Solaris2, `window-main-thread`, which delivers events in a different thread, is available. `Window-main-thread` keeps the toplevel interaction alive. Do not run more than one `window-main-thread`.

21.1 X Event

In the current implementation, an event structure is received in a fixed event buffer (an integer-vector of 25 elements) and the same buffer is reused on all events. The event structure has to be copied when more than one events need to be referenced at the same time.

`Window-main-loop` is the function which captures all events sent from the X server and delivers them to each window where the event happened.

event [variable]
a 25-element integer-vector holding the most recent event structure.

next-event [function]
stores the event structure in `event` and returns it if there is at least one pending event, NIL if there is no pending event.

event-type *event* [function]
returns the keyword symbol representing the event-type in the *event* structure. The event-type keywords are: `:KeyPress` (2), `:KeyRelease` (3), `:ButtonPress` (4), `:ButtonRelease` (5), `:MotionNotify` (6), `:EnterNotify` (7), `:LeaveNotify` (8), `:FocusIn` (9), `:FocusOut` (0), `:KeymapNotify` (1), `:Expose` (12), `:GraphicsExpose` (13), `:NoExpose` (14), `:VisibilityNotify` (15), `:CreateNotify` (16), `:DestroyNotify` (17), `:UnmapNotify` (18), `:MapNotify` (19), `:MapRequest` (20), `:ConfigureNotify` (22), `:ConfigureRequest` (23), `:GravityNotify` (24), `:ResizeRequest` (25), `:CirculateNotify` (26), `:CirculateRequest` (27), `:PropertyNotify` (28), `:SelectionClear` (29), `:SelectionRequest` (30), `:SelectionNotify` (31), `:ColormapNotify` (32), `:ClientMessage` (33), `:MappingNotify` (34), `:LASTEvent` (35).

event-window *event* [function]
returns the window object where the *event* occurred.

event-x *event* [function]
extracts the *x* coordinate, (i.e., the horizontal position of the mouse pointer relatively in the window) out of the *event*.

event-y *event* [function]
extracts the *x* coordinate, (i.e., the vertical position of the mouse pointer relatively in the window) out of the *event*.

event-width *event* [function]
returns the eighth element of the *event* structure which represents the width parameter at the `:configureNotify` event.

event-height *event* [function]
returns the ninth element of the *event* structure which represents the height parameter at the `:configureNotify` event.

event-state *event* [function]
returns a list of keywords representing the mouse button and modifier key state. Keywords are: `:shift, :control, :meta, :left, :middle` and `:right`. For example, if left mouse button is pressed while shift key is down, `(:shift :left)` is returned.

display-events [function]
displays all xwindow events captured by `x:nextevent`. Control-C is the only way to terminate this function.

window-main-loop *&rest forms* [macro]
receives Xevents and delivers them to window objects where the event occurred. According to the event-type, methods in the window's class named `:KeyPress, :KeyRelease, :ButtonPress, :ButtonRelease, :MotionNotify, :EnterNotify, :LeaveNotify` and `:ConfigureNotify` are invoked with *event* as the argument. If *forms* is given, evaluates them each time event arrival is checked.

window-main-thread [function]
Do the same thing as `window-main-loop` in a different thread. `Window-main-thread` is only available

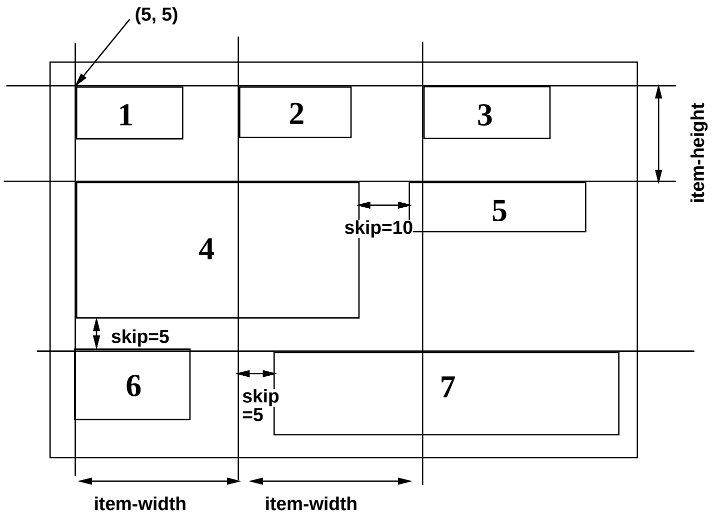

Figure 17: Item lay-out in panel

on Solaris2. `Window-main-thread` installs an error handler which does not enter a read-eval-print loop. After printing the error information, the event processing continues.

21.2 Panel

panel [class]

:super **xwindow**
:slots (pos items fontid
rows columns ;total number of rows and columns
next-x next-y
item-width item-height)

Panel is a xwindow with the capability to lay out panel-items or any xwindows including other panel objects. A panel object supplies the default font for every panel-item created in the panel. Application windows should be defined as subclasses of the `Panel`.

:create *&rest args &key ((:item-height iheight) 30) ((:item-width iwidth) 50) (font font-lucidasans-bold-12) ((:background color) *bisque1*) &allow-other-keys)* [method]

creates and initializes a panel. Since superclass's `:create` is invoked, all creation parameters for **xwindow**, such as *width, height, border-width*, etc., are allowed. *Item-height* and item-width give the minimum height and width for each panel-item.

:items [method]

returns the list of all items associated.

:locate-item *item &optional x y* [method]

Item is any xwindow object, normally a panel-item. If *x* and *y* are given, the item is located there. Otherwise, *item* is located adjacent to the most recently located item. Items are located from top to bottom, from left to right, as shown in **Fig.** 17. `:Locate-item` also adds *item* in the *items* and *subwindows* list, and makes it visible by sending `:map`.

:create-item *klass label receiver method &rest args &key ((font fontid) &allow-other-keys)* [method] creates an instance of the panel-item class specified by *klass* (i.e., `button-item, menu-button-item, slider-item, joystick-item`, etc.), and place the item in the panel using `:locate-item`. *Args* are passed to `klass`'s `:create` method. *Label* is the identification string drawn in the panel item. *Receiver* and *method* specify the event handler called upon the corresponding event.

:delete-items [method]

delete all panel-items.

:create-menubar *&rest args* [method]
&key (font fontid)
&allow-other-keys

creates a *menubar-panel* and locates it at the top of the panel.

The following methods are provided to avoid "subclass's responsibility" warning message when events are sent to panels without event handlers. User applications should override these methods.

:quit *&rest a* [method]

throws `:window-main-loop` and terminates event processing.

:KeyPress *event* [method]

returns NIL.

:KeyRelease *event* [method]

returns NIL.

:ButtonPress *event* [method]

returns NIL.

:ButtonRelease *event* [method]

returns NIL.

:MotionNotify *event* [method]

returns NIL.

:EnterNotify *event* [method]

returns NIL.

:LeaveNotify *event* [method]

returns NIL.

21.2.1 Subpanels (menu-panel and menubar-panel)

menu-panel [class]

:super **panel**
:slots (items item-dots item-height
charwidth charheight
height-offset
highlight-item
color-pixels
active-color)

`Menu-panel` is a kind of panel that can locate only `button-items` and/or `bitmap-button-items`. Unlike `panel`, however, `menu-panel` is normally invisible and is exposed when the `button-item` to which the `menu-panel` is associated is pressed. If a `menu-panel` is made always visible, it becomes a pinned menu. The response of each button-item to mouse events is slightly different from button-items in other panels, as the mouse button has been pressed somewhere outside the button-item. Creation of a `menu-panel` should follow the order described below:

1. create a menu-panel by `(instance menu-panel :create)`.

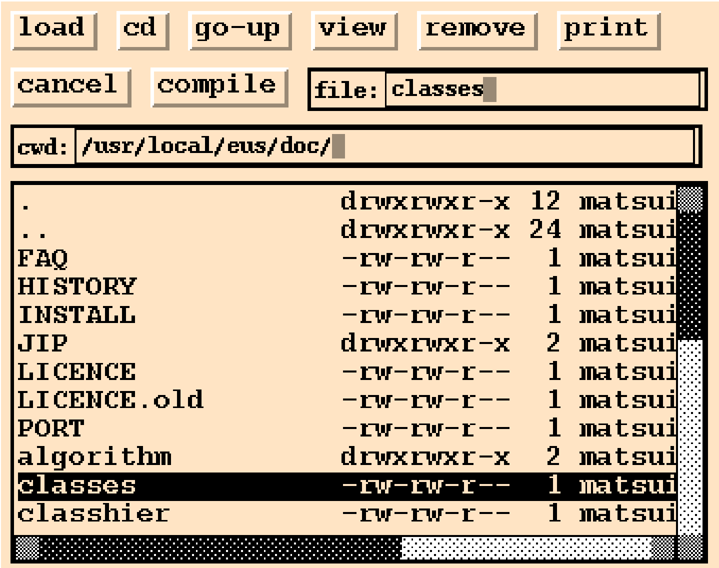

Figure 18: FilePanel window

2. create button-items or/and bitmap-button-items and locate them in the menu-panel by `(send aMenuPanel :create-item button-item "BTN" obj meth)`.

3. create a menu-button-item in another panel and associate the menu-panel with the menu-button-item by `(instance menu-button-item :create "Option" obj meth :menu-window aMenuPanel)`.

:create *&rest args &key (items) (border-width 0) (font font-courb12) (width 100) (height-offset 15) (color *bisque1*) (active *bisque2*) &allow-other-keys)* [method]

create a menu-panel window. The size of the window is expanded each time new menu-item is added.

:create-item *class label receiver method &rest mesg* [method]

adds a menu item in this menu-panel window and attatches the corresponding action. The *receiver* objects receives *mesg* when the mouse button is released on the item.

menubar-panel [class]

:super **panel**
:slots

`Menubar-panel` is a subpanel always located at the top of the parent panel. A menubar-panel resembles with the Macintosh desktop's menubar which lets out several pull-down menus. Panel-items placed in the menubar should be `menu-button-items`. A menubar-panel is created by the panel's `:create-menubar` method.

21.2.2 File Panel

The FilePanel is an application window for the interactive manipulation of files and directories. Using `cd` and `go-up` buttons, any directory can be visited and files contained in the directory are displayed in the `ScrollTextWindow` below. Text files can be displayed in different windows (textViewPanel). Files can also be printed, removed, and compiled by simply cliking buttons. When a file is printed, `a2ps` *file* `| lpr` commands are executed in a forked process.

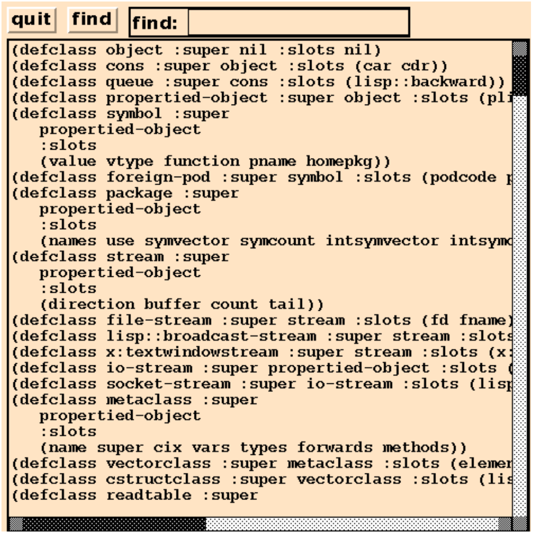

Figure 19: TextViewPanel window

21.2.3 Text View Panel

TextViewPanel is an application window class to display text files (Fig. 19). The program text is shown to demonstrate how one of the simplest application windows is described. In the `:create` method, the quit button and find button, and a text-item to feed the string to be searched for in the file are created. The view-window is a ScrollTextWindow that displays the file with the vertical and horizontal scroll-bars. The TextViewPanel captures `:ConfigureNotify` event to resize the view-window when the outermost title window is resized by the window manager.

```
(defclass TextViewPanel :super panel
        :slots (quit-button find-button find-text view-window))

(defmethod TextViewPanel
 (:create (file &rest args &key (width 400) &allow-other-keys)
    (send-super* :create :width width args)
    (setq quit-button
          (send self :create-item panel-button "quit" self :quit))
    (setq find-button
          (send self :create-item panel-button "find" self :find))
    (setq find-text
          (send self :create-item text-item "find: " self :find))
    (setq view-window
            (send self :locate-item
                (instance ScrollTextWindow :create
                   :width (setq width (- (send self :width) 10))
                   :height (- (setq height (send self :height)) 38)
                   :scroll-bar t :horizontal-scroll-bar t
                   :map nil      :parent self)))
    (send view-window :read-file file))
 (:quit (event)  (send self :destroy))
 (:find (event)
    (let ((findstr (send find-text :value)) (found)
          (nlines (send view-window :nlines)))
        (do ((i 0 (1+ i)))
            ((or (>= i nlines) found))
           (if (substringp findstr (send view-window :line i)) (setq found i)))
        (when found
```

```
          (send view-window :display-selection found)
          (send view-window :locate found))))
 (:resize (w h)
    (setq width w height h)
    (send view-window :resize (- w 10) (- h 38)))
 (:configureNotify (event)
   (let ((newwidth (send self :width))
        (newheight (send self :height)))
       (when (or (/= newwidth width) (/= newheight height))
         (send self :resize newwidth newheight)))  ) )
```

21.3 Panel Items

panel-item [class]

:super **xwindow**
:slots (pos notify-object notify-method fontid label labeldots)

Panel-item is an abstract class for all kinds of panel-item windows to invoke *notify-object*'s *notify-method* when item-specific event occurs.

:notify *&rest args* [method]

invokes *notify-object*'s *notify-method*. Responsive events and arguments passed to *notify-method* are item specific:

button-item The button is pressed and released in the same button-item; the argument is the button-item object.

menu-button-item A menu item is selected; the argument is the menu-button-item object.

choice-item A new choice button is selected; the arguments are the choice-item object and the index number of the choice.

text-item A newline or return is entered; the arguments are the text-item object and the entire line (string).

slider-item The slider nob is grabbed and moved; the arguments are the slider-item object and the new value.

joystick-item The joystick is grabbed and moved; the arguments are the slider-item object, the new x and y values.

:create *name reciever method &rest args &key ((:width w) 100) ((:height h) 100) (font font-courb12) &allow-other-keys* [method]

creates a panel-item. As panel-item is an abstract class, this method should only be called by the subclasses via `send-super`.

button-item [class]

:super **panel-item**
:slots

button-item is the simplest panel-item. Button-item has a rectangular box and a label string in it. When clicked, button-item invokes *notify-object*'s *notify-method* with the panel-item object as the only argument.

:draw-label *&optional (state :top) (color bg-color) (border 2) (offset)* [method]

draws button-item's label.

:create *label revciever method &rest args* [method]
&key width height (font (send parent :gc :font))
(background (send parent :gc :background))
(border-width 0)
(state :top)
&allow-other-keys

creates a button-item. If button's width and height are not given, the sizes are automatically set to accomodate the label string drawn with the given font. Though the border-width is defaulted to 0, pseudo 3D representation embosses the button. The background color and font are defaulted to the ones defined for the parent window, i.e. a panel.

:ButtonPress *event* [method]

changes the background color to gray, as if the button.

:ButtonRelease *event* [method]

changes *event*'s background color to normal.

menu-button-item [class]

:super	**button-item**
:slots	(items item-dots item-labels charwidth charheight menu-window window-pos high-light)

defines a pulldown menu. Though a `menu-button-item` looks like a `button-item`, the `menu-button-item` activates associated `menu-panel` below the button when it is pressed, instead of sending an immediate message to the *notify-object*. The actual message is sent when the mouse button is released on one of the menu items.

:create *label reciever method* [method]
&rest args
&key (menu nil) (items) (state :flat)
&allow-other-keys

creates a pulldown menu button. *Receiver* and *method* arguments has no effect.

:ButtonPress *event* [method]

reverses the appearance of the pulldown-menu and exposes the associated menu-panel below the button.

:ButtonRelease *event* [method]

unmaps the `menu-panel` below this button and reverts the appearance of the button.

bitmap-button-item [class]

:super	**button-item**
:slots	(pixmap-id bitmap-width bitmap-height)

Though `bitmap-button-item`'s function is similar to the `button-item`, its appearance is different. Instead of drawing a simple label string on the button, as is the case for `button-item`, `bitmap-button-item` is drawn by a pixmap which is loaded from a bitmap-file when the button is created.

:draw-label *&optional (state :flat) (color bg-color) (border 2)* [method]

draws a bitmap/pixmap on the button.

:create *bitmap-file reciever method &rest args* [method]
&key width height
&allow-other-keys)

creates bitmap-button-item. The first argument, *bitmap-file* replaces the *label* argument of `button-item`.

:draw-label *&optional (state :flat) (color bg-color) (border 2)* [method]

draw a bitmap/pixmap on the button.

:create-bitmap-from-file *fname* [method]
creates pixmap from the bitmap file named *fname*, and stores its id in *pixmap-id*.

choice-item [class]

:super **button-item**
:slots (choice-list active-choice transient-choice
choice-dots choice-pos button-size)

`choice-item` is a set of round choice buttons. One choice is always active, and only one choice can become active at the same time. `choice-item` provides the similar function as radio-buttons.

:create *label reciever method &rest args* [method]
&key (choices '("0" "1")) (initial-choice 0)
(font (send parent :gc :font))
(button-size 13)
(border-width 0)

create a choice-item-button. Each choice button is a circle of radius *button-size*. When a new choice is selected, *notify-object*'s *notify-method* is invoked with the choice-item object and the index of the choice selected.

:value *&optional (new-choice) (invocation)* [method]
If *new-choice* is given, it is set as the current active choice, and the corresponding circle is filled black. If *invocation* is also specified, *notify-object*'s *notify-method* is invoked. `:Value` returns the current (or new) choice index.

:draw-active-button *&optional (old-choice active-choice) (new-choice active-choice)* [method]
draw active button.

:buttonPress *event* [method]
If the mouse button is pressed on any of the choice buttons, its index is recorded in *transient-choice*. No further action is taken until the mouse button is released.

:buttonRelease *event* [method]
If the mouse button is released on the same button which is already pressed, the *active-choice* is updated and *notify-object*'s *notify-method* is invoked.

slider-item [class]

:super **panel-item**
:slots (min-value max-value value
minlabel maxlabel valueformat
bar-x bar-y bar-width bar-height valuedots label-base
nob-x nob-moving
charwidth)

While `choice-item` is used to select a discrete value, `slider-item` is used for the continuous value in the range between *min-value* and *max-value*. Each moment the value is changed, *notify-object*'s *notify-method* is invoked with the slider-item object and the new value as the arguments.

:create *label reciever method &rest args* [method]
&key (min 0.0) (max 1.0) (parent)
(min-label "") (max-label "") (value-format " 4,2f")
(font font-courb12) (span 100) (border-width 0) (initial-value min)

creates slider-item. The sliding knob is displayed as a small black rectangle on a bar. The left end represents the *min* value and the right end *max* value. The length of the bar stretches for the *span* dots. The current value is displayed to the right of the slider-item label in the *value-format*.

:value *&optional newval invocation* [method]
If *newval* is given, it is set as the current value, and the knob is slided to the corresponding location. If

invocation is also specified non nil, *notify-object*'s *notify-method* is invoked. `:Value` returns the current (or new) value.

joystick-item [class]

:super **panel-item**
:slots (stick-size min-x min-y max-x max-y
center-x center-y stick-x stick-y
value-x value-y
stick-return stick-grabbed
fraction-x fraction-y)

`joystick-item` can be regarded as the two-dimensional slider-item. Two continuous values can be specified by the moving black circle on the coaxial chart that looks like a web (Fig. 20).

:create *name reciever method &rest args* [method]
&key (stick-size 5) (return nil)
(min-x -1.0) (max-x 1.0)
(min-y -1.0) (max-y 1.0)
&allow-other-keys)

Stick-size is the radius of the stick's black circle. The sizes of the circles in the coaxial chart are determined according to the width and height of the joystick-item window. If *return* is non-NIL, the joystick returns to the origin when the mouse button is released. Otherwise, the joystick remains at the released position.

:value *&optional (newx) (newy) (invocation)* [method]

If both *newx* and *newy* are given, they are set as the current values, and the joystick moves to the corresponding location on the coaxial chart. If *invocation* is also specified non nil, *notify-object*'s *notify-method* is invoked with the joystick-item object and x and y values as the arguments. `:Value` returns the list of current (or new) values.

The following short program shows how to use panel-items described above, and Fig. 20 depicts how they appear in a panel.

```
(in-package "X")
(defclass testPanel :super panel
        :slots (quit joy choi sli))
(defmethod testPanel
 (:create (&rest args)
    (send-super* :create :width 210 :height 180
                 :font font-courb12 args)
    (send-super :create-item button-item "quit" self :quit :font font-courb14)
    (send-super :create-item choice-item "choice" self :choice
                :choices '(" A " " B " " C ")
                :font font-courb12)
    (send-super :create-item slider-item "slider" self :slider
                :span 90)
    (send-super :create-item joystick-item "joy" self :joy)
    self)
 (:choice (obj c) (format t "choice: ~S ~d~%" obj c))
 (:slider (obj val) (format t "slider: ~S ~s~%" obj val))
 (:joy (obj x y) (format t "joy: ~S ~s ~s~%" obj x y)) )
(instance testPanel :create)
(window-main-thread)
```

text-item [class]

:super **panel-item**
:slots (textwin)

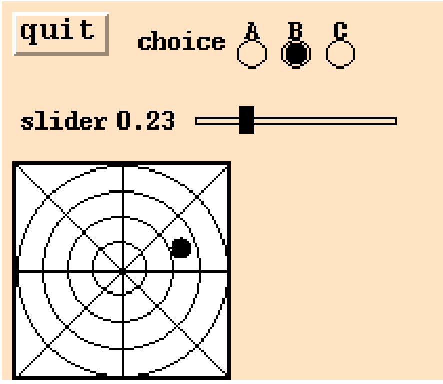

Figure 20: Panel items created in a panel

`Text-item` is used to display or to input one short line of text, such as a file name. A `text-item` has a label string followed by a small textwindow on the right. When the pointer is put in the textwindow, key input is enabled and the characters typed are buffered. Line editing is available in the textwindow: `control-F` and `control-B` to move forward/backward by one character, `del` to delete the character on the left of the cursor, `control-D` to delete the character on the cursor, and any graphical character to insert it at the cursor position. Clicking a mouse button moves the cursor to the clicked character. Hitting an enter (newline) key causes the buffered text to be sent to the *notify-object*'s *notify-method*.

:create *label revciever method &rest args* [method]
&key (font font-courb12) (columns 20) (initial-value) (border-width 0)
&allow-other-keys

creates text-item. Though the linebuffer of the textwindow may have unlimited length, visible portion is restricted to the *columns* characters.

:getstring [method]

returns the string in the key buffer.

21.4 Canvas

canvas [class]

:super **xwindow**
:slots (topleft bottomright)

Canvas is a xwindow to interact with figures or images. Currently, only the region selection capability has been implemented. At the buttonPress event, the canvas begins to draw a rectangle with the topleft corner at the pressed position and bottomright corner at the current pointer. ButtonRelease causes the `notify-method` to be sent to the `notify-object`. Use Xdrawable's methods to draw figures or images in the canvas.

21.5 Text Window

There are three textwindow classes, `TextWindow`, `BufferTextWindow` and `ScrollTextWindow`.

textWindow [class]

:super **xwindow**
:slots (fontid
charwidth charheight charascent dots

```
win-row-max win-col-max
win-row win-col            ;physical current position in window
x y
charbuf                    ; for charcode conversion
keybuf keycount            ;for key input
echo
show-cursor cursor-on      ;boolean
kill delete                ;control character
notify-object notify-method
)
```

realizes virtual terminals usable for displaying messages. The displayed contents are not buffered and there is no way to retrieve a line or a character already displayed in the TextWindow. Basically, `TextWindow` has similar capabilities to the dumb terminals, that are, moving the cursor, erasing lines, erasing areas, scrolling displayed texts, inserting strings, etc. Also, the text cursor can be moved to the position designated by the mouse pointer.

:init *id* [method]

initializes *id*th text-window.

:create *&rest args* [method]
&key width height (font font-courb14) rows columns
(show-cursor nil) (notify-object nil) (notify-method nil)
&allow-other-keys

creates text-window. The sizes of the window may be specified either by *width* and *height* or by *rows* and *columns*. *Notify-object*'s *notify-method* is invoked when a newline character is typed in.

:cursor *flag* [method]

The *flag* can either be `:on, :off` or `:toggle`. The text cursor is addressed by the *win-row* and *win-col*. The text cursor is displayed if *flag* is `:on`, is erased if *flag* is `:off`, or is reversed if *flag* is `:toggle`. This method must be invoked frequently whenever the character at the cursor is updated.

:clear [method]

clears text-window.

:clear-eol *&optional (r win-row) (c win-col) (csr :on)* [method]

clears the rest of the line after the character addressed by r and *c*, including the character at the cursor.

:clear-lines *lines &optional (r win-row)* [method]

clears multiple lines after *r*-th row.

:clear-eos *&optional (r win-row) (c win-col)* [method]

clears the region after the character addressed by *r* and *c* till the end-of-the-screen.

:win-row-max [method]

returns the maximum number of lines displayable in this window.

:win-col-max [method]

returns the maximum number of columns displayable in this window.

:xy *&optional (r win-row) (c win-col)* [method]

calculates the pixel coordinates of the character addressed by *r* and *c*.

:goto *r c &optional (cursor :on)* [method]

moves the cursor to *r*-th row and *c*-th column.

:goback *&optional (csr :on)* [method]

moves the cursor backward by one.

:advance *&optional (n 1)* [method]

moves the cursor forward by *n* characters.

:scroll *&optional (n 1)* [method]
scroll textwindow vertically by *n* lines.

:horizontal-scroll *&optional (n 1)* [method]
horizontally scrolls the text by *n* columns.

:newline [method]
moves cursor to the beginning of the next line.

:putch *ch* [method]
inserts the character *ch* at the cursor position. The rest of the line is moved forward by one.

:putstring *str &optional (e (length str))* [method]
places *str* at the cursor position.

:event-row *event* [method]

:event-col *event* [method]
returns the text cursor position designated by (x, y) in the *event*.

:KeyPress *event* [method]
inserts the character entered at the cursor position. If the character is newline, notification is sent to the *notify-object*.

textWindowStream [class]

:super	**stream**
:slots	(textwin)

`TextWindowStream` is an output stream connected to a TextWindow. Characters or strings output to this stream by using `print, format, write-byte`, etc., are displayed in the textwindow. As usual file streams, the output data are buffered.

:flush [method]
flushes buffered text string and send them to the textwindow. `Finish-output` or writing a newline character to this stream automatically calls this method.

make-text-window-stream *xwin* [function]
makes text-window-stream and returns the stream object.

BufferTextWindow [class]

:super	**TextWindow**
:slots	(linebuf expbuf max-line-length row col)

maintains the line buffer representing the contents of the textwindow. Linebuf is the vector of lines. Expbuf holds tab-expanded text. Only lines displayable in the window are maintained. BufferTextWindows can be used as simple text editors which have several, often only one, lines of text. `Text-item` employs a BufferTextWindow as a displayable line buffer.

:line *n* [method]
returns the contents of the *n*-th line as a string.

:nlines [method]
returns number of lines in the linebuf.

:all-lines [method]
returns the linebuf, which is a vector of strings.

:refresh-line *&optional (r win-row) (c win-col)* [method]
redraws the *r*-th line after the *c*-th column.

:refresh *&optional (start 0)* [method] redraws the lines after the *start*-th line inclusively.

:insert-string *string* [method]
inserts *string* at the cursor position.

:insert *ch* [method]
inserts the character at the cursor.

:delete *n* [method]
deletes *n* characters after the cursor.

expand-tab *src &optional (offset 0)* [function]
Src is a string possibly containing tabs. These tabs are replaced by spaces assuming the tab stops at every 8th position.

ScrollTextWindow [class]

:super	**BufferTextWindow**	
:slots	(top-row top-col	;display-starting position
	scroll-bar-window	
	horizontal-scroll-bar-window	
	selected-line)	

`ScrollTextWindow` defines buffertextwindow with unlimited number of lines, and vertical and horizontal scroll-bars can be attached. ScrollTextWindow can handle `:configureNotify` event to resize itself and accompanying scroll-bar windows, and to redisplay texts. By clicking, a line can be selected.

:create *&rest args &key (scroll-bar nil) (horizontal-scroll-bar nil) &allow-other-keys* [method]
When scroll-bars are needed, specify T to each keyword argument.

:locate *n* [method]
displays the buffered text by placing the *n*-th line at the top of the window.

:display-selection *selection* [method]
Selection represents the location of the selected line. The entire seleced line is displayed highlighted.

:selection [method]
returns the selected line (string).

:read-file *fname* [method]
reads the textfile specified by *fname* into the *linebuf*, expands tabs, and display in the window. The cursor is put at the beginning of the screen.

:display-string *strings* [method]
Strings is a sequence of lines (strings). The *strings* are copied in the linebuf and displayed in the window.

:scroll *n* [method]
vertically scrolls *n* lines.

:horizontal-scroll *n* [method]
horizontally scrolls *n* columns.

:buttonRelease *event* [method]
The line where the mouse pointer is located is selected. If notification is specified when the window is created, *notify-object*'s *notify-method* is invoked.

:resize *w h* [method]
changes the size of the window and redisplays the contents according to the new size. The same message is sent to scroll-bars if attached.

22 PostgreSQL Database

22.1 PostgreSQL

PostgreSQL is a free implementation of the relational database system, which is available from `http://www.postgresql.c` Once PostgreSQL is installed on your computer, EusLisp provides links to the databases via the `libpq.so` library.

Connecting to the Postgres database Instantiate pq:pgsql with proper arguments. In most cases, you just want to specify the database name and the user name. If you don't know, just trust the defaults, namely (instance pq:pgsql :init) is usually ok to make a connection.

Synchronous data transfer There are the synchronous and asynchronous interface in libpq.so. Synchronous transfer is easier. You send SQL commands by :exec method of the pgsql object, and get the result. (send db :exec "select typname,oid from pg_type order by oid") will give you a list of all data types defined in your database.

Asynchronous database access For asynchronous processing, you have to define a function or method to receive a query result as the first argument. Let's assume the receiver function is 'print'. Then a query should be issued by the :sendQuery method with the receiver function name as the second argument. (send db :sendQuery "select oid from pg_type" 'print)

Type conversion Postgres database stores data in a variety of forms internally, but every data item transferred between the database and the client is always converted to the string format. Thus, integer 1234 is "1234", and a symbol 'SYMBOL is "symbol". But, of course, since we want to access a database to store lisp data, they should be handled as lisp integers and lisp symbols. I found the datatype information is stored in the pg_type table. When we get data from a table, we can also retrieve the oid (object id) attributed to each field. By looking up pg_type table with the oid, we can know the datatype name, such as integer, character, date, etc. However, there is no symbol! We can use the 'name' type instead, but still there is incoherency to use as lisp symbol type, since there is no escapes (vertical bar and backslash) and lower-case to upcase conversion. I mean if we use the 'intern' function to change the 'name' object to symbol, it becomes a symbol with the lower case print-name. Do we call string-upcase before interning? Usually it works, but not always, because escapes are ignored. So I defined input and output function for Postgres in 'symbol_io.c'. There is also a Makefile for it. Make symbol_io.so and copy it to /usr/local/pgsql/lib. Invoke psql, and type "ısymbol_io.sql", which will make postgres to load the lisp_symbol_io functions, and and define the symbol type. Call make-type-hashtab function once before any other database retrieval for the faster type look-up. Then, every data transfered from the database is converted properly. Currently, symbol, int, float, char (string), date, time, datetime are coerced to corresponding lisp objects. Other unknown type data are represented by strings.

The following codes put in another file will load this database module, creates the *type-hashtab*, and reads the type list.

```
(load "pgsql")
(in-package "USER")
(unless (boundp 'db)
   (setq db (instance pq:pgsql :init) ))
(send db :exec "select * from family")
(pq:make-type-hashtab db)
(setq types (send db :exec "select typname,oid from pg\_type order by oid"))
```

pgsql [class]

:super **propertied-object**
:slots ...

:init *key host port dbname user password* [method] connects to a database designated by host, port and dbname. Host is defaulted to the localhost. The default port number is 5432. Default values to dbname and user are obtained from the USER environment variable.

:type-conversion *flag* [method]

Basically, every result delivered by a database query consists of a string. If type-conversion is set to NIL, no type conversion is performed, and query result is returned as a list of strings. If type-conversion is set to T, number is coerced to number, and symbol is interned in the current package.

:exec *sql* [method]

sends the SQL command to the database. EusLisp waits for the completion of the database processing and retrieves the results in a synchronous manner.

pq:table-fields *db table* [function]

returns the list of all fields in the table managed in the *db* database. Each list element is again a list, describing the field number starting from one, the symbolic field name, and the field type, such as text, int4, symbol, etc.

pq:table-attributes *db table* [function]

returns a list that describes attributes of the given table in db. The attributes are, name, owner, read-write grants, number of fields, etc.

pq:query *db handler &rest sql* [function]

sends an SQL command composed by the sql arguments to db. If handler is specified, the data retrieval is processed in asynchronous manner. The handler function is invoked when the database processing result arrives. The SQL command is composed by combining *sql* arguments by the *format* function.

pq:tables *db* [function]

returns a list of all tables created in db.

pq:delimit-list *xlist delimiter* [function]

returns a string combining *xlist* with the constant delimter string. For example, (delimit-list '(a b c) 'or) returns "a or b or c". This function is useful to compose SQL commands.

pq:select *db fields table &key where limit limit-offset order-by* [function]

sends an SQL command composed by the argument, and retrieves the result in the synchronous manner. The following example gives a list of id, name and email selected from the address_book table where the email ends with ".go.jp". Number of output lists are limited to 10, and the result is sorted by 'id'.

```
(select db '(id name email) 'address_book
     :where "email like '\*.go.jp'"
     :limit 10
     :order-by 'id)
```

pq:record-count *db table* [function]

returns the number of records in the table. db is a pgsql object.

23 HTTP

23.1 HTTP Client

URL-pathname [class]

:super **pathname**
:slots server port protocol

extends pathname to allow URL notation.

url-pathname *name* [function]

read-http *url &key (timeout 10) (retry 5))* [function]
makes a socket connection to the designated url, and read the html document. The result is a list of tags and plain strings. HTML tags are converted as lists consisting of the tag-name and argument lists. For example, the following html document, results in the following list. Note that tags are represented as lists, in which the directive is represented as a symbol followed by symbols or strings. Whether an argument is represented as symbol or string reflects how the original argument is described.

```
<body bgcolor=#ffa080>
<h1> EusLisp Title</h1>
<li> item1 </li>
<a href="http://www.etl.go.jp/~matsui/eus/euslisp.html"> euslisp</a>
</body>
("HTTP/1.1 200 OK"
 "Date: Sun, 21 May 2000 11:47:00 GMT"
 "Server: Apache/1.3.9 (Unix)"
 "Last-Modified: Sun, 21 May 2000 11:19:35 GMT"
 "ETag: \"4f014-c7-3927c647\""
 "Accept-Ranges: bytes"
 "Content-Length: 199"
 "Content-Type: text/html"
 (head) (title) " Toshihiro Matsui on t570" (/title) (/head)
 (body bgcolor |#FFA080|)
 (h1) " Title Line" (/h1)
 (li) " item1 " (/li)
 (a href "http://www.etl.go.jp/~matsui/eus/euslisp.html")
 " euslisp"
 (/a)
 (/body))
```

extract-html *tag html-list* [function]
returns a list of strings (and tags) sandwitched by tag and /tag.

remove-html-tags *html-list* [function]
removes tags from the html-list leaving only texts (strings).

23.2 HTTP CGI Programming

EusLisp can be used for CGI programming. The following is a typical cgi entry to a EusLisp program. This code piece should be placed under .../cgi-bin/ or under any directories where ExecCGI is allowed. The code piece must have execute permission by the 'nobody' user. Note that CGI programs are executed by httpd whose owner is nobody. You also have to set up some environment variables in the code piece, for nobody does not know anything particular for EusLisp.

```
#! /bin/csh
setenv EUSDIR /usr/local/eus/
```

```
setenv LD_LIBRARY_PATH /usr/local/eus/Linux/lib
/usr/local/bin/eus /usr/local/eus/lib/demo/mycgi.l
```

mycgi.l is a lisp source program, which should load "$EUSDIR/lib/llib/httpcgi.l" at the beginning. The CGI program is responsible for obtaining CGI arguments, generating an html header, and producing html contents. The arguments are obtained by the `get-cgi-query` function, and split to a list by the `parse-cgi-query` function. The parsed list contains pairs of argument-name and argument-value. For example, if the CGI is invoked by href to "/cgi-bin/eus.cgi?user=matsui&age=43", the parsed list gives ((user matsui) (age 43)).

All normal CGI output should go to *cgi-out*. Before any html document, a header should be generated by the `html-header` function. If there is any error message written to *error-output*, it appears in the httpd's error-log. When the work is done and html document finishes by '¡/html¿ tag, the process may close the connection (*cgi-out*) and may exit. Normal exit of the CGI process usually signals the httpd to send the data to http clients.

cgi-out is the output stream to which the generated html document should be sent.

gen *string* [function]

Outputs the string to *cgi-out* stream, which is then forwarded to to the client (browser).

html *args ...* [function]

generates args as one string.

html-table *lst &key heading (table-option "")* [function]

generates an html table.

get-cgi-query [function]

gets the argument to this CGI program. First, the REQUEST_METHOD environment variable is looked up, and the POST/GET method is determined. The query string is obtained from the QUERY_STRING environment variable or from the standard input. Anyways, the result is returned in one string.

parse-http-query *query-string* [function]

html-header [function]

generates the html header, usually a simple string of two lines, "Content-type: text/html%̃%̃".

qval *arg query* [function]

arg (symbol) is searched in the query list, and the value is returned if found. The result is converted to euc encoding from sjis encoding.

23.3 Fast-CGI

Whereas CGI is a convenient method to produce dynamic document on the server side, it is not the very best choice due to a performance reason: the cgi process must be spawned everytime a request arrives, and the process invocation time is not always negligible. In my measurement, the simplest CGI written in EusLisp needs 0.3 sec to respond. In this sense, EusLisp or any other programming system with rich runtime modules is not a very good choice for CGI writing.

Since this invocation load is a common problem for all CGI programs, there is a clever work around called Fast-CGI. The basic idea of the Fast-CGI is to allow CGI processes to keep alive even one CGI request is fulfilled. The httpd process communicates with a fast-cgi process via a TCP connection.

fcgi-connection [class]

:super	**propertied-object**
:slots	cookie host

fcgi-loop *&rest forms* [macro]

repeats evaluation of *forms* each time http connection request is accepted.

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