A Free Implementation of CLIM

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Abstract

McCLIM is a free implementation of the Common Lisp Interface Mangager, or CLIM, specification. In this paper we review the distinguishing features of CLIM, describe the McCLIM implementation, recount some of the history of the McCLIM effort, give a status report, and contemplate future directions.

McCLIM is a portable implementation of the Common Lisp Interface Mangager, or CLIM, specification[9] released under the Lesser GNU Public License (LGPL). CLIM was originally conceived as a library for bringing advanced features of the Symbolics Genera system[3], such as presentations, context sensitive input, sophisticated command processing, and interactive help, to Common Lisp implementations running on stock hardware. The CLIM 2.0 specification added "look-and-feel" support so that CLIM applications could adopt the appearance and behavior of native applications without source code changes.

Several Lisp vendors formed a consortium in the late 80s to share code in a common CLIM implementation, but for a variety of reasons the visibility of CLIM has been limited in the Common Lisp community. The McCLIM project has created an implementation of CLIM that, in the summer of 2002, is almost feature complete. Initially created by merging several developers' individual efforts, McCLIM is being used by several programs including a music editor, a web browser, and an IRC client (see Figure 1). Some non-graphic parts of CLIM have been adopted into the IMHO web server[2]. In this paper we review the distinguishing features of CLIM, describe the McCLIM implementation, recount some of the history of the McCLIM effort, give a stlatus report, and contemplate future directions for McCLIM.

1 CLIM Features and Concepts

CLIM abstracts the input and output features of window systems in order to seperate the applications programmer, and the specification, from any particular system. Graphics are rendered on *sheets*, which correspond to most systems'

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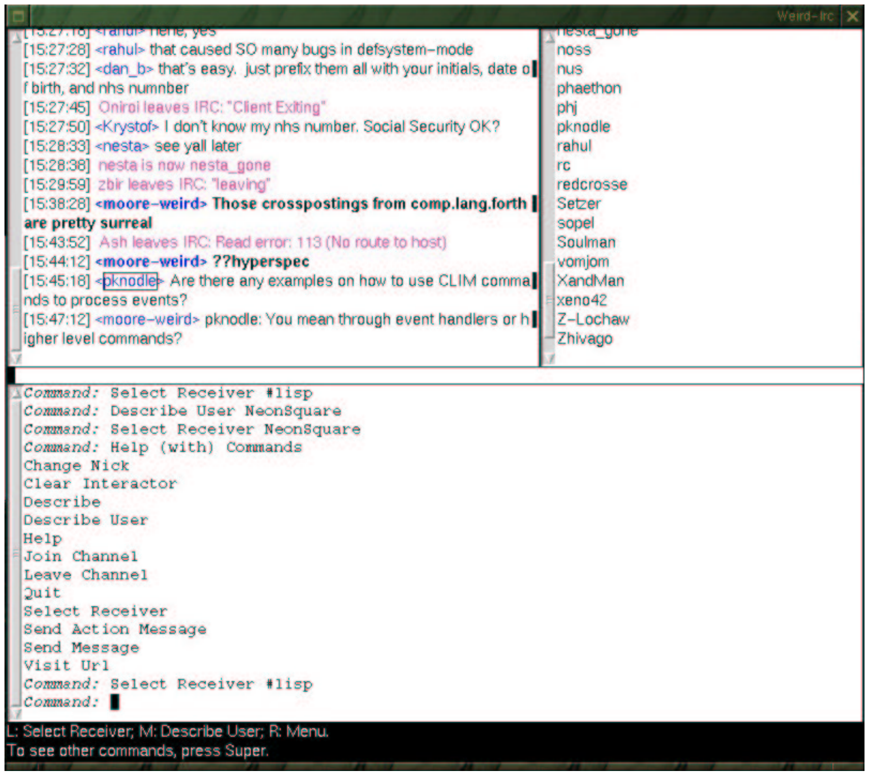

```
[15:27:18] <rahul> hehe, yes
[15:27:28] <rahul> that caused SO many bugs in defsystem-mode
[15:27:32] <dan_b> that's easy.  just prefix them all with your initials, date o
f birth, and nhs numnber
[15:27:45] Oniroi leaves IRC: "Client Exiting"
[15:27:50] <Krystof> I don't know my nhs number. Social Security OK?
[15:28:33] <nesta> see yall later
[15:28:38] nesta is now nesta_gone
[15:29:59] zbir leaves IRC: "leaving"
[15:38:28] <moore-weird> Those crosspostings from comp.lang.forth
are pretty surreal
[15:43:52] Ash leaves IRC: Read error: 113 (No route to host)
[15:44:12] <moore-weird> ??hyperspec
[15:45:18] <pknodle> Are there any examples on how to use CLIM comma
nds to process events?
[15:47:12] <moore-weird> pknodle: You mean through event handlers or h
igher level commands?
```

```
nesta_gone
noss
nus
phaethon
phj
pknodle
rahul
rc
redcrosse
Setzer
sopel
Soulman
vomjom
XandMan
xeno42
Z-Lochaw
Zhivago
```

```
Command: Select Receiver #lisp
Command: Describe User NeonSquare
Command: Select Receiver NeonSquare
Command: Help (with) Commands
Change Nick
Clear Interactor
Describe
Describe User
Help
Join Channel
Leave Channel
Quit
Select Receiver
Send Action Message
Send Message
Visit Url
Command: Select Receiver #lisp
Command:
```

```
L: Select Receiver; M: Describe User; R: Menu.
To see other commands, press Super.
```

Figure 1: Jochen Schmidt's weird-irc IRC client in McCLIM

notion of a window. The root window is represented by a *graft*; visible sheets are direct or indirect children of the graft and are said to be *grafted*. Input events happen in sheets or are associated with sheets. The concrete window system window or "drawable" associated with a sheet is called a *mirror*. CLIM defines generic functions for drawing graphics and text into sheets which generally map directly into the host window system's primitives.

For screen layout CLIM defines a rich set of *pane* classes, interface *gadgets* such as buttons and text fields, methods for composing these panes and gadgets into complete interfaces, and support for user input. CLIM is very tightly integrated with Common Lisp streams. Graphics operations such as drawing lines are performed on an output stream, but that output stream is also a valid argument to standard Lisp output functions such as `format`. Input streams are generalized to return mouse and button gestures as well as keyboard input.

Many GUI toolkits have a prettier appearance than CLIM's default appearance. What distinguishes CLIM are features that are built on top of conventional toolkit features. CLIM output streams support recording – similar to display lists in OpenGL[7] – so that a program does not need to maintain output state. A common example would be a program that writes its output to a continually scrolling window in the style of a conventional terminal application. For input, CLIM extends the traditional Lisp read - eval - print loop into a command loop which reads commands, executes them, and refreshes the application display[10]. A *command* consists of a function and typed arguments that will be supplied to it. There are several ways in which a user can specifiy commands and their arguments. She can choose a simple command from a menu or type the command in an interactor pane, which supports a rich set of editing, completion, and help features.

The user can also enter arguments by clicking on graphic objects on the screen. This is supported by a fundamental feature of CLIM, *presentations*[4]. Program objects, instead of only being printed or represented by screen graphics, are *presented*, which associates the screen output with both the object and a presentation type (which can be different from the object's actual type). In the CLIM command loop one or more input contexts, which expect input of a certain type, are active. Any presentation whose type is a subtype of the input context type can then be clicked on to provide input. Presentation translators enable a presentation to satisfy an input context of a completely different type; in fact, a translator can translate an object to a command, so that an entire command can be entered by clicking on a presentation. For example, an object could be selected for some purpose by clicking on it if there's a translator from the presentation type associated with the object to the "select" command. Translators are also associated with mouse buttons and combinations of modifier keys.

CLIM provides interactive feedback during the input process. If the user moves the mouse pointer over an applicable presentation it will be highlighted, indicating that it will satisfy one of the current input contexts. A mouse documentation pane provides real-time information on the effects of clicking a mouse button with the current modifier keys; this documentation can be unique to each presentation. CLIM also provides other application-building features such as table, text and graph formatting, and an application definition facility which supports both definition of application commands and layout of application screen real estate.

CLIM excels in problem spaces where the user interface is highly dynamic and not specifiable by a static GUI building tool. It also succeeds where the program interface is complex due to the nature of the problem domain. CLIM remains interesting and unique in spite of competion from younger, more attractive toolkits.

2 Implementation of McCLIM

CLIM is specified in terms of protocols defined on CLOS generic functions and classes[6]. Generally the classes are protocol classes, which are not intended to be instantiated but are required superclasses of objects that participate in the protocols. Each protocol class has a corresponding concrete class which can be instantiated and usefully subclassed. By convention a concrete class has the name of its protocol class with `standard-` prepended. For example, the protocol class `application-frame` defines the behavior of a CLIM application's top level window; `standard-application-frame` or a subclass of it is instantiated when starting a CLIM application.

CLIM follows a common Lisp pattern of specifying functions in pairs: a regular function with few required arguments and many keyword arguments, and a generic function in which some of those keyword arguments are required arguments. The regular function is called by application programmers for whom the keyword argument defaults are convenient. It in turn calls the generic function, which can be specialized on arguments that were keyword arguments of the regular function. In our description of the McCLIM implementation we will generally refer to the regular function and not make a distinction between it and the generic function unless needed.

2.1 Language and Host Requirements for McCLIM

McCLIM is written in ANSI Common Lisp[1] and uses common extensions, specifically Gray streams[5] and the Metaobject Protocol[8]. Threads are optional but are required to support multiple applications in a single Lisp image. McCLIM currently runs in CMU Common Lisp (CMUCL), Steel Bank Common Lisp (SBCL), Allegro Common Lisp, and OpenMCL.

McCLIM has backends for interfacing to several different graphics systems. The most robust interface is to the X Window System[12] which uses the CLX Common Lisp bindings. There is also an experimental interface to OpenGL[7] that uses a foreign function interface to directly make OpenGL calls for output and X Window System calls for input. Additionally there is a backend for outputing PostScript from McCLIM graphics.

2.2 Graphics Substrate

CLIM defines a powerful set of operators on *regions*. This includes boolean operations on shapes such as lines, rectangles, collections of rectangles, and general polygons. McCLIM fully implements this region protocol including translation of complex regions to rectangle strips, which is required for most window system clipping operations. McCLIM uses the region protocol in many other parts of the system, particularly for calculating rectangle – rectangle overlap. Regions control both the clipping and transformation of graphics in sheets.

CLIM makes it easy to allow sheets with or without mirrors to be the targets for graphics operations. A sheet without a direct mirror will simply redirect such operations to the mirror of its parent, with a combination of the transformations and regions of itself and its parent.

The CLIM specification is a bit unclear about the terminology here, as sometimes a *mirrored sheet* is considered to be sheet that *can have* a direct mirror, sometimes one that currently *has one*. Given that ungrafted sheet hierarchies can move to different ports, potentially with different underlying windowing systems, the only reasonable interpretation seems to be the first one. Thus, the only use for sheets that are not mirrored would be for sheets that should *never* have a direct mirror.

In McCLIM, we decided to implement mirrored sheets by storing a mirror in all sheets (whether mirrored or not, and whether they have a direct mirror or not). All graphics operations use this mirror for graphics output using either the device region and device transformation or the native region and native transformation. This implementation gives a uniform and fast implementation of all graphics operations. In addition, computing these regions and transformations from those of the parent becomes straightforward in our implementation.

Associated with sheets are *mediums* which hold graphics state such as current foreground and background color. CLIM graphics generic functions such as `draw-line` and `draw-text` dispatch on the medium, render to the sheet's mirror, and use the sheet transformation (and possibly a medium transformation). Most of these operations also have "trampoline" methods, defined on sheets, that immediately dispatch to the medium graphics function.

2.3 Output and Input Streams

Extended output streams are an abstraction layered on top of sheets that support the semantics of Common Lisp streams for character output as well as CLIM graphics operations. CLIM output streams are a subclass of `sheet`, so the sheet graphics functions discussed above "just work." A *text cursor* is maintained which is updated when the Common Lisp printing functions – via Gray Streams interfaces such as `stream-write-char` – print to an output stream. `terpri` ultimately results in a simple movement of the text cursor.

Extended input streams add window system capabilities to Common Lisp input streams. The basic reading function is `read-gesture`, which is similar to the Common Lisp function `read-char` but also implements peeking and timeout.

This function can return pointer gesture objects and keyboard gestures with modifier keys as well as characters. McCLIM implements the generic functions of the Gray streams protocol such as `stream-read-char` and `stream-read-line` by calling this function and filtering out non-character gestures. Thus a program can call any Lisp input function, such as `read`, on an extended input stream and get meaningful results.

Each CLIM sheet has an associated event queue. Events from the host window system are translated to CLIM events and delivered to the queue of the sheet where the event occured. Extended streams in CLIM are subclasses of `sheet`, so McCLIM can use the sheet event queue as the stream buffer. `read-gesture` translates keyboard events to characters when possible as it reads them out of the queue. In order to implement "unreading" McCLIM allows characters to be pushed back on the event queue.

While Common Lisp defines functions that block waiting for input from streams, neither it nor the Gray streams extensions provide any functionality for implementing user-defined streams that block. CLIM implements blocking via two strategies. In multi-threaded implementations, a single thread gets input from the host graphics system and distributes it to waiting applications via queues. Programs wait for input in the queues using the waiting primitives of the thread implementation.

In a single-threaded implementation the backend's event mechanism is used to block the single thread of execution; when an event is available it is put in the stream's event queue and then the same code is invoked that's used in the multi-threaded implementation.

`read-gesture` also takes *wait test* and *input handler* parameters which, if supplied, filter all device events received by an application. The defaults come from special variables and are rarely supplied in application code, so McCLIM can bind these filters dynamically and nest them for its own purposes. The wait tester is invoked when input becomes available. If it returns `nil` waiting will continue; otherwise the input handler is invoked. The input handler can either consume the available input or leave it for `read-gesture` to return.

2.4 Output Recording

CLIM manages the redisplay of output streams for the user by maintaining output records. An output record can contain other output records or information needed to recreate primitive drawing operations such as the operation, current graphics state, or the string associated with drawing text. A stream has a *current output record* which records all graphics and text operations while recording is enabled. A new output record can be established with the `with-new-output-record` macro; it will be a child of the current output record and can be a subclass of `output-record`. In general, then, a stream's output records form a tree rooted at a top level record.

In McCLIM primitive operations are captured via around methods. The bounding box of an output record is incrementally updated as output is added to it, as is the bounding box of the record's parent (and so forth up the tree).

```
(define-presentation-type integer (&optional low high)
  :options ((base 10) radix)
  :inherit-from `((rational ,low ,high) :base ,base :radix ,radix))

(define-presentation-method presentation-typep (object (type integer))
  (and (integerp object)
       (or (eq low '*)
           (<= low object))
       (or (eq high '*)
           (<= object high))))

(defmethod presentation-type-of ((object integer))
  'integer)
```

Figure 2: Example of presentation type definition

Generic functions are provided that map over all the output records that intersect a position and a geometric region. The latter is obviously needed to support redisplay on exposure events and such; the former provides powerful support for mouse input.

2.5 Presentation Types and Presentation Methods

The type of presentation is not the type of its object. In fact, it is not a Lisp type at all; it is a *presentation type*. Presentation types form a parallel lattice to the Common Lisp type system and extend the capabilities of user-defined Lisp types. They are defined via `define-presentation-type`, a `deftype` - like macro. Subtype relationships are implied by the type specification "macroexpansion"; additionally the programmer can write predicate methods for type membership and subtype relations within a type. In addition to parameters, presentation types may also have options which affect the visual representation of presentations. Many builtin Lisp types have presentation type equivalents of the same name. Figure 2 shows the definition of the `integer` presentation type that is built into McCLIM.

Although they are represented as lists, presentation types have many characteristics of CLOS objects. Their parameters and options are similar to class slots, and they have an inheritance relation with their supertypes. However, parameters and options are not inherited from supertypes – they parameterize the supertypes and they may be arbitrarily transformed[1] between the subtype and supertype.

To support dispatching on a single presentation type argument, CLIM provides *presentation generic functions* and *presentation methods* that are similar to their CLOS equivalents – for example, method combination and effective

[1]Actually, there are significant restrictions on the `:inherit-from` function

```
(define-presentation-method present (object (type integer) stream
                                     (view textual-view)
                                     &key acceptably for-context-type)
  (declare (ignore acceptably for-context-type))
  (let ((*print-base* base)
        (*print-radix* radix))
    (princ object stream)))

(define-presentation-method accept ((type integer)
                                    stream (view textual-view)
                                    &key (default nil defaultp)
                                    default-type)
  (let ((*read-base* base))
    (let* ((token (read-token stream)))
      (when (and (zerop (length token))
                 defaultp)
        (return-from accept (values default default-type)))
      (parse-integer token))))
```

Figure 3: Example `present` and `accept` methods

method computation work as expected – but that also make parameters and options available as variables in the methods, properly transformed for the presentation type. In Figure 2, `presentation-typep` is a presentation generic function defined by CLIM. The `type` argument is a presentation type.

Presentation types and methods are implemented in McCLIM using the Metaobject Protocol[8]. A class metaobject of type `presentation-type-class`, a subclass of `standard-class`, is created for each presentation type. The supertypes of the presentation type, retrieved by running the `:inherit-from` function with dummy arguments when a type is defined, become superclasses of the metaobject. Presentation methods are implemented as regular methods with an extra argument, the class prototype of the class corresponding to the presentation type argument. That is, of course, used to compute the effective method in the usual way.

The body of a presentation method is wrapped by code that expands the presentation type argument from its actual type to the supertype expected by the method and binds parameter and option variables in the body. In effective methods that contain many constituent methods this strategy could lead to poor performance because the expansion functions for the most specific classes need to be be run repeatedly as less specific methods are called. Near term future work will include introducing a caching mechanism to mitigate this effect. An alternate strategy, used by the commercial CLIM implementation, is to perform the expansion outside of the method body, in the method combination code. This approach avoids unnecessary expansion, but it breaks all non-standard method combination.

Because hidden arguments are passed to presentation methods, they need to be called with special syntax. However, the application programmer never needs to use that syntax unless she defines new presentation functions that are not in the CLIM specification. The user calls a function in the interface – for example, `present`, and that function calls the presentation generic function of the same name, perhaps after establishing dynamic state and defaulting arguments.

2.6 Input and Output With Presentations

Presentations are implemented as a subclass of `output-record` which stores the associated object and presentation type. The `present` function creates a presentation using `with-new-output-record` and within its dynamic extent invokes the `present` presentation method for the object and presentation type. The `present` method for the `integer` presentation type in Figure 3 shows a typical presentation method that uses presentation type options (`base` and `radix`) to alter its output. The *view* argument – generally supplied from a default view associated with the output stream – provides an additional way to customize the output of the method. `textual-view` is a view for simple text output;[2] other view classes can imply graphics output. As is typical for `textual-view` methods the method body is quite simple; the calling `present` function does most of the work of creating a presentation.

The dual of presentation output, and the motivation for it, is input via presentations. In a CLIM program, the input of a data type is implemented by writing an `accept` method for that data type. A simple `accept` method for `integer` is shown in Figure 3. The `accept` function performs an important step in addition to calling the `accept` method for a type: it establishes an *input context* for the type. Within the dynamic extent of the input context, if the user clicks on a presentation which matches the context's type the context is exited with the object and type from the presentation as values. Nested input contexts may be created by recursive calls to `accept`. Figure 4 shows the control stack when a program prompts for a command and the corresponding input contexts. At this point the user can proceed in several ways:

- type a command name and exit the inner `accept` call, causing the command parser to start parsing command arguments;
- exit the inner `accept` by clicking on a presentation matching `command-name`, perhaps from a list of command names generated by a "Help" command or a menu of possibilities;
- click on a presentation matching `command`, exiting the outer `accept`.

Input contexts are established with the `with-input-context` macro. An abridged version of the use of `with-input-context` in `accept` is shown in

[2]The output might even go to a string stream.

active function call	input context type
`(read-command 'user-command-table)`	
`(accept '(command :command-table 'user-command-table))` `(funcall *command-parser* 'user-command-table)`	`command`
`(accept '(command-name :command-table 'user-command-table))`	`comand-name`

Figure 4: Input function calls and the corresponding dynamic input context

```
(with-input-context (type)
  (object object-type event options)
  ;; Results of this form are returned if no presentation is
  ;; clicked on.
  (funcall-presentation-generic-function
   accept
   type stream view)
  ;; Clauses chosen by matching with presentation-subtypep
  (t
   (values object object-type)))
```

Figure 5: The `with-input-context` form inside `accept`

Figure 5. This macro establishes a context for `type`. If the user clicks on a matching presentation then the variables in the second form are bound and the first matching clause at the tail is executed; otherwise values are returned from the third form are returned.

`with-input-context` binds the input wait test and input handlers described in Section 2.3 and pushes a cons of the type and a continuation onto the internal dynamic variable `*input-context*`. The expansion of the form in Figure 5 is shown in Figure 6. The convoluted nesting of blocks allows for fallthrough into the `cond` form if the context continuation is called while returning all values from the body form if "nothing happens."

The input wait handler is called for pointer events and checks if there is a presentation under the pointer that matches any of the types in `*input-context*`. If the event is a pointer press event and there is a matching presentation the handler funcalls the input context continuation to return to the enclosing `with-input-context`. The wait handler also performs other tasks such as updating any pointer documentation feedback on the screen.

2.7 Input Editing

CLIM specifies an input editing interface that looks, to the user, like a simple Emacs editor with conventional key bindings for ordinary operations such as

```
(block return-block
  (multiple-value-bind (object object-type event options)
      (block context-block
        (let ((*input-context*
               (cons (cons type
                           #'(lambda (object type event options)
                               (return-from context-block
                                 (values object type event options))))
                     *input-context*))
              (*input-wait-test* #'input-context-wait-test)
              (*input-wait-handler* #'input-context-event-handler))
          (return-from return-block
            (funcall-presentation-generic-function
             accept
             type stream view))))
    (cond ((presentation-subtypep type t)
           (values object object-type)))))
```

Figure 6: The expansion of `with-input-context` in Figure 5

cursor motion and character insertion and deletion. From the point of view of the program, input still appears to be coming from a stream. This is acheived through a mechanism very similar to "Lisp machine rubout handling"[11]. Editing can be done within the dynamic extent of a `with-input-editing` macro; any editing change to input that has already been read by the program causes the body of `with-input-editing` to be rerun with the modified input in the stream. `with-input-editing` takes a stream argument which is rebound to an *encapsulating stream* which delegates all generic functions to the original stream except those that read input. These functions process input gestures from original stream as editor commands, update editor state and the screen, and return the next available gesture that isn't an editing command.

The McCLIM input editor uses an editing substrate, called Goatee[3], that is being developed in parallel with McCLIM and which is itself implemented using CLIM graphics and input features. Goatee will eventually be an Emacs-like editor in its own right. Goatee's internal design resembles that of Zmacs: its buffers are represented as linked lists of lines. By using a "real" editor to implement CLIM input editing instead of an ad-hoc editor we leave open the potential of tight integration between all the editing that a user might do across all applications.

[3]Goatee Owes All to Emacs, Evidently

3 McCLIM Development History

Several attempts have been made to create a free implementation of CLIM. In the late 1980s, a supposed project was referenced by the `cons.org` site, but no CLIM code was actually written, at least as far as an external observer could tell.

In 1998, Mike McDonald and Gilbert Baumann independently started working on a free implementation of CLIM.

McDonald called his implementation "McCLIM". He elected to work in a "horizontal" manner, supplying enough code for a large number of chapters of the specification in order to run a simple demo application (a version of the "address book" demo supplied by Franz' CLIM implementation). McDonald's idea was to distribute his code according to some free or open-source license, but only once the address-book demo was fully functional, requiring among other things a fairly complete implementation of presentation types. Unfortunately, McDonald ultimately had to considerably decrease the time spent on this project.

Baumann, on the other hand, decided to work in a more systematic (but perhaps less rewarding) way. He worked "vertically", starting with the chapters on regions and transformations. The main reason for Baumann to work this way was that he needed regions and transformations in his Closure web browser. Rather than inventing a new interface, he decided to use an existing one, i.e, the one given in the CLIM specification. The result of this effort was a fairly complete implementation of regions and transformations. Also for reasons of less available time, Baumann had to abandon further work on CLIM. Baumann decided to make his code available to all according to the GNU LGPL license.

In 1999, Robert Strandh was looking for an interface library for his Gsharp score editor. He had just decided to rewrite the Gsharp editor in Common Lisp, so a fully-functional interface library was required. Having read about CLIM, he decided that CLIM would be a good candidate. Gsharp being distributed according to the GNU GPL, it was out of the question to use commercial version of CLIM. He thus decided to suspend work on Gsharp and first work on getting enough of CLIM to work that Gsharp would be feasible. First, Strandh tried to get McDonald's code in order not to have to rewrite existing functionality, but McDonald maintained his decision not to provide his code. Thus, Strandh started with Baumann's code and started adding many of the basic sheet protocols, code for ports, grafts, and mirrored sheets, and also drawing functions, drawing options, text styles, and drawing in color.

When McDonald realized in early 2000 that his code would no longer be needed with the progress being made, he agreed to distribute his code, also according to the LGPL so that ultimately his code could be integrated into that of Baumann and Strandh. Because McDonald's code contained a partial implementation of regions and transformations, Strandh temporarily abandoned Baumann's code and merged his existing code into that of McDonald. This combination became the code base of McCLIM in that all further modifications were made to this code. In particular, Arthur Lemmens contributed the first code for some of the gadgets in June of 2000 to this code base.

During the LSM 2000 meeting in Bordeaux, Baumann merged his code for regions and translations into the main code base. This event, in our opinion, marked the point at which we were convinced that the McCLIM project would ultimately succeed. There were a sufficient number of people involved and everyone was working with the same code base. Strandh wrote the code for menu bars using this code base.

Various undergraduate student projects contributed code for more gadgets, layout panes, code for manipulating bitmap images, and a file selector gadget. Longer projects by Iban Hatchondo, Julien Boninfante, Arnaud Rouanet, and Lionel Salabartan (all students at the university of Bordeaux) during 2000 and 2001 contributed a better implementation of the layout protocol, the first code for the OpenGL backend (the first backend was CLX), output recording, PostScript output, and several demo applications.

Alexey Dejneka wrote the code for table formatting, bordered output, and more PostScript backend code. He also contributed (and still does) a very large number of bug fixes. Motivated by a comment of Strandh's that "nobody I know of has any clue as to how to implement presentation types,"[13] Tim Moore joined in the fall of 2001. Moore wrote the presentation type system, command completion, input editing, encapsulating streams, the Goatee editor substrate and much more.

Tim Moore, Gilbert Baumann, Alexey Dejneka, and Mike McDonald are currently the major contributors to the McCLIM code.

4 Current Status of McCLIM

As we mentioned earlier, McCLIM is *almost* feature complete, and is making rapid progress toward completeness and beyond. This section provides an overview of the implementation as of this writing (August 2002) with respect to the CLIM 2 specification

Regions, bounding rectangles and transformations are still largely implemented by Gilbert Baumann's original code. Some additions and improvements are necessary, but this code is mostly stable and nearly complete. The entire geometry substrate can thus be considered almost complete.

The same thing holds for the windowing substrate. Sheet properties and sheet protocols are mostly complete and functional, as are ports, grafts and mirrored sheets.

For the sheet and medium output facilities, there is a major gap in McCLIM with respect to general designs, including transparency, patterns, stencils, tiling, etc. There are also some minor gaps such as absence of arbitrary ellipses and elliptical arcs (due to X11 restrictions).

With respect to the extended stream output facilities, basic extended stream output and output recording are mostly implemented, as are features such as table formatting, bordered output and text formatting. Graph formatting is not yet implemented, although it should be fairly easy given that excellent algorithms and (even some code) exist in some archives. Incremental redisplay is not yet implemented.

The presentation type system and command processing are essentially complete. The input editor is quite usable; at this time it lacks support for killing and yanking text and yanking presentation history.

Finally, the part in the specification regarding building applications is partly complete. Most panes and gadgets are implemented, except that the specification is quite vague on the required features of gadgets such as the text-editor gadget. Parts of the features of stream panes are also missing.

5 Conclusions and Future Work

McCLIM is well on its way to becoming a complete implementation of the CLIM 2 specification. As such, it is just another addition to the family of existing CLIM implementations. However, McCLIM does not share any of the code base of the other CLIM implementations. The fact that McCLIM is a completely new implementation makes it easier to improve on features of the other implementations. In particular, the "native" look of McCLIM is more modern than that of the other implementations. A fresh code base with clear licensing also makes it much easier to integrate new features and bug fixes from users.

We believe that McCLIM can represent the beginning of a period of renewed interest for CLIM and, by association, for Common Lisp in general. Certainly, it means that low-budget users such as university students can try out and explore some of the features of an advanced Common Lisp application, until now reserved for professional users.

The first goal is obviously to supply all, or at least most, of the functionality of the specification. We are convinced that this goal is in sight, and that within another year, probably less, this goal will have been reached. But what next?

We think most users will want to use the CLX backend. For that reason, we want to improve performance for that backend. The current system does not handle X11 event very well, and much too much consing degrades performance even more. That said, recent performance improvements make the system quite usable. Gilbert Baumann has done some promising experiments with anti-aliased text using FreeType and the XRender extension to X11.

For a project of this type, it is important to allow as many users as possible to contribute. For that reason, we need to improve the quality of the existing code. A number of temporary kludges need to be replaced by more thought-out code. Comments and documentation strings should be added wherever reasonable.

We are naturally considering several extensions to the CLIM specification, not just in the form of modern panes and gadgets that did not exist when the CLIM specification was written, but also new functionalities of existing features. In particular, we would like to provide arbitrarily transformable fonts, a library for manipulating various kinds of images, support for sound, and 3D drawing capabilities.

Although CLIM documentation is readily available in the form of the specification itself and in vendor manuals, we would like to write our own. There are several reasons for that. First, we need to document holes, ambiguities, and contradictions in the specification as well as the ways in which they were resolved in McCLIM. Next, we are not pleased with the structure of existing manuals. We would like a complete manual starting from a chapter on how to write simple applications using existing functionalities and eventually leading up to mechanisms the advanced user might want to take advantage of in order to add new features to CLIM itself, or to replace existing features with new ones. Implementation-specific documentation is also needed for extensions to the CLIM specification.

Finally, we would like to supply backends for other native windowing systems such as Microsoft Windows and Apple MacOS, and perhaps a backend for GGI.

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