****

**Reference Manual**

**Volume II**

**Advanced Programming Guide**

*Version 6.40 Beta*

*August 21st 2017*

Copyright © 2017 by Gary Riley

**CLIPS Advanced Programming Guide**

Version 6.40 Beta August 21st 2017

**CONTENTS**

License Information i

Preface iii

Section 1: Introduction 1

1.1 C++ Compatibility 1

1.2 Threads and Concurrency 1

Section 2: Installing and Tailoring CLIPS 3

2.1 Installing CLIPS 3

2.1.1 Makefiles 6

2.2 Tailoring CLIPS 8

Section 3: Core Functions 13

3.1 Creating and Destroying Environments 13

3.1.1 CreateEnvironment 13

3.1.2 DestroyEnvironment 13

3.2 Loading Constructs 13

3.2.1 Clear 13

3.2.2 Load 14

3.3 Creating Facts and Instances 14

3.3.1 AssertString 14

3.3.2 MakeInstance 14

3.4 Executing Rules 15

3.4.1 Reset 15

3.4.2 Run 15

3.5 Debugging 15

3.5.1 DribbleOn and DribbleOff 15

3.5.2 Watch and Unwatch 16

3.6 Examples 17

3.6.1 Hello World 17

3.6.2 Debugging 18

Section 4: Eval, Build, and StringBuilder Functions 21

4.1 CLIPS Primitive Values 21

4.1.1 TypeHeader 21

4.1.2 CLIPSValue 22

4.1.3 Symbol, Strings, and Instance Names 22

4.1.4 Integers 23

4.1.5 Floats 23

4.1.6 Multifields 23

4.1.7 Void 24

4.1.8 External Address 24

4.2 Eval and Build 24

4.3 StringBuilder Functions 25

4.3.1 CreateStringBuilder 25

4.3.2 SBAddChar 26

4.3.3 SBAppend 26

4.3.4 SBCopy 26

4.3.5 SBDispose 26

4.3.6 SBReset 26

4.4 Examples 27

4.4.1 Debugging Revisited 27

4.4.2 String Builder Function Call 27

4.4.3 Multifield Iteration 29

4.4.4 Fact Query 31

Section 5: Garbage Collection 35

5.1 Introduction 35

5.2 Embedded Use 36

5.2 Example 38

Section 6: Creating Primitive Values 41

6.1 Primitives 41

6.1.1 Creating CLIPS Symbol, Strings, and Instance Names 41

6.1.2 Creating CLIPS Integers 42

6.1.3 Creating CLIPS Floats 42

6.1.4 Creating Multifields 42

6.1.5 The Void Value 44

6.1.6 Creating External Addresses 44

6.2 Examples 44

6.2.1 StringToMultifield 44

6.2.2 MultifieldBuilder 45

6.2.3 MultifieldBuilder with Eval (TBD) 45

Section 7: Creating Facts and Instances 47

7.1 FactBuilder 47

7.2 Managing Fact Builders 47

7.3 Managing Fact Modifiers 48

7.4 Managing Instance Builders 49

7.5 Managing Instance Modifiers 50

7.6 Assigning Slot Values 51

7.5 Assigning Integer Slot Values 51

7.6 Assigning Float Slot Values 52

7.7 Assigning Symbol, String, and Instance Name Slot Values 53

7.8 Assigning Fact and Instance Values 54

7.9 Assigning Multifield and External Address Slot Values 55

7.10 Examples 56

7.10.1 FactBuilder 56

7.10.2 FactModifier 57

7.10.3 Fact Modifier with Referenced Facts 58

Section 8: User Defined Functions 63

8.1 User Defined Function Types 63

8.2 Registering User Defined Functions 64

8.3 Passing Arguments from CLIPS to User Defined Functions 66

8.4 Examples 68

8.4.1 Euler’s Number 68

8.4.2 Week Days Multifield Constant 69

8.4.3 Cubing a Number 70

8.4.4 Positive Number Predicate 71

8.4.5 Exclusive Or 72

8.4.6 String Reversal 73

8.4.7 Reversing the Values in a Multifield Value 75

8.4.8 Trimming a Multifield 76

8.4.9 Removing Duplicates from a Multifield 78

8.4.10 Prime Factors 79

Section 9: I/O Routers 83

9.1 Introduction 83

9.2 Logical Names 83

9.3 Routers 85

9.4 Router Priorities 86

9.5 Internal I/O Functions 87

9.5.1 ExitRouter 87

9.5.2 Input 87

9.5.3 Output 88

9.6 Router Handling Functions 89

9.6.1 Creating Routers 89

9.6.2 Deleting Routers 91

9.6.3 Activating and Deactivating Routers 91

9.7 Examples 92

9.7.1 Dribble System 92

9.7.2 Better Dribble System 96

9.7.3 Batch System 97

9.7.4 Simple Window System 100

Section 10: Environments 107

10.1 Creating and Destroying Environments 107

10.2 Standard Environment Functions 108

10.2.1 Allocating Environment Data 108

10.2.2 Retrieving Environment Data 109

10.3 Allocating Environment Data 109

Section 11: Creating a CLIPS Run‑time Program 113

11.1 Compiling the Constructs 113

Section 12: Embedding CLIPS 117

12.1 Environment Functions 117

12.1.1 Clear Callback Functions 117

12.1.2 Periodic Callback Functions 118

12.1.3 Reset Callback Functions 119

12.1.4 File Operations 120

12.1.5 Settings 121

12.2 Debugging Functions 122

12.2.1 DribbleActive 122

12.2.2 GetWatchState and SetWatchState 122

12.3 Deftemplate Functions 123

12.3.1 Search, Iteration, and Listing 123

12.3.2 Attributes 124

12.3.3 Deletion 125

12.3.4 Watching Deftemplate Facts 125

12.3.5 Slot Attributes 125

12.3.6 Slot Predicates 126

12.4 Fact Functions 127

12.4.1 Iteration and Listing 127

12.4.2 Attributes 129

12.4.3 Deletion 130

12.4.4 Reference Counts 130

12.4.5 Loading and Saving Facts 131

12.4.6 Settings 132

12.4.7 Detecting Changes to Facts 132

12.5 Deffacts Functions 133

12.5.1 Search, Iteration, and Listing 133

12.5.2 Attributes 134

12.5.3 Deletion 134

12.6 Defrule Functions 135

12.6.1 Search, Iteration, and Listing 135

12.6.2 Attributes 136

12.6.3 Deletion 136

12.6.4 Watch Activations and Firings 137

12.6.5 Breakpoints 137

12.6.6 Matches 138

12.6.7 Refresh 138

12.7 Agenda Functions 139

12.7.1 Iteration and Listing 139

12.7.2 Activation Attributes 140

12.7.3 FocalModule Attributes 141

12.7.4 Rule Fired Callback Functions 141

12.7.6 Manipulating the Focus Stack 143

12.7.7 Manipulating the Agenda 143

12.7.8 Detecting Changes to the Agenda 144

12.7.9 Settings 144

12.7.10 Examples 146

12.8 Defglobal Functions 146

12.8.1 Search, Iteration, and Listing 146

12.8.2 Attributes 148

12.8.3 Deletion 149

12.8.4 Watching and Detecting Changes to Defglobals 149

12.8.5 Reset Globals Behavior 150

12.8.6 Examples 150

12.9 Deffunction Functions 151

12.9.1 Search, Iteration, and Listing 151

12.9.2 Attributes 152

12.9.3 Deletion 153

12.9.4 Watching Deffunctions 153

12.10 Defgeneric Functions 154

12.10.1 Search, Iteration, and Listing 154

12.10.2 Attributes 155

12.10.3 Deletion 155

12.10.4 Watching Defgenerics 156

12.11 Defmethod Functions 156

12.11.1 Iteration and Listing 156

12.11.2 Attributes 157

12.11.3 Deletion 158

12.11.4 Watching Methods 158

12.12 Defclass Functions 159

12.12.1 Search, Iteration, and Listing 159

12.12.2 Class Attributes 160

12.12.3 Deletion 161

12.12.4 Watching Instances and Slots 162

12.12.5 Class Predicates 162

12.12.6 Slot Attributes 163

12.12.7 Slot Predicates 164

12.12.8 Settings 165

12.13 Instance Functions 166

12.13.1 Search, Iteration, and Listing 166

12.13.2 Attributes 168

12.13.3 Deletion 168

12.13.4 Loading and Saving Instances 169

12.13.5 Reference Counts 171

12.13.6 Detecting Changes to Instances 172

12.13.7 Send 172

12.13.8 Example 172

12.14 Defmessage-handler Functions 175

12.14.1 Search, Iteration, and Listing 176

12.14.2 Attributes 177

12.14.3 Deletion 177

12.14.4 Watching Message-Handlers 178

12.14.5 PreviewSend 178

12.14.6 Example 179

12.15 Definstances Functions 181

12.15.1 Search, Iteration, and Listing 181

12.15.2 Attributes 182

12.15.3 Deletion 182

12.16 Defmodule Functions 183

12.16.1 Search, Iteration, and Listing 183

12.16.2 Attributes 184

12.16.3 Current Module 184

12.17 Standard Memory Functions 184

12.17.1 Memory Allocation and Deallocation 185

12.17.2 Settings 185

12.17.3 Memory Tracking 186

12.18 Embedded Application Examples 186

12.18.1 User‑Defined Functions 186

12.18.2 Manipulating Objects and Calling CLIPS Functions 186

Appendix A: Support Information 191

A.1 Questions and Information 191

A.2 Documentation 191

A.3 CLIPS Source Code and Executables 191

Appendix B: Update Release Notes 193

B.1 Version 6.40 193

B.2 Version 6.30 193

Index 197

# License Information

Permission is hereby granted, free of charge, to any person obtaining a copy of this software (the “Software”), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT OF THIRD PARTY RIGHTS. IN NO EVENT SHALL THE AUTHORS BE LIABLE FOR ANY CLAIM, OR ANY SPECIAL INDIRECT OR CONSEQUENTIAL DAMAGES, OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.

# Preface

**About CLIPS**

Developed at NASA’s Johnson Space Center from 1985 to 1996, the ‘C’ Language Integrated Production System (CLIPS) is a rule-based programming language useful for creating expert systems and other programs where a heuristic solution is easier to implement and maintain than an algorithmic solution. Written in C for portability, CLIPS can be installed and used on a wide variety of platforms. Since 1996, CLIPS has been available as public domain software.

**CLIPS Version 6.4**

Version 6.4 of CLIPS includes three major enhancements: a redesigned C Application Programming Interface (API); wrapper classes and example programs for .NET and Java; and Integrated Development Environments (IDEs) with Unicode support for Windows and Java. For a detailed listing of differences between releases of CLIPS, refer to appendix B of the *Basic Programming Guide* and appendix B of the *Advanced Programming Guide*.

**CLIPS Documentation**

Two documents are provided with CLIPS.

• The *CLIPS Reference Manual* which is split into several volumes:

• *Volume I - The Basic Programming Guide* provides information on the CLIPS programming language.

• *Volume II - The Advanced Programming Guide* provides information on compiling CLIPS and use of the C Application Programming Interfaces.

• *Volume III - The Interfaces Guide* provides information on the CLIPS Integrated Development Environments, wrapper classes, and example programs.

• The *CLIPS User’s Guide* provides an introduction to CLIPS and rule-based programming.

# Section 1: Introduction

This manual is the *Advanced Programming Guide* for CLIPS. It describes the Application Programmer Interface (API) that allows users to integrate CLIPS programs with code written in C. It is written with the assump­tion that the user has a basic understanding of both CLIPS and C. It is advised that users complete the *Basic Programming Guide* before reading this manual.

Section 2 of this document describes how to install and tailor CLIPS to meet specific needs. Section 3 describes the core API needed to embed CLIPS within a simple C program. Section 4 describes the API allowing the creation of constructs and the execution of commands and functions. Section 5 describes the API that allows a C program to keep persistent references to data structures subject to garbage collection. Section 6 describes the API for creating CLIPS primitive data values. Section 7 describes the API for creating Facts and Instances. Section 8 describes the API for adding user‑defined functions. Section 9 describes the API for the I/O router system used by CLIPS for processing input and output requests. Section 10 describes the environment API which allows multiple expert systems to be loaded and run concurrently. Section 11 describes how to create run‑time CLIPS programs which allow constructs to be save as C data structures which can be compiled and linked with CLIPS. Section 12 describes the additional APIs that are available for interacting with and retrieving information from CLIPS.

## 1.1 C++ Compatibility

The CLIPS source code can be compiled using either an ANSI C or C++ compiler. To make CLIPS API calls from a C++ program, it is usually easier to do the integration by compiling the CLIPS source files as C++ files. This removes the need to make an *extern "C"* declaration in your C++ program for the CLIPS APIs. Some compilers allow you to specify the whether a file should be compiled as C or C++ code based on the file extension. Other compilers allow you to explicitly specify which compiler to use regardless of the extension (e.g. in gcc the option “-x c++” will compile .c files as C++ files). For compilers that exclusively use the file extension to determine whether the file should be compiled as a C or C++ code, it's necessary to change the .c extension of the CLIPS source files to a .cpp extension.

## 1.2 Threads and Concurrency

The CLIPS architecture is designed to support multiple expert systems running concurrently using a single CLIPS application engine. The environment API, described in section 10, is used to implement this functionality. In order to use multiple environments, CLIPS must be embedded within your program either by linking the CLIPS source code with your program or using a shared library such as a Dynamic Link Library (DLL). The standard command line version of CLIPS as well as the Integrated Development Environments (IDEs) provide access to a single environment. It is not possible to load and run multiple expert systems using these versions of CLIPS.

If multiple environments are created, a single thread of execution can be used to run each expert system. In this situation, one environment must finish executing before control can be passed to another environment. The user explicitly specifies which environment should process each API call. Once execution of an API call for that environment begins, the user must wait for completion of the API call before passing control to another environment.

Most likely, this type of execution control will be used when you need to make several expert systems available to a single end user, but don’t want to go through the process of clearing the current expert system from a single environment, loading another expert system into it, and then resetting the environment. Instead, each expert system is loaded into its own environment, so to change expert systems it is only necessary to switch to the new environment and reset it.

A less likely scenario for this type of execution control is to simulate multiple expert systems running concurrently. In this scenario, each environment is allowed to execute a number of rules before control is switched to the next environment.

Instead of simulating multiple expert systems running concurrently, using the multi-threading capabilities native to the operating system on which CLIPS is running allows concurrent execution to occur efficiently and prevents one environment from blocking the execution of another. In this scenario, each environment uses a single thread of execution. Since each environment maintains its own set of data structures, it is safe to run a separate thread on each environment. This use of environments is most likely for a shared library where it is desirable to have a single CLIPS engine running that is shared by multiple applications.

Warning

Each environment can have at most *one* thread of execution. The CLIPS internal data structures can become corrupted if two CLIPS API calls are executing at the same time for a single environment. For example, you can’t have one thread executing rules and another thread asserting facts for the same environment without some synchronization between the two threads.

# Section 2: Installing and Tailoring CLIPS

This section describes how to install and tailor CLIPS to meet specific needs. Instructions are included for creating a console executable by compiling the portable core CLIPS source files. For instructions on compiling the Windows, macOS, and Java Integrated Development Environments for CLIPS, see the *Utilities and Interfaces Guide*.

## 2.1 Installing CLIPS

CLIPS executables for DOS, Windows, and macOS are available for download from the internet. See Appendix A for details. To tailor CLIPS or to install it on another operating system, the user must port the source code and create a new executable version.

Testing of CLIPS 6.40 included the following software environments:

• Windows 10 Home Premium 32-bit and Windows 7 Professional 64-bit Operating Systems with Visual Studio Community 2015.

• MacOS X 10.12 using Xcode 8.3.

• Ubuntu Linux 16.04 LTS using gcc 5.4.0; Debian Linux 9.1 with gcc 6.3; Fedora Linux 23 with gcc 5.3.1; and CentOS Linux 7 with gcc 4.8.5.

CLIPS is designed for portability and should run on any operating system which supports an ANSI C or C++ compiler. The following steps de­scribe how to create a new executable version of CLIPS:

1) **Load the source code onto the user’s system**

The following C source files are necessary to set up the basic CLIPS system:

|  |  |  |  |
| --- | --- | --- | --- |
| agenda.h | dfinscmp.h | immthpsr.h | prcdrpsr.h |
| analysis.h | drive.h | incrrset.h | prdctfun.h |
| argacces.h | emathfun.h | inherpsr.h | prntutil.h |
| bload.h | engine.h | inscom.h | proflfun.h |
| bmathfun.h | entities.h | insfile.h | reorder.h |
| bsave.h | envrnbld.h | insfun.h | reteutil.h |
| classcom.h | envrnmnt.h | insmngr.h | retract.h |
| classexm.h | evaluatn.h | insmoddp.h | router.h |
| classfun.h | expressn.h | insmult.h | rulebin.h |
| classinf.h | exprnbin.h | inspsr.h | rulebld.h |
| classini.h | exprnops.h | insquery.h | rulebsc.h |
| classpsr.h | exprnpsr.h | insqypsr.h | rulecmp.h |
| clips.h | extnfunc.h | iofun.h | rulecom.h |
| clsltpsr.h | factbin.h | lgcldpnd.h | rulecstr.h |
| commline.h | factbld.h | match.h | ruledef.h |
| conscomp.h | factcmp.h | memalloc.h | ruledlt.h |
| constant.h | factcom.h | miscfun.h | rulelhs.h |
| constrct.h | factfun.h | modulbin.h | rulepsr.h |
| constrnt.h | factgen.h | modulbsc.h | scanner.h |
| crstrtgy.h | facthsh.h | modulcmp.h | setup.h |
| cstrcbin.h | factlhs.h | moduldef.h | sortfun.h |
| cstrccmp.h | factmch.h | modulpsr.h | strngfun.h |
| cstrccom.h | factmngr.h | modulutl.h | strngrtr.h |
| cstrcpsr.h | factprt.h | msgcom.h | symblbin.h |
| cstrnbin.h | factqpsr.h | msgfun.h | symblcmp.h |
| cstrnchk.h | factqury.h | msgpass.h | symbol.h |
| cstrncmp.h | factrete.h | msgpsr.h | sysdep.h |
| cstrnops.h | factrhs.h | multifld.h | textpro.h |
| cstrnpsr.h | filecom.h | multifun.h | tmpltbin.h |
| cstrnutl.h | filertr.h | network.h | tmpltbsc.h |
| default.h | fileutil.h | objbin.h | tmpltcmp.h |
| defins.h | generate.h | objcmp.h | tmpltdef.h |
| developr.h | genrcbin.h | object.h | tmpltfun.h |
| dffctbin.h | genrccmp.h | objrtbin.h | tmpltlhs.h |
| dffctbsc.h | genrccom.h | objrtbld.h | tmpltpsr.h |
| dffctcmp.h | genrcexe.h | objrtcmp.h | tmpltrhs.h |
| dffctdef.h | genrcfun.h | objrtfnx.h | tmpltutl.h |
| dffctpsr.h | genrcpsr.h | objrtgen.h | userdata.h |
| dffnxbin.h | globlbin.h | objrtmch.h | usrsetup.h |
| dffnxcmp.h | globlbsc.h | parsefun.h | utility.h |
| dffnxexe.h | globlcmp.h | pattern.h | watch.h |
| dffnxfun.h | globlcom.h | pprint.h |  |
| dffnxpsr.h | globldef.h | prccode.h |  |
| dfinsbin.h | globlpsr.h | prcdrfun.h |  |

|  |  |  |  |
| --- | --- | --- | --- |
| agenda.c | drive.c | immthpsr.c | prcdrpsr.c |
| analysis.c | emathfun.c | incrrset.c | prdctfun.c |
| argacces.c | engine.c | inherpsr.c | prntutil.c |
| bload.c | envrnbld.c | inscom.c | proflfun.c |
| bmathfun.c | envrnmnt.c | insfile.c | reorder.c |
| bsave.c | evaluatn.c | insfun.c | reteutil.c |
| classcom.c | expressn.c | insmngr.c | retract.c |
| classexm.c | exprnbin.c | insmoddp.c | router.c |
| classfun.c | exprnops.c | insmult.c | rulebin.c |
| classinf.c | exprnpsr.c | inspsr.c | rulebld.c |
| classini.c | extnfunc.c | insquery.c | rulebsc.c |
| classpsr.c | factbin.c | insqypsr.c | rulecmp.c |
| clsltpsr.c | factbld.c | iofun.c | rulecom.c |
| commline.c | factcmp.c | lgcldpnd.c | rulecstr.c |
| conscomp.c | factcom.c | main.c | ruledef.c |
| constrct.c | factfun.c | memalloc.c | ruledlt.c |
| constrnt.c | factgen.c | miscfun.c | rulelhs.c |
| crstrtgy.c | facthsh.c | modulbin.c | rulepsr.c |
| cstrcbin.c | factlhs.c | modulbsc.c | scanner.c |
| cstrccom.c | factmch.c | modulcmp.c | sortfun.c |
| cstrcpsr.c | factmngr.c | moduldef.c | strngfun.c |
| cstrnbin.c | factprt.c | modulpsr.c | strngrtr.c |
| cstrnchk.c | factqpsr.c | modulutl.c | symblbin.c |
| cstrncmp.c | factqury.c | msgcom.c | symblcmp.c |
| cstrnops.c | factrete.c | msgfun.c | symbol.c |
| cstrnpsr.c | factrhs.c | msgpass.c | sysdep.c |
| cstrnutl.c | filecom.c | msgpsr.c | textpro.c |
| default.c | filertr.c | multifld.c | tmpltbin.c |
| defins.c | fileutil.c | multifun.c | tmpltbsc.c |
| developr.c | generate.c | objbin.c | tmpltcmp.c |
| dffctbin.c | genrcbin.c | objcmp.c | tmpltdef.c |
| dffctbsc.c | genrccmp.c | objrtbin.c | tmpltfun.c |
| dffctcmp.c | genrccom.c | objrtbld.c | tmpltlhs.c |
| dffctdef.c | genrcexe.c | objrtcmp.c | tmpltpsr.c |
| dffctpsr.c | genrcfun.c | objrtfnx.c | tmpltrhs.c |
| dffnxbin.c | genrcpsr.c | objrtgen.c | tmpltutl.c |
| dffnxcmp.c | globlbin.c | objrtmch.c | userdata.c |
| dffnxexe.c | globlbsc.c | parsefun.c | userfunctions.c |
| dffnxfun.c | globlcmp.c | pattern.c | utility.c |
| dffnxpsr.c | globlcom.c | pprint.c | watch.c |
| dfinsbin.c | globldef.c | prccode.c |  |
| dfinscmp.c | globlpsr.c | prcdrfun.c |  |

In addition to these core files, the Integrated Development Environments require additional files for compilation. See the *Utilities and Interfaces Guide* for details on compiling the IDEs.

2) **Tailor CLIPS environment and/or features**

Edit the setup.h file and set any special options. CLIPS uses preprocessor definitions to allow machine‑dependent features. The first set of definitions in the setup.h file tells CLIPS on what kind of machine the code is being compiled. The default setting for this definition is GENERIC, which will create a ver­sion of CLIPS that will run on any computer. The user may set the definition for the user’s type of system. If the system type is unknown, the definition should be set to GENERIC (so for this situation you do not need to edit setup.h). Other preprocessor definitions in the setup.h file also allow a user to tailor the features in CLIPS to specific needs. For more information on using the flags, see section 2.2.

Optionally, preprocessor definitions can be set using the appropriate command line argument used by your compiler, removing the need to directly edit the setup.h file. For example, the command line option –DLINUX will work on many compilers to set the preprocessor definition of LINUX to 1.

3) **Compile all of the “.c” files to object code**

Use the standard compiler syntax for the user's machine. The ".h" files are include files used by the other files and do not need to be com­piled. Some options may have to be set, depending on the compiler.

If user‑de­fined functions are needed, compile the source code for those functions as well and modify the UserFunctions definition in userfunctions.c to reflect the user's functions (see section 3 for more on user‑defined functions).

4) **Create the interactive CLIPS executable element**

To create the interactive CLIPS executable, link together all of the object files. This executable will provide the interactive interface defined in section 2.1 of the *Basic Programming Guide*.

### 2.1.1 Makefiles

The makefiles makefile.win, makefile.mac, and makefile.lnx are provided with the core source code to create executables and static libraries for Windows, MacOS, and Linux respectively. The makefiles can be configured to create either release or debug versions of the executables/libraries and to compile the code as C or C++. To create release versions of the executables and libraries with optimizations enabled, set the makefile CONFIGURATION variable to RELEASE. To create debug versions of the executables and libraries with optimizations disabled, set the makefile CONFIGURATION variable to DEBUG. To compile the source code as C, set the makefile COMPILE\_AS variable to C. To compile the source code as C++, set the makefile COMPILE\_AS variable to C++.

**Using the Windows Makefile**

The following steps assume you have Microsoft Visual Studio Community 2015 installed. First, launch the Command Prompt application from the Start menu by selecting *Visual Studio 2015* and then either *VS2015 x64 Native Tools Command Prompt* or *VS2015 x86 Native Tools Command Prompt*. Next, use the cd command to change the current directory to the one containing the core CLIPS source code and makefiles. The following command will then compile CLIPS:

nmake –f makefile.win

When compilation is complete, the executable file clips.exe and the static library file clips.lib will be created in the source directory.

If the CONFIGURATION or COMPILE\_AS makefile variables are changed, the clean action should be run before rebuilding the executable and library:

nmake –f makefile.win clean

**Using the macOS Makefile**

First, launch the Terminal application. Use the cd command to change the current directory to the one containing the core CLIPS source code and makefiles. The following command will then compile CLIPS:

make –f makefile.mac

When compilation is complete, the executable file clips and the static library file libclips.a will be created in the source directory.

If the CONFIGURATION or COMPILE\_AS makefile variables are changed, the clean action should be run before rebuilding the executable and library:

make –f makefile.mac clean

**Using the Linux Makefile**

First, launch the Terminal application. Use the cd command to change the current directory to the one containing the core CLIPS source code and makefiles. The following command will then compile CLIPS:

make –f makefile.lnx

When compilation is complete, the executable file clips and the static library file libclips.a will be created in the source directory.

If the CONFIGURATION or COMPILE\_AS makefile variables are changed, the clean action should be run before rebuilding the executable and library:

make –f makefile.lnx clean

## 2.2 Tailoring CLIPS

CLIPS makes use of **preprocessor definitions** (also referred to in this document as **compiler directives** or **setup flags**) to allow easier porting and recompiling of CLIPS. Compiler directives allow the incorporation of system‑dependent features into CLIPS and also make it easier to tailor CLIPS to specific applications. All avail­able compiler options are controlled by a set of flags defined in the **setup.h** file.

The first flag in **setup.h** indicates on what type of compiler/machine CLIPS is to run. The source code is sent out with the flag for GENERIC CLIPS turned on. When com­piled in this mode, all system‑dependent features of CLIPS are excluded and the program should run on any system. A number of other flags are available in this file, indi­cating the types of compilers/machines on which CLIPS has been compiled previ­ously. If the user's implementation matches one of the available flags, set that flag to 1 and turn the **GENERIC** flag off (set it to 0). The code for most of the features controlled by the compil­er/machine‑type flag is in the **sysdep.c** file.

Many other flags are provided in **setup.h**. Each flag is described below.

**BLOAD** This flag controls access to the binary load command (bload). This would be used to save some memory in systems which require binary load but not save capability. This is off in the standard CLIPS executable.

BLOAD\_AND\_BSAVE

This flag controls access to the binary load and save commands. This would be used to save some memory in systems which require neither binary load nor binary save capability. This is on in the standard CLIPS executable.

BLOAD\_INSTANCES

; This flag controls the ability to load instances in binary format from a file via the **bload‑instances**‑ command (see section 13.11.4.7 of the *Basic Programming Guide*). This is on in the standard CLIPS executable. Turning this flag off can save some memory.

**BLOAD\_ONLY** This flag controls access to the binary and ASCII load commands (bload and load). This would be used to save some memory in systems which require binary load capability only. This flag is off in the standard CLIPS executable.

BSAVE\_INSTANCES

; This flag controls the ability to save instances in binary format to a file via the **bsave‑instances**‑ command (see section 13.11.4.4 of the *Basic Programming Guide*). This is on in the standard CLIPS executable. Turning this flag off can save some memory.

CONSTRUCT\_COMPILER

This flag controls the construct compiler functions. If it is turned on, constructs may be compiled to C code for use in a run‑time module (see section 11). This is off in the standard CLIPS executable.

DEBUGGING\_FUNCTIONS

This flag controls access to commands such as agenda, facts, ppdefrule, ppdeffacts, etc. This would be used to save some memory in BLOAD\_ONLY or RUN\_TIME systems. This flag is on in the standard CLIPS executable.

DEFFACTS\_CONSTRUCT

This flag controls the use of deffacts. If it is off, deffacts are not allowed which can save some memory and performance during resets. This is on in the standard CLIPS executable.

DEFFUNCTION\_CONSTRUCT

; This flag controls the use of deffunction. If it is off, deffunction is not allowed which can save some memory. This is on in the standard CLIPS executable.

DEFGENERIC\_CONSTRUCT

; This flag controls the use of defgeneric and defmethod. If it is off, defgeneric and defmethod are not allowed which can save some memory. This is on in the standard CLIPS executable.

DEFGLOBAL\_CONSTRUCT

; This flag controls the use of defglobal. If it is off, defglobal is not allowed which can save some memory. This is on in the standard CLIPS executable.

DEFINSTANCES\_CONSTRUCT

This flag controls the use of definstances (see section 9.6.1.1 of the *Basic Programming Guide*). If it is off, definstances are not allowed which can save some memory and performance during resets. This is on in the standard CLIPS executable.

DEFMODULE\_CONSTRUCT

; This flag controls the use of the defmodule construct. If it is off, then new defmodules cannot be defined (however the MAIN module will exist). This is on in the standard CLIPS executable.

DEFRULE\_CONSTRUCT

This flag controls the use of the defrule construct. If it is off, the defrule construct is not recognized by CLIPS. This is on in the standard CLIPS executable.

DEFTEMPLATE\_CONSTRUCT

; This flag controls the use of deftemplate. If it is off, deftemplate is not allowed which can save some memory. This is on in the standard CLIPS executable.

**EXTENDED\_MATH\_FUNCTIONS**This flag indicates whether the extend­ed math package should be included in the compilation. If this flag is turned off (set to 0), the final executable will be about 25‑30K smaller, a consideration for machines with limited memory. This is on in the standard CLIPS executable.

FACT\_SET\_QUERIES

; This flag determines if the fact‑set query functions are available. These functions are **any‑factp**‑, **do‑for‑fact**‑‑, **do‑for‑all‑facts**‑‑‑, **delayed‑do‑for‑all‑facts**‑‑‑‑,, **find‑fact**‑, and **find‑all‑facts**‑‑,. This is on in the standard CLIPS executable. Turning this flag off can save some memory.

INSTANCE\_SET\_QUERIES

; This flag determines if the instance‑set query functions are available. These functions are **any‑instancep**‑, **do‑for‑instance**‑‑, **do‑for‑all‑instances**‑‑‑, **delayed‑do‑for‑all‑instances**‑‑‑‑,, **find‑instance**‑, and **find‑all‑instances**‑‑,. This is on in the standard CLIPS executable. Turning this flag off can save some memory.

**IO\_FUNCTIONS** This flag controls access to the I/O functions in CLIPS. These functions are **close**, **format**, **get-char**, **open**, **print**, **println**, **printout**, **put-char**, **read**, **readline**, **read-number**, **rename**, **remove**, and **set-locale**. If this If this flag is off, these functions are not available. This would be used to save some memory in systems which used custom I/O routines. This is on in the standard CLIPS executable.

MULTIFIELD\_FUNCTIONS

This flag controls access to the multifield manipulation func­tions in CLIPS. These functions are **delete$**, **delete-member$**, **explode$**, **first$**, **foreach**, **implode$**, **insert$**, **member$**, **nth$**, **progn$**, **replace$**, **replace-member$**, **rest$**, **subseq$**, and **subsetp**. The functions **create$**, **expand$**, and **length$** are always available regardless of the setting of this flag. This would be used to save some memory in systems which performed limited or no operations with multifield values. This flag is on in the standard CLIPS executable.

OBJECT\_SYSTEM

; This flag controls the use of defclass, definstances, and defmessage-handler. If it is off, these constructs are not allowed which can save some memory. This is on in the standard CLIPS executable.

PROFILING\_FUNCTIONS

This flag controls access to the profiling func­tions in CLIPS. These functions are **get-profile-percent-threshold**, **profile**, **profile-info**, **profile-reset**, and **set-profile-percent-threshold**. This flag is on in the standard CLIPS executable.

**RUN\_TIME** This flag will create a run‑time version of CLIPS for use with compiled constructs. It should be turned on only *after* the constructs-to-c function has been used to generate the C code representation of the constructs, but *before* compiling the constructs C code. See section 11 for a de­scription of how to use this. This is off in the standard CLIPS executable.

STRING\_FUNCTIONS

This flag controls access to the string manipulation functions in CLIPS. These functions are **build**, **eval**, **lowcase**, **string-to-field**, **str-cat**, **str‑compare**‑, **str‑index**‑, **str‑length**‑, **sub‑string**‑, **sym-cat**, and **upcase**. This would be used to save some memory in systems which perform limited or no operations with strings. This flag is on in the standard CLIPS executable.

**TEXTPRO\_FUNCTIONS**This flag controls the CLIPS text-processing functions. It must be turned on to use the **fetch**, **get-region**, **print-region**, and **toss** functions in a user‑defined help system. This is on in the standard CLIPS executable.

WINDOW\_INTERFACE

This flagindicates that a windowed interface is being used. This is off in the standard CLIPS executable.

# Section 3: Core Functions

The core functions can be used to embed CLIPS within a simple C program for situations where the user interacts with CLIPS through a text-only computer interface and there is no need for the C program to retrieve information from CLIPS. This removes the need for users to have to interact in any way with the CLIPS command prompt.

## 3.1 Creating and Destroying Environments

### 3.1.1 CreateEnvironment

Environment \*CreateEnvironment();

The function **CreateEnvironment** creates and initializes a CLIPS environment. A pointer of type **Environment \*** is returned to identify the target for other functions which operate on environments. If any error occurs, a null pointer is returned.

### 3.1.2 DestroyEnvironment

bool DestroyEnvironment(  
 Environment \*env);

The function **DestroyEnvironment** deallocates all memory associated with an environment. Parameter **env** is a pointer to a previously created environment. This function returns true if successful; otherwise, it returns false. It should not be called to destroy an environment that is currently executing.

## 3.2 Loading Constructs

### 3.2.1 Clear

bool Clear(  
 Environment \*env);

The function **Clear** is the C equivalent of the CLIPS **clear** command. Parameter **env** is a pointer to a previously created environment. This function removes all constructs and associated data from the specified environment. It returns true if successful; otherwise, it returns false.

### 3.2.2 Load

int Load(  
 Environment \*env,  
 const char \*fileName);

The function **Load** is the C equivalent of the CLIPS **load** command. Parameter **env** is a pointer to a previously created environment; and parameter **fileName** is a full or partial path string to an ASCII or UTF-8 text file containing CLIPS constructs. This function returns 0 if an error occurred opening the file; -1 if errors occurred while parsing constructs contained in the file; and 1 if no errors occurred.

## 3.3 Creating Facts and Instances

### 3.3.1 AssertString

Fact \*AssertString(  
 Environment \*env,  
 const char \*str);

The function **AssertString** is the C equivalent of the CLIPS **assert-string** command. Parameter **env** is a pointer to a previously created environment; and parameter **str** is a pointer to a character array containing the text representation of an ordered or deftemplate fact. An example ordered fact string is "(colors red green blue)". An example deftemplate fact string is "(person (name Fred Jones) (age 37))". A pointer of type **Fact \*** is returned if a fact is successfully created or already exists; otherwise, a null pointer is returned. If the return value from **AssertString** is persistently stored in a variable or data structure for later reference, then the function **IncrementFactReferenceCount** should be called to insure that the reference remains valid even if the fact has been retracted.

### 3.3.2 MakeInstance

Instance \*MakeInstance(  
 Environment \*env,  
 const char \*str);

The function **MakeInstance** is the C equivalent of the CLIPS **make‑instance**‑ function. Parameter **env** is a pointer to a previously created environment; and parameter **str** is a pointer to a character array containing the text representation of an instance. Example instances strings are "([p1] of POINT)" and "(of POINT (x 1) (y 1))". Unlike the CLIPS **make-instance** function, slot overrides in the **instanceString** parameter to the function **MakeInstance** are restricted to constants; function calls are not permitted. This function returns a pointer of type **Instance \*** if an instance is successfully created; otherwise, a null pointer it returned. If the return value from **MakeInstance** is persistently stored in a variable or data structure for later reference, then the function **IncrementInstanceReferenceCount** should be called to insure that the reference remains valid even if the instance has been deleted.

## 3.4 Executing Rules

### 3.4.1 Reset

void Reset(  
 Environment \*env);

The function **Reset** is the C equivalent of the CLIPS **reset** command. Parameter **env** is a pointer to a previously created environment. This function removes all facts and instances; creates facts and instances defined in deffacts and definstances constructs; and resets the values of global variables in the specified environment.

### 3.4.2 Run

long long Run(  
 Environment \*env,  
 long long limit);

The function **Run** is the C equivalent of the CLIPS **run** command. Parameter **env** is a pointer to a previously created environment; and parameter **limit** parameter is the maximum number of rules that will fire before the function returns. If the **limit** parameter value is negative, rules will fire until the agenda is empty. The return value of this function is the number of rules that were fired.

## 3.5 Debugging

### 3.5.1 DribbleOn and DribbleOff

bool DribbleOn(  
 Environment \*env,  
 const char \*fileName);

bool DribbleOff(  
 Environment \*env);

The function **DribbleOn** is the C equivalent of the CLIPS **dribble-on** command. Parameter **env** is a pointer to a previously created environment; and parameter **fileName** is a full or partial path string to the dribble file to be created. This function returns true if the dribble file is successfully opened; otherwise, it returns false.

The function **DribbleOff** is the C equivalent of the CLIPS **dribble-off** command. Parameter **env** is a pointer to a previously created environment. This function returns true if the dribble file is successfully closed; otherwise, it returns false.

### 3.5.2 Watch and Unwatch

void Watch(  
 Environment \*env,  
 WatchItem item);

void Unwatch(  
 Environment \*env,  
 WatchItem item);

typedef enum  
 {  
 ALL,  
 FACTS,  
 INSTANCES,  
 SLOTS,  
 RULES,  
 ACTIVATIONS,  
 MESSAGES,  
 MESSAGE\_HANDLERS,  
 GENERIC\_FUNCTIONS,  
 METHODS,  
 DEFFUNCTIONS,  
 COMPILATIONS,  
 STATISTICS,  
 GLOBALS,  
 FOCUS  
 } WatchItem;

The function **Watch** is the C equivalent of the CLIPS **watch** command. The function **Unwatch** is the C equivalent of the CLIPS **unwatch** command. Parameter **env** is a pointer to a previously created environment; and parameter **item** is one of the specified **WatchItem** enumeration values to be enabled (for watch) or disabled (for unwatch). If the **ALL** enumeration value is specified, then all watch items will be enabled (for watch) or disabled (for unwatch).

## 3.6 Examples

### 3.6.1 Hello World

This example demonstrates how to load and run rules from a C program. The following output shows how you would typically perform this task from the CLIPS command prompt:

CLIPS> (load "hello.clp")

\*

TRUE

CLIPS> (reset)

CLIPS> (run)

Hello World!

CLIPS>

To achieve the same result from a C program, first create a text file named *hello.clp* with the following contents:

(defrule hello

=>

(println "Hello World!"))

Next, change the contents of the main.c source file to the following:

#include "clips.h"

int main()

{

Environment \*env;

env = CreateEnvironment();

// The file hello.clp must be in the same directory

// as the CLIPS executable or you must specify the

// full directory path as part of the file name.

Load(env,"hello.clp");

Reset(env);

Run(env,-1);

DestroyEnvironment(env);

}

Finally, recompile the CLIPS source code to create an executable.

The following output will be produced when the program is run:

Hello World!

### 3.6.2 Debugging

This example demonstrates how to generate and capture debugging information from a C program. The following output shows how you would typically perform this task from the CLIPS command prompt:

CLIPS> (load sort.clp)

%\*

TRUE

CLIPS> (watch facts)

CLIPS> (watch rules)

CLIPS> (watch activations)

CLIPS> (dribble-on "sort.dbg")

TRUE

CLIPS> (reset)

CLIPS> (assert (list (numbers 61 31 27 48)))

==> f-1 (list (numbers 61 31 27 48))

==> Activation 0 sort: f-1

==> Activation 0 sort: f-1

<Fact-1>

CLIPS> (run)

FIRE 1 sort: f-1

<== f-1 (list (numbers 61 31 27 48))

<== Activation 0 sort: f-1

==> f-1 (list (numbers 31 61 27 48))

==> Activation 0 sort: f-1

FIRE 2 sort: f-1

<== f-1 (list (numbers 31 61 27 48))

==> f-1 (list (numbers 31 27 61 48))

==> Activation 0 sort: f-1

==> Activation 0 sort: f-1

FIRE 3 sort: f-1

<== f-1 (list (numbers 31 27 61 48))

<== Activation 0 sort: f-1

==> f-1 (list (numbers 27 31 61 48))

==> Activation 0 sort: f-1

FIRE 4 sort: f-1

<== f-1 (list (numbers 27 31 61 48))

==> f-1 (list (numbers 27 31 48 61))

CLIPS> (dribble-off)

TRUE

CLIPS>

To achieve the same result from a C program, first create a text file named *sort.clp* with the following contents:

(deftemplate list

(multislot numbers))

(defrule sort

?f <- (list (numbers $?b ?x ?y&:(> ?x ?y) $?e))

=>

(modify ?f (numbers ?b ?y ?x ?e)))

Next, change the contents of the main.c source file to the following:

int main()

{

Environment \*env;

env = CreateEnvironment();

Load(env,"sort.clp");

Watch(env,FACTS);

Watch(env,RULES);

Watch(env,ACTIVATIONS);

DribbleOn(env,"sort.dbg");

Reset(env);

AssertString(env,"(list (numbers 61 31 27 48))");

Run(env,-1);

DribbleOff(env);

DestroyEnvironment(env);

}

Finally, recompile the CLIPS source code to create an executable.

The following output will be produced when the program is run:

==> f-1 (list (numbers 61 31 27 48))

==> Activation 0 sort: f-1

==> Activation 0 sort: f-1

FIRE 1 sort: f-1

<== f-1 (list (numbers 61 31 27 48))

<== Activation 0 sort: f-1

==> f-2 (list (numbers 31 61 27 48))

==> Activation 0 sort: f-2

FIRE 2 sort: f-2

<== f-2 (list (numbers 31 61 27 48))

==> f-3 (list (numbers 31 27 61 48))

==> Activation 0 sort: f-3

==> Activation 0 sort: f-3

FIRE 3 sort: f-3

<== f-3 (list (numbers 31 27 61 48))

<== Activation 0 sort: f-3

==> f-4 (list (numbers 27 31 61 48))

==> Activation 0 sort: f-4

FIRE 4 sort: f-4

<== f-4 (list (numbers 27 31 61 48))

==> f-5 (list (numbers 27 31 48 61))

The file *sort.dbg* will contain the same output that is printed to the screen.

# Section 4: Eval, Build, and StringBuilder Functions

The **Eval** function provides a mechanism for executing functions and commands in CLIPS and returning a value from CLIPS back to C. This is useful for executing commands from C in a similar manner to using the CLIPS command prompt. In conjunction with the fact and instance query functions, it is also a useful mechanism for retrieving the results of a CLIPS program.

The **Build** function provides a mechanism for defining individual constructs in a similar manner to using the CLIPS command prompt. Much like entering constructs at the command prompt, this functionality is primarily useful in examples and tutorials.

Since many CLIPS functions (including **Eval** and **Build**) take string arguments that may need to be created dynamically, CLIPS provides **StringBuilder** functions that automate the allocation, construction, and resizing of strings as character data is appended.

## 4.1 CLIPS Primitive Values

CLIPS wraps the underlying C representation of its primitive data types within C structure types that share a common **header** field containing type information. This allows CLIPS primitive values to be passed as a single pointer that can be examined for type to determine the C primitive type stored in the structure.

There are nine C types for used to represent CLIPS primitive values: **TypeHeader** for any CLIPS primitive value; **CLIPSLexeme** for symbols, strings, and instance names, **CLIPSFloat** for floats; **CLIPSInteger** for integers; **CLIPSVoid** for void; **Fact** for facts; **Instance** for instances; **CLIPSExternalAddress** for external addresses; and **Multifield** for multifields.

### 4.1.1 TypeHeader

The C **TypeHeader** type is used to store the CLIPS primitive value type.

typedef struct typeHeader

{

unsigned short type;

} TypeHeader;

The integer stored in the **type** field is one of the following predefined constants:

EXTERNAL\_ADDRESS\_TYPE

FACT\_ADDRESS\_TYPE

FLOAT\_TYPE

INSTANCE\_ADDRESS\_TYPE

INSTANCE\_NAME\_TYPE

INTEGER\_TYPE

MULTIFIELD\_TYPE

STRING\_TYPE

SYMBOL\_TYPE

VOID\_TYPE

### 4.1.2 CLIPSValue

The C **CLIPSValue** type encapsulates all of the CLIPS primitive types. Functions returning primitive values from CLIPS to C have parameters of type **CLIPSValue \***. The return value of the function is stored in the **CLIPSValue** structure allocated by caller. The **header** field of the **CLIPSValue** union can be examined to determine the CLIPS primitive value type and then the appropriate field from the **CLIPSValue** union can be examined to retrieve the C representation of the type.

typedef struct clipsValue

{

union

{

void \*value;

TypeHeader \*header;

CLIPSLexeme \*lexemeValue;

CLIPSFloat \*floatValue;

CLIPSInteger \*integerValue;

CLIPSVoid \*voidValue;

Fact \*factValue;

Instance \*instanceValue;

Multifield \*multifieldValue;

CLIPSExternalAddress \*externalAddressValue;

};

} CLIPSValue;

### 4.1.3 Symbol, Strings, and Instance Names

The C **CLIPSLexeme** type is used to represent CLIPS symbol, string, and instance name primitive types.

typedef struct clipsLexeme

{

TypeHeader header;

const char \*contents;

} CLIPSLexeme;

The **contents** field of the **CLIPSLexeme** contains the C string associated with the CLIPS primitive value. This value should not be changed by user code.

### 4.1.4 Integers

The C **CLIPSInteger** type is used to represent CLIPS integers.

typedef struct clipsInteger

{

TypeHeader header;

long long contents;

} CLIPSInteger;

The **contents** field of the **CLIPSInteger** contains the C long long associated with the CLIPS primitive value. This value should not be changed by user code.

### 4.1.5 Floats

The C **CLIPSFloat** type is used to represent CLIPS floats.

typedef struct clipsFloat

{

TypeHeader header;

double contents;

} CLIPSInteger;

The **contents** field of the **CLIPSFloat** contains the C double associated with the CLIPS primitive value. This value should not be changed by user code.

### 4.1.6 Multifields

The C **Multifield** type is used to represent CLIPS multifields.

typedef struct multifield

{

TypeHeader header;

size\_t length;

CLIPSValue \*contents;

} Multifield;

The **length** field contains the number of CLIPS primitive values contained in the **Multifield** type. The **contents** field is a pointer to an array containing a number of CLIPValue structs that is specified by the length field.

### 4.1.7 Void

The **CLIPSVoid** type is used to represent the CLIPS void value.

typedef struct clipsVoid

{

TypeHeader header;

} CLIPSVoid;

### 4.1.8 External Address

The **CLIPSExternalAddress** struct is used to represent CLIPS external addresses.

typedef struct clipsExternalAddress

{

TypeHeader header;

void \*contents;

} CLIPSExternalAddress;

The **contents** field of the **CLIPSExternalAddress** contains the external address associated with the CLIPS primitive value. This value should not be changed by user code.

## 4.2 Eval and Build

bool Eval(  
 Environment \*env,  
 const char \*str,  
 CLIPSValue \*cv);

bool Build(  
 Environment \*env,  
 const char \*str);

The function **Eval** is the C equivalent of the CLIPS **eval** command. The function **Build** is the C equivalent of the CLIPS **build** command. For both functions, the **env** parameter is a pointer to a previously created environment. The **str** parameter for the **Eval** function is a string containing a CLIPS command or function call; and for the **Build** function is a string containing a construct definition. If no errors occur, both functions return true; otherwise, they return false. If the **cv** parameter value for the **Eval** function is not a null pointer, then the return value of the CLIPS command or function call is stored in the **CLIPSValue** structure allocated by the caller and referenced by the pointer.

## 4.3 StringBuilder Functions

The CLIPS **StringBuilder** functions provide a mechanism for dynamically creating strings of varying length, automatically resizing the **content** output string as character data is added. A StringBuilder is created using the **CreateStringBuilder** function. Character data can then be append to the StringBuilder using the **SBAddChar** and **SBAppend** functions. To build additional strings, the **SBReset** function can be called to reset the **StringBuilder** to its initial state. Once it is no longer needed, the StringBuilder can be deallocated using the **SBDispose** function.

The **StringBuilder** type definition with public fields is:

typedef struct stringBuilder

{

char \*contents;

size\_t length;

} StringBuilder;

The **contents** field of the **StringBuilder** type is a pointer to a character array containing all of the characters that have been appended by calls to the **SBAddChar** and **SBAppend** functions. The value of the **contents** field can change if appending to the **StringBuilder** exceeds the current capacity, so it is recommended to always directly retrieve the **contents** field from the **StringBuilder** pointer. Use the **SBCopy** function to create a copy of the **contents** field if desired; otherwise, the **contents** field should never be directly modified.

The **length** field of the **StringBuilder** type contains the number of characters in the **contents** field not including the null character at the end of the string.

### 4.3.1 CreateStringBuilder

StringBuilder \*CreateStringBuilder(  
 Environment \*env,  
 size\_t capacity);

The function **CreateStringBuilder** creates and initializes a value of type **StringBuilder**. Parameter **env** is a pointer to a previously created environment; and parameter **capacity** is the initial size of the character array used by the **StringBuilder** for constructing strings. The initial size does not limit the maximum size of the **contents** string. The capacity of the StringBuilder will be increased if the string size becomes larger than the initial capacity. If successful, this function returns a pointer of type **StringBuilder \*** to identify the target of other functions accepting a **StringBuilder** parameter; if any error occurs, a null pointer is returned.

### 4.3.2 SBAddChar

void SBAddChar(  
 StringBuilder \*sb,  
 int c);

The function **SBAddChar** appends the single character specified by parameter **c** to the **contents** string of the previously allocated **StringBuilder** specified by parameter **sb**. If the **c** parameter value is a backspace, then the last character of the **contents** string is removed.

### 4.3.3 SBAppend

void SBAppend(  
 StringBuilder \*sb,  
 const char \*str);

The function **SBAppend** appends the string specified by parameter **str** to the **contents** string of the previously allocated **StringBuilder** specified by parameter **sb**.

### 4.3.4 SBCopy

char \*SBCopy(  
 StringBuilder \*sb);

The function **SBCopy** returns a copy of **contents** string of the previously allocated **StringBuffer** specified by parameter **sb**. The memory allocated for this string will not be freed by CLIPS, so it is necessary for the user’s code to call the **free** C library function to deallocate the memory once it is no longer needed.

### 4.3.5 SBDispose

void SBDispose(  
 StringBuilder \*sb);

The function **SBDispose** deallocates all memory associated with previously allocated **StringBuilder** specified by parameter **sb**.

### 4.3.6 SBReset

void SBReset(  
 StringBuilder \*sb);

The function **SBReset** resets the **StringBuilder** specified by parameter **sb** to its initial capacity. The **contents** string is set to an empty string and the **length** of the **StringBuilder** is set to 0.

## 4.4 Examples

### 4.4.1 Debugging Revisited

This example reimplements the debugging example from section 3.6.2 but uses the **Build** function for adding constructs and the **Eval** function for issuing commands.

#include "clips.h"

int main()

{

Environment \*env;

env = CreateEnvironment();

Build(env,"(deftemplate list"

" (multislot numbers))");

Build(env,"(defrule sort"

" ?f <- (list (numbers $?b ?x ?y&:(> ?x ?y) $?e))"

" =>"

" (modify ?f (numbers ?b ?y ?x ?e)))");

Eval(env,"(watch facts)",NULL);

Eval(env,"(watch rules)",NULL);

Eval(env,"(watch activations)",NULL);

Eval(env,"(dribble-on sort.dbg)",NULL);

Eval(env,"(reset)",NULL);

Eval(env,"(assert (list (numbers 61 31 27 48)))",NULL);

Eval(env,"(run)",NULL);

Eval(env,"(dribble-off)",NULL);

DestroyEnvironment(env);

}

### 4.4.2 String Builder Function Call

This example illustrates using the **StringBuilder** and **Eval** functions to construct and evaluate a function call. The **PrintString** and **PrintCLIPSValue** **Router** functions (described in Section 9) are used to print the value and type of each field in the multifield return value.

#include "clips.h"

int main()

{

Environment \*env;

StringBuilder \*sb;

CLIPSValue cv;

char \*fullName;

// Create an Environment

// and StringBuilder.

env = CreateEnvironment();

sb = CreateStringBuilder(env,512);

// Get the first name.

Write(env,"First Name: ");

Eval(env,"(read)",&cv);

if (cv.header->type == SYMBOL\_TYPE)

{ SBAppend(sb,cv.lexemeValue->contents); }

else

{ SBAppend(sb,"John"); }

SBAppend(sb," ");

// Get the last name.

Write(env,"Last Name: ");

Eval(env,"(read)",&cv);

if (cv.header->type == SYMBOL\_TYPE)

{ SBAppend(sb,cv.lexemeValue->contents); }

else

{ SBAppend(sb,"Doe"); }

// Get a copy of the full name

// constructed by the StringBuilder.

fullName = SBCopy(sb);

// Create a function call to convert

// the full name to upper case.

SBReset(sb);

SBAppend(sb,"(upcase \"");

SBAppend(sb,fullName);

SBAppend(sb,"\")");

// Evaluate the function call

// and print the results.

Eval(env,sb->contents,&cv);

Write(env,"Result is ");

Writeln(env,cv.lexemeValue->contents);

// Free the fullName

free(fullName);

// Dispose of the StringBuilder

// and the Environment.

SBDispose(sb);

DestroyEnvironment(env);

}

The resulting output (with input in bold) is:

First Name: **Sally**

Last Name: **Jones**

Result is SALLY JONES

### 4.4.3 Multifield Iteration

This example illustrates iteration over the values contained in a **Multifield**.

#include "clips.h"

int main()

{

Environment \*env;

StringBuilder \*sb;

CLIPSValue cv;

// Create an Environment

// and StringBuilder.

env = CreateEnvironment();

sb = CreateStringBuilder(env,512);

// Call the CLIPS readline function to

// capture a list of values in a string.

Write(env,"Enter a list of values: ");

Eval(env,"(readline)",&cv);

// Call the CLIPS create$ function to generate

// a multifield value from the string.

SBAppend(sb,"(create$ ");

SBAppend(sb,cv.lexemeValue->contents);

SBAppend(sb,")");

Eval(env,sb->contents,&cv);

// Iterate over each value in the

// multifield and print its type.

for (size\_t i = 0; i < cv.multifieldValue->length; i++)

{

WriteCLIPSValue(env,STDOUT,&cv.multifieldValue->contents[i]);

switch(cv.multifieldValue->contents[i].header->type)

{

case INTEGER\_TYPE:

Write(env," is an integer\n");

break;

case FLOAT\_TYPE:

Write(env," is a float\n");

break;

case STRING\_TYPE:

Write(env," is a string\n");

break;

case SYMBOL\_TYPE:

Write(env," is a symbol\n");

break;

case INSTANCE\_NAME\_TYPE:

Write(env," is an instance name\n");

break;

}

}

// Dispose of the StringBuilder

// and the Environment.

SBDispose(sb);

DestroyEnvironment(env);

}

The resulting output (with input in bold) is:

Enter a list of values: **a "b" [c] 1.2 3**

a is a symbol

"b" is a string

[c] is an instance name

1.2 is a float

3 is an integer

### 4.4.4 Fact Query

This example illustrates how to use the **StringBuilder** and **Eval** functions to dynamically construct and assert a fact, retrieve values from CLIPS function calls, and use a fact query to retrieve a slot value from a fact after rules have executed.

The first section of code for this example (that includes the function **CreateNumbers**) demonstrates the construction of a **list** fact with a **numbers** slot containing zero or more integers. The number of integers to be created is specified by the **howMany** parameter.

#include "clips.h"

void CreateNumbers(Environment \*,StringBuilder \*,int);

void PrintNumbers(Environment \*);

void CreateNumbers(

Environment \*env,

StringBuilder \*sb,

int howMany)

{

CLIPSValue cv;

// Append the opening parentheses

// for the fact and the slot.

SBAppend(sb,"(list (numbers");

// Loop adding the specified

// number of random integers

for (int i = 0; i < howMany; i++)

{

// Generate a random number in the

// range 0 - 99. Convert the integer

// on the CLIPS side to a symbol.

Eval(env,"(sym-cat (random 0 99))",&cv);

// Add the string value of the

// integer to the slot.

SBAppend(sb," ");

SBAppend(sb,cv.lexemeValue->contents);

}

// Append the closing parentheses

// for the slot and the fact.

SBAppend(sb,"))");

// Assert the fact.

Watch(env,FACTS);

AssertString(env,sb->contents);

Unwatch(env,FACTS);

// Clear the StringBuilder.

SBReset(sb);

}

The next section of code (that includes the **PrintNumbers** function) demonstrates how to use a query function to retrieve a slot value from a fact; and how to iterate through the contents of a multifield value. The **Write** and **WriteCLIPSValue** **Router** functions (described in Section 9) are used to print the slot value.

void PrintNumbers(

Environment \*env)

{

CLIPSValue cv;

// This do-for-fact query call will find the first list

// fact -- there should just be one -- and return the

// value of the numbers slot in the variable cv.

Eval(env,"(do-for-fact ((?f list)) TRUE ?f:numbers)",&cv);

// The numbers slot should be a multifield value.

if (cv.header->type == MULTIFIELD\_TYPE)

{

Write(env,"Sorted list is (");

// Iterate over each value in the

// multifield and print it.

for (size\_t i = 0; i < cv.multifieldValue->length; i++)

{

if (i != 0) Write(env," ");

WriteCLIPSValue(env,STDOUT,&cv.multifieldValue->contents[i]);

}

Write(env,")\n");

}

}

The final section of code (that includes the **main** function) generates a list of random numbers (using the **CreateNumbers** function), sorts them (using the **sort** rule), prints the sorted numbers (using the **PrintNumbers** function), and then repeats the process a second time.

int main()

{

Environment \*env;

StringBuilder \*sb;

// Create an Environment

// and StringBuilder.

env = CreateEnvironment();

sb = CreateStringBuilder(env,512);

// Seed the random number generator so that

// different numeric values are generated

// each time the program is run.

Eval(env,"(seed (integer (time)))",NULL);

// Create the sorting constructs

Build(env,"(deftemplate list"

" (multislot numbers))");

Build(env,"(defrule sort"

" ?f <- (list (numbers $?b ?x ?y&:(> ?x ?y) $?e))"

" =>"

" (modify ?f (numbers ?b ?y ?x ?e)))");

// Create a list, sort it,

// and print the results.

Reset(env);

CreateNumbers(env,sb,5);

Run(env,-1);

PrintNumbers(env);

// Create another list, sort

// it, and print the results.

Reset(env);

CreateNumbers(env,sb,7);

Run(env,-1);

PrintNumbers(env);

// Dispose of the StringBuilder

// and the Environment.

SBDispose(sb);

DestroyEnvironment(env);

}

The resulting output is:

==> f-1 (list (numbers 43 76 3 55 87))

Sorted list is (3 43 55 76 87)

==> f-1 (list (numbers 73 17 7 84 68 54 67))

Sorted list is (7 17 54 67 68 73 84)

Note that the sorted integers displayed will vary since the generated random integers are dependent on the implementation of the C **rand** library function as well as the seeding of the random number generator using the current time.

# Section 5: Garbage Collection

## 5.1 Introduction

As a CLIPS program executes, it allocates and deallocates numerous types of data structures. In many cases, some data structures cannot be immediately deallocated because outstanding references to the data structure still exist. Data which has been marked for later deallocation is referred to as **garbage**. The process of deallocating this garbage is referred to as **garbage collection**. CLIPS only performs garbage collection when it can determine that it is safe to deallocate the data structures marked for deallocation.

The following example illustrates several important concepts:

CLIPS>

(deftemplate person

(slot full-name))

CLIPS>

(defrule print-name

?f <- (person (full-name ?name))

=>

(retract ?f)

(println "Name is " ?name))

CLIPS> (assert (person (full-name (readline))))

**John Doe**

<Fact-1>

CLIPS> (run)

Name is John Doe

CLIPS>

In this example, the RHS of the **print-name** rule first retracts the **person** fact bound on the LHS of the rule; and then prints the value of the **full-name** slot contained in this fact. The **assert** command creates a **person** fact with the **full-name** slot set to the value returned by a call to the **readline** function; and this assertion activates the rule. This fact contains the string **"John Doe"** returned by the **readline** function. The **"John Doe"** string is initially considered to be garbage when created within the **readline** function since there are no persistent references to it, but it is not garbage collected because this value is returned from the function and is thus temporarily referenced by the code that called the **readline** function. When this string is asserted as part of the **person** fact in the **assert** command, it now has a persistent reference and is no longer considered garbage subject to collection.

When the **run** command is issued, the **print-name** rule fires. The first action of the rule retracts the **person** fact bound on the LHS of the rule. The fact is now considered to be garbage. The symbol **"John Doe"** contained in the fact is also marked as being garbage since the fact contains the only reference to it. The next action in the rule prints the value of the full-name slot from the **person** fact. Since CLIPS retrieves this value from the fact, if the fact and symbols associated with it had been immediately deallocated when the **retract** command was executed, these values would not be available when the **printout** command is executed.

Since garbage created by the RHS actions may be accessed by other RHS actions, CLIPS does not initiate garbage collection for garbage created by RHS actions until the rule has finished firing. In this example, once the **print-name** rule has finished firing, since there are no outstanding references to the **person** fact or the **"John Doe"** string, the data structures associated with these references can be deallocated.

If you use one of the interactive CLIPS executables, all garbage collection is handled automatically for you including garbage created when entering commands and by constructs which execute code (such as defrules and deffunctions).

Embedded applications, however, can generate garbage when invoking certain API calls to CLIPS. Since C doesn’t support automatic garbage collection, the embedding application must make use of the garbage collection API provided by CLIPS to trigger garbage collection safely for some cases.

TBD CVRetain

TBD CVRelease

## 5.2 Embedded Use

The following **main** routine is an example of how garbage collection affects whether you can safely access data returned by CLIPS.

int main()

{

Environment \*env;

CLIPSValue cv;

const char \*str1, \*str2;

env = CreateEnvironment();

Eval(env,"(sym-cat abc def)",&cv);

str1 = cv.lexemeValue->contents;

// Safe to refer to str1 here. \*/

Eval(env,"(sym-cat ghi jkl)",&cv);

str2 = cv.lexemeValue->contents;

// Not safe to refer to str1 here.

// Safe to refer to str2 here.

}

The first call to **Eval** triggers garbage collection, but since no data has been returned yet to the embedding program this does not cause any problems. The **contents** field of the **CLIPSLexeme** returned in the variable **cv** is assigned to the variable **str1** which can be safely referenced.

The second call to **Eval** also triggers garbage collection. In this case, however, the value returned by the prior call to **Eval** will be garbage collected as a result. Therefore it is not safe to reference the value stored in the variable **str1** after this point. This is a problem if, for example, you want to compare the values of variables **str1** and **str2**.

There are two ways to work around this problem. The first is to create your own copies of the **contents** field of the CLIPS primitive values. This is easily done for the contents of a **CLIPSInteger** or **CLIPSFloat**, but is inconvenient for a **CLIPSLexeme** since you have to determine the size of the **contents** string, allocate space for a copy, copy the contents, and then delete the copy once it’s no longer needed.

The second way is to create a garbage collection block. When a garbage collection block is started, primitive values that become garbage are attached to the block. These values are not garbage collected until the block ends. Blocks can be nested allowing you to selectively release garbage at the appropriate point.

void GCBlockStart(  
 Environment \*env,  
 GCBlock \*gcb);

void GCBlockEnd(  
 Environment \*env,  
 GCBlock \*gcb);

The function **GCBlockStart** starts a garbage collection block for the environment specified by the parameter **env** storing garbage collection information in the **GCBlock** specified by parameter **gcb**.

The function **GCBlockEnd** ends the garbage collection block for the environment specified by the parameter **env** freeing the garbage in the **GCBlock** specified by parameter **gcb**.

The use of these functions is demonstrated in the following revised **main** routine:

int main()

{

Environment \*env;

CLIPSValue cv;

const char \*str1, \*str2;

GCBlock gcb;

env = CreateEnvironment();

GCBlockStart(env,&gcb);

Eval(env,"(sym-cat abc def)",&cv);

str1 = cv.lexemeValue->contents;

// Safe to refer to str1 here.

Eval(env,"(sym-cat ghi jkl)",&cv);

str2 = cv.lexemeValue->contents;

// Safe to refer to str1 here.

// Safe to refer to str2 here.

GCBlockEnd(env,&gcb);

// Not safe to refer to str1 here.

// Not safe to refer to str2 here.

}

In this case, the second call to **Eval** doesn’t garbage collect the string referenced by *str1*, so it is safe to refer to this string after the call. Calling **GCBlockEnd** after the second call to **Eval** triggers garbage collection for both **str1** and **str2**, so it is no longer safe to reference either of these strings.

## 5.2 Example

This example illustrates using the use of the **GCBlockStart** and **GCBlockEnd** functions to create a garbage collection block.

int main()

{

Environment \*env;

StringBuilder \*sb;

CLIPSValue first, last, cv;

GCBlock gcb;

// Create an Environment

// and StringBuilder.

env = CreateEnvironment();

sb = CreateStringBuilder(env,512);

// Start the garbage collection block

GCBlockStart(env,&gcb);

// Get the first name.

PrintString(env,STDOUT,"First Name: ");

Eval(env,"(read)",&first);

// Get the last name.

PrintString(env,STDOUT,"Last Name: ");

Eval(env,"(read)",&last);

// Create a function call to convert

// the full name to upper case.

SBAppend(sb,"(upcase \"");

if (first.header->type == SYMBOL\_TYPE)

{ SBAppend(sb,first.lexemeValue->contents); }

else

{ SBAppend(sb,"John"); }

SBAppend(sb," ");

if (last.header->type == SYMBOL\_TYPE)

{ SBAppend(sb,last.lexemeValue->contents); }

else

{ SBAppend(sb,"Doe"); }

SBAppend(sb,"\")");

// Evaluate the function call

// and print the results.

Eval(env,sb->contents,&cv);

PrintString(env,STDOUT,"Result is ");

PrintString(env,STDOUT,cv.lexemeValue->contents);

PrintString(env,STDOUT,"\n");

// End the garbage collection block

GCBlockEnd(env,&gcb);

// Dispose of the StringBuilder

// and the Environment.

SBDispose(sb);

DestroyEnvironment(env);

}

The resulting output (with input in bold) is:

First Name: **Sally**

Last Name: **Jones**

Result is SALLY JONES

# Section 6: Creating Primitive Values

Section 4 demonstrated how to examine primitive values returned by CLIPS. Sometimes, it is necessary for C code to create primitive values. For example, to set the slot value of a fact.

Blah blah blah. At any time, there will just be one primitive value of any given type.

## 6.1 Primitives

CLIPS provides several data structures for representing its primitive values.

CLIPS uses symbol tables to store all symbols, string;s, and instance names. Symbol tables increase both performance and memory efficiency during execution

### 6.1.1 Creating CLIPS Symbol, Strings, and Instance Names

CLIPSLexeme \*CreateSymbol(  
 Environment \*env,  
 const char \*str);

CLIPSLexeme \*CreateString(  
 Environment \*env,  
 const char \*str);

CLIPSLexeme \*CreateInstanceName(  
 Environment \*env,  
 const char \*str);

CLIPSLexeme \*CreateBoolean(  
 Environment \*env,  
 bool b);

CLIPSLexeme \*FalseSymbol(  
 Environment \*env);

CLIPSLexeme \*TrueSymbol(  
 Environment \*env);

The functions **CreateSymbol**, **CreateString**, and **CreateInstanceName** create primitive values with **type** field values of SYMBOL\_TYPE, STRING\_TYPE, and INSTANCE\_NAME\_TYPE respectively. Parameter **env** is a pointer to a previously created environment; and parameter **str** is a pointer to a character array containing the text that will be assigned to the **contents** field of the CLIPS symbol, string, or instance name being created. The return value of these functions is a pointer to a **CLIPSLexeme** type.

The function **CreateBoolean** creates a primitive value with **type** field value of SYMBOL\_TYPE. Parameter **env** is a pointer to a previously created environment. If parameter **b** is true, a pointer to the **CLIPSLexeme** for the symbol TRUE is returned; otherwise a pointer to the **CLIPSLexeme** for the symbol FALSE is returned.

The function **FalseSymbol** returns a pointer to the **CLIPSLexeme** for the symbol FALSE. The function **TrueSymbol** returns a pointer to the **CLIPSLexeme** for the symbol TRUE.

### 6.1.2 Creating CLIPS Integers

CLIPSInteger \*CreateInteger(  
 Environment \*env,  
 long long ll);

The function **CreateInteger** creates a primitive value with a **type** field value of INTEGER\_TYPE. Parameter **env** is a pointer to a previously created environment; and parameter **ll** is the C integer value that will be assigned to the **contents** field of the CLIPS integer being created. The return value of this function is a pointer to a **CLIPSInteger** type.

### 6.1.3 Creating CLIPS Floats

CLIPSFloat \*CreateFloat(  
 Environment \*theEnv,  
 double dbl);

The function **CreateFloat** creates a primitive value with a **type** field value of FLOAT\_TYPE. Parameter **env** is a pointer to a previously created environment; and parameter **dbl** is the C double value that will be assigned to the **contents** field of the CLIPS float being created. The return value of this function is a pointer to a **CLIPSFloat** type.

### 6.1.4 Creating Multifields

Multifield \*EmptyMultifield(  
 Environment \*env);

Multifield \*StringToMultifield(  
 Environment \*env,  
 const char \*str);

MultifieldBuilder \*CreateMultifieldBuilder(  
 Environment \*env,  
 size\_t capacity);

void MBAppend(  
 MultifieldBuilder \*mb,  
 CLIPSValue \*value);

void MBAppendUDFValue(  
 MultifieldBuilder \*mb,  
 UDFValue \*);

Multifield \*MBCreate(  
 MultifieldBuilder \*mb);

void MBReset(  
 MultifieldBuilder \*mb);

void MBDispose(  
 MultifieldBuilder \*mb);

The function **EmptyMultifield** returns a multifield primitive value of length 0.

The function **StringToMultifield** parses and creates a **Multifield** value from the values contained in the parameter **str**. For example, if the **str** parameter value is "1 4.5 c", a multifield with three values—the integer **1**, the float **4.5**, and the symbol **c**—will be created.

The function **MBAppend** appends the **CLIPSValue** specified by the parameter **v** to the end of the multifield being created by the **MultifieldBuilder** specified by parameter **mb**

The function **MBAppendUDFValue** appends the **UDFValue** specified by the parameter **v** to the end of the multifield being created by the **MultifieldBuilder** specified by parameter **mb**

The function **MBCreate** creates and returns a **Multifield** based on values appended to the **MultifieldBuilder** specified by parameter **mb**. The length of the **MultifieldBuilder** is reset to 0 after this function is called.

The function **MBReset** resets the **MultifieldBuilder** specified by parameter **mb** to its initial capacity. Any values previously appended are removed and the **length** of the **MultifieldBuilder** is set to 0.

The function **MBDispose** deallocates all memory associated with previously allocated **MultifieldBuilder** specified by parameter **mb**.

### 6.1.5 The Void Value

CLIPSVoid \*VoidConstant(  
 Environment \*env);

The function **VoidConstant** returns a pointer to the CLIPS void primitive value.

### 6.1.6 Creating External Addresses

CLIPSExternalAddress \*CreateCExternalAddress(  
 Environment \*theEnv,  
 void \*ea);

Creates a CLIPS external address value from a C void pointer. Note that it is up to the user to make sure that external addresses remain valid within CLIPS.

## 6.2 Examples

### 6.2.1 StringToMultifield

Define main as the following:

int main()

{

Environment \*env;

Multifield \*mf;

env = CreateEnvironment();

mf = StringToMultifield(env,"\"abc\" 3 4.5");

Write(env,"Created multifield is ");

WriteMultifield(env,STDOUT,mf);

Write(env,"\n");

DestroyEnvironment(env);

}

The resulting output is:

Created multifield is ("abc" 3 4.5)

### 6.2.2 MultifieldBuilder

Define main as the following:

int main()

{

Environment \*env;

MultifieldBuilder \*mb;

Multifield \*mf;

env = CreateEnvironment();

mb = CreateMultifieldBuilder(env,10);

MBAppendString(mb,"abc");

MBAppendInt(mb,3);

MBAppendFloat(mb,4.5);

mf = MBCreate(mb);

Write(env,"Created multifield is ");

WriteMultifield(env,STDOUT,mf);

Write(env,"\n");

MBAppendSymbol(mb,"def");

MBAppendInstanceName(mb,"i1");

mf = MBCreate(mb);

Write(env,"Created multifield is ");

WriteMultifield(env,STDOUT,mf);

Write(env,"\n");

MBDispose(mb);

DestroyEnvironment(env);

}

The resulting output is:

Created multifield is ("abc" 3 4.5)

Created multifield is (def [i1])

### 6.2.3 MultifieldBuilder with Eval (TBD)

Define main as the following:

int main()

{

Environment \*env;

MultifieldBuilder \*mb;

CLIPSValue v;

Multifield \*mf;

env = CreateEnvironment();

mb = CreateMultifieldBuilder(env,10);

v.lexemeValue = CreateString(env,"abc");

MBAppend(mb,&v);

v.integerValue = CreateInteger(env,3);

MBAppend(mb,&v);

v.floatValue = CreateFloat(env,4.5);

MBAppend(mb,&v);

mf = MBCreate(mb);

Write(env,"Created multifield is ");

WriteMultifield(env,STDOUT,mf);

Write(env,"\n");

v.lexemeValue = CreateSymbol(env,"def");

MBAppend(mb,&v);

v.lexemeValue = CreateInstanceName(env,"i1");

MBAppend(mb,&v);

mf = MBCreate(mb);

Write(env,"Created multifield is ");

WriteMultifield(env,STDOUT,mf);

Write(env,"\n");

MBDispose(mb);

DestroyEnvironment(env);

}

The resulting output is:

Created multifield is ("abc" 3 4.5)

Created multifield is (def [i1])

# Section 7: Creating Facts and Instances

Blah blah blah.

## 7.1 FactBuilder

Blah blah blah

typedef struct stringBuilder

{

char \*contents;

size\_t length;

} StringBuilder;

## 7.2 Managing Fact Builders

FactBuilder \*CreateFactBuilder(  
 Environment \*env,  
 const char \*name);

Fact \*FBAssert(  
 FactBuilder \*fb);

void FBDispose(  
 FactBuilder \*fb);

bool FBSetDeftemplate(  
 FactBuilder \*fb,  
 const char \*name);

void FBAbort(  
 FactBuilder \*fb);

The function **CreateFactBuilder** allocates and initializes a struct of type **FactBuilder**. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the name of the deftemplate that will be created by the fact builder. If successful, this function returns a pointer to the created **FactBuilder**; otherwise, it returns a null pointer.

The function **FBAssert** asserts the fact based on slot assignments made to the fact builder specified by parameter **fb**. Slots which have not been explicitly assigned a value are set to their default value. If successful, this function returns a pointer to the asserted **Fact**; otherwise it returns a null pointer. Slot assignments are discarded after the fact is asserted, so slot values need to be reassigned if the fact builder is used to build another fact.

The function **FBDispose** deallocates the memory associated with the **FactBuilder** specified by parameter **fb**.

The function **FBSetDeftemplate** changes the type of fact created by the fact builder to the deftemplate specified by the parameter **name**. Any slot values that have been assigned to the builder are discarded. This function returns true if the deftemplate was successfully changed; otherwise, it returns false.

The function **FBAbort** discards the slot value assignments that have been made for the fact builder specified by parameter **fb**.

## 7.3 Managing Fact Modifiers

FactModifier \*CreateFactModifier(  
 Environment \*env,  
 Fact \*f);

Fact \*FMModify(  
 FactModifier \*fm);

void FMDispose(  
 FactModifier \*fm);

bool FMSetFact(  
 FactModifier \*fm,  
 Fact \*f);

void FMAbort(  
 FactModifier \*fm);

The function **CreateFactModifier** allocates and initializes a struct of type **FactModifier**. Parameter **env** is a pointer to a previously created environment; and parameter **f** is a pointer to the **Fact** to be modified. If successful, this function returns a pointer to the created **FactModifier**; otherwise, it returns a null pointer.

The function **FMModify** modifies the fact based on slot assignments made to the fact modifier specified by parameter **fm**. If successful, this function returns a pointer to the modified **Fact**; otherwise it returns a null pointer. Slot assignments are discarded after the fact is asserted, so slot values need to be reassigned if the fact builder is used to modify another fact.

The function **FMDispose** deallocates the memory associated with the **FactModifier** specified by parameter **fm**.

The function **FMSetFact** changes the fact being modified to the value specified by parameter **f**. Any slot values that have been assigned to the modifier are discarded. This function returns true if the fact was successfully changed; otherwise, it returns false.

The function **FMAbort** discards the slot value assignments that have been made for the fact modifier specified by parameter **fm**.

## 7.4 Managing Instance Builders

InstanceBuilder \*CreateInstanceBuilder(  
 Environment \*env,  
 const char \*name);

Instance \*IBMake(  
 InstanceBuilder \*ib);

void IBDispose(  
 InstanceBuilder \*ib);

bool IBSetDefclass(  
 InstanceBuilder \*ib,  
 const char \*name);

void IBAbort(  
 InstanceBuilder \*ib);

The function **CreateInstanceBuilder** allocates and initializes a struct of type **InstanceBuilder**. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the name of the instance defclass that will be created by the instance builder. If successful, this function returns a pointer to the created **InstanceBuilder**; otherwise, it returns a null pointer.

The function **IBMakes** creates the instance based on slot assignments made to the instance builder specified by parameter **ib**. Slots which have not been explicitly assigned a value are set to their default value. If the parameter **name** is a null pointer, then an instance name is generated for the newly created instance; otherwise, the **name** parameter value is used as the instance name. If successful, this function returns a pointer to the created **Instance**; otherwise it returns a null pointer. Slot assignments are discarded after the instance is created, so slot values need to be reassigned if the instance builder is used to build another instance.

The function **IBDispose** deallocates the memory associated with the **InstanceBuilder** specified by parameter **ib**.

The function **FBSetDefclass** changes the type of instance created by the instance builder to the defclass specified by the parameter **name**. Any slot values that have been assigned to the builder are discarded. This function returns true if the defclass was successfully changed; otherwise, it returns false.

The function **IBAbort** discards the slot value assignments that have been made for the instance builder specified by parameter **ib**.

## 7.5 Managing Instance Modifiers

InstanceModifier \*CreateInstanceModifier(  
 Environment \*env,  
 Instance \*i);

Instance \*IMModify(  
 InstanceModifier \*im);

void IMDispose(  
 InstanceModifier \*im);

bool IMSetInstance(  
 InstanceModifier \*im,  
 Instance \*i);

void IMAbort(  
 InstanceModifier \*im);

The function **CreateInstanceModifier** allocates and initializes a struct of type **InstanceModifier**. Parameter **env** is a pointer to a previously created environment; and parameter **i** is a pointer to the **Instance** to be modified. If successful, this function returns a pointer to the created **InstanceModifier**; otherwise, it returns a null pointer.

The function **IMModify** modifies the instance based on slot assignments made to the instance modifier specified by parameter **im**. If successful, this function returns a pointer to the modified **Instance**; otherwise it returns a null pointer. Slot assignments are discarded after the instance is modified, so slot values need to be reassigned if the instance builder is used to modify a different instance.

The function **IMDispose** deallocates the memory associated with the **InstanceModifier** specified by parameter **im**.

The function **IMSetInstance** changes the instance being modified to the value specified by parameter **i**. Any slot values that have been assigned to the modifier are discarded. This function returns true if the instance was successfully changed; otherwise, it returns false.

The function **IMAbort** discards the slot value assignments that have been made for the instance modifier specified by parameter **im**.

## 7.6 Assigning Slot Values

|  |  |
| --- | --- |
| bool FBPutSlot(  FactBuilder \*fb,  const char \*name,  CLIPSValue \*v); | bool IBPutSlot(  InstanceBuilder \*ib,  const char \*name,  CLIPSValue \*v); |
| bool FMPutSlot(  FactModifier \*fm,  const char \*name,  CLIPSValue \*v); | bool IMPutSlot(  InstanceModifier \*im,  const char \*name,  CLIPSValue \*v); |

The function **FBPutSlot** sets the slot specified by the parameter **name** to the value specified by parameter **v** for the fact builder specified by parameter **fb**. This function returns true if the slot was successfully set; otherwise, it returns false.

The function **FMPutSlot** sets the slot specified by the parameter **name** to the value specified by parameter **v** for the fact modifier specified by parameter **fm**. This function returns true if the slot was successfully set; otherwise, it returns false.

The function **IBPutSlot** sets the slot specified by the parameter **name** to the value specified by parameter **v** for the instance builder specified by parameter **ib**. This function returns true if the slot was successfully set; otherwise, it returns false.

The function **IMPutSlot** sets the slot specified by the parameter **name** to the value specified by parameter **v** for the instance modifier specified by parameter **im**. This function returns true if the slot was successfully set; otherwise, it returns false.

## 7.5 Assigning Integer Slot Values

|  |  |
| --- | --- |
| bool FBPutSlotCLIPSInteger(  FactBuilder \*fb,  const char \*name,  CLIPSInteger \*i); | bool FMPutSlotCLIPSInteger(  FactModifier \*fm,  const char \*name,  CLIPSInteger \*i); |
| bool FBPutSlotInt(  FactBuilder \*fb,  const char \*name,  int i); | bool FMPutSlotInt(  FactModifier \*fm,  const char \*name,  int i); |
| bool FBPutSlotLong(  FactBuilder \*fb,  const char \*name,  long i); | bool FMPutSlotLong(  FactModifier \*fm,  const char \*name,  long i); |
| bool FBPutSlotLongLong(  FactBuilder \*fb,  const char \*name,  long long i); | bool FMPutSlotLongLong(  FactModifier \*fm,  const char \*name,  long long i); |
| bool IBPutSlotCLIPSInteger(  InstanceBuilder \*ib,  const char \*name,  CLIPSInteger \*i); | bool IMPutSlotCLIPSInteger(  InstanceModifier \*im,  const char \*name,  CLIPSInteger \*i); |
| bool IBPutSlotInt(  InstanceBuilder \*ib,  const char \*name,  int i); | bool IMPutSlotInt(  InstanceModifier \*im,  const char \*name,  int i); |
| bool IBPutSlotLong(  InstanceBuilder \*ib,  const char \*name,  long i); | bool IMPutSlotLong(  InstanceModifier \*im,  const char \*name,  long i); |
| bool IBPutSlotLongLong(  InstanceBuilder \*ib,  const char \*name,  long long i); | bool FMPutSlotLongLong(  InstanceModifier \*im,  const char \*name,  long long i); |

These functions assign an integer value in one of various forms to a **FactBuilder** (for parameter **fb**), **FactModifier** (for parameter **fm**), **InstanceBuilder** (for parameter ib), or **InstanceModifier** (for parameter **im**). Parameter **name** is the slot of either the fact or instance to be assigned. Parameter i is the value assigned to the slot: a **CLIPSInteger**, int, long, or long long value. These functions return true if the slot was successfully set; otherwise, they return false.

## 7.6 Assigning Float Slot Values

|  |  |
| --- | --- |
| bool FBPutSlotCLIPSFloat(  FactBuilder \*fb,  const char \*name,  CLIPSFloat \*f); | bool FMPutSlotCLIPSFloat(  FactModifier \*fm,  const char \*name,  CLIPSFloat \*f); |
| bool FBPutSlotFloat(  FactBuilder \*fb,  const char \*name,  float f); | bool FMPutSlotFloat(  FactModifier \*fm,  const char \*name,  float f); |
| bool FBPutSlotDouble(  FactBuilder \*fb,  const char \*name,  double f); | bool FMPutSlotDouble(  FactModifier \*fm,  const char \*name,  double f); |
| bool IBPutSlotCLIPSFloat(  InstanceBuilder \*ib,  const char \*name,  CLIPSFloat \*f); | bool IMPutSlotCLIPSFloat(  InstanceModifier \*im,  const char \*name,  CLIPSFloat \*f); |
| bool IBPutSlotFloat(  InstanceBuilder \*ib,  const char \*name,  float f); | bool IMPutSlotFloat(  InstanceModifier \*im,  const char \*name,  float f); |
| bool IBPutSlotDouble(  InstanceBuilder \*ib,  const char \*name,  double f); | bool IMPutSlotDouble(  InstanceModifier \*im,  const char \*name,  double f); |

These functions assign a floating point value in one of various forms to a **FactBuilder** (for parameter **fb**), **FactModifier** (for parameter **fm**), **InstanceBuilder** (for parameter ib), or **InstanceModifier** (for parameter **im**). Parameter **name** is the slot of either the fact or instance to be assigned. Parameter **f** is the value assigned to the slot: a **CLIPSFloat**, float, or double value. These functions return true if the slot was successfully set; otherwise, they return false.

## 7.7 Assigning Symbol, String, and Instance Name Slot Values

|  |  |
| --- | --- |
| bool FBPutSlotCLIPSLexeme(  FactBuilder \*fb,  const char \*name,  CLIPSLexeme \*lex); | bool FMPutSlotCLIPSLexeme(  FactModifier \*fm,  const char \*name,  CLIPSLexeme \*lex); |
| bool FBPutSlotInstanceName(  FactBuilder \*fb,  const char \*name,  const char \*lex); | bool FMPutSlotInstanceName(  FactModifier \*fm,  const char \*name,  const char \*lex); |
| bool FBPutSlotString(  FactBuilder \*fb,  const char \*name,  const char \*lex); | bool FMPutSlotString(  FactModifier \*fm,  const char \*name,  const char \*lex); |
| bool FBPutSlotSymbol(  FactBuilder \*fb,  const char \*name,  const char \*lex); | bool FMPutSlotSymbol(  FactModifier \*fm,  const char \*name,  const char \*lex); |
| bool IBPutSlotCLIPSLexeme(  InstanceBuilder \*ib,  const char \*name,  CLIPSLexeme \*lex); | bool IMPutSlotCLIPSLexeme(  InstanceModifier \*im,  const char \*name,  CLIPSLexeme \*lex); |
| bool IBPutSlotInstanceName(  InstanceBuilder \*ib,  const char \*name,  const char \*lex); | bool IMPutSlotInstanceName(  InstanceModifier \*im,  const char \*name,  const char \*lex); |
| bool IBPutSlotString(  InstanceBuilder \*ib,  const char \*name,  const char \*lex); | bool IMPutSlotString(  InstanceModifier \*im,  const char \*name,  const char \*lex); |
| bool IBPutSlotSymbol(  InstanceBuilder \*ib,  const char \*name,  const char \*lex); | bool IMPutSlotSymbol(  InstanceModifier \*im,  const char \*name,  const char \*lex); |

These functions assign a lexeme value (symbol, string, or instance name) in one of various forms to a **FactBuilder** (for parameter **fb**), **FactModifier** (for parameter **fm**), **InstanceBuilder** (for parameter ib), or **InstanceModifier** (for parameter **im**). Parameter **name** is the slot of either the fact or instance to be assigned. Parameter **lex** is the value assigned to the slot: a **CLIPSLexeme** or C string. These functions return true if the slot was successfully set; otherwise, they return false.

## 7.8 Assigning Fact and Instance Values

|  |  |
| --- | --- |
| bool FBPutSlotFact(  FactBuilder \*fb,  const char \*name,  Fact \*f); | bool IBPutSlotFact(  InstanceBuilder \*ib,  const char \*name,  Fact \*f); |
| bool FBPutSlotInstance(  FactBuilder \*fb,  const char \*name,  Instance \*i); | bool IBPutSlotInstance(  InstanceBuilder \*ib,  const char \*name,  Instance \*i); |
| bool FMPutSlotFact(  FactModifier \*fm,  const char \*name,  Fact \*f); | bool IMPutSlotFact(  InstanceModifier \*im,  const char \*name,  Fact \*f); |
| bool FMPutSlotInstance(  FactModifier \*fm,  const char \*name,  Instance \*i); | bool IMPutSlotInstance(  InstanceModifier \*im,  const char \*name,  Instance \*i); |

These functions assign a fact or instance value to a **FactBuilder** (for parameter **fb**), **FactModifier** (for parameter **fm**), **InstanceBuilder** (for parameter ib), or **InstanceModifier** (for parameter **im**). Parameter **name** is the slot of either the fact or instance to be assigned. Parameter **f** is the **Fact** value assigned to the slot; or parameter **i** is the **Instance** value assigned to the slot. These functions return true if the slot was successfully set; otherwise, they return false.

## 7.9 Assigning Multifield and External Address Slot Values

|  |  |
| --- | --- |
| bool FBPutSlotExternalAddress(  FactBuilder \*fb,  const char \*name,  CLIPSExternalAddress \*ea); | bool IBPutSlotExternalAddress(  InstanceBuilder \*ib,  const char \*name,  CLIPSExternalAddress \*ea); |
| bool FBPutSlotMultifield(  FactBuilder \*fb,  const char \*name,  Multifield \*mf); | bool IBPutSlotMultifield(  InstanceBuilder \*ib,  const char \*name,  Multifield \*mf); |
| bool FMPutSlotExternalAddress(  FactModifier \*fm,  const char \*name,  CLIPSExternalAddress \*ea); | bool IMPutSlotExternalAddress(  FactModifier \*im,  const char \*name,  CLIPSExternalAddress \*ea); |
| bool FMPutSlotMultifield(  FactModifier \*fm,  const char \*name,  Multifield \*mf); | bool IMPutSlotMultifield(  InstanceModifier \*im,  const char \*name,  Multifield \*mf); |

These functions assign an external address or multifield value to a **FactBuilder** (for parameter **fb**), **FactModifier** (for parameter **fm**), **InstanceBuilder** (for parameter ib), or **InstanceModifier** (for parameter **im**). Parameter **name** is the slot of either the fact or instance to be assigned. Parameter **ea** is the **CLIPSExternalAddress** value assigned to the slot; or parameter **mf** is the **Multifield** value assigned to the slot. These functions return true if the slot was successfully set; otherwise, they return false.

## 7.10 Examples

### 7.10.1 FactBuilder

Blah blah blah:

int main()

{

Environment \*theEnv;

FactBuilder \*theFB;

CLIPSValue cv;

theEnv = CreateEnvironment();

Build(theEnv,"(deftemplate person"

" (slot name)"

" (slot gender)"

" (slot age)"

" (slot marital-status (default single))"

" (multislot hobbies))");

theFB = CreateFactBuilder(theEnv,"person");

// Technique #1

FBPutSlotString(theFB,"name","Mary Sue Smith");

FBPutSlotSymbol(theFB,"gender","female");

FBPutSlotInt(theFB,"age",25);

FBAssert(theFB);

// Technique #2

FBPutSlotCLIPSLexeme(theFB,"name",CreateString(theEnv,"Sam Jones"));

FBPutSlotCLIPSLexeme(theFB,"gender",CreateSymbol(theEnv,"male"));

FBPutSlotCLIPSInteger(theFB,"age",CreateInteger(theEnv,48));

FBPutSlotCLIPSLexeme(theFB,"marital-status",CreateSymbol(theEnv,"married"));

FBPutSlotMultifield(theFB,"hobbies",StringToMultifield(theEnv,"reading skiing"));

FBAssert(theFB);

// Technique #3

cv.lexemeValue = CreateString(theEnv,"John Doe");

FBPutSlot(theFB,"name",&cv);

cv.lexemeValue = CreateSymbol(theEnv,"male");

FBPutSlot(theFB,"gender",&cv);

cv.integerValue = CreateInteger(theEnv,73);

FBPutSlot(theFB,"age",&cv);

cv.lexemeValue = CreateSymbol(theEnv,"widowed");

FBPutSlot(theFB,"marital-status",&cv);

cv.multifieldValue = StringToMultifield(theEnv,"gardening");

FBPutSlot(theFB,"hobbies",&cv);

FBAssert(theFB);

FBDispose(theFB);

Eval(theEnv,"(do-for-all-facts ((?f person)) (ppfact ?f))",NULL);

DestroyEnvironment(theEnv);

}

The resulting output is:

(person

(name "Mary Sue Smith")

(gender female)

(age 25)

(marital-status single)

(hobbies))

(person

(name "Sam Jones")

(gender male)

(age 48)

(marital-status married)

(hobbies reading skiing))

(person

(name "John Doe")

(gender male)

(age 73)

(marital-status widowed)

(hobbies gardening))

### 7.10.2 FactModifier

Blah blah blah:

int main()

{

Environment \*theEnv;

FactModifier \*theFM;

Fact \*theFact;

theEnv = CreateEnvironment();

Build(theEnv,"(deftemplate print"

" (slot value))");

Build(theEnv,"(defrule print"

" (print (value ?v))"

" =>"

" (println ?v))");

theFact = AssertString(theEnv,"(print (value \"Beginning\"))");

Run(theEnv,-1);

theFM = CreateFactModifier(theEnv,theFact);

FMPutSlotString(theFM,"value","Middle");

FMModify(theFM);

Run(theEnv,-1);

FMPutSlotString(theFM,"value","End");

FMModify(theFM);

Run(theEnv,-1);

FMDispose(theFM);

DestroyEnvironment(theEnv);

}

The resulting output is:

Beginning

Middle

End

### 7.10.3 Fact Modifier with Referenced Facts

Blah blah blah:

int main()

{

Environment \*theEnv;

FactBuilder \*theFB;

FactModifier \*theFM;

CLIPSValue cv;

Fact \*sensors[2];

long long sensorValues[2] = { 6, 5 };

theEnv = CreateEnvironment();

// Create a deftemplate and defrule

Build(theEnv,"(deftemplate sensor"

" (slot id)"

" (multislot range)"

" (slot value))");

Build(theEnv,"(defrule sensor-value-out-of-range"

" (sensor (id ?id) (value ?value) (range ?lower ?upper))"

" (test (or (< ?value ?lower) (> ?value ?upper)))"

" =>"

" (println ?id \" value \" ?value "

" \" out of range \" ?lower \" - \" ?upper))");

// Watch changes to facts

Watch(theEnv,FACTS);

// Create the facts

theFB = CreateFactBuilder(theEnv,"sensor");

FBPutSlotSymbol(theFB,"id","sensor-1");

FBPutSlotMultifield(theFB,"range",StringToMultifield(theEnv,"4 8"));

FBPutSlotLongLong(theFB,"value",sensorValues[0]);

sensors[0] = FBAssert(theFB);

Retain(theEnv,&sensors[0]->header);

FBPutSlotSymbol(theFB,"id","sensor-2");

FBPutSlotMultifield(theFB,"range",StringToMultifield(theEnv,"2 7"));

FBPutSlotLongLong(theFB,"value",sensorValues[1]);

sensors[1] = FBAssert(theFB);

Retain(theEnv,&sensors[1]->header);

FBDispose(theFB);

// Seed the random number generator

Eval(theEnv,"(seed (integer (time)))",NULL);

// Create the FactModifier

theFM = CreateFactModifier(theEnv,NULL);

// Loop through 4 cycles of changes

for (int cycle = 1; cycle < 5; cycle++)

{

Write(theEnv,"Cycle #");

WriteInteger(theEnv,STDOUT,cycle);

Write(theEnv,"\n");

// Loop through each sensor

for (int s = 0; s < 2; s++)

{

Fact \*oldValue = sensors[s];

FMSetFact(theFM,oldValue);

// Change the sensor value

Eval(theEnv,"(random -3 3)",&cv);

sensorValues[s] += cv.integerValue->contents;

FMPutSlotLongLong(theFM,"value",sensorValues[s]);

sensors[s] = FMModify(theFM);

Retain(theEnv,&sensors[s]->header);

Release(theEnv,&oldValue->header);

}

// Execute Rules

Run(theEnv,-1);

}

// Dispose of the FactModifier

FMDispose(theFM);

DestroyEnvironment(theEnv);

}

The resulting output is:

==> f-1 (sensor (id sensor-1) (range 4 8) (value 6))

==> f-2 (sensor (id sensor-2) (range 2 7) (value 5))

Cycle #1

<== f-1 (sensor ... (value 6))

==> f-1 (sensor ... (value 9))

<== f-2 (sensor ... (value 5))

==> f-2 (sensor ... (value 3))

sensor-1 value 9 out of range 4 - 8

Cycle #2

<== f-1 (sensor ... (value 9))

==> f-1 (sensor ... (value 10))

sensor-1 value 10 out of range 4 - 8

Cycle #3

<== f-1 (sensor ... (value 10))

==> f-1 (sensor ... (value 13))

<== f-2 (sensor ... (value 3))

==> f-2 (sensor ... (value 2))

sensor-1 value 13 out of range 4 - 8

Cycle #4

<== f-1 (sensor ... (value 13))

==> f-1 (sensor ... (value 16))

<== f-2 (sensor ... (value 2))

==> f-2 (sensor ... (value 1))

sensor-2 value 1 out of range 2 - 7

sensor-1 value 16 out of range 4 - 8

Note that the specific values will vary because of calls to the random function.

# Section 8: User Defined Functions

CLIPS provides a collection of system defined functions and commands for a variety of purposes. In addition, the deffunction construct can be used to create new functions and commands within a CLIPS program. In some cases, however, it is necessary to integrate functions written in C with the CLIPS C source code. This may be for performance reasons; to integrate existing code written in C; or to integrate a C library.

Functions written in C that are integrated with CLIPS using the protocols described in this section are referred to as User Defined Functions (UDFs) and can be used in the same manner as system defined functions and commands. In fact, the system defined functions and commands provided by CLIPS are integrated using the protocols described in this section. Note that while the word ‘command’ is typically used throughout this documentation to refer to a function that has no return value, the protocols used to implement functions and commands are the same.

This section describes the protocols for registering UDFs, passing arguments to them, and returning values from them. Prototypes for the functions listed in this section can be included by using the **clips.h** header file.

## 8.1 User Defined Function Types

The interface between a function reference in CLIPS code and the C code which implements the function is handled by creating a function of type **UserDefinedFunction**:

typedef void UserDefinedFunction(  
 Environment \*env,  
 UDFContext \*udfc,  
 UDFValue \*out);

typedef struct udfContext  
 {  
 void \*context;  
 } UDFContext;

typedef struct udfValue  
 {  
 union  
 {  
 void \*value;  
 TypeHeader const \*header;  
 CLIPSLexeme \*lexemeValue;  
 CLIPSFloat \*floatValue;  
 CLIPSInteger \*integerValue;  
 CLIPSVoid \*voidValue;  
 Multifield \*multifieldValue;  
 Fact \*factValue;  
 Instance \*instanceValue;  
 CLIPSExternalAddress \*externalAddressValue;  
 };  
 size\_t begin;  
 size\_t range;  
 } UDFValue;

A **UserDefinedFunction** is passed three parameters: **env** is a pointer to the **Environment** in which the UDF is executed; **udfc** is a pointer to a **UDFContext**; and **out** is a pointer to a **UDFValue**.

The **UDFContext** type contains the public field **context**, a pointer to user data supplied when the UDF is registered, as well as several private fields used to track UDF argument requests (through the **udfc** parameter value).

The **UDFValue** type is used both for returning a value from a UDF (through the **out** parameter value) as well as requesting argument values passed to the UDF. The **UDFValue** type is similar to the **CLIPSValue** type, but also includes **begin** and **range** fields. These fields allow you to manipulate multifield values within a UDF without creating a new multifield. The **begin** field represents the starting position and the **range** field represents the number of values within a multifield. For example, if a UDFValue contained the multifield (a b c d), setting the **begin** field to 1 and the **range** field to 2 would change the UDFValue to the multifield (b c).

## 8.2 Registering User Defined Functions

bool AddUDF(  
 Environment \*env,  
 const char \*clipsName,  
 const char \*returnTypes,  
 unsigned short minArgs,  
 unsigned short maxArgs,  
 const char \*argTypes,  
 UserDefinedFunction \*cfp,  
 const char \*cName,  
 void \*context);

UDFs must be registered with CLIPS using the function **AddUDF** before they can be referenced from CLIPS code. Calls to **AddUDF** can be made in the function **UserFunctions** contained in the CLIPS **userfunctions.c** file. Within **UserFunctions**, a call should be made for every function which is to be integrated with CLIPS. The user’s source code then can be compiled and linked with CLIPS. Alternately, the user can call **AddUDF** from their own initialization code—the only restrictions is that it must be called after CLIPS has been initialized and before the UDF is referenced.

Parameter **env** is a pointer to a previously defined environment; parameter **clipsName** is the name associated with the UDF when it is called from within CLIPS; parameter **returnsTypes** is a string containing character codes indicating the CLIPS types returned by the UDF; parameter **minArgs** is the minimum number of arguments that must be passed to the UDF; parameter **maxArgs** is the maximum number of arguments that may be passed to the UDF; parameter **argTypes** is a string containing one or more groups of character codes specifying the allowed types for arguments; parameter **cfp** is a pointer to a function of type **UserDefinedFunction** to be invoked by CLIPS; parameter **cName** is the name of the UDF as specified in the C source code; and parameter **context** is a user supplied pointer to data that is passed to the UDF when it is invoked through the **UDFContext** paramter. This function returns true if the UDF was successfully added; otherwise, false is returned.

User‑defined functions override system functions. If the user defines a function which is the same as one of the defined functions already provided, the user function will be executed in its place.

If the **returnTypes** parameter value is a null pointer, then CLIPS assumes that the UDF can return any valid type. Specifying one or more type character codes, however, allows CLIPS to detect errors when the return value of a UDF is used as a parameter value to a function that specifies the types allowed for that parameter. The following codes are supported for return values and argument types:

|  |  |
| --- | --- |
| **Type Code** | **Type** |
| b | Boolean |
| d | Double Precision Float |
| e | External Address |
| f | Fact Address |
| i | Instance Address |
| l | Long Long Integer |
| m | Multifield |
| n | Instance Name |
| s | String |
| y | Symbol |
| v | Void—No Return Value |
| \* | Any Type |

One or more characters can be specified. For example, "l" indicates the UDF returns an integer; "ld" indicates the UDF returns an integer or float; and "syn" indicates the UDF returns a symbol, string, or instance name.

The **minArgs** and **maxArgs** parameter values can be specified as the constant **UNBOUNDED** to indicate that there is no restriction on the minimum or maximum number of arguments.

If the **argTypes** parameter value is a null pointer, then there are no argument type restrictions. One or more character argument types can also be specified, separated by semicolons. The first type specified is the default type (used when no other type is specified for an argument), followed by types for specific arguments. For example, "ld" indicates that the default argument type is an integer or float; "ld;s" indicates that the default argument type is an integer or float, and the first argument must be a string; "\*;;m" indicates that the default argument type is any type, and the second argument must be a multifield; ";sy;ld" indicates that the default argument type is any type, the first argument must be a string or symbol; and the second argument type must be an integer or float.

## 8.3 Passing Arguments from CLIPS to User Defined Func­tions

Unlike a C function call, CLIPS does immediately evaluate all of the arguments in a function call and directly pass the resulting values to the C function implementating the UDF. Instead arguments are evaluated and supplied when requested through argument access functions.

CLIPS will generate an error and terminate the invocation of a UDF before it is called if the incorrect number of arguments is supplied (either there are fewer arguments than the minimum specified or more arguments than the maximum specified).

Several access functions are provided to retrieve arguments:

unsigned UDFArgumentCount(  
 UDFContext \*udfc);

bool UDFFirstArgument(  
 UDFContext \*udfc,  
 unsigned expectedType,  
 UDFValue \*out);

bool UDFNextArgument(  
 UDFContext \*udfc,  
 unsigned expectedType,  
 UDFValue \*out);

bool UDFNthArgument(  
 UDFContext \*udfc,  
 unsigned n,  
 unsigned expectedType,  
 UDFValue \*out);

bool UDFHasNextArgument(  
 UDFContext \*udfc);

void UDFThrowError(  
 UDFContext \*udfc);

The function **UDFArgumentCount** returns the number of arguments passed to the UDF. At the point the UDF is invoked, the argument count has been verified to fall within the range specified by the minimum and maximum number of arguments specified in the call to **AddUDF**. Thus a UDF should only need to check the argument count if the minimum and maximum number of arguments are not the same.

The function **UDFFirstArgument** retrieves the first argument passed to the UDF. Parameter **udfc** is a pointer to the UDFContext; parameter **expectedType** is a bit field containing the expcted types for the argument; and parameter **out** is a pointer to a UDFValue in which the retrieved argument value is stored. This function returns true if the argument was successfully retrieved and is the expected type; otherwise, it returns false.

The function **UDFNextArgument** retrieves the argument following the previously retrieved argument (either from **UDFFirstArgument**, **UDFNextArgument**, or **UDFNthArgument**). It retrieves the first argument if no arguments have been previously retrieved. Parameter **udfc** is a pointer to the UDFContext; parameter **expectedType** is a bit field containing the expcted types for the argument; and parameter **out** is a pointer to a UDFValue in which the retrieved argument value is stored. This function returns true if the argument was successfully retrieved and is the expected type; otherwise, it returns false.

The function **UDFNthArgument** retrieves a specific argument passed to the UDF. Parameter **udfc** is a pointer to the UDFContext; parameter **n** is the index of the argument to be retrieved (with indices starting at 1); parameter **expectedType** is a bit field containing the expcted types for the argument; and parameter **out** is a pointer to a UDFValue in which the retrieved argument value is stored. This function returns true if the argument was successfully retrieved and is the expected type; otherwise, it returns false.

The function **UDFHasNextArgument** returns true if there is an argument is available to be retrieved; otherwise, it returns false. The “next” argument is considered to be the first argument if no previous call to **UDFFirstArgument**, **UDFNextArgument**, or **UDFNthArgument** has been made; otherwise it is the next argument following the most recent call to one of those functions.

The function **UDFThrowError** can be used by a **UDF** to indicate that an error has occurred and execution should terminate.

The functions **UDFFirstArgument**, **UDFNextArgument**, and **UDFNthArgument** use bit fields rather than character codes to indicate the types allowed for the **expectedType** parameter value. The following constants are defined for specifying bit codes:

|  |  |
| --- | --- |
| **Type Bit Code** | **Type** |
| FLOAT\_BIT | Float |
| INTEGER\_BIT | Integer |
| SYMBOL\_BIT | Symbol |
| STRING\_BIT | String |
| MULTIFIELD\_BIT | Multifield |
| EXTERNAL\_ADDRESS\_BIT | External Address |
| FACT\_ADDRESS\_BIT | Fact Address |
| INSTANCE\_ADDRESS\_BIT | Instance Address |
| INSTANCE\_NAME\_BIT | Instance Name |
| VOID\_BIT | Void |
| BOOLEAN\_BIT | Boolean |
| NUMBER\_BITS | Float, Integer |
| LEXEME\_BITS | Symbol, String |
| ADDRESS\_BITS | External Address, Fact Address, Instance Address |
| INSTANCE\_BITS | Instance Address, Instance Name |
| SINGLEFIELD\_BITS | Number, Lexeme, Address, Instance Name |
| ANY\_TYPE\_BITS | Void, Singlefield, Multifield |

These bit codes can be combined using the C | operator. For example, the following code indicates that an argument should either be an integer or symbol:

INTEGER\_BIT | SYMBOL\_BIT

## 8.4 Examples

### 8.4.1 Euler’s Number

This example demonstrates returning a mathematical constant, Euler’s number, from a user defined function.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **e**; the return value type is a float; the UDF does not expect any arguments; and the C implementation of the UDF is the function **EulersNumber**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"e","d",0,0,NULL,EulersNumber,"EulersNumber",NULL);

}

The implementation of the CLIPS function **e** in the C function **EulersNumber** uses the function **CreateFloat** to create the return value. The C library function **exp** is used to calculate the value for Euler’s number.

#include <math.h>

void EulersNumber(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

out->floatValue = CreateFloat(env,exp(1.0));

}

After creating a new executable including the UDF code, the function **e** can be invoked within CLIPS.

CLIPS> **(e)**

2.71828182845905

CLIPS>

### 8.4.2 Week Days Multifield Constant

This example demonstrates returning a multifield constant, the weekdays, from a user defined function.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **weekdays**; the return value type is a multifield value; the UDF does not expect any arguments; and the C implementation of the UDF is the function **Weekdays**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"weekdays","m",0,0,NULL,Weekdays,"Weekdays",NULL);

}

The implementation of the CLIPS function **weekdays** in the C function **Weekdays** uses the function **StringToMultifield** to create the return value.

void Weekdays(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

out->multifieldValue =

StringToMultifield(env,"Monday Tuesday Wednesday Thursday Friday");

}

After creating a new executable including the UDF code, the function **week-days** can be invoked within CLIPS.

CLIPS> **(weekdays)**

(Monday Tuesday Wednesday Thursday Friday)

CLIPS>

### 8.4.3 Cubing a Number

This example demonstrates a user defined function that cubes a numeric argument value and returns either an integer or float depending upon the type of the argument value.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **cube**; the return value type is an integer or float value; the UDF expects one argument that must be an integer or a float; and the C implementation of the UDF is the function **Cube**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"cube","ld",1,1,"ld",Cube,"Cube",NULL);

}

The implementation of the CLIPS function **cube** in the C function **Cube** uses the function **UDFFirstArgument** to retrieve the numeric argument passed to the function. If the argument value is an integer, the function **CreateInteger** is used to create the return value. If the argument value is a float, the function **CreateFloat** is used to create the return value.

void Cube(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

UDFValue theArg;

// Retrieve the first argument.

if (! UDFFirstArgument(udfc,NUMBER\_BITS,&theArg))

{ return; }

// Cube the argument.

if (theArg.header->type == INTEGER\_TYPE)

{

long long integerValue = theArg.integerValue->contents;

integerValue = integerValue \* integerValue \* integerValue;

out->integerValue = CreateInteger(env,integerValue);

}

else /\* the type must be FLOAT \*/

{

double floatValue = theArg.floatValue->contents;

floatValue = floatValue \* floatValue \* floatValue;

out->floatValue = CreateFloat(env,floatValue);

}

}

After creating a new executable including the UDF code, the function **cube** can be invoked within CLIPS.

CLIPS> **(cube 3)**

27

CLIPS> **(cube 3.5)**

42.875

CLIPS>

### 8.4.4 Positive Number Predicate

This example demonstrates a user defined function that returns a boolean value indicating whether a numeric argument value is positive.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **positivep**; the return value type is a boolean value (either the symbol TRUE or FALSE); the UDF expects one argument that must be an integer or a float; and the C implementation of the UDF is the function **Positivep**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"positivep","b",1,1,"ld",Positivep,"Positivep",NULL);

}

The implementation of the CLIPS function **positivep** in the C function **Positivep** uses the function **UDFFirstArgument** to retrieve the numeric argument passed to the function. The function **CreateBoolean** is used to create the return value.

void Positivep(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

UDFValue theArg;

bool b;

// Retrieve the first argument.

if (! UDFFirstArgument(udfc,NUMBER\_BITS,&theArg))

{ return; }

// Determine if the value is positive.

if (theArg.header->type == INTEGER\_TYPE)

{ b = (theArg.integerValue->contents > 0); }

else /\* the type must be FLOAT \*/

{ b = (theArg.floatValue->contents > 0.0); }

out->lexemeValue = CreateBoolean(env,b);

}

After creating a new executable including the UDF code, the function **positivep** can be invoked within CLIPS.

CLIPS> **(positivep -3)**

FALSE

CLIPS> **(positivep 4.5)**

TRUE

CLIPS>

### 8.4.5 Exclusive Or

This example demonstrates a user defined function that returns a boolean value indicating whether an odd number of its arguments values are true (exclusive or).

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **xor**; the return value type is a boolean value (either the symbol TRUE or FALSE); the UDF expects at least two arguments; and the C implementation of the UDF is the function **Xor**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"xor","b",2,UNBOUNDED,NULL,Xor,"Xor",NULL);

}

The implementation of the CLIPS function **xor** in the C function **Xor** uses the functions **UDFHasNextArgument** and **UDFNextArgument** to retrieve the variable number of arguments passed to the function. Any value other than the symbol FALSE is considered to be “TRUE” by CLIPS, so when counting the number of argument values to be true, each argument is compared for inequality to the return value of the **FalseSymbol** function. Finally, the function **CreateBoolean** is used to create the return value.

void Xor(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

UDFValue theArg;

int trueCount = 0;

while (UDFHasNextArgument(udfc))

{

UDFNextArgument(udfc,ANY\_TYPE\_BITS,&theArg);

if (theArg.value != FalseSymbol(env))

{ trueCount++; }

}

out->lexemeValue = CreateBoolean(env,trueCount % 2);

}

After creating a new executable including the UDF code, the function **xor** can be invoked within CLIPS.

CLIPS> **(xor TRUE FALSE)**

TRUE

CLIPS> **(xor FALSE FALSE)**

FALSE

CLIPS> **(xor TRUE FALSE TRUE FALSE TRUE)**

TRUE

CLIPS>

### 8.4.6 String Reversal

This example demonstrates a user defined function that reverses the characters in a CLIPS symbol, string, or instance name.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **reverse**; the return value type is a string, symbol, or instance name; the UDF expects one argument that must be a string, symbol, or instance name; and the C implementation of the UDF is the function **Reverse**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"reverse","syn",1,1,"syn",Reverse,"Reverse",NULL);

}

The implementation of the CLIPS function **reverse** in the C function **Reverse** uses the function **UDFFirstArgument** to retrieve the lexeme argument (string, symbol, or instance name) passed to the function. The function **genalloc** is used to allocate temporary memory for reversing the order of characters in the string. Depending upon the argument value type, the function **CreateString**, **CreateSymbol**, or **CreateInstanceName** is used to create the return value. Finally, the function **genfree** is used to deallocate the temporary memory.

void Reverse(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

UDFValue theArg;

const char \*theString;

char \*tempString;

size\_t length, i;

// Retrieve the first argument.

if (! UDFFirstArgument(udfc,LEXEME\_BITS | INSTANCE\_NAME\_BIT,&theArg))

{ return; }

theString = theArg.lexemeValue->contents;

// Allocate temporary space to store the reversed string.

length = strlen(theString);

tempString = (char \*) genalloc(env,length + 1);

// Reverse the string.

for (i = 0; i < length; i++)

{ tempString[length - (i + 1)] = theString[i]; }

tempString[length] = '\0';

// Set the return value before deallocating

// the temporary reversed string.

switch (theArg.header->type)

{

case STRING\_TYPE:

out->lexemeValue = CreateString(env,tempString);

break;

case SYMBOL\_TYPE:

out->lexemeValue = CreateSymbol(env,tempString);

break;

case INSTANCE\_NAME\_TYPE:

out->lexemeValue = CreateInstanceName(env,tempString);

break;

}

// Deallocate temporary space

genfree(env,tempString,length+1);

}

After creating a new executable including the UDF code, the function **reverse** can be invoked within CLIPS.

CLIPS> **(reverse abcd)**dcbaCLIPS> **(reverse "xyz")**"zyx"CLIPS> **(reverse [ijk])**[kji]CLIPS>

### 8.4.7 Reversing the Values in a Multifield Value

This example demonstrates a user defined function that creates a multifield value comprised from its arguments values, but in reverse order.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **reverse$**; the return value type is a multifield value; the UDF expects any number of arguments; and the C implementation of the UDF is the function **ReverseMF**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"reverse$","m",0,UNBOUNDED,NULL,ReverseMF,"ReverseMF",NULL);

}

The implementation of the CLIPS function **reverse$** in the C function **ReverseMF** uses the functions **UDFArgumentCount** and **UDFNthArgument** to retrieve arguments passed to the function in reverse order. A multifield builder is created using the function **CreateMultifieldBuilder**. Each function argument is appended to the multifield builder using the function **MBAppendUDFValue**. The return value is created using **MBCreate**. Finally, the multifield builder is deallocated using the function **MBDispose**.

void ReverseMF(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

UDFValue theArg;

MultifieldBuilder \*mb;

unsigned argCount;

// Create the multifield builder.

mb = CreateMultifieldBuilder(env,20);

// Iterate over the argument

// values in reverse order.

argCount = UDFArgumentCount(udfc);

for (unsigned i = argCount; i != 0; i--)

{

// Append the Nth argument

// to the multifield builder

UDFNthArgument(udfc,i,ANY\_TYPE\_BITS,&theArg);

MBAppendUDFValue(mb,&theArg);

}

// Create the return value.

out->multifieldValue = MBCreate(mb);

// Dispose of the multifield value.

MBDispose(mb);

}

After creating a new executable including the UDF code, the function **reverse$** can be invoked within CLIPS.

CLIPS> **(reverse$ 1 2 3)**

(3 2 1)

CLIPS> (reverse$ a 6 (create$ 6.3 5.4) "s")

("s" 6.3 5.4 6 a)  
CLIPS>

### 8.4.8 Trimming a Multifield

This example demonstrates a user defined function that trims values from the beginning and end of a multifield value.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **trim$**; the return value type is a multifield value; the UDF expects three arguments (the default type is an integer and the first argument must be a multiefield value); and the C implementation of the UDF is the function **Trim**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"trim$","m",3,3,"l;m",Trim,"Trim",NULL);

}

The implementation of the CLIPS function **trim$** in the C function **Trim** uses the functions **UDFFirstArgument** and **UDFNextArgument** to retrieve arguments passed to the function. The first argument is a multifield value; and the second and third arguments are integers (the number of values to trim from the beginning and end of the multifield value). If the trim values are negative or exceed the number of values contained in the multifield, then the functions **PrintString** and **UDFThrowError** are used to indicate an error; otherwise the **begin** and **range** fields of the argument value stored in the return value parameter **out** are modified to trim the appropriate number of values from the beginning and end of the multifield.

void Trim(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

long long front, back;

UDFValue arg;

// Retrieve the arguments.

UDFFirstArgument(udfc,MULTIFIELD\_BIT,out);

UDFNextArgument(udfc,INTEGER\_BIT,&arg);

front = arg.integerValue->contents;

UDFNextArgument(udfc,INTEGER\_BIT,&arg);

back = arg.integerValue->contents;

// Detect errors.

if ((front < 0) || (back < 0))

{

Writeln(env,"Trim$ indices cannot be negative.");

UDFThrowError(udfc);

return;

}

if ((front + back) > (long long) out->multifieldValue->length)

{

Writeln(env,"Trim$ exceeds length of multifield.");

UDFThrowError(udfc);

return;

};

// Adjust the begin and range.

out->begin += (size\_t) front;

out->range -= (size\_t) (front + back);

}

After creating a new executable including the UDF code, the function **trim$** can be invoked within CLIPS.

CLIPS> **(trim$ (create$ a b c d e f g) 1 2)**

(b c d e)

CLIPS> **(trim$ (create$ a b c) -1 2)**

Trim$ indices cannot be negative.

(a b c)

CLIPS>

### 8.4.9 Removing Duplicates from a Multifield

This example demonstrates a user defined function that removes duplicate values from a multifield value.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **compact$**; the return value type is a multifield value; the UDF expects one argument that must be a multifield value; and the C implementation of the UDF is the function **Compact**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"compact$","m",1,1,"m",Compact,"Compact",NULL);

}

The implementation of the CLIPS function **compact$** in the C function **Compact** uses the function **UDFFirstArgument** to retrieve the multifield argument value passed to the function. A multifield builder is created using the function **CreateMultifieldBuilder**. The **begin** and **range** fields are used to iterate over the values of the multifield argument value. If the value is not contained within the multifield builder, then it is added using the **MBAppend** function. The return value of the function is created using the **MBCreate** function. Finally, the multifield builder is deallocated using the function **MBDispose**.

void Compact(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

UDFValue arg;

MultifieldBuilder \*mb;

size\_t i, j;

// Retrieve the argument.

UDFFirstArgument(udfc,MULTIFIELD\_BIT,&arg);

// Create the multifield builder.

mb = CreateMultifieldBuilder(env,20);

// Iterate over each value in the multifield

// and add it to the compacted multifield if

// it is not already present.

for (i = arg.begin; i < (arg.begin + arg.range); i++)

{

// Look for the value in the multifield builder.

for (j = 0; j < mb->length; j++)

{

if (arg.multifieldValue->contents[i].value == mb->contents[j].value)

{ break; }

}

// If the value wasn't found, add it.

if (j == mb->length)

{ MBAppend(mb,&arg.multifieldValue->contents[i]); }

}

// Create the return value.

out->multifieldValue = MBCreate(mb);

// Dispose of the multifield builder.

MBDispose(mb);

}

After creating a new executable including the UDF code, the function **compact$** can be invoked within CLIPS.

CLIPS> **(compact$ (create$ a b c))**

(a b c)

CLIPS> **(compact$ (create$ a a b c b c d))**

(a b c d)

CLIPS>

### 8.4.10 Prime Factors

This example demonstrates a user defined function that determines the prime factors of an integer.

The **AddUDF** function call required in **UserFunctions** specifies that the CLIPS function name is **prime-factors**; the return value type is an integer; the UDF expects one argument that must be an integer; and the C implementation of the UDF is the function **PrimeFactors**.

void UserFunctions(

Environment \*env)

{

AddUDF(env,"prime-factors","m",1,1,"l",PrimeFactors,"PrimeFactors",NULL);

}

The implementation of the CLIPS function **prime-factors** in the C function **PrimeFactor** uses the function **UDFFirstArgument** to retrieve the integer argument value passed to the function. If the integer is less than 2, the return value is created using the function **EmptyMultifield** to indicate that there are no prime factors. Otherwise, a multifield builder is created using the function **CreateMultifieldBuilder**. A trial division algorithm is then used to determine the prime factors and, as each is found, it is added to the multifield builder using the **MBAppendLongLong** function. The return value of the function is created using the **MBCreate** function. Finally, the multifield builder is deallocated using the function **MBDispose**.

#include <math.h>

void PrimeFactors(

Environment \*env,

UDFContext \*udfc,

UDFValue \*out)

{

UDFValue value;

long long num, p, upper;

MultifieldBuilder \*mb;

// Retrieve the integer argument.

UDFFirstArgument(udfc,INTEGER\_BIT,&value);

num = value.integerValue->contents;

// Integers less than 2 don't have

// a prime factorization.

if (num < 2)

{

out->multifieldValue = EmptyMultifield(env);

return;

}

// Create the multifield builder.

mb = CreateMultifieldBuilder(env,10);

// Determine the prime factors.

upper = (long long) sqrt(num);

for (p = 2; p <= upper; p++)

{

if ((p \* p) > num) break;

while ((num % p) == 0)

{

MBAppendLongLong(mb,p);

num /= p;

}

}

if (num > 1)

{ MBAppendLongLong(mb,num); }

// Set the return value.

out->multifieldValue = MBCreate(mb);

// Dispose of the multifield builder.

MBDispose(mb);

}

After creating a new executable including the UDF code, the function **prime-factor** can be invoked within CLIPS.

CLIPS> **(prime-factors 1)**

()

CLIPS> **(prime-factors 3)**

(3)

CLIPS> **(prime-factors 128)**

(2 2 2 2 2 2 2)

CLIPS> **(prime-factors 5040)**

(2 2 2 2 3 3 5 7)

CLIPS> **(prime-factors 1257383)**

(373 3371)

CLIPS> **(prime-factors 6469693230)**

(2 3 5 7 11 13 17 19 23 29)

CLIPS>

# Section 9: I/O Routers

The **I/O router** system provided in CLIPS is quite flexible and will allow a wide va­riety of interfaces to be developed and easily attached to CLIPS. The system is rela­tively easy to use and is explained fully in sections 9.1 through 9.4. The CLIPS I/O functions for using the router system are described in sections 9.5 and 9.6, and finally, in section 9.7, some examples are included which show how I/O routing could be used for simple interfaces.

## 9.1 Introduction

The problem that originally inspired the idea of I/O routing will be considered as an introduction to I/O routing. Because CLIPS was designed with portability as a major goal, it was not possible to build a sophisticated user interface that would support many of the features found in the interfaces of commercial expert system building tools. A prototype was built of a semi‑portable interface for CLIPS using the CURSES screen manage­ment package. Many problems were encountered during this effort in­volving both portability concerns and CLIPS internal features. For example, every statement in the source code which used the C print function, **printf**, for printing to the terminal had to be replaced by the CURSES function, **wprintw**, which would print to a window on the terminal. In addition to changing function call names, different types of I/O had to be di­rected to different windows. The tracing information was to be sent to one window, the command prompt was to appear in another window, and output from printout statements was to be sent to yet another window.

This prototype effort pointed out two major needs: First, the need for generic I/O func­tions that would remain the same regardless of whether I/O was directed to a standard terminal interface or to a more complex interface (such as windows); and second, the need to be able to specify different sources and destinations for I/O. I/O routing was designed in CLIPS to handle these needs. The concept of I/O routing will be further explained in the following sections.

## 9.2 Logical Names

One of the key concepts of I/O routing is the use of **logical names**. An analogy will be useful in explaining this concept. Consider the Acme company which has two com­puters: computers X and Y. The Acme company stores three data sets on these two computers: a personnel data set, an accounting data set, and a documenta­tion data set. One of the employees, Joe, wishes to update the payroll in­formation in the accounting data set. If the payroll information was located in directory A on computer Y, Joe's command would be

update Y:[A]payroll

If the data were moved to directory B on computer X, Joe’s command would have to be changed to

update X:[B]payroll

To update the payroll file, Joe must know its location. If the file is moved, Joe must be informed of its new location to be able to update it. From Joe’s point of view, he does not care where the file is located physically. He simply wants to be able to specify that he wants the information from the accounting data set. He would rather use a com­mand like

update accounting:payroll

By using logical names, the information about where the ac­counting files are located physically can be hidden from Joe while still allowing him to access them. The loca­tions of the files are equated with logical names as shown here.

accounting = X:[A]

documentation = X:[C]

personnel = Y:[B]

Now, if the files are moved, Joe does not have to be informed of their relocation so long as the logical names are updated. This is the power of using logical names. Joe does not have to be aware of the physical location of the files to access them; he only needs to be aware that accounting is the logical name for the location of the account­ing data files. Logical names allow reference to an object without having to un­derstand the details of the implementation of the reference.

In CLIPS, logical names are used to send I/O requests without having to know which device and/or function is handling the request. Consider the message that is printed in CLIPS when rule tracing is turned on and a rule has just fired. A typical message would be

FIRE 1 example‑rule: f‑1

The routine that requests this message be printed should not have to know where the message is being sent. Different routines are required to print this message to a stan­dard terminal, a window interface, or a printer. The tracing routine should be able to send this message to a logical name (for example, **trace-out**) and should not have to know if the device to which the message is being sent is a terminal or a printer. The logical name **trace-out** allows tracing information to be sent simply to “the place where tracing information is displayed.” In short, logical names allow I/O requests to be sent to specific locations without having to specify the details of how the I/O request is to be handled.

Many functions in CLIPS make use of logical names. Both the **printout** and **format** functions require a logical name as their first argument. The **read** func­tion can take a logical name as an optional argument. The **open** function causes the association of a logical name with a file, and the **close** function removes this as­sociation.

Several logical names are predefined by CLIPS and are used extensively throughout the system code. These are

**Name Description**

**stdin** The default for all user inputs. The **read** and **readline** functions read from **stdin** if **t** is specified as the logical name.

**stdout** The default for all user outputs. The **format** and **printout** functions send output to **stdout** if **t** is specified as the logical name.

**stderr** All error messages are sent to this logical name.

**stdwrn** All warning messages are sent to this logical name.

Within CLIPS code, these predefined logical names should be specified in lower case (and typically the only one you’ll use is **t** and depending upon which function you’re using this will be mapped to either **stdin** or **stdout**). Within C code, these logical names can be specified using constants that have been defined in upper case: STDIN, STDOUT, STDERR, and STDWRN.

## 9.3 Routers

The use of logical names solves two problems. Logical names make it easy to create generic I/O functions, and they allow the specification of different sources and destinations for I/O. The use of logical names allows CLIPS to ignore the specifics of an I/O request. However, such requests must still be specified at some level. I/O routers are provided to handle the specific details of a request.

A router consists of three components. The first component is a function which can determine whether the router can handle an I/O request for a given logical name. The router which recognizes I/O requests that are to be sent to the serial port may not recognize the same logical names as that which recognizes I/O re­quests that are to be sent to the terminal. On the other hand, two routers may recog­nize the same logical names. A router that keeps a log of a CLIPS session (a drib­ble file) may recog­nize the same logical names as that which handles I/O re­quests for the terminal.

The second component of a router is its priority. When CLIPS receives an I/O request, it begins to query each router to discover whether it can handle an I/O re­quest. Routers with high priorities are queried before routers with low priorities. Priorities are very important when dealing with one or more routers that can each process the same I/O request. This is particularly true when a router is going to redefine the stan­dard user interface. The router associated with the standard interface will handle the same I/O requests as the new router; but, if the new router is given a higher priority, the standard router will never receive any I/O requests. The new router will “intercept” all of the I/O requests. Priorities will be discussed in more detail in the next section.

The third component of a router consists of the functions which actually handle an I/O request. These include functions for printing strings, getting a character from an input buffer, returning a character to an input buffer, and a function to clean up (e.g., close files, remove windows) when CLIPS is exited.

## 9.4 Router Priorities

Each I/O router has a priority. Priority determines which routers are queried first when determining the router that will handle an I/O request. Routers with high priorities are queried before routers with low priorities. Priorities are assigned as integer values (the higher the integer, the higher the priority). Priorities are important because more than one router can handle an I/O request for a single logical name, and they enable the user to define a custom interface for CLIPS. For example, the user could build a custom router which han­dles all logical names normally handled by the default router associated with the standard interface. The user adds the custom router with a priority higher than the priority of the router for the standard interface. The custom router will then intercept all I/O requests intended for the standard interface and spe­cially process those re­quests to the custom interface.

Once the router system sends an I/O request out to a router, it considers the request satisfied. If a router is going to share an I/O request (i.e., process it) then allow other routers to process the request also, that router must deactivate itself and call **PrintString** again. These types of routers should use a priority of either 30 or 40. An example is given in appendix 9.7.2.

**Priority Router Description**

50 Any router that uses “unique” logical names and does not want to share I/O with catch-all routers.

40 Any router that wants to grab standard I/O and is willing to share it with other routers. A dribble file is a good example of this type of router. The dribble file router needs to grab all output that normally would go to the terminal so it can be placed in the dribble file, but this same output also needs to be sent to the router which displays output on the terminal.

30 Any router that uses “unique” logical names and is willing to share I/O with catch‑all routers.

20 Any router that wants to grab standard logical names and is not willing to share them with other routers.

10 This priority is used by a router which redefines the default user inter­face I/O router. Only one router should use this priority.

0 This priority is used by the default router for handling stan­dard and file logical names. Other routers should not use this priority.

## 9.5 Internal I/O Functions

The following functions are called internally by CLIPS. These functions search the list of active routers and determine which router should handle an I/O request. Some routers may wish to deactivate themselves and call one of these functions to allow the next router to process an I/O request. Prototypes for these functions can be included by using the **clips.h** header file or the **router.h** header file.

### 9.5.1 ExitRouter

void ExitRouter(  
 Environment \*env,  
 int code);

The function **ExitRouter** calls the exit function callback associated with each active router before exiting CLIPS. Parameter **env** is a pointer to a previously created environment; and parameter **code** is an integer passed to the callback as well as the system **exit** function once all callbacks have been executed. User code that detects an unrecoverable error should call this function rather than calling the system **exit** function so that routers have the opportunity to execute cleanup code.

### 9.5.2 Input

int ReadRouter(  
 Environment \*env,  
 const char \*logicalName);

int UnreadRouter(  
 Environment \*env,  
 const char \*logicalName,  
 int ch);

The function **ReadRouter** queries all active routers to retrieve character input. This function should be used in place of **getc** to ensure that character input from the function can be received from a custom interface. Parameter **env** is a pointer to a previously created environment; and parameter **logicalName** is the query string that must be recognized by the router to be invoked to handle the I/O request. The get character function callback for that router is invoked and the return value of that callback is returned by this function.

The function **UnreadRouter** queries all active routers to push character input back into an input source. This function should be used in place of **ungetc** to ensure that character input works properly using a custom interface. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the query string that must be recognized by the router to be invoked to handle the I/O request; and parameter **ch** is the character to be pushed back to the input source. The unget character function callback for that router is invoked. The return value for this function is the parameter value **ch** if the character is successfully pushed back to the input source; otherwise, -1 is returned.

### 9.5.3 Output

void Write(  
 Environment \*env,  
 const char \*str);

void WriteCLIPSValue(  
 Environment \*env,  
 const char \*logicalName,  
 CLIPSValue \*cv);

void WriteFloat(  
 Environment \*env,  
 const char \*logicalName,  
 double d);

void WriteInteger(  
 Environment \*env,  
 const char \*logicalName,  
 long long l);

void Writeln(  
 Environment \*env,  
 const char \*str);

void WriteString(  
 Environment \*env,  
 const char \*logicalName,  
 const char \*str);

void WriteMultifield(  
 Environment \*env,  
 const char \*logicalName,  
 Multifield \*mf);

void WriteUDFValue(  
 Environment \*env,  
 const char \*logicalName,  
 UDFValue \*udfv);

The functions **Write**, **WriteCLIPSValue**, **WriteFloat**, **WriteInteger**, **Writeln**, **WriteString**, **WriteMultifield**, and **WriteUDFValue** direct output to a router for display. Using these functions in place of **printf** ensures that output will be displayed appropriately whether CLIPS is run as part of a console application, integrated development environment, or custom interface. By default, output from these functions will use **printf** for display if no other routers are detected to handle the output request.

For all of these functions, parameter **env** is a pointer to a previously created environment. For all function except **Write** and **Writeln**, the parameter **logicalName** is the query string that must be recognized by a router to indicate it can handle the output request. All active routers are queried in order of their priority until the query function callback for a router returns true to indicate if handles the specified logical name. The **Write** and **Writeln** functions automatically sent output to the STDOUT logical name.

The remaining parameter for all of these functions is the value to be printed. The parameters **d**, **l**, and **str** are the C types double, long long, and a char pointer to a null-terminated string. Parameter **mf** is a pointer to a **Multifield**. Parameters **cv** and **udfv** are pointers to **CLIPSValue** and **UDFValue** types that have been allocated and populated with data by the caller. The **Writeln** function additionally prints a carriage return after printing the **str** parameter.

## 9.6 Router Handling Functions

The following functions are used for creating, deleting, and handling I/O routers. They are intended for use within user‑defined functions. Prototypes for these functions can be included by using the **clips.h** header file or the **router.h** header file.

### 9.6.1 Creating Routers

bool AddRouter(  
 Environment \*env,  
 const char \*name,  
 int priority,  
 RouterQueryFunction \*queryCallback,  
 RouterWriteFunction \*writeCallback,  
 RouterReadFunction \*readCallback,  
 RouterUnreadFunction \*unreadCallback,  
 RouterExitFunction \*exitCallback,  
 void \*context);

typedef bool RouterQueryFunction(  
 Environment \*env,  
 const char \*logicalName,  
 void \*context);

typedef void RouterWriteFunction(  
 Environment \*env,  
 const char \*logicalName,  
 const char \*str,  
 void \*context);

typedef void RouterExitFunction(  
 Environment \*environment,  
 int code,  
 void \*context);

typedef int RouterReadFunction(  
 Environment \*env,  
 const char \*logicalName,  
 void \*context);

typedef int RouterUnreadFunction(  
 Environment \*env,  
 const char \*logicalName,  
 int ch,  
 void \*context);

The function **AddRouter** creates and activates a new router. Parameter **env** is a pointer to a previously created environment; parameter **name** is a string that uniquely identifies the router for removal using **DeleteRouter**; parameters **queryCallback**, **writeCallback**, **readCallback**, **unreadCallback**, and **exitCallback** are pointers to callback functions; parameter **priority** is the priority of the router used to determine the order in which routers are queried (higher priority routers are queried first); and parameter **context** is a user supplied pointer to data that is passed to the router callback functions when they are invoked (a null pointer should be used if there is no data that needs to be passed to the router callback functions). The **queryCallback** parameter value must be a non-null function pointer, otherwise the other router callback functions will never be invoked. If the router does not handle output requests, the **writeCallback** parameter value should be a null pointer. If the router does not handle input requests, the **readCallback** and **unreadCallback** parameter values should be null pointers. This function returns true if the router was successfully added; otherwise, it returns false.

The **RouterQueryFunction** type has three parameters: **env** is a pointer to a previously created environment; **logicalName** is the logical name associated with the I/O request; and **context** is the user supplied data pointer provided when the router was created. This function should return true if the **logicalName** parameter value is recognized by this router; otherwise, it should return false.

The **RouterWriteFunction** type has four parameters: **env** is a pointer to a previously created environment; **logicalName** is the logical name associated with the I/O request; **str** is the null character terminated string to be printed; and **context** is the user supplied data pointer provided when the router was created.

The **RouterExitFunction** type has three parameters: **env** is a pointer to a previously created environment; **code** is the exit code value (either the value passed to the CLIPS **exit** command or the C **ExitRouter** function); and **context** is the user supplied data pointer provided when the router was created.

The **RouterReadFunction** type has three parameters: **env** is a pointer to a previously created environment; **logicalName** is the logical name associated with the I/O request;and **context** is the user supplied data pointer provided when the router was created. The return value of this function is an integer character code or -1 to indicate EOF (end of file).

The **RouterUnreadFunction** type has four parameters: **env** is a pointer to a previously created environment; **logicalName** is the logical name associated with the I/O request; **ch** is the character code to be pushed back into the router input source; and **context** is the user supplied data pointer provided when the router was created. The return value of this function should be the **ch** parameter value if the function successfully pushes the character code; otherwise, it should return -1 (EOF).

### 9.6.2 Deleting Routers

bool DeleteRouter(  
 Environment \*env,  
 const char \*name);

The function **DeleteRouter** removes previously created router. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the string used to identify the router when it was added using **AddRouter**. The function returns true if the router was successfully deleted; otherwise, it returns false.

### 9.6.3 Activating and Deactivating Routers

bool ActivateRouter(  
 Environment \*env,  
 const char \*name);

bool DeactivateRouter(  
 Environment \*env,  
 const char \*name);

The function **ActivateRouter** activates the I/O router specified by parameter **name** (the string used to identify the router when it was created using **AddRouter**). The activated router will be queried to see if it can handle an I/O re­quest. Newly created routers do not have to be activated. This function returns true if the router exists and was successfully activated; otherwise, false is returned.

The function **DeactivateRouter** deactivates the I/O router specified by parameter **name** (the string used to identify the router when it was created using **AddRouter**). The deactivated router will not be queried to see if it can handle an I/O re­quest. This function returns true if the router exists and was successfully deactivated; otherwise, false is returned.

## 9.7 Examples

The following examples demonstrate the use of the I/O router system. These exam­ples show the necessary C code for implementing the basic capabilities described.

### 9.7.1 Dribble System

Write the necessary functions that will divert all error information to the file named "error.txt".

/\*

First of all, we need to create an environment data structure for storing a file pointer to the dribble file which will contain the error information. The data position is offset to prevent conflict with other examples in this document. We also need to declare prototypes for the functions used in this example.

\*/

#include <stdio.h>

#include <stdlib.h>

#include "clips.h"

#define DRIBBLE\_DATA USER\_ENVIRONMENT\_DATA + 1

struct dribbleData

{

FILE \*traceFP;

};

#define DribbleData(theEnv) \

((struct dribbleData \*) GetEnvironmentData(theEnv,DRIBBLE\_DATA))

bool QueryTraceCallback(Environment \*,const char \*,void \*);

void WriteTraceCallback(Environment \*,const char \*,const char \*,void \*);

void ExitTraceCallback(Environment \*environment,int,void \*);

void TraceOn(Environment \*,UDFContext \*,UDFValue \*);

void TraceOff(Environment \*,UDFContext \*,UDFValue \*);

/\*

We want to recognize any output that is sent to the logical name STDERR because all tracing information is sent to this logical name. The query function for our router is defined below.

\*/

bool QueryTraceCallback(

Environment \*environment,

const char \*logicalName,

void \*context)

{

if (strcmp(logicalName,STDERR) == 0) return(true);

return(false);

}

/\*

We now need to define a function which will print the tracing in¬formation to our trace file. The print function for our router is defined below. The context argument is used to retrieve the FILE pointer that will be supplied when AddRouter is called.

\*/

void WriteTraceCallback(

Environment \*environment,

const char \*logicalName,

const char \*str,

void \*context)

{

FILE \*theFile = (FILE \*) context;

fprintf(theFile,"%s",str);

}

/\*

When we exit CLIPS the trace file needs to be closed. The exit function for our router is defined below. The context argument is used to retrieve the FILE pointer that will be supplied when AddRouter is called.

\*/

void ExitTraceCallback(

Environment \*environment,

int exitCode,

void \*context)

{

FILE \*theFile = (FILE \*) context;

fclose(theFile);

}

/\*

There is no need to define a get character or ungetc character function since this router does not handle input.

A function to turn the trace mode on needs to be defined. This function will check if the trace file has already been opened. If the file is already open, then nothing will happen. Otherwise, the trace file will be opened and the trace router will be creat¬ed. This new router will intercept tracing information intended for the user interface and send it to the trace file. The trace on function is defined below.

\*/

void TraceOn(

Environment \*environment,

UDFContext \*context,

UDFValue \*returnValue)

{

if (DribbleData(environment)->traceFP == NULL)

{

DribbleData(environment)->traceFP = fopen("error.txt","w");

if (DribbleData(environment)->traceFP == NULL)

{

returnValue->lexemeValue = environment->FalseSymbol;

return;

}

}

else

{

returnValue->lexemeValue = environment->FalseSymbol;

return;

}

AddRouter(environment,

"trace", /\* Router name \*/

20, /\* Priority \*/

QueryTraceCallback, /\* Query function \*/

WriteTraceCallback, /\* Write function \*/

NULL, /\* Read function \*/

NULL, /\* Unread function \*/

ExitTraceCallback, /\* Exit function \*/

DribbleData(environment)->traceFP); /\* Context \*/

returnValue->lexemeValue = environment->TrueSymbol;

}

/\*

A function to turn the trace mode off needs to be defined. This function will check if the trace file is already closed. If the file is already closed, then nothing will happen. Otherwise, the trace router will be deleted and the trace file will be closed. The trace off function is defined below.

\*/

void TraceOff(

Environment \*environment,

UDFContext \*context,

UDFValue \*returnValue)

{

if (DribbleData(environment)->traceFP != NULL)

{

DeleteRouter(environment,"trace");

if (fclose(DribbleData(environment)->traceFP) == 0)

{

DribbleData(environment)->traceFP = NULL;

returnValue->lexemeValue = environment->TrueSymbol;

return;

}

}

DribbleData(environment)->traceFP = NULL;

returnValue->lexemeValue = environment->FalseSymbol;

}

/\*

Now add the definitions for these functions to the UserFunctions func­tion in file "userfunctions.c".

\*/

void UserFunctions(

Environment \*env)

{

if (! AllocateEnvironmentData(env,DRIBBLE\_DATA,

sizeof(struct dribbleData),NULL))

{

printf("Error allocating environment data for DRIBBLE\_DATA\n");

exit(EXIT\_FAILURE);

}

AddUDF(env,"tron","b",0,0,NULL,TraceOn,"tron",NULL);

AddUDF(env,"troff","b",0,0,NULL,TraceOff,"troff",NULL);

}

/\*

Compile and link the appropriate files. The trace functions should now be accessible within CLIPS as external functions. For Example:

CLIPS> (tron)

TRUE

CLIPS> (+ 2 3)

5

CLIPS> (\* 3 a)

CLIPS> (troff)

TRUE

CLIPS> (exit)

The file error.txt will now contain the following text:

[ARGACCES5] Function \* expected argument #2 to be of type integer or float

\*/

### 9.7.2 Better Dribble System

Modify example 1 so the error information is sent to the terminal as well as to the dribble file.

/\*

This example requires a modification of the WriteTraceCallback function. After the error string is printed to the file, the trace router must be deactivated. The error string can then be sent through the WriteString function so that the next router in line can handle the output. After this is done, then the trace router can be reactivated.

\*/

void WriteTraceCallback(

Environment \*environment,

const char \*logicalName,

const char \*str,

void \*context)

{

FILE \*theFile = (FILE \*) context;

fprintf(theFile,"%s",str);

DeactivateRouter(environment,"trace");

WriteString(environment,logicalName,str);

ActivateRouter(environment,"trace");

}

/\*

The TraceOn function must also be modified. The priority of the router should be 40 instead of 20 since the router passes the output along to other routers.

\*/

void TraceOn(

Environment \*environment,

UDFContext \*context,

UDFValue \*returnValue)

{

if (DribbleData(environment)->traceFP == NULL)

{

DribbleData(environment)->traceFP = fopen("error.txt","w");

if (DribbleData(environment)->traceFP == NULL)

{

returnValue->lexemeValue = environment->FalseSymbol;

return;

}

}

else

{

returnValue->lexemeValue = environment->FalseSymbol;

return;

}

AddRouter(environment,

"trace", /\* Router name \*/

40, /\* Priority \*/

QueryTraceCallback, /\* Query function \*/

WriteTraceCallback, /\* Write function \*/

NULL, /\* Read function \*/

NULL, /\* Unread function \*/

ExitTraceCallback, /\* Exit function \*/

DribbleData(environment)->traceFP); /\* Context \*/

returnValue->lexemeValue = environment->TrueSymbol;

}

### 9.7.3 Batch System

Write the necessary functions that will allow batch input from the file "batch.txt" to the CLIPS top‑level interface. ***Note that this example only works in the console version of CLIPS***.

/\*

First of all, we need a file pointer to the batch file which will contain the batch command information.

\*/

#include <stdio.h>

#include <stdlib.h>

#include "clips.h"

#define BATCH\_DATA USER\_ENVIRONMENT\_DATA + 2

struct batchData

{

FILE \*batchFP;

StringBuilder \*batchBuffer;

};

#define BatchData(theEnv) \

((struct batchData \*) GetEnvironmentData(theEnv,BATCH\_DATA))

bool QueryMybatchCallback(Environment \*,const char \*,void \*);

int ReadMybatchCallback(Environment \*,const char \*,void \*);

int UnreadMybatchCallback(Environment \*,const char \*,int,void \*);

void ExitMybatchCallback(Environment \*environment,int,void \*);

void MybatchOn(Environment \*,UDFContext \*,UDFValue \*);

/\*

We want to recognize any input requested from the logical name "stdin" because all user input is received from this logical name. The recognizer function for our router is defined below.

\*/

bool QueryMybatchCallback(

Environment \*environment,

const char \*logicalName,

void \*context)

{

if (strcmp(logicalName,STDIN) == 0) return true;

return false;

}

/\*

We now need to define a function which will get and unget charac­ters from our batch file. The get and ungetc character functions for our router are defined below.

\*/

int ReadMybatchCallback(

Environment \*environment,

const char \*logicalName,

void \*context)

{

int rv;

rv = getc(BatchData(environment)->batchFP);

if (rv == EOF)

{

Write(environment,BatchData(environment)->batchBuffer->contents);

SBDispose(BatchData(environment)->batchBuffer);

BatchData(environment)->batchBuffer = NULL;

DeleteRouter(environment,"mybatch");

fclose(BatchData(environment)->batchFP);

return ReadRouter(environment,logicalName);

}

SBAddChar(BatchData(environment)->batchBuffer,rv);

if ((rv == '\n') || (rv == '\r'))

{

Write(environment,BatchData(environment)->batchBuffer->contents);

SBReset(BatchData(environment)->batchBuffer);

}

return rv;

}

int UnreadMybatchCallback(

Environment \*environment,

const char \*logicalName,

int ch,

void \*context)

{

SBAddChar(BatchData(environment)->batchBuffer,'\b');

return ungetc(ch,BatchData(environment)->batchFP);

}

/\*

When we exit CLIPS the batch file needs to be closed. The exit function for our router is defined below.

\*/

void ExitMybatchCallback(

Environment \*environment,

int exitCode,

void \*context)

{

FILE \*theFile = (FILE \*) context;

if (BatchData(environment)->batchBuffer != NULL)

{

SBDispose(BatchData(environment)->batchBuffer);

BatchData(environment)->batchBuffer = NULL;

}

fclose(theFile);

}

/\*

There is no need to define a print function since this router does not handle output except for echoing the command line.

Now we define a function that turns the batch mode on.

\*/

void MybatchOn(

Environment \*environment,

UDFContext \*context,

UDFValue \*returnValue)

{

BatchData(environment)->batchFP = fopen("batch.txt","r");

if (BatchData(environment)->batchFP == NULL)

{

returnValue->lexemeValue = environment->FalseSymbol;

return;

}

if (BatchData(environment)->batchBuffer == NULL)

{ BatchData(environment)->batchBuffer = CreateStringBuilder(environment,80); }

AddRouter(environment,

"mybatch", /\* Router name \*/

20, /\* Priority \*/

QueryMybatchCallback, /\* Query function \*/

NULL, /\* Write function \*/

ReadMybatchCallback, /\* Read function \*/

UnreadMybatchCallback, /\* Unread function \*/

ExitMybatchCallback, /\* Exit function \*/

BatchData(environment)->batchFP); /\* context \*/

returnValue->lexemeValue = environment->TrueSymbol;

}

/\*

Now add the definition for this function to the UserFunctions function in file "userfunctions.c".

\*/

void UserFunctions(

Environment \*env)

{

if (! AllocateEnvironmentData(env,BATCH\_DATA,

sizeof(struct batchData),NULL))

{

printf("Error allocating environment data for BATCH\_DATA\n");

exit(EXIT\_FAILURE);

}

AddUDF(env,"mybatch","b",0,0,NULL,MybatchOn,"MybatchOn",NULL);

}

/\*

Compile and link the appropriate files. The batch function should now be accessible within CLIPS as external function. For Example, create the file batch.txt with the

following content:

(+ 2 3)

(\* 4 5)

Launch CLIPS and enter a (mybatch) command:

CLIPS> (mybatch)

TRUE

CLIPS> (+ 2 3)

5

CLIPS> (\* 4 5)

20

CLIPS>

\*/

### 9.7.4 Simple Window System

Write the necessary functions using CURSES (a screen management function available in UNIX) that will allow a top/bottom split screen interface. Output sent to the logical name **top** will be printed in the upper win­dow. All other screen I/O should go to the lower window. (NOTE: Use of CURSES may require linking with special libraries. On UNIX systems try using –lcurses when linking.)

/\*

First of all, we need some pointers to the windows and a flag to indicate that the windows have been initialized.

\*/

#include <stdio.h>

#include <stdlib.h>

#include <curses.h>

#include "clips.h"

#define CURSES\_DATA USER\_ENVIRONMENT\_DATA + 3

struct cursesData

{

WINDOW \*lowerWindow, \*upperWindow;

bool windowsInitialized;

bool useSave;

int saveChar;

bool sendReturn;

char buffer[512];

int charLocation;

};

#define CursesData(theEnv) \

((struct cursesData \*) GetEnvironmentData(theEnv,CURSES\_DATA))

bool QueryScreenCallback(Environment \*,const char \*,void \*);

void WriteScreenCallback(Environment \*,const char \*,const char \*,void \*);

int ReadScreenCallback(Environment \*,const char \*,void \*);

int UnreadScreenCallback(Environment \*,const char \*,int,void \*);

void ExitScreenCallback(Environment \*environment,int,void \*);

void ScreenOn(Environment \*,UDFContext \*,UDFValue \*);

void ScreenOff(Environment \*,UDFContext \*,UDFValue \*);

/\*

We want to intercept any I/O requests that the standard interface would handle. In addition, we also need to handle requests for the logical name top. The recognizer function for our router is defined below.

\*/

bool QueryScreenCallback(

Environment \*environment,

const char \*logicalName,

void \*context)

{

if ((strcmp(logicalName,STDOUT) == 0) ||

(strcmp(logicalName,STDIN) == 0) ||

(strcmp(logicalName,STDERR) == 0) ||

(strcmp(logicalName,STDWRN) == 0) ||

(strcmp(logicalName,"top") == 0) )

{ return true; }

return false;

}

/\*

We now need to define a function which will print strings to the two windows. The print function for our router is defined below.

\*/

void WriteScreenCallback(

Environment \*environment,

const char \*logicalName,

const char \*str,

void \*context)

{

struct cursesData \*theData = (struct cursesData \*) context;

if (strcmp(logicalName,"top") == 0)

{

wprintw(theData->upperWindow,"%s",str);

wrefresh(theData->upperWindow);

}

else

{

wprintw(theData->lowerWindow,"%s",str);

wrefresh(theData->lowerWindow);

}

}

/\*

We now need to define a function which will get and unget characters from the lower window. CURSES uses unbuffered input so we will simulate buffered input for CLIPS. The get and ungetc char­acter functions for our router are defined below.

\*/

int ReadScreenCallback(

Environment \*environment,

const char \*logicalName,

void \*context)

{

struct cursesData \*theData = (struct cursesData \*) context;

int rv;

if (theData->useSave)

{

theData->useSave = false;

return theData->saveChar;

}

if (theData->buffer[theData->charLocation] == '\0')

{

if (theData->sendReturn == false)

{

theData->sendReturn = true;

return '\n';

}

wgetnstr(theData->lowerWindow,&theData->buffer[0],511);

theData->charLocation = 0;

}

rv = theData->buffer[theData->charLocation];

if (rv == '\0') return '\n';

theData->charLocation++;

theData->sendReturn = false;

return rv;

}

int UnreadScreenCallback(

Environment \*environment,

const char \*logicalName,

int ch,

void \*context)

{

struct cursesData \*theData = (struct cursesData \*) context;

theData->useSave = true;

theData->saveChar = ch;

return ch;

}

/\*

When we exit CLIPS CURSES needs to be deactivated. The exit function for our router is defined below.

\*/

void ExitScreenCallback(

Environment \*environment,

int exitCode,

void \*context)

{

endwin();

}

/\*

Now define a function that turns the screen mode on.

\*/

void ScreenOn(

Environment \*environment,

UDFContext \*context,

UDFValue \*returnValue)

{

int halfLines, i;

/\* Has initialization already occurred? \*/

if (CursesData(environment)->windowsInitialized)

{

returnValue->lexemeValue = environment->FalseSymbol;

return;

}

/\* Reroute I/O and initialize CURSES. \*/

initscr();

echo();

CursesData(environment)->windowsInitialized = true;

CursesData(environment)->useSave = false;

CursesData(environment)->sendReturn = true;

CursesData(environment)->buffer[0] = '\0';

CursesData(environment)->charLocation = 0;

AddRouter(environment,

"screen", /\* Router name \*/

10, /\* Priority \*/

QueryScreenCallback, /\* Query function \*/

WriteScreenCallback, /\* Write function \*/

ReadScreenCallback, /\* Read function \*/

UnreadScreenCallback, /\* Unread function \*/

ExitScreenCallback, /\* Exit function \*/

CursesData(environment)); /\* Context \*/

/\* Create the two windows. \*/

halfLines = LINES / 2;

CursesData(environment)->upperWindow = newwin(halfLines,COLS,0,0);

CursesData(environment)->lowerWindow = newwin(halfLines - 1,COLS,halfLines + 1,0);

/\* Both windows should be scrollable. \*/

scrollok(CursesData(environment)->upperWindow,TRUE);

scrollok(CursesData(environment)->lowerWindow,TRUE);

/\* Separate the two windows with a line. \*/

for (i = 0 ; i < COLS ; i++)

{ mvaddch(halfLines,i,'-'); }

refresh();

wclear(CursesData(environment)->upperWindow);

wclear(CursesData(environment)->lowerWindow);

wmove(CursesData(environment)->lowerWindow,0,0);

returnValue->lexemeValue = environment->TrueSymbol;

}

/\*

Now define a function that turns the screen mode off.

\*/

void ScreenOff(

Environment \*environment,

UDFContext \*context,

UDFValue \*returnValue)

{

/\* Is CURSES already deactivated? \*/

if (CursesData(environment)->windowsInitialized == false)

{

returnValue->lexemeValue = environment->FalseSymbol;

return;

}

CursesData(environment)->windowsInitialized = false;

/\* Remove I/O rerouting and deactivate CURSES. \*/

DeleteRouter(environment,"screen");

endwin();

returnValue->lexemeValue = environment->TrueSymbol;

}

/\*

Now add the definitions for these functions to the UserFunctions func­tion in file "userfunctions.c".

\*/

void UserFunctions(

Environment \*env)

{

if (! AllocateEnvironmentData(env,CURSES\_DATA,

sizeof(struct cursesData),NULL))

{

printf("Error allocating environment data for CURSES\_DATA\n");

exit(EXIT\_FAILURE);

}

AddUDF(env,"screen-on","b",0,0,NULL,ScreenOn,"ScreenOn",NULL);

AddUDF(env,"screen-off","b",0,0,NULL,ScreenOff,"ScreenOff",NULL);

}

/\*

Compile and link the appropriate files. The screen functions should now be accessible within CLIPS as external functions. For Example

CLIPS> (screen-on)

CLIPS> (printout top "Hello World" crlf)

•

•

•

CLIPS> (screen-off)

\*/

# Section 10: Environments

CLIPS provides the ability to create multiple environments into which programs can be loaded and run. Each environment maintains its own set of data structures and can be run independently of the other environments. In many cases, the program’s main function will create a single environment to be used as the argument for all embedded API calls. In other cases, such as creating shared libraries or DLLs, new instances of environments will be created as they are needed.

## 10.1 Creating and Destroying Environments

Environments are created using the **CreateEnvironment** function. The return value of the **CreateEnvironment** function is an anonymous (void \*) pointer to an **environmentData** data structure. This pointer should be used for the embedded API function calls require an environment pointer argument.

If you have integrated code with CLIPS and use multiple concurrent environments, any functions or extensions which use global data should allocate this data for each environment by using the **AllocateEnvironmentData** function, otherwise one environment may overwrite the data used by another environment.

Once you are done with an environment, it can be deleted with the **DestroyEnvironment** function call. This will deallocate all memory associated with that environment.

The following is an of example of a main program which makes use of multiple environments:

#include "clips.h"

int main()

{

Environment \*theEnv1, \*theEnv2;

theEnv1 = CreateEnvironment();

theEnv2 = CreateEnvironment();

Load(theEnv1,"program1.clp");

Load(theEnv2,"program2.clp");

Reset(theEnv1);

Reset(theEnv2);

Run(theEnv1,-1);

Run(theEnv2,-1);

DestroyEnvironment(theEnv1);

DestroyEnvironment(theEnv2);

}

## 10.2 Standard Environment Functions

The following functions are used to create and manipulate environments. Prototypes for these functions can be included by using the **clips.h** header file or the **envrnmnt.h** header file.

### 10.2.1 Allocating Environment Data

bool AllocateEnvironmentData(  
 Environment \*env,  
 unsigned id,  
 size\_t size,  
 EnvironmentCleanupFunction f);

bool AddEnvironmentCleanupFunction(  
 Environment \*env,  
 const char \*name,  
 EnvironmentCleanupFunction f,  
 int p);

typedef void EnvironmentCleanupFunction(  
 Environment \*environment);

The function **AllocateEnvironmentData** allocates memory for storage of data in an environment. Parameter **env** is a pointer to a previously created environment; parameter **id** is an integer that uniquely identifies the data for other functions which reference it; parameter **size** is the amount of memory allocated; and parameter **f** is a callback function invoked when an environment is destroyed. The lowest integer value available for use by user code for the **id** parameter value is specified by the constant USER\_ENVIRONMENT\_DATA. This function returns true if the environment data was successfully allocated; otherwise, it returns false.

If the **f** parameter value is not a null pointer, then the specified callback function is invoked when the associated environment is destroyed. CLIPS automatically handles the allocation and deallocation of the base storage for environment data (the amount of data specified by the **size** parameter value). If the base storage includes pointers to memory allocated by user code, then this should be deallocated either by an **EnvironmentCleanupFunction** function specified by this function or the function **AddEnvironmentCleanupFunction**.

Environment cleanup functions specified using by the **AllocateEnvironmentData** function are called in ascending order of their **id** parameter value. If the deallocation of your environment data has order dependencies, you can either assign the ids appropriately to achieve the proper order or you can use the **AddEnvironmentCleanupFunction** function to more explicitly specify the order in which your environment data must be deallocated.

The function **AddEnvironmentCleanupFunction** adds a callback function to the list of functions invoked when an environment is destroyed. Parameter **env** is a pointer to a previously created environment; parameter **name** is a string that uniquely identifies the callback; parameter **f** is a pointer to the callback function of type **EnvironmentCleanupFunction**; and parameter **p** is the priority of the callback function. The **priority** parameter determines the order in which the callback functions are invoked (higher priority items are called first); the values -2000 to 2000 are reserved for internal use by CLIPS. This function returns true if the callback function was successfully added; otherwise, it returns false.

Environment cleanup functions created using this function are called after all the cleanup functions associated with environment data created using **AllocateEnvironmentData** have been called.

### 10.2.2 Retrieving Environment Data

void \*GetEnvironmentData(  
 Environment \*env,  
 unsigned id);

The function **GetEnvironmentData** returns a pointer to the environment data associated with the identifier specified by parameter **id**.

## 10.3 Allocating Environment Data

If your user-defined functions (or other extensions) make use of global data that could differ for each environment, you should allocate this data with the **AllocateEnvironmentData** function. A call to this function has four arguments. The first is a generic pointer to the environment to which the data is being added.

The second argument is the integer position index. This is the value that you will pass in to the **GetEnvironmentData** function to retrieve the allocated environment data. This position index must be unique and if you attempt to use an index that has already been allocated, then the call to **AllocateEnvironmentData** will fail returning FALSE. To avoid collisions with environment positions predefined by CLIPS, use the macro constant USER\_ENVIRONMENT\_DATA as the base index for any position indices you define. This constant will always be greater than the largest predefined position index used by CLIPS. The maximum number of environment position indices is specified by the macro constant MAXIMUM\_ENVIRONMENT\_POSITIONS found in the envrnmnt.h header file. A call to **AllocateEnvironmentData** will fail if the position index is greater than or equal this value. If this happens, you can simply increase the value of this macro constant to provide more environment positions.

The third argument is an integer indicating the size of the environment data that needs to be allocated. Typically you’ll define a struct containing the various values you want stored in the environment data and use the sizeof operator to pass in the size of the struct to the function. When an environment is created directly using **CreateEnvironment**, CLIPS automatically allocates memory of the size specified, initializes the memory to contain all zeroes, and stores the memory in the environment position associated with position index. When the environment is destroyed using **DestroyEnvironment**, CLIPS automatically deallocates the memory originally allocated for each environment data position. If the environment data contains pointers to memory that you allocate, it is your responsibility to deallocate this memory. You can do this by either specifying a cleanup function as the fourth argument in your **AllocateEnvironmentData** call or by adding a cleanup function using the **AddEnvironmentCleanupFunction** function.

The fourth argument is a pointer to a cleanup function. If this argument is not NULL, then the cleanup function associated with this environment position is called whenever an environment is deallocated using the **DestroyEnvironment** function. The cleanup functions are called in ascending order of the position indices.

As an example of allocating environment data, we’ll look at a **get-index** function that returns an integer index starting with one and increasing by one each time it is called. For example:

CLIPS> (get-index)

1

CLIPS> (get-index)

2

CLIPS> (get-index)

3

CLIPS>

Each environment will need global data to store the current value of the index. The C source code that implements the environment data first needs to specify the position index and specify a data structure for storing the data:

#define INDEX\_DATA USER\_ENVIRONMENT\_DATA + 0

struct indexData

{

long index;

};

#define IndexData(theEnv) \

((struct indexData \*) GetEnvironmentData(theEnv,INDEX\_DATA))

First, the position index GET\_INDEX\_DATA is defined as USER\_ENVIRONMENT\_DATA with an offset of zero. If you were to define additional environment data, the offset would be increased each time by one to get to the next available position. Next, the *indexData* struct is defined. This struct contains a single member, *index*, which will use to store the next value returned by the **get-index** function. Finally, the IndexData macro is defined which merely provides a convenient mechanism for access to the environment data.

The next step in the C source code is to add the initialization code to the **UserFunctions** function:

void UserFunctions(

Environment \*env)

{

if (! AllocateEnvironmentData(env,INDEX\_DATA,

sizeof(struct indexData),NULL))

{

Writeln(env,"Error allocating environment data for INDEX\_DATA");

ExitRouter(env,EXIT\_FAILURE);

}

IndexData(env)->index = 1;

AddUDF(env,"get-index","l",0,0,NULL,GetIndex,"GetIndex",NULL);

}

First, the call to **AllocateEnvironmentData** is made. If this fails, then an error message is printed and a call to **ExitRouter** is made to terminate the program. Otherwise, the *index* member of the environment data is initialized to one. If a starting value of zero was desired, it would not be necessary to perform any initialization since the value of *index* is automatically initialized to zero when the environment data is initialized. Finally, **AddUDF** is called to register the **get-index** function.

The last piece of the C source code is the **GetIndex** C function which implements the **get-index** function:

void GetIndex(Environment \*,UDFContext \*,UDFValue \*);

void GetIndex(

Environment \*env,

UDFContext \*context,

UDFValue \*returnValue)

{

returnValue->integerValue = CreateInteger(env,IndexData(env)->index++);

}

# Section 11: Creating a CLIPS Run‑time Program

## 11.1 Compiling the Constructs

This section describes the procedure for creating a CLIPS run‑time module‑. A run‑time program compiles all of the constructs (defrule, deffacts, deftemplate, etc.) into a single executable and reduces the size of the executable image. A run-time program will not run any faster than a program loaded using the **load** or **bload** commands. The **constructs-to-c** command used to generate a run-time program creates files containing the C data structures that would dynamically be allocated if the **load**; or **bload** command was used. With the exception of some initialization routines, the **constructs-to-c** command does not generate any executable code. The primary benefits of creating a run-time program are: applications can be delivered as a single executable file; loading constructs as part of an executable is faster than loading them from an text or binary file; the CLIPS portion of the run-time program is smaller because the code needed to parse constructs can be discarded; and less memory is required to represent your program’s constructs since memory for them is statically rather than dynamically allocated.

Creating a run‑time module can be achieved with the following steps:

1) Start CLIPS and load in all of the constructs that will constitute a run‑time module. Call the **constructs‑to‑c**‑‑ command using the following syntax:

(constructs‑to‑c <file‑name> <id> [<target-path> [<max-elements>]])

where <file‑name> is a string or a symbol, <id> is an integer, <target-path> is a string or symbol, and the <max-elements> is an integer. For example, if the construct file loaded was named "expert.clp", the conversion command might be

(constructs‑to‑c exp 1)

This command would store the converted constructs in several output files ("exp1\_1.c", "exp1\_2.c", ... , "exp7\_1.c") and use a module id of 1 for this collection of constructs. The use of the module id will be discussed in greater detail later. Once the con­version is complete, exit CLIPS. For large systems, this output may be *very* large (> 200K). If <target‑path> is specified, it is prepended to the name of the file when it is created, allowing target directory to be specified for the generated files. For example, specifying the target path Temp\ on a Unix system would place the generated files in the directory Temp (assuming that it already exists).

It is possible to limit the size of the generated files by using the <max‑elements> argument. This argument indicates the maximum number of structures which may be placed in a single array stored in a file. Where possible, if this number is exceeded new files will be created to store additional information. This feature is useful for compilers that may place a limitation on the size of a file that may be compiled.

Note that the .c extension is added by CLIPS. When giving the file name prefix, users should consider the maximum number of characters their system allows in a file name.

Constraint information associated with constructs is not saved to the C files generated by the **constructs-to-c** command unless dynamic constraint checking is enabled (using the **set-dynamic-constraint-checking** command).

2) Set the RUN\_TIME setup flag in the **setup.h** header file to 1 and compile all of the c files just generated.

3) Modify the **main.c** module for embedded operation. Unless the user has other specific uses, the argc and argv arguments to the main function should be elimi­nated. Also do *not* call the **CommandLoop** or **RerouteStdin** functions which are normally called from the **main** function of a command line version of CLIPS. Do *not* define any functions in **UserFunctions** functions. These functions are not called during initialization. All of the function definitions have already been compiled in the 'C' constructs code. In order for your run-time program to be loaded, a function must be called to initialize the constructs module. This function is defined in the 'C' constructs code, and its name is dependent upon the id used when translating the constructs to 'C' code. The name of the function is **InitCImage\_<id>** where <id> is the integer used as the construct module <id>. In the example above, the function name would be **InitCImage\_1**. The return value of this function is a pointer to an environment (see section 9) which was created and initialized to contain your run-time program. This initialization steps probably would be followed by any user initialization, then by a reset and run. Finally, when you are finished with a run-time module, you can call **DestroyEnvironment** to remove it. An example **main.c** file would be

#include <stdio.h>  
#include "clips.h"  
  
main()  
 {

Environment \*env;

extern Environment \*InitCImage\_1(void);

env = InitCImage\_1();

•  
 • /\* Any user Initialization \*/  
 •  
 Reset(env);

Run(env,-1);

•  
 • /\* Any other code \*/  
 •

DestroyEnvironment(env);  
 }

4) Recompile all of the CLIPS source code (the RUN\_TIME flag should still be 1). This causes several modifications in the CLIPS code. The run‑time CLIPS module does not have the capability to load new constructs. Do NOT change any other compiler flags.

5) Link all regular CLIPS modules together with any user‑defined function modules and the 'C' construct modules. Any user-defined functions must have global scope.

6) The run‑time module which includes user constructs is now ready to run.

Note that individual constructs may not be added or removed in a run‑time environment. Because of this, the **load** function is not available for use in run-time programs. The clear command will also not remove any constructs (although it will clear facts and instances). Use calls to the InitCImage­\_... functions to clear the environment and replace it with a new set of constructs. In addition, the **build** function does not work in a run‑time environment.

Since new constructs can’t be added, a run-time program can’t dynamically load a deffacts or definstances construct. To dynamically load facts and/or instances in a run-time program, the CLIPS **load-facts** and **load-instances** functions or the C **LoadFacts** and **LoadInstances** functions should be used in place of deffacts and definstances constructs.

 Important Note

Each call to separate **InitCImage** functions creates a unique environment into which the run-time program is loaded. Only the first call to a given **InitCImage** function will create an environment containing the specified run-time program. Subsequent calls have no effect and a value of NULL is returned by the function. Once the **DestroyEnvironment** function has been called to remove an environment created by an **InitCImage** call, there is no way to reload the run‑time program.

# Section 12: Embedding CLIPS

CLIPS was designed to be embedded within other programs. When CLIPS is used as an em­bedded application­, the user must provide a main program. Calls to CLIPS are made like any other subroutine. To embed CLIPS, add the following include state­ments to the user’s main program file:

#include "clips.h"

Most of the embedded API function calls require an environment pointer argument. Each environment represents a single instance of the CLIPS engine which can load and run a program. A program must create at least one environment in order to make embedded API calls. In many cases, the program’s main function will create a single environment to be used as the argument for all embedded API calls. In other cases, such as creating shared libraries or DLLs, new instances of environments will be created as they are needed. New environments can be created by calling the function **CreateEnvironment** (see section 9).

To create an embedded program, compile and link all of the user’s code with all CLIPS files *except* **main.c**. If a library is being created, it may be necessary to use different link options or compile and link “wrapper” source code with the CLIPS source files. Otherwise, the embedded program must provide a replacement main function for the one normally provided by CLIPS.

When running CLIPS as an embedded pro­gram, many of the capabilities available in the interactive interface (in addition to others) are available through function calls. The functions are documented in the following sec­tions. Prototypes for these functions can be included by using the **clips.h** header file.

## 12.1 Environment Functions

The following function calls control the CLIPS environment:

### 12.1.1 Clear Callback Functions

bool AddClearFunction(  
 Environment \*env,  
 const char \*name,  
 VoidCallFunction \*f,  
 int p,  
 void \*context);

bool RemoveClearFunction(  
 Environment \*env,  
const char \*name);

typedef void VoidCallFunction(  
 Environment \*env,   
 void \*context);

The function **AddClearFunction** adds a callback function to the list of functions invoked when the CLIPS **clear** command is executed. Parameter **env** is a pointer to a previously created environment; parameter **name** is a string that uniquely identifies the callback for removal using **RemoveClearFunction**; parameter **f** is a pointer to the callback function of type **VoidCallFunction**; parameter **p** is the priority of the callback function; and parameter **context** is a user supplied pointer to data that is passed to the callback function when it is invoked (a null pointer should be used if there is no data that needs to be passed to the callback function). The **priority** parameter determines the order in which the callback functions are invoked (higher priority items are called first); the values -2000 to 2000 are reserved for internal use by CLIPS. This function returns true if the callback function was successfully added; otherwise, it returns false.

The function **RemoveClearFunction** removes a callback function from the list of functions invoked when the CLIPS **clear** command is executed. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the string used to identify the callback when it was added using **AddClearFunction**. The function returns true if the callback was successfully removed; otherwise, it returns false.

### 12.1.2 Periodic Callback Functions

bool AddPeriodicFunction(   
 Environment \*env,  
 const char \*name  
 VoidCallFunction \*f,  
 int p,  
 void \*context);

bool RemovePeriodicFunction(  
 Environment \*env,  
const char \*name);

typedef void VoidCallFunction(  
 Environment \*env,   
 void \*context);

The function **AddPeriodicFunction** adds a callback function to the list of functions invoked periodically when CLIPSis executing. Among other possible uses, this functionality allows event processing during execution when CLIPS is embedded within an application that must periodically perform tasks. Care should be taken not to use any operations in a periodic function which would affect CLIPS data structures constructively or destructively, i.e. CLIPS internals may be examined but not modified during a periodic callback.

Parameter **env** is a pointer to a previously created environment; parameter **name** is a string that uniquely identifies the callback for removal using **RemovePeriodicFunction**; parameter **f** is a pointer to the callback function of type **VoidCallFunction**; parameter **p** is the priority of the callback function; and parameter **context** is a user supplied pointer to data that is passed to the callback function when it is invoked (a null pointer should be used if there is no data that needs to be passed to the callback function). The **priority** parameter determines the order in which the callback functions are invoked (higher priority items are called first); the values -2000 to 2000 are reserved for internal use by CLIPS. This function returns true if the callback function was successfully added; otherwise, it returns false.

The function **RemovePeriodicFunction** removes a callback function from the list of functions invoked periodically when CLIPS is executing. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the string used to identify the callback when it was added using **AddPeriodicFunction**. The function returns true if the callback was successfully removed; otherwise, it returns false.

### 12.1.3 Reset Callback Functions

bool AddResetFunction(  
 Environment \*env,  
 const char \*name,  
 VoidCallFunction \*f,  
 int p,  
 void \*context);

bool RemoveResetFunction(  
 Environment \*env,  
const char \*name);

typedef void VoidCallFunction(  
 Environment \*env,   
 void \*context);

The function **AddResetFunction** adds a callback function to the list of functions invoked when the CLIPS **reset** command is executed. Parameter **env** is a pointer to a previously created environment; parameter **name** is a string that uniquely identifies the callback for removal using **RemoveResetFunction**; parameter **f** is a pointer to the callback function of type **VoidCallFunction**; parameter **p** is the priority of the callback function; and parameter **context** is a user supplied pointer to data that is passed to the callback function when it is invoked (a null pointer should be used if there is no data that needs to be passed to the callback function). The **priority** parameter determines the order in which the callback functions are invoked (higher priority items are called first); the values -2000 to 2000 are reserved for internal use by CLIPS. This function returns true if the callback function was successfully added; otherwise, it returns false.

The function **RemoveResetFunction** removes a callback function from the list of functions invoked when the CLIPS **reset** command is executed. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the string used to identify the callback when it was added using **AddResetFunction**. The function returns true if the callback was successfully removed; otherwise, it returns false.

### 12.1.4 File Operations

bool BatchStar(  
 Environment \*env  
 const char \*fileName);

bool Bload(   
 Environment \*env,  
 const char \*fileName);

bool Bsave(  
 Environment \*env,  
 const char \*fileName);

bool Save(  
 Environment \*env,  
 const char \*fileName);

The function **BatchStar** is the C equivalent of the CLIPS **batch\*** command. The **env** parameter is a pointer to a previously created environment; the **filename** parameter is a full or partial path string to an ASCII or UTF-8 file containing CLIPS functions, commands, and constructs. This function returns true if the file was successfully opened; otherwise, it returns false.

The function **Bload** is the C equivalent of the CLIPS **bload** command. The **env** parameter is a pointer to a previously created environment; the **filename** parameter is a full or partial path string to a binary save file that was created using the C **Bsave** function or the CLIPS **bsave** command. This function returns true if the file was successfully opened; otherwise, it returns false.

The function **Bsave** is the C equivalent of the CLIPS **bsave** command. The **env** parameter is a pointer to a previously created environment; the **filename** parameter is a full or partial path string for the binary save file to be created. This function returns true if the file was successfully created; otherwise, it returns false.

The function **Save** is the C equivalent of the CLIPS **save** command. The **env** parameter is a pointer to a previously created environment; the **fileName** parameter is a full or partial path string for the text save file to be created. This function returns true if the file was successfully created; otherwise, it returns false.

### 12.1.5 Settings

bool GetDynamicConstraintChecking(  
 Environment \*env);

bool GetSequenceOperatorRecognition(  
 Environment \*env);

bool SetDynamicConstraintChecking(  
 Environment \*env,  
 bool b);

bool SetSequenceOperatorRecognition(  
 Environment \*env,  
 bool b);

The function **GetDynamicConstraintChecking** is the C equivalent of the CLIPS **get‑dynamic‑constraint‑checking**‑‑‑ command. The **env** parameter is a pointer to a previously created environment. This function returns true if the dynamic constraint checking behavior is enabled; otherwise, it returns false.

The function **GetSequenceOperatorRecognition** is the C equivalent of the CLIPS **get-sequence-operator-recognition** command. Parameter **env** is a pointer to a previously created environment. This function returns true if the sequence operator recognition behavior is enabled; otherwise, it returns false.

The function **SetDynamicConstraintChecking** is the C equivalent of the CLIPS command **set‑dynamic‑constraint-checking**‑‑. The **env** parameter is a pointer to a previously created environment; the **b** parameter is the new setting for the behavior (either true to enable it or false to disable it). This function returns the old setting for the behavior.

The function **SetSequenceOperatorRecognition** is the C equivalent of the CLIPS **set-sequence-operator-recognition** command. Parameter **env** is a pointer to a previously created environment; and parameter **b** is the new setting for the behavior (either true to enable it or false to disable it). This function returns the old setting for the behavior.

## 12.2 Debugging Functions

The following function call controls the CLIPS debugging aids:

### 12.2.1 DribbleActive

bool DribbleActive(  
 Environment \*env);

The function **DribbleActive** returns true if the environment specified by parameter **env** has an active dribble file for capturing output; otherwise, it returns false.

### 12.2.2 GetWatchState and SetWatchState

bool GetWatchState(  
 Environment \*env,  
 WatchItem item);

void SetWatchState(  
 Environment \*env,  
 WatchItem item,  
 bool b);

typedef enum  
 {  
 ALL,  
 FACTS,  
 INSTANCES,  
 SLOTS,  
 RULES,  
 ACTIVATIONS,  
 MESSAGES,  
 MESSAGE\_HANDLERS,  
 GENERIC\_FUNCTIONS,  
 METHODS,  
 DEFFUNCTIONS,  
 COMPILATIONS,  
 STATISTICS,  
 GLOBALS,  
 FOCUS  
 } WatchItem;

The function **GetWatchState** returns the current state of the watch item specified by the parameter **item** in the environment specified by the parameter **env**: true if the watch item is enabled; otherwise, false. If ALL is specified for the parameter **item**, the return value of this function is undefined.

The function **SetWatchState** sets the state of the watch item specified by the parameter **item** in the environment specified by the parameter **env**. If parameter **b** is true, the watch item is enabled; otherwise, it is disabled. If ALL is specified for the parameter **item**, then all watch items are set to the state specified by parameter **b**.

## 12.3 Deftemplate Functions

The following function calls are used for manipulating deftemplates.

### 12.3.1 Search, Iteration, and Listing

Deftemplate \*FindDeftemplate(  
 Environment \*env,  
 const char \*name);

Deftemplate \*GetNextDeftemplate(  
 Environment \*env,  
 Deftemplate \*d);

void GetDeftemplateList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDeftemplates(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

The function **FindDeftemplate** searches for the deftemplate specified by parameter **name** in the environment specified by parameter **env**. This function returns a pointer to the named deftemplate if it exists; otherwise, it returns a null pointer.

The function **GetNextDeftemplate** provides iteration support for the list of deftemplates in the current module. If parameter **d** is a null pointer, then a pointer to the first **Deftemplate** in the current module is returned by this function; otherwise, a pointer to the next **Deftemplate** following the **Deftemplate** specified by parameter **d** is returned. If parameter **d** is the last **Deftemplate** in the current module, a null pointer is returned.

The function **GetDeftemplateList** is the C equivalent of the CLIPS **get-deftemplate-list** function. Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of deftemplate names—is stored in the **out** parameter value. If parameter **d** is a null pointer, then deftemplates in all modules will be included in parameter **out**; otherwise, only deftemplates in the specified module will be included.

The function **ListDeftemplates** is the C equivalent of the CLIPS **list‑deftemplates**‑ command). Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a defmodule. If parameter **d** is a null pointer, then deftemplates in all modules will be listed; otherwise, only deftemplates in the specified module will be listed.

### 12.3.2 Attributes

const char \*DeftemplateModule(  
 Deftemplate \*d);

const char \*DeftemplateName(  
 Deftemplate \*d);

const char \*DeftemplatePPForm(  
 Deftemplate \*d);

void DeftemplateSlotNames(  
 Deftemplate \*d,  
 CLIPSValue \*out);

The function **DeftemplateModule** is the C equivalent of the CLIPS **deftemplate-module** command. The return value of this function is the name of the module in which the deftemplate specified by parameter **d** is defined.

The function **DeftemplateName** returns the name of the deftemplatespecified by the **d** parameter.

The function **DeftemplatePPForm** returns the text representation of the **Deftemplate** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

The function **DeftemplateSlotNames** is the C equivalent of the CLIPS **deftemplate-slot-names** function. Parameter **d** is a pointer to a **Deftemplate**; and parameter **out** is a pointer to a **CLIPSValue** allocated by the caller. The output of the function call—a multifield containing the deftemplate’s slot names—is stored in the **out** parameter value. For implied deftemplates, a multifield value containing the single symbol *implied* is returned.

### 12.3.3 Deletion

bool DeftemplateIsDeletable(  
 Deftemplate \*d);

bool Undeftemplate(  
 Deftemplate \*d,  
 Environment \*env);

The function **DeftemplateIsDeletable** returns true if the deftemplate specified by parameter **d** can be deleted; otherwise it returns false.

The **Undeftemplate** function is the C equivalent of the CLIPS **undeftemplate** command. It deletes the deftemplate specified by parameter **d**; or if parameter **d** is a null pointer, it deletes all deftemplates in the environment specified by parameter **env**. This function returns true if the deletion is successful; otherwise, it returns false.

### 12.3.4 Watching Deftemplate Facts

bool DeftemplateGetWatch(  
 Deftemplate \*d);

void DeftemplateSetWatch(  
 Deftemplate \*d,  
 bool b);

The function **DeftemplateGetWatch** returns true if facts are being watched for thedeftemplate specified by the **d** parameter value; otherwise, it returns false.

The function **DeftemplateSetWatch** sets the fact watch state for the deftemplate specified by the **d** parameter value to the value specified by the parameter **b**.

### 12.3.5 Slot Attributes

bool DeftemplateSlotAllowedValues(  
 Deftemplate \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool DeftemplateSlotCardinality(  
 Deftemplate \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool DeftemplateSlotRange(  
 Deftemplate \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool DeftemplateSlotDefaultValue(   
 Deftemplate \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool DeftemplateSlotTypes(  
 Deftemplate \*d,  
 const char \*name,  
 CLIPSValue \*out);

The function **DeftemplateSlotAllowedValues** is the C equivalent of the CLIPS **deftemplate-slot‑allowed-values**‑ function. The function **DeftemplateSlotCardinality** is the C equivalent of the CLIPS **deftemplate-slot-cardinality** function. The function **DeftemplateSlotRange** is the C equivalent of the CLIPS **deftemplate-slot‑range**‑ function. The function **DeftemplateSlotDefaultValue** is the C equivalent of the CLIPS **deftemplate-slot-default-value** function. The function **DeftemplateSlotTypes** is the C equivalent of the CLIPS **deftemplate-slot-types** function.

Parameter **d** is a pointer to a **Deftemplate**; parameter **name** specifies a valid slot name for the specified deftemplate; and parameter **out** is a pointer to a **CLIPSValue** allocated by the caller. The output of the function call—a multifield containing the attribute values—is stored in the **out** parameter value. These function return true if a valid slot name was specified and the output value is successfully set; otherwise, false is returned.

### 12.3.6 Slot Predicates

bool DeftemplateSlotExistP(  
 Deftemplate \*d,  
 const char \*name);

bool DeftemplateSlotMultiP(  
 Deftemplate \*d,  
 const char \*name);

bool DeftemplateSlotSingleP(  
 Deftemplate \*d,  
 const char \*name);

DefaultType DeftemplateSlotDefaultP(  
 Deftemplate \*deftemplatePtr,  
 const char \*slotName);

typedef enum  
 {  
 NO\_DEFAULT,  
 STATIC\_DEFAULT,  
 DYNAMIC\_DEFAULT  
 } DefaultType;

The function **DeftemplateSlotExistp** is the C equivalent of the CLIPS **deftemplate-slot-existp** function. Parameter **d** is a pointer to a **Deftemplate**; and parameter **name** specifies a slot name. This function returns true if specified slot exists; otherwise it returns false.

The function **DeftemplateSlotMultiP** is the C equivalent of the CLIPS **deftemplate-slot-multip** function. Parameter **d** is a pointer to a **Deftemplate**; and parameter **name** specifies a valid slot name. This function returns true if the specified slot is a multifield slot; otherwise it returns false.

The function **DeftemplateSlotSingleP** is the C equivalent of the CLIPS **deftemplate-slot-singlep** function. Parameter **d** is a pointer to a **Deftemplate**; and parameter **name** specifies a valid slot name. This function returns true if the specified slot is a single-field slot; otherwise it returns false.

The function **DeftemplateSlotDefaultP** is the C equivalent of the CLIPS **deftemplate-slot-defaultp** function. Parameter **d** is a pointer to a **Deftemplate**; and parameter **name** specifies a valid slot name. This function returns the **DefaultType** enumeration for the specified slot.

## 12.4 Fact Functions

The following function calls manipulate and display information about facts.

### 12.4.1 Iteration and Listing

Fact \*GetNextFact(  
 Environment \*env,  
 Fact \*f);

Fact \*GetNextFactInTemplate(  
 Deftemplate \*d,  
 Fact \*f);

void GetFactList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void Facts(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d,  
 long long start,  
 long long end,  
 long long max);

void PPFact(  
 Fact \*f,  
 const char \*logicalName,  
 bool ignoreDefaults);

The function **GetNextFact** provides iteration support for the list of facts in an environment. If parameter **f** is a null pointer, then a pointer to the first **Fact** in the environment specified by parameter **env** is returned by this function; otherwise, a pointer to the next **Fact** following the **Fact** specified by parameter **f** is returned. If parameter **f** is the last **Fact** in the specified environment, a null pointer is returned.

The function **GetNextFactInTemplate** provides iteration support for the list of facts belonging to a deftemplate. If parameter **f** is a null pointer, then a pointer to the first **Fact** for the deftemplate specified by parameter **d** is returned by this function; otherwise, a pointer to the next **Fact** of the specified deftemplate following the **Fact** specified by parameter **f** is returned. If parameter **f** is the last **Fact** for the specified deftemplate, a null pointer is returned.

Do not call **GetNextFact** or **GetNextFactInTemplate** with a pointer to a fact that has been retracted. If the return value of these functions is stored as part of a persistent data structure or in a static data area, then the function **IncrementFactCount** should be called to insure that the fact cannot be disposed while external references to the fact still exist.

The function **GetFactList** is the C equivalent of the CLIPS **get-fact-list** function. Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of fact addresses—is stored in the **out** parameter value. If parameter **d** is a null pointer, then all facts in all modules will be included in parameter **out**; otherwise, only facts associated with deftemplates in the specified module will be included.

The function **Facts** is the C equivalent of the CLIPS **facts** command. Parameter env is a pointer to a previously created environment; parameter **logicalName** is the router output destination; parameter **d** is a pointer to a **Defmodule**; parameter **start** is the lower fact index range of facts to be listed; parameter **end** is the upper fact index range of facts to be listed; and parameter **max** is the maximum number of facts to be listed. If parameter **d** is a non-null pointer, then only facts visible to the specified module are printed; otherwise, all facts will be printed. A value of -1 for the **start**, **end**, or **max** parameter indicates the parameter is unspecified and should not restrict the facts that are listed.

The function **PPFact** is the C equivalent of the CLIPS **ppfact** command. Parameter **f** is a pointer to the **Fact** to be displayed; parameter **logicalName** is the router output destination; and parameter **ignoreDefaults** is a boolean flag indicating whether slots should be excluded from display if their current value is the same as their static default value.

### 12.4.2 Attributes

Deftemplate \*FactDeftemplate(  
 Fact \*f);

long long FactIndex(  
 Fact \*f);

void FactPPForm(  
 Fact \*f,  
 StringBuilder \*sb);

void FactSlotNames(  
 Fact \*f,  
 CLIPSValue \*out);

bool GetFactSlot(  
 Fact \*f,  
 const char \*name,  
 CLIPSValue \*out);

The function **FactDeftemplateModule** returns a pointer to the **Deftemplate** associated with the **Fact** specified by parameter **f**.

The function **FactIndex** is the C equivalent of the CLIPS **fact-index** command. It returns the fact-index of the fact specified by parameter **f**.

The function **FactPPForm** stores the text representation of the **Fact** specified by the **f** parameter in the **StringBuilder** specified by parameter **sb**.

The function **FactSlotNames** is the C equivalent of the CLIPS **fact-slot-names** function. Parameter **f** is a pointer to a **Fact**; and parameter **out** is a pointer to a **CLIPSValue** allocated by the caller. The output of the function call—a multifield containing the facts’s slot names—is stored in the **out** parameter value. For ordered facts, a multifield value containing the single symbol *implied* is returned.

The function **GetFactSlot** retrieves the slot value specified by parameter **name** from the fact specified by parameter **f** and stores it in parameter **out**, a **CLIPSValue** allocated by the caller. This function returns true if the slot value was successfully retrieved; otherwise, it returns false. For ordered facts—which have an implied multifield slot—a null pointer should be used for the **name** parameter value.

### 12.4.3 Deletion

bool Retract(  
 Fact \*f);

bool RetractAllFacts(  
 Environment \*env);

The function **Retract** is the C equivalent of the CLIPS **retract** command. Parameter **f** is the fact to be retracted. This function returns true if the fact is successfully retract; otherwise it returns false. The caller of **Retract** is responsible for insuring that the fact passed as an argument is still valid. The functions **IncrementFactReferenceCount** and **DecrementFactReferenceCount** can be used to inform CLIPS whether a fact is still in use. This function can trigger garbage collection.

The function **RetractAllFacts** retracts all of the facts in the environment specified by parameter **env**. It returns true if all facts were successfully retracted; otherwise, it returns false.

### 12.4.4 Reference Counts

void IncrementFactReferenceCount( // TBD FactRetain  
 Fact \*f);

void DecrementFactReferenceCount( // TBD FactRelease  
 Fact \*f);

bool FactExistp(  
 Fact \*f);

The function **IncrementFactReferenceCount** should be called for each external copy of a pointer to a fact to let CLIPS know that such an outstanding external reference exists. As long as an fact’s reference count is greater than zero, CLIPS will not release its memory because there may be outstanding pointers to the fact. However, the fact can still be *functionally*retracted, i.e. the fact will *appear* to no longer be in the fact-list. The fact address always can be safely *examined* using the fact access functions as long as the count for the fact is greater than zero. Retracting an already retracted fact will have no effect. Note that this function only needs to be called if you are storing pointers to facts that may later be referenced by external code after the fact has been retracted.

The function **DecrementFactCount** should *only* be called to reverse the effects of a previous call to **IncrementFactCount**.

The function **FactExistp** the C equivalent of the CLIPS **fact-existp** function. It returns true if the fact has not been retracted. The parameter **f** must be a **Fact** that has a reference count greater than 0.

### 12.4.5 Loading and Saving Facts

bool LoadFacts(  
 Environment \*env,  
 const char \*fileName);

bool LoadFactsFromString(  
 Environment \*env,  
 const char \*str,  
 long length);

bool SaveFacts(  
 Environment \*env,  
 const char \*filename,  
 SaveScope scope);

typedef enum  
 {  
 LOCAL\_SAVE,  
 VISIBLE\_SAVE  
 } SaveScope;

The function **LoadFacts** is the C equivalent of the CLIPS **load-facts** command. Parameter **env** is a pointer to a previously created environment; and parameter **fileName** is a full or partial path string to an ASCII or UTF-8 file containing facts. This function returns true if no errors occurred while loading facts; otherwise, it returns false.

The function **LoadFactsFromString** loads a set of facts from a string input source (much like the **LoadFacts** function only using a string for input rather than a file). Parameter **env** is a pointer to a previously created environment; parameter **str** is a string containing facts; and parameter **length** is the maximum number of characters to be read from the input string. If the **length** parameter value is -1, then the **str** parameter value must be terminated by a null character; otherwise, the **length** parameter value indicates the maximum number characters that will be read from the **str** parameter value. This function returns true if no error occurred while loading facts; otherwise, it returns false.

The function **SaveFacts** is the C equivalent of the CLIPS **save-facts** command. Parameter **env** is a pointer to a previously created environment; parameter **fileName** is a full or partial path string to the fact save file that will be created; and parameter **scope** indicates whether all facts visible to the current module should be saved (VISIBLE\_SAVE) or just those associated with deftemplates defined in the current module (LOCAL\_SAVE). This function returns true if no errors occurred while saving facts; otherwise, it returns false.

### 12.4.6 Settings

bool GetFactDuplication(  
 Environment \*env);

bool SetFactDuplication(  
 Environment \*env,  
 bool b);

The function **GetFactDuplication** is the C equivalent of the CLIPS **get-fact-duplication** command. The **env** parameter is a pointer to a previously created environment. This function returns the boolean value corresponding to the current setting.

The function **SetFactDuplication** is the C equivalent of the CLIPS **set‑fact‑duplication**‑‑ command. The **env** parameter is a pointer to a previously created environment; the parameter **b** is the new setting for the behavior. This function returns the old setting for the behavior.

### 12.4.7 Detecting Changes to Facts

bool GetFactListChanged(  
 Environment \*env);

void SetFactListChanged(  
 Environment \*env,  
 bool b);

The function **GetFactsChanged** returns true if changes to facts for the environment specified by parameter **env** have occurred (either assertions, retractions, or modifications); otherwise, it returns false. To track future changes, **SetFactsChanged** should reset the change tracking value to false.

The function **SetFactsChanged** sets the facts change tracking value for the environment specified by the parameter **env** to the value specified by the parameter **b**.

## 12.5 Deffacts Functions

The following function calls are used for manipulating deffacts.

### 12.5.1 Search, Iteration, and Listing

Deffacts \*FindDeffacts(  
 Environment \*env,  
 const char \*name);

Deffacts \*GetNextDeffacts(  
 Environment \*env,  
 Deffacts \*d);

void GetDeffactsList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDeffacts(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

The function **FindDeffacts** searches for the deffacts specified by parameter **name** in the environment specified by parameter **env**. This function returns a pointer to the named deffacts if it exists; otherwise, it returns a null pointer.

The function **GetNextDeffacts** provides iteration support for the list of deffacts in the current module. If parameter **d** is a null pointer, then a pointer to the first **Deffacts** in the current module is returned by this function; otherwise, a pointer to the next **Deffacts** following the **Deffacts** specified by parameter **d** is returned. If parameter **d** is the last **Deffacts** in the current module, a null pointer is returned.

The function **GetDeffactsList** is the C equivalent of the CLIPS **get-deffacts-list** function. Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of deffacts names—is stored in the **out** parameter value. If parameter **d** is a null pointer, then deffacts in all modules will be included in parameter **out**; otherwise, only deffacts in the specified module will be included.

The function **ListDeffacts** is the C equivalent of the CLIPS **list‑deffacts**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a defmodule. If parameter **d** is a null pointer, then deffacts in all modules will be listed; otherwise, only deffacts in the specified module will be listed.

### 12.5.2 Attributes

const char \*DeffactsModule(  
 Deffacts \*d);

const char \*DeffactsName(  
 Deffacts \*d);

const char \*DeffactsPPForm(  
 Deffacts \*d);

The function **DeffactsModule** is the C equivalent of the CLIPS **deffacts-module** function. The return value of this function is the name of the module in which the deffacts specified by parameter **d** is defined.

The function **DeffactsName** returns the name of the deffactsspecified by the **d** parameter.

The function **DeffactsPPForm** returns the text representation of the **Deffacts** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

### 12.5.3 Deletion

bool DeffactsIsDeletable(  
 Deffacts \*d);

bool Undeffacts(  
 Deffacts \*d,  
 Environment \*env);

The function **DeffactsIsDeletable** returns true if the deffacts specified by parameter **d** can be deleted; otherwise it returns false.

The **Undeffacts** function is the C equivalent of the CLIPS **undeffacts** command. It deletes the deffacts specified by parameter **d**; or if parameter **d** is a null pointer, it deletes all deffacts in the environment specified by parameter **env**. This function returns true if the deletion is successful; otherwise, it returns false.

## 12.6 Defrule Functions

The following function calls are used for manipulating defrules.

### 12.6.1 Search, Iteration, and Listing

Defrule \*FindDefrule(  
 Environment \*env,  
 const char \*name);

Defrule \*GetNextDefrule(  
 Environment \*env,  
 Defrule \*d);

void GetDefruleList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDefrules(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

The function **FindDefrule** searches for the defrule specified by the **name** parameter in the environment specified by the **env** parameter. This function returns a pointer to the named defrule if it exists; otherwise, it returns a null pointer.

The function **GetNextDefrule** provides iteration support for the list of defrules in the current module. If the **d** parameter value is a null pointer, then a pointer to the first **Defrule** in the current module is returned by this function; otherwise, the next **Defrule** following the **d** parameter value is returned. If the **d** parameter is the last **Defrule** in the current module, a null pointer is returned.

The function **GetDefruleList** is the C equivalent of the CLIPS **get-defrule-list** function. The **env** parameter is a pointer to a previously created environment; the **out** parameter is a pointer to a **CLIPSValue** allocated by the caller; and the **d** parameter is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of defrule names—is stored in the **out** parameter value. If the parameter **d** is a null pointer, then defrules in all modules will be included in the out parameter value; otherwise, only defrules in the specified module will be included.

The function **ListDefrules** is the C equivalent of the CLIPS **list‑defrules**‑ command. The **env** parameter is a pointer to a previously created environment; the **logicalName** parameter is the router output destination; and the **d** parameter is a pointer to a defmodule. If the parameter **d** is a null pointer, then defrules in all modules will be listed; otherwise, only defrules in the specified module will be listed.

### 12.6.2 Attributes

const char \*DefruleModule(  
 Defrule \*d);

const char \*DefruleName(  
 Defrule \*d);

const char \*DefrulePPForm(  
 Defrule \*d);

The function **DefruleModule** is the C equivalent of the CLIPS **defrule-module** command). The return value of this function is the name of the module in which the **Defrule** specified by the **d** parameter is defined.

The function **DefruleName** returns the name of the **Defrule** specified by the **d** parameter.

The function **DefrulePPForm** returns the text representation of the **Defrule** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

### 12.6.3 Deletion

bool DefruleIsDeletable(  
 Defrule \*d);

bool Undefrule(  
 Defrule \*d,  
 Environment \*env);

The function **DefruleIsDeletable** returns true if the **Defrule** specified by the **d** parameter value can be deleted; otherwise it returns false.

The function **Undefrule** is the C equivalent of the CLIPS **undefrule** command. It deletes the defrule specified by the **d** parameter; or if the **d** parameter is a null pointer, it deletes all defrules in the environment specified by the **env** parameter. The function returns true if the deletion was successful; otherwise, it returns false.

### 12.6.4 Watch Activations and Firings

bool DefruleGetWatchActivations(  
 Defrule \*d);

bool DefruleGetWatchFirings(  
 Defrule \*d);

void DefruleSetWatchActivations(  
 Defrule \*d,  
 bool b);

void DefruleSetWatchFirings(  
 Defrule \*d,  
 bool b);

The function **DefruleGetWatchActivations** returns true if rule activations are being watched for thedefrule specified by the **d** parameter value; otherwise, it returns false.

The function **DefruleGetWatchFirings** returns true if rule firings are being watched for the **Defrule** specified by the **d** parameter; otherwise, it returns false.

The function **DefruleSetWatchActivations** sets the rule activations watch state for the defrule specified by the **d** parameter value to the value specified by the parameter **b**.

The function **DefruleSetWatchFirings** sets the rule firings watch state for the defrule specified by the **d** parameter value to the value specified by the parameter **b**.

### 12.6.5 Breakpoints

bool DefruleHasBreakpoint(  
 Defrule \*d);

bool RemoveBreak(  
 Defrule \*d);

void SetBreak(  
 Defrule \*d);

void ShowBreaks(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

The function **DefruleHasBreakpoint** returns true if the defrule specified by the **d** parameter value has a breakpoint set; otherwise it returns false.

The function **RemoveBreak** is the C equivalent of the CLIPS **remove-break** command. It returns false if a breakpoint does not exist for the defrule specified by the **d** parameter value; otherwise, it removes the breakpoint and returns true;

The function **SetBreak** is the C equivalent of the CLIPS **set-break** command. It sets a breakpoint for the defrule specified by the **d** parameter value.

The function **ShowBreaks** is the C equivalent of the CLIPS **show-breaks** command. The **env** parameter is a pointer to a previously created environment; the **logicalName** parameter is the router output destination; and the **d** parameter is a pointer to a defmodule. If the parameter **d** is a null pointer, then breakpoints for defrules in all modules will be listed; otherwise, only breakpoints for defrules in the specified module will be listed.

### 12.6.6 Matches

void Matches(  
 Defrule \*d,  
 Verbosity v,  
 CLIPSValue \*out);

typedef enum  
 {  
 VERBOSE,  
 SUCCINCT,  
 TERSE  
 } Verbosity;

The function **Matches** is the C equivalent of the CLIPS **matches** command. The **d** parameter is a pointer to a **Defrule**; the **v** parameter specifies the level of information displayed in the printed output; and the **out** parameter is a pointer to a CLIPSValue allocated by the caller. The output of the function call—a multifield containing three integer fields indicating the number of pattern matches, partial matches, and activations—is stored in the **out** parameter value.

### 12.6.7 Refresh

void Refresh(  
 Defrule \*d);

The function **Refresh** is the C equivalent of the CLIPS **refresh** command.

## 12.7 Agenda Functions

The following function calls are used for manipulating the agenda.

### 12.7.1 Iteration and Listing

Activation \*GetNextActivation(  
 Environment \*env,  
 Activation \*a);

FocalModule \*GetNextFocus(  
 Environment \*env,  
 FocalModule \*fm);

void GetFocusStack(  
 Environment \*env,  
 CLIPSValue \*out);

void Agenda(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

void ListFocusStack(  
 Environment \*env,  
 const char \*logicalName);

The function **GetNextActivation** provides iteration support for the list of activations on the agenda of the current module in an environment. If parameter **a** is a null pointer, then a pointer to the first **Activation** on the agenda of the current module in the environment specified by parameter **env** is returned by this function; otherwise, a pointer to the next **Activation** following the **Activation** specified by parameter **a** is returned. If parameter **a** is the last **Activation** on the agenda of the current module in the specified environment, a null pointer is returned.

The function **GetNextFocus** provides iteration support for the list of modules on the focus stack of an environment. If parameter **fm** is a null pointer, then a pointer to the first **FocusModule** on the focus stack in the environment specified by parameter **env** is returned by this function; otherwise, a pointer to the next **FocusModule** following the **FocusModule** specified by parameter **fm** is returned. If parameter **fm** is the last **FocusModule** on the agenda of the current module in the specified environment, a null pointer is returned.

The function **GetFocusStack** is the C equivalent of the CLIPS **get-focus-stack** function. Parameter **env** is a pointer to a previously created environment; and parameter **out** is a pointer to a **CLIPSValue** allocated by the caller. The output of the function call—a multifield containing a list of defmodule names—is stored in the **out** parameter value.

The function **Agenda** is the C equivalent of the CLIPS **agenda** command. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a **Defmodule**. If parameter **d** is a null pointer, then the agenda of every module is listed; otherwise, only the agenda of the specified module is listed.

The function **ListFocusStack** is the C equivalent of the CLIPS **list-focus-stack** command. Parameter **env** is a pointer to a previously created environment; and parameter **logicalName** is the router output destination.

### 12.7.2 Activation Attributes

const char \*ActivationRuleName(  
 Activation \*a);

void ActivationPPForm(  
 Activation \*a,  
 StringBuilder \*sb);

int ActivationGetSalience(  
 Activation \*a);

int ActivationSetSalience(  
 Activation \*a,  
 int s);

The function **ActivationRuleName** returns the name of the defrule that generated the activation specified by parameter **a**.

The function **ActivationPPForm** stores the text representation of the **Activation** specified by parameter **a** in the **StringBuilder** specified by parameter **sb**.

The function **ActivationGetSalience** returns the salience of the activation specified by parameter **a**. This salience value may be different from the the salience value of the defrule which generated the activation (due to dynamic salience).

The function **ActivationSetSalience** sets the salience of the activation specified by parameter **a** to the integer specified by parameter **s**. Salience values greater than 10,000 will assign the value 10,000 instead and salience values less than -10,000 will assign the value -10 instead. The function **ReorderAgenda** should be called after salience values have been changed to update the agenda.

### 12.7.3 FocalModule Attributes

const char \*FocalModuleName(  
 FocalModule \*fm);

Defmodule \*FocalModuleModule(  
 FocalModule \*fm);

The function **FocalModuleName** returns the name of the defmodule associated with the **FocalModule** specified by parameter **fm**.

The function **FocalModuleModule** returns a pointer to the **Defmodule** associated with the **FocalModule** specified by parameter **fm**.

### 12.7.4 Rule Fired Callback Functions

bool AddBeforeRuleFiresFunction(  
 Environment \*env,  
 const char \*name,  
 RuleFiredFunction \*f,  
 int p,  
 void \*context);

bool AddAfterRuleFiresFunction(  
 Environment \*env,  
 const char \*name,  
 RuleFiredFunction \*f,  
 int p,  
 void \*context);

bool RemoveBeforeRuleFiresFunction(  
 Environment \*env,  
 const char \*name);

bool RemoveAfterRuleFiresFunction(  
 Environment \*env,  
 const char \*name);

typedef void RuleFiredFunction(  
 Environment \*env,  
 Activation \*a,  
 void \*context);

The function **AddBeforeRuleFiresFunction** adds a callback function to the list of functions invoked after a rule executes. Parameter **env** is a pointer to a previously created environment; parameter **name** is a string that uniquely identifies the callback for removal using **RemoveBeforeRuleFiresFunction**; parameter **f** is a pointer to the callback function of type **RuleFiredFunction**; parameter **p** is the priority of the callback function; and parameter **context** is a user supplied pointer to data that is passed to the callback function when it is invoked (a null pointer should be used if there is no data that needs to be passed to the callback function). The **priority** parameter determines the order in which the callback functions are invoked (higher priority items are called first); the values -2000 to 2000 are reserved for internal use by CLIPS. This function returns true if the callback function was successfully added; otherwise, it returns false.

The function **AddAfterRuleFiresFunction** adds a callback function to the list of functions invoked after a rule executes. Parameter **env** is a pointer to a previously created environment; parameter **name** is a string that uniquely identifies the callback for removal using **RemoveAfterRuleFiresFunction**; parameter **f** is a pointer to the callback function of type **RuleFiredFunction**; parameter **p** is the priority of the callback function; and parameter **context** is a user supplied pointer to data that is passed to the callback function when it is invoked (a null pointer should be used if there is no data that needs to be passed to the callback function). The **priority** parameter determines the order in which the callback functions are invoked (higher priority items are called first); the values -2000 to 2000 are reserved for internal use by CLIPS. This function returns true if the callback function was successfully added; otherwise, it returns false.

When invoked, the **RuleFiredFunction** is passed parameter **a** that is a pointer to the **Activation** being executed. In the event that no rules are executed, the callbacks added by **AddAfterRuleFiresFunction** are invoked once with the parameter value **a** set to a null pointer.

The function **RemoveBeforeRuleFiresFunction** removes a callback function from the list of functions invoked before a rule executes. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the string used to identify the callback when it was added using **AddBeforeRuleFiresFunction**. The function returns true if the callback was successfully removed; otherwise, it returns false.

The function **RemoveAfterRuleFiresFunction** removes a callback function from the list of functions invoked after a rule executes. Parameter **env** is a pointer to a previously created environment; and parameter **name** is the string used to identify the callback when it was added using **AddAfterRuleFiresFunction**. The function returns true if the callback was successfully removed; otherwise, it returns false.

### 12.7.6 Manipulating the Focus Stack

void ClearFocusStack(  
 Environment \*env);

void Focus(  
 Defmodule \*d);

Defmodule \*PopFocus(  
 Environment \*env);

Defmodule \*GetFocus(  
 Environment \*env);

The function **ClearFocusStack** is the C equivalent of the CLIPS **clear-focus-stack** command.

The function **Focus** is the C equivalent of the CLIPS **focus** command.

The function **PopFocus** is the C equivalent of the CLIPS **pop-focus** function. It removes the current focus from the focus stack and returns the **Defmodule** associated with that focus.

The function **GetFocus** is the C equivalent of the CLIPS **get-focus** function. It returns a pointer to the **Defmodule** that is the current focus on the focus stack. A null pointer is returned if the focus stack is empty.

### 12.7.7 Manipulating the Agenda

void RefreshAgenda(  
 Defmodule \*d);

void RefreshAllAgendas(  
 Environment \*env);

void ReorderAgenda(  
 Defmodule \*d);

void ReorderAllAgendas(  
 Environment \*env);

void DeleteActivation(  
 Activation \*a);

void DeleteAllActivations(  
 Defmodule \*d);

The function **RefreshAgenda** is the C equivalent of the CLIPS **refresh-agenda** command. For the agenda of the module specified by parameter **d**, it recomputes the salience values for all activations and then reorders the agenda.

The function **RefreshAllAgendas** invokes the **RefreshAgenda** function for every module in the evironment specified by parameter **env**.

The function **ReorderAgenda** reorders the agenda of the module specified by parameter **d** using the current conflict resolution strategy and current activation saliences.

The function **ReorderAllAgendas** invokes the **ReorderAgenda** function for every module in the evironment specified by parameter **env**.

The function **DeleteActivation** removes an activation from its agenda.

The function **DeleteAllActivations** removes all activations from the agenda of the module specified by parameter **d**;

### 12.7.8 Detecting Changes to the Agenda

bool GetAgendaChanged(  
 Environment \*env);

void SetAgendaChanged(  
 Environment \*env,  
 bool b);

The function **GetAgendaChanged** returns true if changes to the agenda for the environment specified by parameter **env** have occurred (either activations, firings, or deactivations); otherwise, it returns false. To track future changes, **SetAgendaChanged** should reset the change tracking value to false.

The function **SetAgendaChanged** sets the agenda change tracking value for the environment specified by the parameter **env** to the value specified by the parameter **b**.

### 12.7.9 Settings

SalienceEvaluationType GetSalienceEvaluation(  
 Environment \*env);

SalienceEvaluationType SetSalienceEvaluation(  
 Environment \*env,  
 SalienceEvaluationType set);

StrategyType GetStrategy(  
 Environment \*env);

StrategyType SetStrategy(  
 Environment \*env,  
 StrategyType st);

typedef enum  
 {  
 WHEN\_DEFINED,  
 WHEN\_ACTIVATED,  
 EVERY\_CYCLE  
 } SalienceEvaluationType;

typedef enum  
 {  
 DEPTH\_STRATEGY,  
 BREADTH\_STRATEGY,  
 LEX\_STRATEGY,  
 MEA\_STRATEGY,  
 COMPLEXITY\_STRATEGY,  
 SIMPLICITY\_STRATEGY,  
 RANDOM\_STRATEGY  
 } StrategyType;

The function **GetSalienceEvaluation** is the C equivalent of the CLIPS **get-salience-evaluation** command. The **env** parameter is a pointer to a previously created environment. This function returns the enumeration value corresponding to the current setting.

The function **SetSalienceEvaluation** is the C equivalent of the CLIPS **set-salience-evaluation** command). The **env** parameter is a pointer to a previously created environment; and the parameter **set** is the new setting for the behavior. This function returns the old setting for the behavior.

The function **GetStrategy** is the C equivalent of the CLIPS **get-strategy** command. The **env** parameter is a pointer to a previously created environment. This function returns the enumeration value corresponding to the current setting.

The function **SetStrategy** is the C equivalent of the CLIPS **set-strategy** command. The **env** parameter is a pointer to a previously created environment; and the parameter **st** is the new setting for the behavior. This function returns the old setting for the behavior.

### 12.7.10 Examples

#### 12.7.10.1 Calling a Function After Each Rule Firing

The following code is a simple example that prints a period after each rule firing:

#include "clips.h"

void PrintPeriod(Environment \*,Activation \*,void \*);

int main()

{

Environment \*env;

env = CreateEnvironment();

Build(env,"(defrule loop"

" ?f <- (loop)"

" =>"

" (retract ?f)"

" (assert (loop)))");

AssertString(env,"(loop)");

AddAfterRuleFiresFunction(env,"print-dot",PrintPeriod,0,NULL);

Run(env,20);

Write(env,"\n");

}

void PrintPeriod(

Environment \*env,

Activation \*a,

void \*context)

{

Write(env,".");

}

When run, the program produces the following output:

....................

## 12.8 Defglobal Functions

The following function calls are used for manipulating defglobals.

### 12.8.1 Search, Iteration, and Listing

Defglobal \*FindDefglobal(  
 Environment \*env,  
 const char \*name);

Defglobal \*GetNextDefglobal(  
 Environment \*env,  
 Defglobal \*d);

void GetDefglobalList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDefglobals(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

void ShowDefglobals(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

The function **FindDefglobal** searches for the defrule specified by the **name** parameter in the environment specified by the **env** parameter. For example, to retrieve the value of the global variable ?\*x\*, use the value "x" for the **name** parameter. This function returns a pointer to the named defglobal if it exists; otherwise, it returns a null pointer.

The function **GetNextDefglobal** provides iteration support for the list of defglobals in the current module. If parameter **d** is a null pointer, then a pointer to the first **Defglobal** in the current module is returned by this function; otherwise, a pointer to the next **Defglobal** following the **Defglobal** specified by parameter **d** is returned. If parameter **d** is the last **Defglobal** in the current module, a null pointer is returned.

The function **GetDefglobalList** is the C equivalent of the CLIPS **get-defglobal-list** function). The **env** parameter is a pointer to a previously created environment; the **out** parameter is a pointer to a **CLIPSValue** allocated by the caller; and the **d** parameter is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of defglobal names—is stored in the **out** parameter value. If the parameter **d** is a null pointer, then defglobals in all modules will be included in the out parameter value; otherwise, only defglobals in the specified module will be included.

The function **ListDefglobals** is the C equivalent of the CLIPS **list‑defglobals**‑ command. The parameter **env** is a pointer to a previously created environment; the parameter **logicalName** is the router output destination; and the parameter **d** is a pointer to a defmodule. If the parameter **d** is a null pointer, then defglobals in all modules will be listed; otherwise, only defglobals in the specified module will be listed.

The function **ShowDefglobals** is the C equivalent of the CLIPS **show‑defglobals**‑ command. The parameter **env** is a pointer to a previously created environment; the parameter **logicalName** is the router output destination; and the parameter **d** is a pointer to a defmodule. If the parameter **d** is a null pointer, then defglobals in all modules will be listed with their current value; otherwise, only defglobals in the specified module will be listed with their current value.

### 12.8.2 Attributes

const char \*DefglobalModule(  
 Defglobal \*d);

const char \*DefglobalName(  
 Defglobal \*d);

const char \*DefglobalPPForm(  
 Defglobal \*d);

void DefglobalValueForm(  
 Defglobal \*d,  
 StringBuilder \*sb);

void DefglobalGetValue(  
 Defglobal \*d,  
 CLIPSValue \*out);

void DefglobalSetValue(  
 Defglobal \*d,  
 CLIPSValue \*in);

The function **DefglobalModule** is the C equivalent of the CLIPS **defglobal-module** command. The return value of this function is the name of the module in which the **Defglobal** specified by the **d** parameter is defined.

The function **DefglobalName** returns the name of the defglobal specified by parameter **d**.

The function **DefglobalPPForm** returns the text representation of the defglobal specified by parameter **d**. The null pointer is returned if the text representation is not available.

The function **DefglobalValueForm** returns a string representation of a defglobal and its current value. Parameter **d** is a pointer to a **Defglobal**; and parameter **sb** is a pointer to a **StringBuilder** allocated by the caller in which the representation is stored.

The function **DefglobalGetValue** returns the value of the defglobal specified by parameter **d** in parameter **out**, a **CLIPSValue** allocated by the caller.

The function **DefglobalSetValue** sets the value of the defglobal specified by parameter **d** to the value specified by parameter **in**, a **CLIPSValue** allocated by the caller. This function can trigger garbage collection.

### 12.8.3 Deletion

bool DefglobalIsDeletable(  
 Defglobal \*d);

bool Undefglobal(  
 Defglobal \*d,  
 Environment \*env);

The function **DefglobalIsDeletable** returns true if the defglobal specified by parameter **d** can be deleted; otherwise it returns false.

The function **Undefglobal** is the C equivalent of the CLIPS **undefglobal** command. It deletes the defglobal specified by parameter **d**; or if parameter **d** is a null pointer, it deletes all defglobals in the environment specified by parameter **env**. The function returns true if the deletion was successful; otherwise, it returns false.

### 12.8.4 Watching and Detecting Changes to Defglobals

bool DefglobalGetWatch(  
 Defglobal \*d);

void DeftemplateSetWatch(  
 Deftemplate \*d,  
 bool b);

bool GetGlobalsChanged(  
 Environment \*env);

void SetGlobalsChanged(  
 Environment \*env,  
 bool b);

The function **DefglobalGetWatch** returns true if thedefglobal specified by parameter **d** is being watched; otherwise, it returns false.

The function **DefglobalSetWatch** sets the watch state for the defglobal specified by parameter **d**. If parameter **b** is true, the watch state is enabled; otherwise, it is disabled.

The function **GetGlobalsChanged** returns true if changes to global variables for the environment specified by parameter **env** have occurred (either additions, deletions, or value modifications); otherwise, it returns false. To track future changes, **SetGlobalsChanged** should reset the change tracking value to false.

The function **SetGlobalsChanged** sets the global change tracking value for the environment specified by the parameter **env** to the value specified by the parameter **b**.

### 12.8.5 Reset Globals Behavior

bool GetResetGlobals(  
 Environment \*env);

bool SetResetGlobals(  
 Environment \*env,  
 bool b);

The function **GetResetGlobals** is the C equivalent of the CLIPS **get‑reset‑globals**‑‑ command. Parameter **env** is a pointer to a previously created environment. This function returns true if the behavior is enabled; otherwise, it returns false.

The function **SetResetGlobals** is the C equivalent of the CLIPS **set‑reset‑globals**‑‑ command). Parameter **env** is a pointer to a previously created environment; and parameter **b** is the new setting for the behavior (either true to enable it or false to disable it). This function returns the old setting for the behavior.

### 12.8.6 Examples

#### 12.8.6.1 Listing, Watching, and Setting the Value of Defglobals

int main()

{

Environment \*env;

CLIPSValue value;

env = CreateEnvironment();

Build(env,"(defglobal ?\*x\* = 3)");

Build(env,"(defglobal ?\*y\* = (create$ a b c))");

Write(env,"Listing Globals:\n\n");

ListDefglobals(env,STDOUT,NULL);

Write(env,"\nShowing Values:\n\n");

ShowDefglobals(env,STDOUT,NULL);

Write(env,"\nSetting Values:\n\n");

Watch(env,GLOBALS);

Eval(env,"(\* 3 4)",&value);

DefglobalSetValue(FindDefglobal(env,"x"),&value);

value.lexemeValue = CreateString(env,"123 Main St.");

DefglobalSetValue(FindDefglobal(env,"y"),&value);

DestroyEnvironment(env);

}

When run, the program produces the following output:

Listing Globals:

MAIN:

x

y

For a total of 2 defglobals.

Showing Values:

MAIN:

?\*x\* = 3

?\*y\* = (a b c)

Setting Values:

:== ?\*x\* ==> 12 <== 3

:== ?\*y\* ==> "123 Main St." <== (a b c)

## 12.9 Deffunction Functions

The following function calls are used for manipulating deffunctions.

### 12.9.1 Search, Iteration, and Listing

Deffunction \*FindDeffunction(  
 Environment \*env,  
 const char \*name);

Deffunction \*GetNextDeffunction(   
 Environment \*env,  
 Deffunction \*d);

void GetDeffunctionList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDeffunctions(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

The function **FindDeffunction** searches for the deffunction specified by parameter **name** in the environment specified by parameter **env**. This function returns a pointer to the named deffunction if it exists; otherwise, it returns a null pointer.

The function **GetNextDeffunction** provides iteration support for the list of deffunctions in the current module. If parameter **d** is a null pointer, then a pointer to the first **Deffunction** in the current module is returned by this function; otherwise, a pointer to the next **Deffunction** following the **Deffunction** specified by parameter **d** is returned. If parameter **d** is the last **Deffunction** in the current module, a null pointer is returned.

The function **GetDeffunctionList** is the C equivalent of the CLIPS **get-deffunction-list** function. Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of deffunction names—is stored in the **out** parameter value. If parameter **d** is a null pointer, then deffunctions in all modules will be included in parameter **out**; otherwise, only deffunctions in the specified module will be included.

The function **ListDeffunctions** is the C equivalent of the CLIPS **list‑deffunctions**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a defmodule. If parameter **d** is a null pointer, then deffunctions in all modules will be listed; otherwise, only deffunctions in the specified module will be listed.

### 12.9.2 Attributes

const char \*DeffunctionModule(  
 Deffunction \*d);

const char \*DeffunctionName(  
 Deffunction \*d);

const char \*DeffunctionPPForm(  
 Deffunction \*d);

The function **DeffunctionModule** is the C equivalent of the CLIPS **deffunction-module** command. The return value of this function is the name of the module in which the deffunction specified by parameter **d** is defined.

The function **DeffunctionName** returns the name of the deffunctionspecified by the **d** parameter.

The function **DeffunctionPPForm** returns the text representation of the **Deffunction** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

### 12.9.3 Deletion

bool DeffunctionIdDeletable(  
 Deffunction \*d);

bool Undeffunction(  
 Deffunction \*d,  
 Environment \*env);

The function **DeffactsIsDeletable** returns true if the deffacts specified by parameter **d** can be deleted; otherwise it returns false.

The function **Undeffunction** is the C equivalent of the CLIPS **undeffunction** command). It deletes the deffacts specified by parameter **d**; or if parameter **d** is a null pointer, it deletes all deffacts in the environment specified by parameter **env**. This function returns true if the deletion is successful; otherwise, it returns false.

### 12.9.4 Watching Deffunctions

bool DeffunctionGetWatch(  
 Deffunction \*d);

void DeffunctionSetWatch(  
 Deffunction \*d,  
 bool b);

The function **DeffunctionGetWatch** returns true if the watch state is enabled for thedeffunction specified by the **d** parameter value; otherwise, it returns false.

The function **DeffunctionSetWatch** sets the watch state for the deffunction specified by the **d** parameter value to the value specified by the parameter **b**.

## 12.10 Defgeneric Functions

The following function calls are used for manipulating generic functions.

### 12.10.1 Search, Iteration, and Listing

Defgeneric \*FindDefgeneric(  
 Environment \*env,  
 const char \*name);

Defgeneric \*GetNextDefgeneric(  
 Environment \*env,  
 Defgeneric \*d);

void GetDefgenericList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDefgenerics(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

The function **FindDefgeneric** searches for the defgeneric specified by parameter **name** in the environment specified by parameter **env**. This function returns a pointer to the named defgeneric if it exists; otherwise, it returns a null pointer.

The function **GetNextDefgeneric** provides iteration support for the list of defgenerics in the current module. If parameter **d** is a null pointer, then a pointer to the first **Defgeneric** in the current module is returned by this function; otherwise, a pointer to the next **Defgeneric** following the **Defgeneric** specified by parameter **d** is returned. If parameter **d** is the last **Defgeneric** in the current module, a null pointer is returned.

The function **GetDefgenericList** is the C equivalent of the CLIPS **get-defgeneric-list** function. Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of defgeneric names—is stored in the **out** parameter value. If parameter **d** is a null pointer, then defgenerics in all modules will be included in parameter **out**; otherwise, only defgenerics in the specified module will be included.

The function **ListDefgenerics** is the C equivalent of the CLIPS **list‑defgenerics**‑ command). Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a defmodule. If parameter **d** is a null pointer, then defgenerics in all modules will be listed; otherwise, only defgenerics in the specified module will be listed.

### 12.10.2 Attributes

const char \*DefgenericModule(  
 Defgeneric \*d);

const char \*DefgenericName(  
 Defgeneric \*d);

const char \*DefgenericPPForm(  
 Defgeneric \*d);

The function **DefgenericModule** is the C equivalent of the CLIPS **defgeneric-module** command. The return value of this function is the name of the module in which the defgeneric specified by parameter **d** is defined.

The function **DefgenericName** returns the name of the defgenericspecified by the **d** parameter.

The function **DefgenericPPForm** returns the text representation of the **Defgeneric** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

### 12.10.3 Deletion

bool DefgenericIsDeletable(  
 Defgeneric \*d);

bool Undefgeneric(  
 Defgeneric \*d,  
 Environment \*env);

The function **DefgenericIsDeletable** returns true if the defgeneric specified by parameter **d** can be deleted; otherwise it returns false.

The function **Undefgeneric** is the C equivalent of the CLIPS **undefgeneric** command. It deletes the defgeneric specified by parameter **d**; or if parameter **d** is a null pointer, it deletes all defgenerics in the environment specified by parameter **env**. This function returns true if the deletion is successful; otherwise, it returns false.

### 12.10.4 Watching Defgenerics

bool DefgenericGetWatch(  
 Defgeneric \*d);

void DefgenericSetWatch(  
 Defgeneric \*d,  
 bool b);

The function **DefgenericGetWatch** returns true if execution is being watched for thedefgeneric specified by the **d** parameter value; otherwise, it returns false.

The function **DefgenericSetWatch** sets the watch state for the defgeneric specified by the **d** parameter value to the value specified by the parameter **b**.

## 12.11 Defmethod Functions

The following function calls are used for manipulating generic function methods.

### 12.11.1 Iteration and Listing

unsigned GetNextDefmethod(  
 Defgeneric \*d,  
 unsigned index);

void GetDefmethodList(  
 Environment \*environment,  
 CLIPSValue \*out,  
 Defgeneric \*d);

void ListDefmethods(  
 Environment \*env,  
 const char \*logicalName,  
 Defgeneric \*d);

The function **GetNextDefmethod** provides iteration support for the list of defmethods for a defgeneric. If parameter **index** is a 0, then a pointer to the first **Defmethod** for the defgeneric specified by parameter **d** is returned by this function; otherwise, a pointer to the next **Defmethod** following the **Defmethod** specified by parameter **index** is returned. If parameter **index** is the last **Defmethod** for the specified defgeneric, 0 is returned.

The function **GetDefmethodList** is the C equivalent of the CLIPS **get‑defmethod-list**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defgeneric**. The output of the function call—a multifield containing a list of defmethod name and index pairs—is stored in the **out** parameter value. If parameter **d** is a null pointer, then defmethods for all defgenerics will be included in parameter **out**; otherwise, only defmethods for the specified defgeneric will be included.

The function **ListDefmethods** is the C equivalent of the CLIPS **list‑defmethods**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a defgeneric. If parameter **d** is a null pointer, then defmethods for all defgenerics will be listed; otherwise, only defmethods for the specified defgeneric will be listed.

### 12.11.2 Attributes

void DefmethodDescription(  
 Defgeneric \*d,  
 unsigned index,  
 StringBuilder \*sb);

const char \*DefmethodPPForm(  
 Defgeneric \*d,  
 unsigned index);

void GetMethodRestrictions(  
 Defgeneric \*d,  
 unsigned index,  
 CLIPSValue \*out);

The function **DefmethodDescription** provides a synopsis of a method’s parameter restrictions. Parameter **d** is a pointer to a **Defgeneric**; parameter **index** is the method index; and parameter **sb** is a pointer to a **StringBuilder** allocated by the caller in which the method description is stored.

The function **DefmethodPPForm** returns the text representation of the **Defmethod** specified by parameter **d,** the generic function, and parameter **index**, the method index. The null pointer is returned if the text representation is not available.

The function **GetMethodRestrictions** is the C equivalent of the CLIPS **get‑method-restrictions**‑ function. Parameter **d** is a pointer to a generic function; parameter **index** is a method index; and parameter **out** is a pointer to a CLIPSValue allocated by the caller. The output of the function call—a multifield containing the method restrictions—is stored in the **out** parameter value.

### 12.11.3 Deletion

bool DefmethodIsDeletable(  
 Defgeneric \*d,  
 unsigned index);

bool Undefmethod(  
 Defgeneric \*d,  
 unsigned index,  
 Environment \*env);

The function **DefmethodIsDeletable** returns true if the defmethod specified by parameter **d**, the generic function, and **index**, the method index, can be deleted; otherwise it returns false.

The function **Undefmethod** is the C equivalent of the CLIPS **undefmethod** command. It deletes the defmethod specified by parameter **d**, parameter **index**, and parameter **env**. If parameter **d** is a null pointer and parameter **index** is 0, it deletes all methods for all generic functions in the environment specified by parameter **env**; if parameter **d** is not a null pointer and parameter **index** is 0, it deletes all methods of the generic function; otherwise, the defmethod specified by the generic function and method index is deleted. This function returns true if the deletion is successful; otherwise, it returns false.

### 12.11.4 Watching Methods

bool DefmethodGetWatch(  
 Defgeneric \*d,  
 unsigned index);

void DefmethodSetWatch(  
 Defgeneric \*d,  
 unsigned index,  
 bool b);

The function **DefmethodGetWatch** returns true if the method specified by parameter **d**, the generic function, and parameter **index**, the method index, is being watched; otherwise, it returns false.

The function **DefmethodSetWatch** sets the method watch state for the defmethod specified by the **d** parameter, the generic function, and parameter **index**, the method index, to the value specified by the parameter **b**.

## 12.12 Defclass Functions

The following function calls are used for manipulating defclasses.

### 12.12.1 Search, Iteration, and Listing

Defclass \*FindDefclass(  
 Environment \*env,  
 const char \*name);

Defclass \*GetNextDefclass(  
 Environment \*env,  
 Defclass \*d);

void GetDefclassList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDefclasses(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d);

void BrowseClasses(,  
 Defclass \*d,  
 const char \*logicalName);

void DescribeClass(  
 Defclass \*d,  
 const char \*logicalName);

The function **FindDefclass** searches for the defclass specified by parameter **name** in the environment specified by parameter **env**. This function returns a pointer to the named defclass if it exists; otherwise, it returns a null pointer.

The function **GetNextDefclass** provides iteration support for the list of defclasses in the current module. If parameter **d** is a null pointer, then a pointer to the first **Defclass** in the current module is returned by this function; otherwise, a pointer to the next **Defclass** following the **Defclass** specified by parameter **d** is returned. If parameter **d** is the last **Defclass** in the current module, a null pointer is returned.

The function **GetDefclassList** is the C equivalent of the CLIPS **get-defclass-list** function). Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of defclass names—is stored in the **out** parameter value. If parameter **d** is a null pointer, then defclasses in all modules will be included in parameter **out**; otherwise, only defclasses in the specified module will be included.

The function **ListDefclass** is the C equivalent of the CLIPS **list‑defclass**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a defmodule. If parameter **d** is a null pointer, then defclasses in all modules will be listed; otherwise, only defclasses in the specified module will be listed.

The function **BrowseClasses** is the C equivalent of the CLIPS **browse‑classes**‑ command. It prints a “graph” of all classes which inherit from the class specified by parameter **d** to the router output destination specified by the **logicalName** parameter.

The function **DescribeClass** is the C equivalent of the CLIPS **describe‑class**‑ command. It prints a summary of the class specified by parameter **d** to the router output destination specified by the **logicalName** parameter. This summary includes abstract/concrete behavior, slots and facets (direct and inherited), and recognized message-handlers (direct and inherited).

### 12.12.2 Class Attributes

const char \*DefclassModule(  
 Defclass \*d);

const char \*DefclassName(  
 Defclass \*d);

const char \*DefclassPPForm(  
 Defclass \*d);

void ClassSlots(  
 Defclass \*d,  
 CLIPSValue \*out,  
 bool inherit);

void ClassSubclasses(  
 Defclass \*d,  
 CLIPSValue \*out,  
 bool inherit);

void ClassSuperclasses(  
 Defclass \*d,  
 CLIPSValue \*out,  
 bool inherit);

The function **DefclassModule** is the C equivalent of the CLIPS **defclass-module** function. The return value of this function is the name of the module in which the defclass specified by parameter **d** is defined.

The function **DefclassName** returns the name of the defclassspecified by the **d** parameter.

The function **DefclassPPForm** returns the text representation of the **Defclass** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

The function **ClassSlots** is the C equivalent of the CLIPS **class-slots** command. Parameter **d** is a pointer to a **Defclass**; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **inherit** is a boolean flag. The output of the function call—a multifield containing the defclass’s slot names—is stored in the **out** parameter value. If the **inherit** parameter is true, then inherited slots are included; otherwise, only slot explicitly defined by the class are included.

The function **ClassSubclasses** is the C equivalent of the CLIPS **class-subclasses** command. Parameter **d** is a pointer to a **Defclass**; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **inherit** is a boolean flag. The output of the function call—a multifield containing the defclass’s subclass names—is stored in the **out** parameter value. If the **inherit** parameter is true, then inherited subclasses are included; otherwise, only direct subclasses explicitly defined by the class are included.

The function **ClassSuperclasses** is the C equivalent of the CLIPS **class-superclasses** command. Parameter **d** is a pointer to a **Defclass**; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **inherit** is a boolean flag. The output of the function call—a multifield containing the defclass’s superclass names—is stored in the **out** parameter value. If the **inherit** parameter is true, then inherited superclasses are included; otherwise, only direct superclasses explicitly defined by the class are included.

### 12.12.3 Deletion

bool DefclassIsDeletable(  
 Defclass \*d);

bool Undefclass(  
 Defclass \*d,  
 Environment \*env);

The function **DefclassIsDeletable** returns true if the defclass specified by parameter **d** can be deleted; otherwise it returns false.

The **Undefclass** function is the C equivalent of the CLIPS **undefclass** command. It deletes the defclass specified by parameter **d**; or if parameter **d** is a null pointer, it deletes all defclasses in the environment specified by parameter **env**. This function returns true if the deletion is successful; otherwise, it returns false.

### 12.12.4 Watching Instances and Slots

bool DefclassGetWatchInstances(  
 Defclass \*d);

bool DefclassGetWatchSlots(  
 Defclass \*d);

void DefclassSetWatchInstances(  
 Defclass \*d,  
 bool b);

void DefclassSetWatchSlots(  
 Defclass \*d,  
 bool b);

The function **DefclassGetWatchInstances** returns true if instances (creations and deletions) are being watched for thedefclass specified by the **d** parameter value; otherwise, it returns false.

The function **DefclassGetWatchSlots** returns true if slot changes are being watched for thedefclass specified by the **d** parameter value; otherwise, it returns false.

The function **DeftemplateSetWatchInstances** sets the instances creation and deletion watch state for the defclass specified by the **d** parameter value to the value specified by the parameter **b**.

The function **DeftemplateSetWatchSlots** sets the slot changes watch state for the defclass specified by the **d** parameter value to the value specified by the parameter **b**.

### 12.12.5 Class Predicates

bool ClassAbstractP(  
 Defclass \*d);

bool ClassReactiveP(  
 Defclass \*d);

bool SubclassP(  
 Defclass \*d1,  
 Defclass \*d2);

bool SuperclassP(  
 Defclass \*d1,  
 Defclass \*d2);

The function **ClassAbstractP** is the C equivalent of the CLIPS **class-abstractp** command. It returns true if the defclass specified by parameter **d** is abstract; otherwise, it returns false.

The function **ClassReactiveP** is the C equivalent of the CLIPS **class-reactivep** command. It returns true if the defclass specified by parameter **d** is reactive; otherwise, it returns false.

The function **SubclassP** returns true if the class specified by parameter **d1** is a subclass of the class specified by parameter **d2**; otherwise, it returns false.

The function **SuperclassP** returns true if the class specified by parameter **d1** is a superclass of the class specified by parameter **d2**; otherwise, it returns false.

### 12.12.6 Slot Attributes

bool SlotAllowedClasses(  
 Defclass \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool SlotAllowedValues(  
 Defclass \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool SlotCardinality(  
 Defclass \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool SlotDefaultValue(  
 Defclass \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool SlotFacets(  
 Defclass \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool SlotRange(  
 Defclass \*d,  
 const char \*name,  
 CLIPSValue \*out);

bool SlotSources(  
 Defclass \*d,  
 const char \*name  
 CLIPSValue \*out);

bool SlotTypes(  
 Defclass \*d,  
 const char \*name,  
 CLIPSValue \*out);

The function **SlotAllowedClasses** is the C equivalent of the CLIPS **slot‑allowed-classes**‑ function. The function **SlotAllowedValues** is the C equivalent of the CLIPS **slot‑allowed-values**‑ function. The function **SlotCardinality** is the C equivalent of the CLIPS **slot-cardinality** function. The function **SlotDefaultValue** is the C equivalent of the CLIPS **slot-default-value** function. The function **SlotFacets** is the C equivalent of the CLIPS **slot-facets** command. The function **SlotRange** is the C equivalent of the CLIPS **slot‑range**‑ function. The function **SlotSources** is the C equivalent of the CLIPS **slot-sources** command. The function **SlotTypes** is the C equivalent of the CLIPS **slot-types** function.

Parameter **d** is a pointer to a **Defclass**; parameter **name** specifies a valid slot name for the specified defclass; and parameter **out** is a pointer to a **CLIPSValue** allocated by the caller. The output of the function call—a multifield containing the attribute values—is stored in the **out** parameter value. These function return true if a valid slot name was specified and the output value is successfully set; otherwise, false is returned.

### 12.12.7 Slot Predicates

bool SlotDirectAccessP(  
 Defclass \*d,  
 const char \*name);

bool SlotExistP(  
 Defclass \*d,  
 const char \*name,  
 bool inherit);

bool SlotInitableP(  
 Defclass \*d,  
 const char \*name);

bool SlotPublicP(  
 Defclass \*d,  
 const char \*name);

bool SlotWritableP(  
 Defclass \*d,  
 const char \*name);

The function **SlotDirectAccessP** is the C equivalent of the CLIPS **slot-direct-accessp** function. Parameter **d** is a pointer to a **Defclass**; and parameter **name** specifies a slot name. This function returns true if the slot is directly accessible; otherwise, it returns false.

The function **SlotExistP** is the C equivalent of the CLIPS **slot-existp** function. Parameter **d** is a pointer to a **Defclass**; parameter **name** specifies a slot name; and parameter **inherit** is a boolean flag. This function returns true if the specified slot exists; otherwise, it returns false. If the **inherit** parameter value is true, then inherited classes will be searched for the slot; otherwise, only the specified class will be searched.

The function **SlotInitableP** is the C equivalent of the CLIPS **slot-initablep** function. Parameter **d** is a pointer to a **Defclass**; and parameter **name** specifies a slot name. This function returns true if the slot is initable; otherwise, it returns false.

The function **SlotPublicP** is the C equivalent of the CLIPS **slot-publicp** function. Parameter **d** is a pointer to a **Defclass**; and parameter **name** specifies a slot name. This function returns true if the slot is public; otherwise, it returns false.

The function **SlotWritableP** is the C equivalent of the CLIPS **slot-writablep** function. Parameter **d** is a pointer to a **Defclass**; and parameter **name** specifies a slot name. This function returns true if the slot is writable; otherwise, it returns false.

### 12.12.8 Settings

ClassDefaultsMode GetClassDefaultsMode(  
 Environment \*env);

ClassDefaultsMode SetClassDefaultsMode(  
 Environment \*env,  
 ClassDefaultsMode mode);

typedef enum  
 {  
 CONVENIENCE\_MODE,  
 CONSERVATION\_MODE  
 } ClassDefaultsMode;

The function **GetClassDefaultsMode** is the C equivalent of the CLIPS **get‑class‑defaults‑mode**‑‑‑ command. The **env** parameter is a pointer to a previously created environment. This function returns the ClassDefaultsMode enumeration corresponding to the current setting.

The function **SetClassDefaultsMode** the C equivalent of the CLIPS command **set‑class‑defaults-mode**‑‑). The **env** parameter is a pointer to a previously created environment; the **mode** parameter is the new setting for the behavior. This function returns the old setting for the behavior.

## 12.13 Instance Functions

The following function calls are used for manipulating instances.

### 12.13.1 Search, Iteration, and Listing

Instance \*FindInstance(  
 Environment \*env,  
 Defmodule \*d,  
 const char \*name,  
 bool searchImports);

Instance \*GetNextInstance(  
 Environment \*env,  
 Instance \*i);

Instance \*GetNextInstanceInClass(  
 Defclass \*d,  
 Instance \*i);

Instance \*GetNextInstanceInClassAndSubclasses(  
 Defclass \*\*d,  
 Instance \*i,  
 UDFValue \*iterator);

void Instances(  
 Environment \*env,  
 const char \*logicalName,  
 Defmodule \*d,  
 const char \*className,  
 bool listSubclasses);

The function **FindInstance** searches for the named instance specified by parameter **name** in the module specified by parameter **d** in the environment specified by parameter **env**. If parameter **d** is a null pointer, then the current module will be searched. If parameter **searchImports** is true, then imported modules will also be searched for the instance. If the named instance is found, a pointer to it is returned; otherwise, the null pointer is returned.

The function **GetNextInstance** provides iteration support for the list of instance in an environment. If parameter **i** is a null pointer, then a pointer to the first **Instance** in the environment specified by parameter **env** is returned by this function; otherwise, a pointer to the next **Instance** following the **Instance** specified by parameter **i** is returned. If parameter **i** is the last **Instance** in the specified environment, a null pointer is returned.

The function **GetNextInstanceInClass** provides iteration support for the list of instances belonging to a defclass. If parameter **i** is a null pointer, then a pointer to the first **Instance** for the defclass specified by parameter **d** is returned by this function; otherwise, a pointer to the next **Instance** of the specified defclass following the **Instance** specified by parameter **i** is returned. If parameter **i** is the last **Instance** for the specified defclass, a null pointer is returned.

The function **GetNextInstanceInClassAndSubclasses** provides iteration support for the list of instances belonging to a defclass and its subclasses. If parameter **i** is a null pointer, then a pointer to the first **Instance** for the defclass or subclasses specified by parameter **d** is returned by this function; otherwise, a pointer to the next **Instance** of the specified defclass or its subclasses following the **Instance** specified by parameter **i** is returned. If parameter **i** is the last **Instance** for the specified defclass or its subclasses, a null pointer is returned. Parameter **d** is a pointer to a pointer to a **Defclass** declared by the caller. As the subclasses of the specified class are iterated through to find instances, the value referenced by the **d** parameter value is updated to indicate the class of the instance returned by this function. Parameter **iterator** is a pointer to a **UDFValue** declared by the caller that is used to store instance iteration information; no initialization of this argument is required and the values stored in this argument are not intended for examination by the calling function.

The function **Instances** is the C equivalent of the CLIPS **instances** command. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; parameter **d** is a pointer to a **Defmodule**; parameter **name** is the name of a defclass; and parameter **listSubclasses** is a boolean value indicating whether instances of subclasses should be listed. If parameter **d** is a null pointer, then all instances of all classes in all modules are listed (and the parameters values for **name** and **listSubclasses** are ignored). If parameter **d** is not a null pointer and parameter **name** is a null pointer, all instance of all classes in the specified module are listed (and parameter **listSubclasses** is ignored).

### 12.13.2 Attributes

Defclass \*InstanceClass(  
 Instance \*i);

const char \*InstanceName(  
 Instance \*i);

void InstancePPForm(  
 Instance \*i,  
 StringBuilder \*sb);

bool DirectGetSlot(  
 Instance \*i,  
 const char \*name,  
 CLIPSValue \*out);

The function **InstanceClass** returns a pointer to the **Defclass** associated with the **Instance** specified by parameter **i**.

The function **InstanceName** returns the instance name of the **Instance** specified by parameter **i**.

The function **InstancePPForm** stores the text representation of the **Instance** specified by the parameter **i** in the **StringBuilder** specified by parameter **sb**.

The function **DirectGetSlot** is the C equivalent of the CLIPS **dynamic‑get**‑ function. It retrieves the slot value specified by parameter **name** from the instance specified by parameter **i** and stores it in parameter **out**, a **CLIPSValue** allocated by the caller. This function returns true if the slot value was successfully retrieved; otherwise, it returns false. This function bypasses message‑passing.

The function **DirectPutSlot** is the C equivalent of the CLIPS **dynamic‑put**‑ function. It sets the slot value specified by parameter **name** of the instance specified by parameter **i** to the value stored in parameter **in**, a **CLIPSValue** allocated and set by the caller. This function returns true if the slot value was successfully set; otherwise, it returns false. This function bypasses message‑passing.

### 12.13.3 Deletion

bool UnmakeInstance(  
 Instance \*i);

bool UnmakeAllInstances(  
 Environment \*env);

bool DeleteInstance(  
 Instance \*i);

bool DeleteAllInstances(  
 Environment \*env);

The function **UnmakeInstance** deletes the instance specified by parameter **i** using message-passing. The function **UnmakeAllInstances** deletes all instances in the environment specified by parameter **env** using message-passing. Both functions returns true if deletion is successful; otherwise, false is returned.

The function **DeleteInstance** directly deletes the instance specified by parameter **i** bypassing message-passing. The function **DeleteAllInstances** directly deletes all instances in the environment specified by parameter **env** bypassing message-passing. Both functions returns true if deletion is successful; otherwise, false is returned.

### 12.13.4 Loading and Saving Instances

long BinaryLoadInstances(  
 Environment \*env,  
 const char \*fileName);

long LoadInstances(  
 Environment \*env,  
 const char \*fileName);

long LoadInstancesFromString(  
 Environment \*env,  
 const char \*str,  
 long length);

long RestoreInstances(  
 Environment \*env,  
 const char \*fileName);

long RestoreInstancesFromString(  
 Environment \*env,  
 const char \*str,  
 long length);

long BinarySaveInstances(  
 Environment \*env,  
 const char \*fileName,  
 SaveScope saveCode);

long SaveInstances(  
 Environment \*env,  
 const char \*fileName,  
 SaveScope saveCode);

typedef enum  
 {  
 LOCAL\_SAVE,  
 VISIBLE\_SAVE  
 } SaveScope;

The function **BinaryLoadInstances** is the C equivalent of the CLIPS **bload‑instances**‑ command. Parameter **env** is a pointer to a previously created environment; and parameter **fileName** is a full or partial path string to binary instances save file created using **BinarySaveInstances**. This function returns the number of instances loaded, or -1 if an error occurs.

The function **LoadInstances** is the C equivalent of the CLIPS **load-instances** command. Parameter **env** is a pointer to a previously created environment; and parameter **fileName** is a full or partial path string to an ASCII or UTF-8 file containing instances. This function returns the number of instances loaded, or -1 if an error occurs.

The function **LoadInstancesFromString** loads a set of instances from a string input source (much like the **LoadInstances** function only using a string for input rather than a file). Parameter **env** is a pointer to a previously created environment; parameter **str** is a string containing instances; and parameter **length** is the maximum number of characters to be read from the input string. If the **length** parameter value is -1, then the **str** parameter value must be terminated by a null character; otherwise, the **length** parameter value indicates the maximum number characters that will be read from the **str** parameter value. This function returns the number of instances restored, or -1 if an error occurs.

The function **RestoreInstances** is the C equivalent of the CLIPS **restore-instances** command. Parameter **env** is a pointer to a previously created environment; and parameter **fileName** is a full or partial path string to an ASCII or UTF-8 file containing instances. This function returns the number of instances restored, or -1 if an error occurs.

The function **RestoreInstancesFromString** loads a set of instances from a string input source (much like the **RestoreInstances** function only using a string for input rather than a file). Parameter **env** is a pointer to a previously created environment; parameter **str** is a string containing instances; and parameter **length** is the maximum number of characters to be read from the input string. If the **length** parameter value is -1, then the **str** parameter value must be terminated by a null character; otherwise, the **length** parameter value indicates the maximum number characters that will be read from the **str** parameter value. This function returns the number of instances restored, or -1 if an error occurs.

The function **BinarySaveInstances** is the C equivalent of the CLIPS **bsave-instances** command. Parameter **env** is a pointer to a previously created environment; parameter **fileName** is a full or partial path string to the binary instances save file that will be created; and parameter **scope** indicates whether all instances visible to the current module should be saved (VISIBLE\_SAVE) or just those associated with defclasses defined in the current module (LOCAL\_SAVE). This function returns the number of instances saved.

The function **SaveInstances** is the C equivalent of the CLIPS **save-instances** command. Parameter **env** is a pointer to a previously created environment; parameter **fileName** is a full or partial path string to the instance save file that will be created; and parameter **scope** indicates whether all instances visible to the current module should be saved (VISIBLE\_SAVE) or just those associated with defclasses defined in the current module (LOCAL\_SAVE).

### 12.13.5 Reference Counts

void IncrementInstanceReferenceCount( // TBD RetainInstance  
 Instance \*i);

void DecrementInstanceReferenceCount( // TBD ReleaseInstance  
 Instance \*i);

bool ValidInstanceAddress(  
 Instance \*i);

The function **IncrementInstanceReferenceCount** should be called for each external copy of a pointer to an instance to let CLIPS know that such an outstanding external reference exists. As long as an instance’s reference count is greater than zero, CLIPS will not release its memory because there may be outstanding pointers to the instance. However, the instance can still be *functionally*deleted, i.e. the instance will *appear* to no longer be in the system. The instance address always can be safely *examined* using the instance access functions as long as the count for the instance is greater than zero. These functions will recognize when an instance has been functionally deleted.

The function **DecrementInstanceReferenceCount** should *only* be called to reverse the effects of a previous call to **IncrementInstanceReferenceCount**. As long as an instance's count is greater than zero, the memory allocated to it cannot be released for other use.

The function **ValidInstanceAddress** determines if an instance referenced by an address still exists. It returns true if the instance still exists; otherwise, it returns false. The parameter **i** must be a **Instance** that has a reference count greater than 0.

### 12.13.6 Detecting Changes to Instances

bool GetInstancesChanged(  
 Environment \*env);

void SetInstancesChanged(  
 Environment \*env,  
 bool b);

The function **GetInstancesChanged** returns true if changes to instances for the environment specified by parameter **env** have occurred (either creations, deletions, or slot value changes); otherwise, it returns false. To track future changes, **SetInstanceChanged** should reset the change tracking value to false.

The function **SetInstancesChanged** sets the instances change tracking value for the environment specified by the parameter **env** to the value specified by the parameter **b**.

### 12.13.7 Send

void Send(  
 Environment \*env,  
 CLIPSValue \*in,  
 const char \*msg,  
 const char \*msgArgs  
 CLIPSValue \*out);

The function **Send** is the C equivalent of the CLIPS **send** function. Parameter **env** is a pointer to a previously created environment; parameter **in** is a CLIPSValue allocated and assigned the value of the object (instance, instance name, symbol, etc.) to receive the message; parameter **msg** is the message to be received; parameter **msgArgs** is a string containing the constants arguments to the message separated by spaces (a null pointer indicates no arguments); and parameter **out** is a CLIPSValue allocated by the caller that is assigned the return value of the message call. If the calling function does not need to examine the return value of the message, a null pointer can be specified for the **out** parameter value. This function can trigger garbage collection.

### 12.13.8 Examples

#### 12.13.8.1 Instance Iteration

#include "clips.h"

int main()

{

Environment \*theEnv;

UDFValue iterate;

Instance \*theInstance;

Defclass \*theClass;

theEnv = CreateEnvironment();

Build(theEnv,"(defclass A (is-a USER))");

Build(theEnv,"(defclass B (is-a USER))");

MakeInstance(theEnv,"(a1 of A)");

MakeInstance(theEnv,"(a2 of A)");

MakeInstance(theEnv,"(b1 of B)");

MakeInstance(theEnv,"(b2 of B)");

theClass = FindDefclass(theEnv,"USER");

for (theInstance = GetNextInstanceInClassAndSubclasses(&theClass,NULL,&iterate);

theInstance != NULL;

theInstance = GetNextInstanceInClassAndSubclasses(&theClass,

theInstance,&iterate))

{ Writeln(theEnv,InstanceName(theInstance)); }

DestroyEnvironment(theEnv);

}

The output when running this example is:

a1

a2

b1

b2

#### 12.13.8.2 Send TBD

#include "clips.h"

int main()

{

Environment \*theEnv;

char \*cs;

//CLIPSValue insdata;

theEnv = CreateEnvironment();

Build(theEnv,"(defclass MY-CLASS (is-a USER))");

// Note the use of escape characters to embed quotation marks.

// (defmessage-handler MY-CLASS my-msg (?x ?y ?z)

// (printout t ?x " " ?y " " ?z crlf))

cs = "(defmessage-handler MY-CLASS my-msg (?x ?y ?z)"

" (printout t ?x \" \" ?y \" \" ?z crlf))";

Build(theEnv,cs);

//insdata.instanceValue = MakeInstance(theEnv,"(my-instance of MY-CLASS)");

//Send(theEnv,&insdata,"my-msg","1 abc 3",NULL);

Eval(theEnv,"(send [my-instance] my-msg 1 abc 3)",NULL);

DestroyEnvironment(theEnv);

}

#### 12.13.8.3 Example B TBD

#include "clips.h"

/\*===========\*/

/\* Incorrect \*/

/\*===========\*/

void InstanceReferenceExampleIncorrect(

void \*theEnv)

{

void \*myInstancePtr;

myInstancePtr = EnvFindInstance(theEnv,NULL,"my-instance",TRUE);

/\*===========================================\*/

/\* Instance my-instance could be potentially \*/

/\* deleted during the run. \*/

/\*===========================================\*/

EnvRun(theEnv,-1L);

/\*===========================================\*/

/\* This next function call could dereference \*/

/\* a dangling pointer and cause a crash. \*/

/\*===========================================\*/

EnvDeleteInstance(theEnv,myInstancePtr);

}

/\*=========\*/

/\* Correct \*/

/\*=========\*/

void InstanceReferenceExampleCorrect(

void \*theEnv)

{

void \*myInstancePtr;

myInstancePtr = EnvFindInstance(theEnv,NULL,"my-instance",TRUE);

/\*=====================================================\*/

/\* The instance is correctly marked so that a dangling \*/

/\* pointer cannot be created during the run. \*/

/\*=====================================================\*/

EnvIncrementInstanceCount(theEnv,myInstancePtr);

EnvRun(theEnv,-1L);

EnvDecrementInstanceCount(theEnv,myInstancePtr);

/\*===========================================================\*/

/\* The instance can now be safely deleted using the pointer. \*/

/\*===========================================================\*/

EnvDeleteInstance(theEnv,myInstancePtr);

}

## 12.14 Defmessage-handler Functions

The following function calls are used for manipulating defmessage‑handlers.

### 12.14.1 Search, Iteration, and Listing

unsigned FindDefmessageHandler(  
 Defclass \*d,  
 const char \*name,  
 const char \*type);

unsigned GetNextDefmessageHandler(  
 Defclass \*d,  
 unsigned id);

void GetDefmessageHandlerList(  
 Environment \*env,  
 Defclass \*d,  
 CLIPSValue \*out,  
 bool inherited);

void ListDefmessageHandlers(  
 Environment \*env,  
 Defclass \*d,  
 const char \*logicalName,  
 bool inherited);

The function **FindDefmessageHandler** searches for the defmessage-handler specified by parameters **name** and **type** in the defclass specified by parameter **d**. Parameter **type** should be one of the following values: "around", "before", "primary", or "around". This function returns an integer id for the defmessage-handler if it exists; otherwise, it returns 0.

The function **GetNextDefmessageHandler** provides iteration support for the list of defmessage-handlers for a defclass. If parameter **id** is a 0, then the integer id to the first defmessage-handler for the defclass specified by parameter **d** is returned by this function; otherwise, the integer id to the next defmessage-handler following the defmessage-handler specified by parameter **id** is returned. If parameter **id** is the last defmessage-handler for the specified defclass, 0 is returned.

The function **GetDefmessageHandlerList** is the C equivalent of the CLIPS **get‑defmessage-handler-list**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **d** is a pointer to a **Defclass**; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **inherited** is a boolean value that indicates whether inherited message-handlers are included. The output of the function call—a multifield containing a list of class name/handler name/handler type triplets—is stored in the **out** parameter value. If parameter **d** is a null pointer, then message-handlers for all defclasses will be included in parameter **out**; otherwise, only message-handlers for the specified defclass will be included.

The function **ListDefmessageHandlers** is the C equivalent of the CLIPS **list‑defmessage-handlers**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **d** is a pointer to a defclass; parameter **logicalName** is the router output destination; and parameter **inherited** is a boolean value that indicates whether inherited message-handlers are listed. If parameter **d** is a null pointer, then defmessage-handlers for all defclasses will be listed; otherwise, only defmessage-handlers for the specified defclass will be listed.

### 12.14.2 Attributes

const char \*DefmessageHandlerName(  
 Defclass \*defclassPtr,  
 unsigned id);

const char \*DefmessageHandlerPPForm(  
 Defclass \*d,  
 unsigned id);

const char \*GetDefmessageHandlerType(  
 Defclass \*d,  
 unsigned id);

The function **DefmessageHandlerName** returns the name of the defmessage-handlerspecified by parameters **d**, a **Defclass**, and **id**, the message-handler id.

The function **DefmessageHandlerPPForm** returns the text representation of the defmessage-handler specified by parameter **d,** a defclass, and parameter **id**, a message-handler id. The null pointer is returned if the text representation is not available.

The function **DefmessageHandlerType** returns the type of the defmessage-handler specified by parameter **d,** a defclass, and parameter **id**, a message-handler id. The return value of this function is one of the following values: "around", "before", "primary", or "around".

### 12.14.3 Deletion

bool DefmessageHandlerIsDeletable(  
 Defclass \*d,  
 unsigned id);

bool UndefmessageHandler(  
 Defclass \*d,  
 unsigned id,  
 Environment \*env);

The function **DefmessageHandleIsDeletable** returns true if the defmessage-handler specified by parameter **d**, a defclass, and **id**, a message-handler id, can be deleted; otherwise it returns false.

The function **UndefmessageHandler** is the C equivalent of the CLIPS **undefmessage-handler** command. It deletes the defmessage-handler specified by parameter **d**, parameter **d**, and parameter **env**. If parameter **d** is a null pointer and parameter **id** is 0, it deletes all message-handlers for all classes in the environment specified by parameter **env**; if parameter **d** is not a null pointer and parameter **id** is 0, it deletes all message-handlers of the defclass; otherwise, the defmessage-handler specified by the defclass and message-handler id is deleted. This function returns true if the deletion is successful; otherwise, it returns false.

### 12.14.4 Watching Message-Handlers

bool DefmessageHandlerGetWatch(  
 Defclass \*d,  
 unsigned id);

void DefmessageHandlerSetWatch(  
 Defclass \*d,  
 unsigned id,  
 bool b);

The function **DefmessageHandlerGetWatch** returns true if the message-handler specified by parameter **d**, the defclass, and parameter **id**, the message-handler id, is being watched; otherwise, it returns false.

The function **DefmessageHandlerSetWatch** sets the message-handler watch state for the defmessage-handler specified by parameter **d**, the defclass, and parameter **id**, the message-handler id, to the value specified by the parameter **b**.

### 12.14.5 PreviewSend

void PreviewSend(  
 Defclass \*d,  
 const char \*logicalName,  
 const char \*message);

The function **PreviewSend** is the C equivalent of the CLIPS **preview‑send**‑ command. Parameter **d** is a pointer to a defclass; parameter **logicalName** is the router output destination; and parameter **message** is the name of the message-handler to be previewed.

### 12.14.6 Example

This example demonstrates how to preview a send message and watch specific message-handlers when a message is executed. The following output shows how you would typically perform this task from the CLIPS command prompt:

CLIPS> (defclass A (is-a USER))

CLIPS> (defmessage-handler A foo (?x))

CLIPS> (defmessage-handler A foo before (?x))

CLIPS> (defmessage-handler A foo after (?x))

CLIPS> (defclass B (is-a A))

CLIPS> (defmessage-handler B foo (?x) (call-next-handler))

CLIPS> (defmessage-handler B foo around (?x) (call-next-handler))

CLIPS> (preview-send B foo)

>> foo around in class B

| >> foo before in class A

| << foo before in class A

| >> foo primary in class B

| | >> foo primary in class A

| | << foo primary in class A

| << foo primary in class B

| >> foo after in class A

| << foo after in class A

<< foo around in class B

CLIPS> (watch message-handlers A foo primary)

CLIPS> (watch message-handlers B foo around)

CLIPS> (make-instance [b1] of B)

[b1]

CLIPS> (send [b1] foo 3)

HND >> foo around in class B

ED:1 (<Instance-b1> 3)

HND >> foo primary in class A

ED:1 (<Instance-b1> 3)

HND << foo primary in class A

ED:1 (<Instance-b1> 3)

HND << foo around in class B

ED:1 (<Instance-b1> 3)

FALSE

CLIPS>

To achieve the same result from a C program, change the contents of the main.c source file to the following:

#include "clips.h"

int main()

{

Environment \*env;

Defclass \*classA, \*classB;

env = CreateEnvironment();

Build(env,"(defclass A (is-a USER))");

Build(env,"(defmessage-handler A foo (?x))");

Build(env,"(defmessage-handler A foo before (?x))");

Build(env,"(defmessage-handler A foo after (?x))");

Build(env,"(defclass B (is-a A))");

Build(env,"(defmessage-handler B foo (?x) (call-next-handler))");

Build(env,"(defmessage-handler B foo around (?x) (call-next-handler))");

classA = FindDefclass(env,"A");

classB = FindDefclass(env,"B");

Write(env,"Preview Send:\n\n");

PreviewSend(classB,STDOUT,"foo");

Write(env,"\nWatch Handlers and Send Message:\n\n");

DefmessageHandlerSetWatch(classA,

FindDefmessageHandler(classA,"foo","primary"),

true);

DefmessageHandlerSetWatch(classB,

FindDefmessageHandler(classB,"foo","around"),

true);

MakeInstance(env,"([b1] of B)");

Eval(env,"(send [b1] foo 3)",NULL);

DestroyEnvironment(env);

}

The following output will be produced when the program is run:

Preview Send:

>> foo around in class B

| >> foo before in class A

| << foo before in class A

| >> foo primary in class B

| | >> foo primary in class A

| | << foo primary in class A

| << foo primary in class B

| >> foo after in class A

| << foo after in class A

<< foo around in class B

Watch Handlers and Send Message:

HND >> foo around in class B

ED:1 (<Instance-b1> 3)

HND >> foo primary in class A

ED:1 (<Instance-b1> 3)

HND << foo primary in class A

ED:1 (<Instance-b1> 3)

HND << foo around in class B

ED:1 (<Instance-b1> 3)

## 12.15 Definstances Functions

The following function calls are used for manipulating definstances.

### 12.15.1 Search, Iteration, and Listing

Definstances \*FindDefinstances(  
 Environment \*env,  
 const char \*name);

Definstances \*GetNextDefinstances(  
 Environment \*env,  
 Definstances \*d);

void GetDefinstancesList(  
 Environment \*env,  
 CLIPSValue \*out,  
 Defmodule \*d);

void ListDefinstances(  
 Environment \*env,  
 char \*logicalName,  
 Defmodule \*d);

The function **FindDefinstances** searches for the definstances specified by parameter **name** in the environment specified by parameter **env**. This function returns a pointer to the named definstances if it exists; otherwise, it returns a null pointer.

The function **GetNextDefinstances** provides iteration support for the list of definstances in the current module. If parameter **d** is a null pointer, then a pointer to the first **Definstances** in the current module is returned by this function; otherwise, a pointer to the next **Definstances** following the **Definstancess** specified by parameter **d** is returned. If parameter **d** is the last **Deffacts** in the current module, a null pointer is returned.

The function **GetDefinstancesList** the C equivalent of the CLIPS **get-definstances-list** function. Parameter **env** is a pointer to a previously created environment; parameter **out** is a pointer to a **CLIPSValue** allocated by the caller; and parameter **d** is a pointer to a **Defmodule**. The output of the function call—a multifield containing a list of definstances names—is stored in the **out** parameter value. If parameter **d** is a null pointer, then definstancess in all modules will be included in parameter **out**; otherwise, only definstancess in the specified module will be included.

The function **ListDefinstances** is the C equivalent of the CLIPS **list‑definstances**‑ command. Parameter **env** is a pointer to a previously created environment; parameter **logicalName** is the router output destination; and parameter **d** is a pointer to a defmodule. If parameter **d** is a null pointer, then definstances in all modules will be listed; otherwise, only definstances in the specified module will be listed.

### 12.15.2 Attributes

const char \*DefinstancesModule(  
 Definstances \*d);

const char \*DefinstancesName(  
 Definstances \*d);

const char \*DefinstancesPPForm(  
 Definstances \*d);

The function **DefinstancesModule** is the C equivalent of the CLIPS **definstances-module** command.

The function **DefinstancesName** returns the name of the deffactsspecified by the **d** parameter.

The function **DefinstancePPForm** returns the text representation of the **Definstancess** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

### 12.15.3 Deletion

bool DefinstancesIsDeletable(  
 Definstances \*d);

bool Undefinstances(  
 Definstances \*d,  
 Environment \*env);

The function **DefinstancesIsDeletable** returns true if the definstances specified by parameter **d** can be deleted; otherwise it returns false.

The function **Undefinstances** is the C equivalent of the CLIPS **undefinstances** command. It deletes the definstances specified by parameter **d**; or if parameter **d** is a null pointer, it deletes all definstances in the environment specified by parameter **env**. This function returns true if the deletion is successful; otherwise, it returns false.

## 12.16 Defmodule Functions

The following function calls are used for manipulating defmodules.

### 12.16.1 Search, Iteration, and Listing

Defmodule \*FindDefmodule(  
 Environment \*env,  
 const char \*name);

Defmodule \*GetNextDefmodule(  
 Environment \*env,  
 Defmodule \*d);

void GetDefmoduleList(  
 Environment \*env,  
 CLIPSValue \*out);

void ListDefmodules(  
 Environment \*env,  
 const char \*logicalName);

The function **FindDefmodule** searches for the defmodule specified by parameter **name** in the environment specified by parameter **env**. This function returns a pointer to the named defmodule if it exists; otherwise, it returns a null pointer.

The function **GetNextDefmodule** provides iteration support for the list of defmodules. If parameter **d** is a null pointer, then a pointer to the first **Defmodule** in the environment is returned by this function; otherwise, a pointer to the next **Defmodule** following the **Defmodule** specified by parameter **d** is returned. If parameter **d** is the last **Defmodule** in the environment, a null pointer is returned.

The function **GetDefmoduleList** is the C equivalent of the CLIPS **get-defmodule-list** function. Parameter **env** is a pointer to a previously created environment; and parameter **out** is a pointer to a **CLIPSValue** allocated by the caller. The output of the function call—a multifield containing a list of defmodule names—is stored in the **out** parameter value.

The function **ListDefmodules** is the C equivalent of the CLIPS **list‑defmodules**‑ command. Parameter **env** is a pointer to a previously created environment; and parameter **logicalName** is the router output destination.

### 12.16.2 Attributes

const char \*DefmoduleName(  
 Defmodule \*d);

const char \*DefmodulePPForm(  
 Defmodule \*d);

The function **DefmoduleName** returns the name of the defmodulespecified by the **d** parameter.

The function **DefmodulePPForm** returns the text representation of the **Defmodule** specified by the **d** parameter. The null pointer is returned if the text representation is not available.

### 12.16.3 Current Module

Defmodule \*GetCurrentModule(  
 Environment \*env);

Defmodule \*SetCurrentModule(  
 Environment \*env,  
 Defmodule \*d);

The function **GetCurrentModule** is the C equivalent of the CLIPS **get-current-module** function. Parameter **env** is a pointer to a previously created environment. This function returns a pointer to the current environment.

The function **SetCurrentModule** is the C equivalent of the CLIPS **set-current-module** function. Parameter **env** is a pointer to a previously created environment; and parameter **d** is a pointer to a **Defmodule** that will become the current module. The return value of this function is the prior current module.

## 12.17 Standard Memory Functions

CLIPS provides functions that can be used to monitor and control memory usage.

### 12.17.1 Memory Allocation and Deallocation

void \*genalloc(  
 Environment \*env,  
 size\_t size);

void genfree(  
 Environment \*env,  
 void \*ptr,  
 size\_t size);

The function **genalloc** allocates a block of memory using the CLIPS memory management routines. CLIPS caches memory to improve to performance. Calls to genalloc will first attempt to allocate memory from the cache before making a call to the C library **malloc** function. Parameter **env** is a pointer to a previously allocated environment; and parameter **size** is the number of bytes to be allocated. This function returns a pointer to a memory block of the specified size if successful; otherwise, a null pointer is returned.

The function **genfree** returns a block of memory to the CLIPS memory management routines. Calls to **genfree** adds the freed memory to the CLIPS cache for later reuse. The CLIPS **ReleaseMem** function can be used to clear the cache and release memory back to the operating system. Parameter **env** is a pointer to a previously allocated environment; parameter **ptr** is a pointer to memory previously allocated by **genalloc**; and parameter **size** is the size in bytes of the block of memory.

### 12.17.2 Settings

bool GetConserveMemory(  
 Environment \*env);

bool SetConserveMemory(  
 Environment \*env,  
 bool b;)

The function **GetConserveMemory** returns the current value of the conserve memory behavior. If enabled (true), newly loaded constructs do not have their text (printy print) representation stored with the construct. If there is no need to save or pretty print constructs, this will reduce the amount of memory needed to load constructs.

The function **SetConserveMemory** sets the conserve memory behavior for the environment specified by the parameter **env** to the value specified by the parameter **b**. Changing the value for this behavior does not affect existing constructs.

### 12.17.3 Memory Tracking

long MemRequests(  
 Environment \*env);

long MemUsed(  
 Environment \*env);

long ReleaseMem(  
 Environment \*env,  
 long limit);

The function **MemRequests** is the C equivalent of the CLIPS **mem-requests** command. The return value of this function is the number of memory requests currently held by CLIPS. When used in conjunction with **MemoryUsed**, the user can estimate the number of bytes CLIPS requests per call to **malloc**.

The function **MemUsed** is the C equivalent of the CLIPS **mem-used** command. The return value of this function is the total number of bytes requested and currently held by CLIPS. The number of bytes used does not include any overhead for memory management or data creation. It does include all free memory being held by CLIPS for later use; there­fore, it is not a completely accurate measure of the amount of mem­ory actually used to store or process information. It is used primarily as a minimum indication.

The function **ReleaseMem** is the C equivalent of the CLIPS **release-mem** command. It allows free memory being cached by CLIPS to be returned to the operating system. Parameter **env** is a previously allocated environment; and parameter **limit** is the amount of memory to be released. If the **limit** parameter value is 0 or less, then all cached memory will be released; otherwise, cached memory will be released until the amount of released memory exceeds the **limit** parameter value. The return value of this function is the amount of cached memory released.

## 12.18 Embedded Application Examples

### 12.18.1 User‑Defined Functions

### 12.18.2 Manipulating Objects and Calling CLIPS Functions

This section lists the steps needed to define and use an embedded CLIPS application. The example illustrates how to call deffunctions and generic functions as well as manipulate objects from C.

1) Copy all of the CLIPS source code file to the user directory.

2) Define a new main routine in a new file.

#include "clips.h"

int main()

{

Environment \*env;

Instance \*c1, \*c2, \*c3;

CLIPSValue insdata, result;

env = CreateEnvironment();

/\*=============================================\*/

/\* Load the code for handling complex numbers. \*/

/\*=============================================\*/

Load(env,"complex.clp");

/\*=========================================================\*/

/\* Create two complex numbers. Message-passing is used to \*/

/\* create the first instance c1, but c2 is created and has \*/

/\* its slots set directly. \*/

/\*=========================================================\*/

c1 = MakeInstance(env,"(c1 of COMPLEX (real 1) (imag 10))");

c2 = CreateRawInstance(env,FindDefclass(env,"COMPLEX"),"c2");

result.integerValue = CreateInteger(env,3);

DirectPutSlot(c2,"real",&result);

result.integerValue = CreateInteger(env,-7);

DirectPutSlot(c2,"imag",&result);

/\*===========================================================\*/

/\* Call the function '+' which has been overloaded to handle \*/

/\* complex numbers. The result of the complex addition is \*/

/\* stored in a new instance of the COMPLEX class. \*/

/\*===========================================================\*/

Eval(env,"(+ [c1] [c2])",&result);

c3 = FindInstance(env,NULL,result.lexemeValue->contents,true);

/\*=======================================================\*/

/\* Print out a summary of the complex addition using the \*/

/\* "print" and "magnitude" messages to get information \*/

/\* about the three complex numbers. \*/

/\*=======================================================\*/

Write(env,"The addition of\n\n");

insdata.instanceValue = c1;

Send(env,&insdata,"print",NULL,NULL);

Write(env,"\nand\n\n");

insdata.instanceValue = c2;

Send(env,&insdata,"print",NULL,NULL);

Write(env,"\nis\n\n");

insdata.instanceValue = c3;

Send(env,&insdata,"print",NULL,NULL);

Write(env,"\nand the resulting magnitude is ");

Send(env,&insdata,"magnitude",NULL,&result);

WriteCLIPSValue(env,STDOUT,&result);

Write(env,"\n");

return 0;

}

3) Define constructs which use the new function in a file called **complex.clp** (or any file; just be sure the call to **Load** loads all necessary constructs prior to execution).

(defclass COMPLEX

(is-a USER)

(slot real)

(slot imag))

(defmethod + ((?a COMPLEX) (?b COMPLEX))

(make-instance of COMPLEX

(real (+ (send ?a get-real) (send ?b get-real)))

(imag (+ (send ?a get-imag) (send ?b get-imag)))))

(defmessage-handler COMPLEX magnitude ()

(sqrt (+ (\*\* ?self:real 2) (\*\* ?self:imag 2))))

4) Compile all CLIPS files, *except* **main.c**, along with all user files.

5) Link all object code files.

6) Execute new CLIPS executable. The output is:

The addition of

[c1] of COMPLEX

(real 1)

(imag 10)

and

[c2] of COMPLEX

(real 3)

(imag -7)

is

[gen1] of COMPLEX

(real 4)

(imag 3)

and the resulting magnitude is 5.000000

# Appendix A: Support Information

## A.1 Questions and Information

The URL for the CLIPS Web page is <http://www.clipsrules.net>.

Questions regarding CLIPS can be posted to one of several online forums including the CLIPS Expert System Group, <http://groups.google.com/group/CLIPSESG/>, the SourceForge CLIPS Forums, <http://sourceforge.net/forum/?group_id=215471>, and Stack Overflow, <http://stackoverflow.com/questions/tagged/clips>.

Inquiries related to the use or installation of CLIPS can be sent via electronic mail to [support@clipsrules.net](mailto:support@clipsrules.net).

## A.2 Documentation

The CLIPS Reference Manuals and other documentation is available at <http://www.clipsrules.net/?q=Documentation>.

*Expert Systems: Principles and Programming*, 4th Edition, by Giarratano and Riley comes with a CD-ROM containing CLIPS 6.22 executables (DOS, Windows XP, and Mac OS), documentation, and source code. The first half of the book is theory oriented and the second half covers rule-based, procedural, and object-oriented programming using CLIPS.

## A.3 CLIPS Source Code and Executables

CLIPS executables and source code are available on the SourceForge web site at <http://sourceforge.net/projects/clipsrules/files>.

# Appendix B: Update Release Notes

The following sections denote the changes and bug fixes for CLIPS versions 6.30 and 6.40.

## B.1 Version 6.40

• **EnvClear** – This function now returns a Boolean value.

• **Compiler Directives** – The **ALLOW\_ENVIRONMENT\_GLOBALS** flag has been removed. The **VAX\_VMS** flag has been removed.

## B.2 Version 6.30

• **CLIPS Java Native Interface** – The **CLIPSJNI** project contains libraries and example programs demonstrating the integration of CLIPS with Java. See section 10 for more information.

• **Windows Integration Examples** – Several example projects are available demonstrating the creation of C++ wrapper classes, static libraries, and dynamic link libraries. See section 11 for more information.

• **External Function 64-bit Interface** - Several functions and macros have been modified to support “long long” integers:

**DOToLong** (see section 3.2.3)

**DOPToLong** (see section 3.2.3)

**EnvAddLong** (see section 3.3.5)

**EnvFacts** (see section 4.4.9)

**EnvFactIndex** (see section 4.4.8)

**EnvDefineFunction** ‘g’ argument (see section 3.1)

**EnvRtnLong** (see section 3.2.2)

**EnvRun** (see section 4.7.20)

**ValueToLong** (see section 3.3.5)

• **Compiler Directives** – The **ENVIRONMENT\_API\_ONLY** flag has been removed. The **EX\_MATH** flag has been renamed to the **EXTENDED\_MATH\_FUNCTIONS** flag. The **BASIC\_IO** and **EXT\_IO** flags have been combined into the **IO\_FUNCTIONS** flag. The preprocessor definition flags in setup.h are now conditionally defined only if they are undefined (which allows you to define the flags from a makefile or project without editing setup.h). The **MAC\_MCW**, **WIN\_MCW**, and **WIN\_BTC** flags have been removed. The associated compilers are no longer supported.

• **Environment Globals** – The **ALLOW\_ENVIRONMENT\_GLOBALS** flag now defaults to 0. The use of functions previously enabled by this flag is deprecated. These functions include **GetCurrentEnvironment**, **GetEnvironmentByIndex**, **GetEnvironmentIndex**, **InitializeEnvironment**, **SetCurrentEnvironment**, and **SetCurrentEnviromentByIndex**.

• **Garbage Collection** – The mechanism used for garbage collection has been modified. See section 1.4 for information for more details. The EnvDecrementGCLocks function now performs garbage collection if the lock count is reduced to 0.

• **MicroEMACS Editor** – The built-in MicroEMACS editor is no longer supported. The associated source files and **EMACS\_EDITOR** compiler directive flag have been removed.

• **Block Memory** – Block memory allocation is no longer supported. The associated source code and **BLOCK\_MEMORY** compiler directive flag have been removed.

• **Help Functions** – The **help** and **help-path** funtions are no longer supported. The **HELP\_FUNCTIONS** compiler directive flag has been removed.

• **External Addresses** – The method of retrieving and returning an external address from a user defined function has changed (see sections 3.2.3, 3.3.4, and 3.3.5).

• **Deleted Source Files** – The following source files have been removed:

**cmptblty.h**

**ed.h**

**edbasic.c**

**edmain.c**

**edmisc.c**

**edstruct.c**

**edterm.c**

• **Logical Name Defintions** – Added logical name constants **STDIN** and **STDOUT** that can be used in place of the strings "stdin" and "stdout".

• **Command and Function Changes** ‑ The following commands and functions have been changed:

• **constructs-to-c** (see section 5.1). A target directory path can be specified for the files generated by this command.

• **EnvMatches** (see section 4.6.13). The number of parameter for this function has changed.

• **EnvSaveFacts** (see section 4.4.24). The number of parameter for this function has changed.

• **EnvSaveInstances** (see section 4.13.23). The number of parameter for this function has changed.

• **EnvBinarySaveInstances** (see section 4.13.2). The number of parameter for this function has changed.

• **EnvDefineFunction** (see section 3.1). New return types ‘g’ (long long integer) and ‘y’ (fact address) have been added.

• **EnvReleaseMem** (see section 8.2.4). The number of parameter for this function has changed.

# Index

ActivateRouter **93**

ActivationGetSalience **142**

ActivationPPForm **142**

ActivationRuleName **142**

ActivationSetSalience **142**

AddAfterRuleFiresFunction **143**

AddBeforeRuleFiresFunction **143**

AddClearFunction **119**

AddEnvironmentCleanupFunction **110**, 112

AddPeriodicFunction **120**

AddResetFunction **121**

AddRouter **91**

AddUDF **66**, **67**

AddUDFm 113

Advanced Programming Guide iii

Agenda 227

agenda 11, **141**, 142

AllocateEnvironmentData 109, **110**, 111

ALLOW\_ENVIRONMENT\_GLOBALS 223, 228

any‑factp 12

any‑instancep 12

assert-string 16

AssertString **16**

AUXILARY\_MESSAGE\_HANDLERS 226

Basic Programming Guide iii, 1

BASIC\_IO 224

batch\* 122

BatchStar 227

BatchStar **122**

BinaryLoadInstances **171**

BinarySaveInstances **171**

BLOAD **10**, 115, **122**

BLOAD\_AND\_BSAVE **10**

BLOAD\_INSTANCES **10**

BLOAD\_ONLY **10**, 11

bload‑instances 10, 172

BLOCK\_MEMORY 224

browse‑classes 162

BrowseClasses **161**

bsave 10, **122**, 123

BSAVE\_INSTANCES **10**

bsave‑instances 10, 173

build 13, **26**, 117

C 193

class-abstractp 165

ClassAbstractP **164**

class-reactivep 165

ClassReactiveP **164**

class-slots 163

ClassSlots **162**

class-subclasses 163

ClassSubclasses **162**

class-superclasses 163

ClassSuperclasses **162**

Clear **15**, 120

clear-focus-stack 145

ClearFocusStack **145**

CLIPSJNI 223

close 12, 87

cmptblty.h 224

CommandLoop 116

compiler directives **9**

CONFLICT\_RESOLUTION\_STRATEGIES 226

CONSTRUCT\_COMPILER **10**

constructs-to-c 13, **115**, 225, 226

create$ 12

CreateCExternalAddress **46**

CreateEnvironment **15**, 109, 112, 119

CreateFactBuilder **49**

CreateFactModifier **50**

CreateFloat **44**

CreateInstanceBuilder **51**

CreateInstanceModifier **52**

CreateInstanceName **43**

CreateInteger **44**

CreateMultifieldBuilder **45**

CreateString **43**

CreateStringBuilder **27**

CreateSymbol **43**

DeactivateRouter **93**

DeallocateEnvironmentData 227

DEBUGGING\_FUNCTIONS **11**

DecrementFactReferenceCount 132

DecrementGCLocks 227

DecrementInstanceReferenceCount **173**

DefclassGetWatchInstances **164**

DefclassGetWatchSlots **164**

DefclassIsDeletable **163**

defclass-module 163

DefclassModule **162**

DefclassName **162**

DefclassPPForm **162**

DefclassSetWatchInstances **164**

DefclassSetWatchSlots **164**

DEFFACTS\_CONSTRUCT **11**

DeffactsIsDeletable **136**

deffacts-module 136

DeffactsModule **136**

DeffactsName **136**

DeffactsPPForm **136**

DEFFUNCTION\_CONSTRUCT **11**

DeffunctionIsDeletable **155**

deffunction-module 155

DeffunctionModule **154**

DeffunctionName **154**

DeffunctionPPForm **155**

DeffunctionSetWatch **155**

DEFGENERIC\_CONSTRUCT **11**

DefgenericGetWatch **158**

DefgenericIsDeletable **157**

defgeneric-module 157

DefgenericModule **157**

DefgenericName **157**

DefgenericPPForm **157**

DefgenericSetWatch **158**

DEFGLOBAL\_CONSTRUCT **11**

DefglobalGetWatch **151**

DefglobalIsDeletable **151**

defglobal-module 150

DefglobalModule **150**

DefglobalName **150**

DefglobalPPForm **150**

DefglobalSetValue **150**

DefglobalValueForm **150**

DEFINSTANCES\_CONSTRUCT **11**

DefinstancesIsDeletable **184**

definstances-module 184

DefinstancesModule **184**

DefinstancesName **184**

DefinstancesPPForm **184**

DefmessageHandlerGetWatch **180**

DefmessageHandlerIsDeletable **179**

DefmessageHandlerName **179**

DefmessageHandlerPPForm **179**

DefmessageHandlerSetWatch **180**

DefmessageHandlerType **179**

DefmethodDescription **159**

DefmethodGetWatch **160**

DefmethodIsDeletable **160**

DefmethodPPForm **159**

DefmethodSetWatch **160**

DEFMODULE\_CONSTRUCT **11**

DefmoduleName **186**

DefmodulePPForm **186**

DEFRULE\_CONSTRUCT **11**

DefruleGetWatchActivations **139**

DefruleGetWatchFirings **139**

DefruleHasBreakpoint **139**

DefruleIsDeletable **138**

defrule-module 138

DefruleModule **138**

DefruleName **138**

DefrulePPForm **138**

DefruleSetWatchActivations **139**

DefruleSetWatchFirings **139**

DEFTEMPLATE\_CONSTRUCT **12**

DeftemplateGetWatch **127**

DeftemplateIsDeletable **127**

deftemplate-module 126

DeftemplateModule **126**

DeftemplateName **126**

DeftemplateSetWatch **127**, **151**

deftemplate-slot‑allowed-values 128

DeftemplateSlotAllowedValues **127**, 225

deftemplate-slot-cardinality 128

DeftemplateSlotCardinality **128**, 225

deftemplate-slot-defaultp 129

DeftemplateSlotDefaultP **129**, 225

deftemplate-slot-default-value 128

DeftemplateSlotDefaultValue **128**, 225

deftemplate-slot-existp 129

DeftemplateSlotExistP **128**, 225

deftemplate-slot-multip 129

DeftemplateSlotMultiP **128**, 225

deftemplate-slot-names 126

DeftemplateSlotNames **126**, 225

deftemplate-slot‑range 128

DeftemplateSlotRange **128**, 225

deftemplate-slot-singlep 129

DeftemplateSlotSingleP **129**, 225

deftemplate-slot-types 128

DeftemplateSlotTypes **128**, 225

delayed‑do‑for‑all‑facts 12

delayed‑do‑for‑all‑instances 12

delete$ 12

DeleteActivation **145**

DeleteAllActivations **145**

DeleteAllInstances **171**

DeleteInstance **171**

DeleteRouter **93**

describe‑class 162

DescribeClass **161**

DestroyEnvironment **15**, 109, 112

DirectGetSlot **170**

do‑for‑all‑facts 12

do‑for‑all‑instances 12

do‑for‑fact 12

do‑for‑instance 12

DOPToLong 223

DOToLong 223

DribbleActive **124**

dribble-off 18

DribbleOff **17**

dribble-on 18

DribbleOn **17**

DYNAMIC\_SALIENCE 226

dynamic‑get 170

dynamic‑put 170

ed.h 224

edbasic.c 224

edmain.c 224

edmisc.c 224

edstruct.c 224

edterm.c 224

EMACS\_EDITOR 224

embedded application 119

EmptyMultifield **44**

EnvAddLong 223

EnvBatchStar 227

EnvBinarySaveInstances 225

EnvDecrementFactCount **210**

EnvDefineFunction 223, 225

EnvFactDeftemplate 227

EnvFactExistp 227

EnvFactIndex 223

EnvFactList 227

EnvFacts 223

EnvFactSlotNames 227

EnvFalseSymbol 226

EnvFindDefgeneric **156**

EnvGetActivationSalience 227

EnvGetNextInstanceInClassAndSubclasses 227

ENVIRONMENT\_API\_ONLY 223, 224, 228

environmentData 109

EnvLoadInstancesFromString 227

EnvMatches 225

EnvReleaseMem 225

EnvRestoreInstancesFromString 227

envrnmnt.c 228

envrnmnt.h 112, 228

EnvRun 223

EnvSaveFacts 225

EnvSaveInstances 225

EnvSetOutOfMemoryFunction 227

EnvTrueSymbol 226

eval 13, **26**

EX\_MATH 223

explode$ 12

EXT\_IO 224

EXTENDED\_MATH\_FUNCTIONS 9, **12**, 223

extobj.h 228

FACT\_SET\_QUERIES **12**, 226

FactDeftemplate 227

FactDeftemplate **131**, 227

FactExistp 227

fact-existp 133

FactExistp **132**

fact-index 131

FactIndex **131**

FactList 227

FactPPForm **131**

factqpsr.c 226

factqpsr.h 227

factqury.c 227

factqury.h 227

facts 11, **130**, 131

FactSlotName **131**

FactSlotNames 227

fact-slot-names 132

FalseSymbol **43**, 226

FBAbort **49**

FBAssert **49**

FBDispose **49**

FBPutSlot **53**

FBPutSlotCLIPSFloat **54**

FBPutSlotCLIPSInteger **53**

FBPutSlotCLIPSLexeme **55**, **56**

FBPutSlotDouble **55**

FBPutSlotExternalAddress **57**

FBPutSlotFact **56**, **57**

FBPutSlotFloat **54**

FBPutSlotInstance **56**, **57**

FBPutSlotInstanceName **55**, **56**

FBPutSlotInt **53**

FBPutSlotLong **54**

FBPutSlotLongLong **54**

FBPutSlotMultifield **57**

FBPutSlotString **55**, **56**

FBPutSlotSymbol **56**

FBSetDeftemplate **49**

fetch 13

files

header

clips.h 65, 89, 91, 110, 119

envrnmnt.h 110

router.h 89, 91

setup.h **8**, 9, 116

source

main.c 116, 119, 190

sysdep.c **10**

userfunctions.c 8, 67, 226

find‑all‑facts 12

find‑all‑instances 12

FindDefclass **161**

FindDeffacts **135**

FindDeffunction **153**

FindDefglobal **148**

FindDefinstances **183**

FindDefmessageHandler **178**

FindDefmodule **185**

FindDefrule **137**

FindDeftemplate **125**

find‑fact 12

find‑instance 12

FindInstance **168**

first$ 12

FMAbort **50**

FMDispose **50**

FMModify **50**

FMPutSlot **53**

FMPutSlotCLIPSFloat **54**

FMPutSlotCLIPSInteger **53**

FMPutSlotCLIPSLexeme **55**, **56**

FMPutSlotDouble **55**

FMPutSlotFloat **54**

FMPutSlotInstanceName **55**, **56**

FMPutSlotInt **53**

FMPutSlotLong **54**

FMPutSlotLongLong **54**

FMPutSlotString **55**, **56**

FMPutSlotSymbol **56**

FMSetFact **50**

Focus **145**

format 12, 87

functions

argument access 68

external 68

Library

getc 90

malloc 188

garbage collection **37**

GCBlockEnd **39**

GCBlockStart **39**

genalloc **187**

GENERIC **10**

genfree **187**

GetAgendaChanged **146**

get‑class‑defaults‑mode 168

GetClassDefaultsMode **167**, 228

GetConserveMemory **187**

GetcRouter **89**

GetCurrentEnvironment 224

get-current-module 186

GetCurrentModule **186**

get-defclass-list 161

GetDefclassList **161**

get-deffacts-list 136

GetDeffactsList **135**

get-deffunction-list 154

GetDeffunctionList **154**

GetDeffunctionWatch **155**

get-defgeneric-list 156

GetDefgenericList **156**

get-defglobal-list 149

GetDefglobalList **149**

GetDefglobalValue **150**

get-definstances-list 183

GetDefinstancesList **183**

get‑defmessage-handler-list 178

GetDefmessageHandlerList **178**

get‑defmethod-list 158

GetDefmethodList **158**

get-defmodule-list 185

GetDefmoduleList **185**

get-defrule-list 137

GetDefruleList **137**

get-deftemplate-list 126

GetDeftemplateList **125**

GetDeftemplatePPForm **126**

get‑dynamic‑constraint‑checking 123

GetDynamicConstraintChecking **123**

GetEnvironmentByIndex 224, 227

GetEnvironmentData **111**

GetEnvironmentIndex 224

get-fact-duplication 134

GetFactDuplication **134**

get-fact-list 130

GetFactList **130**

GetFactListChanged **134**

GetFactSlot **131**

get-focus 145

GetFocus **145**

get-focus-stack 142

GetFocusStack **141**

GetGlobalsChanged **151**

GetInstancesChanged **174**

get‑method-restrictions 159

GetMethodRestrictions **159**

GetNextActivation **141**

GetNextDefclass **161**

GetNextDeffacts **135**

GetNextDeffunction **154**

GetNextDefgeneric **156**

GetNextDefglobal **149**

GetNextDefinstances **183**

GetNextDefmessageHandler **178**

GetNextDefmethod **158**

GetNextDefmodule **185**

GetNextDefrule **137**

GetNextDeftemplate **125**

GetNextFact **129**

GetNextFactInTemplate **130**, 226

GetNextFocus **141**

GetNextInstance **168**

GetNextInstanceInClass **168**

GetNextInstanceInClassAndSubclasses 227

GetNextInstanceInClassAndSubclasses **168**

get-profile-percent-threshold 13

get‑reset‑globals 152

GetResetGlobals **152**

get-salience-evaluation 147

GetSalienceEvaluation **146**

get-sequence-operator-recognition 123

GetSequenceOperatorRecognition **123**

get-strategy 147

GetStrategy **147**

GetWatchState **124**

**help** 224

HELP\_FUNCTIONS 224

**help-path** 224

I/O router **85**, 94

priority **88**

IBAbort **51**

IBDispose **51**

IBMake **51**

IBPutSlot **53**

IBPutSlotCLIPSFloat **55**

IBPutSlotCLIPSInteger **54**

IBPutSlotDouble **55**

IBPutSlotFloat **55**

IBPutSlotInt **54**

IBPutSlotLong **54**

IBPutSlotLongLong **54**

IBSetDefclass **51**

IMAbort **52**

IMDispose **52**

IMModify **52**

IMPERATIVE\_MESSAGE\_HANDLERS 226

IMPERATIVE\_METHODS 226

implode$ 12

IMPutSlot **53**

IMPutSlotCLIPSFloat **55**

IMPutSlotCLIPSInteger **54**

IMPutSlotDouble **55**

IMPutSlotFloat **55**

IMPutSlotInt **54**

IMSetInstance **52**

INCREMENTAL\_RESET 226

IncrementFactCount 130

IncrementFactReferenceCount 16, 17, 132

IncrementGCLocks 227

IncrementInstanceCount **173**

InitCImage 116

InitializeEnvironment 224

insert$ 12

installation of CLIPS 5

Instance manipulation from C **168**

INSTANCE\_PATTERN\_MATCHING 226

INSTANCE\_SET\_QUERIES **12**

InstanceClass **170**

InstanceName **170**

InstancePPForm **170**

Instances **168**, 169

integration 1

Interfaces Guide iii

IO\_FUNCTIONS **12**, 224

list‑defclass 162

ListDefclasses **161**

list‑deffacts 136

ListDeffacts **135**

list‑deffunctions 154

ListDeffunctions **154**

list‑defgenerics 156

ListDefgenerics **156**

list‑defglobals 149

ListDefglobals **149**

list‑definstances 184

ListDefinstances **183**

list‑defmessage-handlers 179

ListDefmessageHandlers **89**, **178**

list‑defmethods 159

ListDefmethods **158**

list‑defmodules 186

ListDefmodules **185**

list‑defrules 138

ListDefrules **137**

list‑deftemplates 126

ListDeftemplates **125**

list-focus-stack 142

ListFocusStack **141**

load 10, **16**, 115, 117, 190

load-facts 117, 133

LoadFacts 117, **133**

LoadFactsFromString **133**

load-instances 117, 172

LoadInstances 117, **171**

LoadInstancesFromString 227

LoadInstancesFromString **171**

logical names **85**

stdin **87**

stdout **87**

t **87**

werror **87**

wwarning **87**

LOGICAL\_DEPENDENCIES 226

lowcase 13

MAC\_MCW 224

main 116, 189

make‑instance 16

MakeInstance **16**

Matches **140**

MAXIMUM\_ENVIRONMENT\_POSITIONS 112

MBAppend **45**

MBAppendUDFValue **45**

MBCreate **45**

MBDispose **45**

MBReset **45**

member$ 12

MemoryUsed **188**

mem-requests 188

MemRequests **188**

mem-used 188

MemUsed **188**

MULTIFIELD\_FUNCTIONS **12**, 13

nth$ 12

OBJECT\_SYSTEM **12**

open 12, 87

pop-focus 145

PopFocus **145**

portability 1

ppdeffacts 11

ppdefrule 11

PPFact **130**, 131, 225

**preprocessor definitions** 9

preview‑send 180

PreviewSend **180**

PrintCLIPSValue **90**

PrintFloat **90**

PrintInteger **90**

PrintMultifield **90**

printout 12, 87

print-region 13

PrintRouter 88

PrintString **90**

PrintUDFValue **91**

profile 13

profile-info 13

profile-reset 13

PROFILING\_FUNCTIONS **13**

progn$ 12

read 12, 87

readline 12, 87

Reference Manual iii

Refresh **140**, 141

refresh-agenda 146

RefreshAgenda **145**

RefreshAllAgendas **145**

release-mem 188

ReleaseMem 187, **188**

RemoveAfterRuleFiresFunction **143**

RemoveBeforeRuleFiresFunction **143**

remove-break 140

RemoveBreak **139**

RemoveClearFunction **120**

RemovePeriodicFunction **120**

RemoveResetFunction **121**

ReorderAgenda **145**

ReorderAllAgendas **145**

replace$ 12

RerouteStdin 116

Reset **17**, 121, 122

rest$ 12

restore-instances 172

RestoreInstances **171**

RestoreInstancesFromString 227

RestoreInstancesFromString **171**

Retract **132**

Run **17**

RUN\_TIME 11, **13**, 116

run‑time module 115

Save **122**, 123

save-facts 134

SaveFacts **133**

save-instances 173

SaveInstances **172**

Send **174**

SetAgendaChanged **146**

set-break 140

SetBreak **139**

set‑class‑default-mode 168

SetClassDefaultsMode **167**, 228

SetConserveMemory **187**

SetCurrentEnvironment 224

SetCurrentEnvironmentByIndex 224

set-current-module 186

SetCurrentModule **186**

set-dynamic-constraint-checking 116, 123

SetDynamicConstraintChecking **123**

set‑fact‑duplication 134

SetFactDuplication **134**

SetFactListChanged **134**

SetGlobalsChanged **151**

SetInstancesChanged **174**

SetOutOfMemoryFunction 227

set-profile-percent-threshold 13

set‑reset‑globals 152

SetResetGlobals **152**

set-salience-evaluation 147

SetSalienceEvaluation **146**

set-sequence-operator-recognition 123

SetSequenceOperatorRecognition **123**

set-strategy 147

SetStrategy **147**

setup flags **9**

SetWatchState **124**

SHORT\_LINK\_NAMES 226

show-breaks 140

ShowBreaks **139**

show‑defglobals 150

ShowDefglobals **149**

shrtlnkn.h 226

slot‑allowed-classes 166

SlotAllowedClasses **165**, 225

slot‑allowed-values 166

SlotAllowedValues **165**

slot-cardinality 166

SlotCardinality **165**

slot-default-value 166

SlotDefaultValue **165**

slot-direct-accessp 167

SlotDirectAccessP **166**

slot-existp 167

SlotExistP **166**

slot-facets 166

SlotFacets **165**

slot-initablep 167

SlotInitableP **167**

slot-publicp 167

SlotPublicP **167**

slot‑range 166

SlotRange **166**

slot-sources 166

SlotSources **166**

slot-types 166

SlotTypes **166**

slot-writablep 167

SlotWritableP **167**

str-cat 13

str‑compare 13

str‑index 13

STRING\_FUNCTIONS **13**

StringBuilderAddChar **28**

StringBuilderAppend **28**

StringBuilderCopy **28**

StringBuilderDispose **28**

StringToMultifield **45**

str‑length 13

SubclassP **165**

subseq$ 12

subsetp 12

sub‑string 13

SuperclassP **165**

symbol 43

sym-cat 13

TEXTPRO\_FUNCTIONS **13**

toss 13

TrueSymbol 226

UDFArgumentCount **68**

UDFNextArgument **68**

UDFNthArgument **69**

Undefclass **163**, 164

Undeffacts **136**, 137

Undeffunction **155**

Undefgeneric **157**

Undefglobal **151**

Undefinstances **184**, 185

undefmessage-handler 180

UndefmessageHandler **179**

Undefmethod **160**

Undefrule **138**

Undeftemplate **127**

UngetcRouter **89**

UnmakeAllInstances **170**

UnmakeInstance **170**

Unwatch **18**

upcase 13

USER\_ENVIRONMENT\_DATA **111**

User’s Guide iii

**UserFunctions** 67, 116

ValidInstanceAddress **173**

ValueToLong 223

VAX\_VMS 223

VoidConstant **46**

Watch **18**

WIN\_BTC 224

WIN\_MCW 224

WINDOW\_INTERFACE **13**