bridge™

A programming language for novice users to easily generate HTML forms

F I N A L P R O J E C T R E P O R T

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1. Introduction

The Bridge programming language provides an ability for novice users to develop web pages without necessarily being familiar with any HTML syntax. As implied by the name, the language provides novice users a *bridge* to web based applications. It does so by providing users an intuitive and easy to learn syntax which is simple enough to read and understand, but at the same time powerful enough to create complex HTML pages. The language is also intended to be used by student developers as a tool for quickly creating prototypes. While HTML is certainly the most fundamental and simple building block of any web based application, it is tedious, time consuming and error prone to write manually. Bridge addresses these issues by providing a fairly concise set of keywords and an intuitive way to use them. From the perspective of novice users, the language will allow them to be shielded from all of the underlying HTML and from the perspective of student developers, the language will allow them to focus on their application code – for example web services running on a Java backend, and use Bridge to quickly validate and demonstrate web service calls with a web page. Programs written in Bridge will be all one-file programs. In the process of interpreting, if the Bridge compiler comes across any errors, it will inform the user of the problem with user friendly error messages and when possible also provide a recommended way of solving the problem, similar to how common programming languages do. Once interpreted, the resulting HTML code needs to be saved in a .html file which can then be opened in any browser.

1.1 Motivation

The idea for developing the Bridge programming language stemmed from two main motivations. First, it provided me an opportunity to learn how to build a compiler for a language and in the process, understand the many intricacies involved with which I was largely unfamiliar at the beginning of the project. While the idea of a programming language to generate HTML code is simple, it nevertheless provided me ample challenges to work my way through the concepts learned in the class and to apply them in the form of an elegant, concise language and its compiler. The second motivation came from having felt the need of such a language as a student developer myself in the past semesters – a language which would allow me to quickly prototype a web page to demonstrate or simply test some of the backend application features. Having a concise, yet robust language that will help me accomplish this will be useful for me in my other classes in the upcoming semesters as it will save me the time of developing a test user interface for the application, time that I can then use for focusing on the backend application features.

2. Language Tutorial

Generating HTML pages using Bridge is as easy as the following –

1. Run bridge.byte executable
2. Type in a Bridge program, ctrl-Z to run
3. Save the resulting HTML code in a .html file and open in a browser

Bridge Program

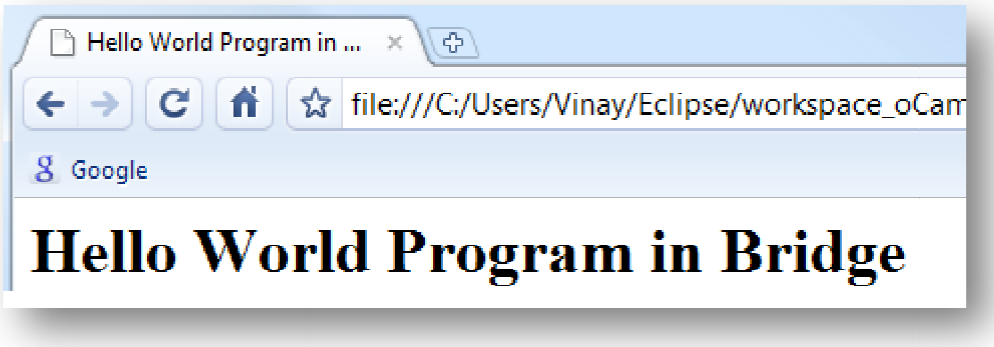
While the formal usage of the language is defined in the language reference manual, this section presents a simple practical example to demonstrate how a novice users can easily get up to speed with understanding and writing Bridge programs. The following is a complete Bridge program which generates a basic Hello World HTML page –

```
run() {
open("");
title("Hello World Program in Bridge");
header1("Hello World Program in Bridge");
close("");
}
```

Generated HTML Code

```
<html>
<body>
<title>Hello World Program in Bridge</title>
<h1>Hello World Program in Bridge</h1>
</body>
</html>
```

Generated HTML Page in a Browser



The following is a more realistic User Information From generated using Bridge –

Bridge Program

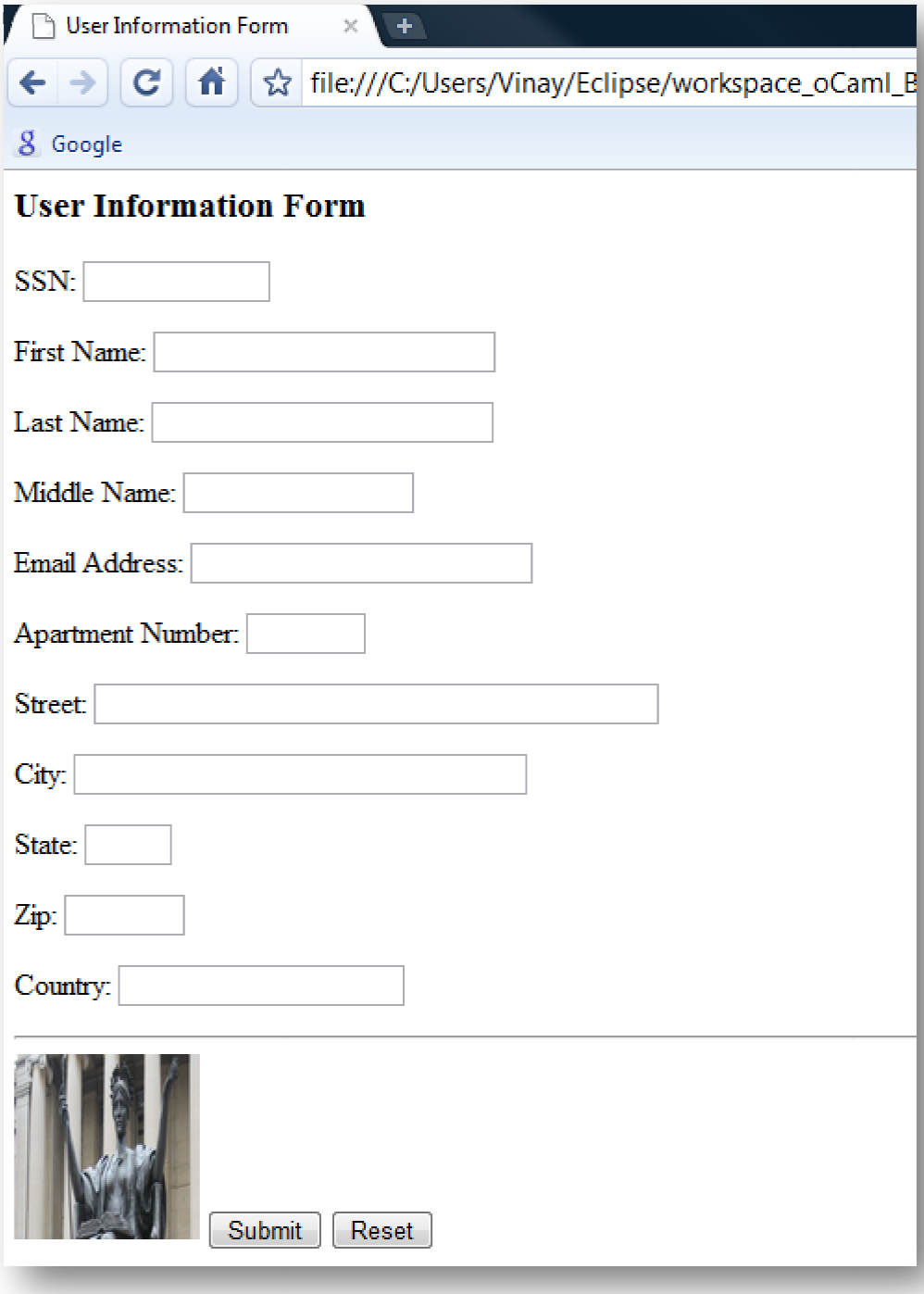
```
userinfo() {
declare ssn;
declare fName;
declare mName;
declare lName;
declare email;

ssn input= "SSN: ", "11", "11";
fName input= "First Name: ", "25", "20";
lName input= "Last Name: ", "25", "20";
mName input= "Middle Name: ", "15", "10";
email input= "Email Address: ", "25", "20";

insert(ssn);
insert(fName);
insert(lName);
insert(mName);
insert(email);
}

address() {
declare apt;
declare street;
declare city;
declare state;
declare zip;
declare country;

apt input= "Apartment Number: ", "5", "5";
street input= "Street: ", "45", "40";
city input= "City: ", "35", "30";
state input= "State: ", "2", "2";
zip input= "Zip: ", "5", "5";
country input= "Country: ", "20", "20";

insert(apt);
insert(street);
insert(city);
insert(state);
```

```
insert(zip);
insert(country);
}

horizontalLine() {
insert("line");
}

image(source, width, height) {
declare image1;
image1 image= source, width, height;
insert(image1);
}

form() {
declare form1;
form1 form= "POST", "/action.do";
insert(form1);
}

run() {
open("");
title("User Information Form");
form();
header3("User Information Form");
userinfo();
address();
horizontalLine();
image("100", "100",
"C:\Users\Vinay\Pictures\cu_home_alma_mater.jpg");

insert(button "submit", "Submit");
insert(button "reset", "Reset");
close("");
}
```

Generated HTML Code

```
<html>
<body>
<title>User Information Form</title>
<form onsubmit="return true" method="POST"
action="/action.do">
<h3>User Information Form</h3>
<p>SSN:  <input type="text" maxlength="11"
name="11" size="11">
<p>First Name:  <input type="text" maxlength="25"
name="20" size="25">
<p>Last Name:  <input type="text" maxlength="25"
name="20" size="25">
<p>Middle Name:  <input type="text" maxlength="15"
name="10" size="15">
<p>Email Address:  <input type="text"
maxlength="25" name="20" size="25">
<p>Apartment Number:  <input type="text"
maxlength="5" name="5" size="5">
<p>Street:  <input type="text" maxlength="45"
name="40" size="45">
<p>City:  <input type="text" maxlength="35"
name="30" size="35">
<p>State:  <input type="text" maxlength="2"
name="2" size="2">
<p>Zip:  <input type="text" maxlength="5" name="5"
size="5">
<p>Country:  <input type="text" maxlength="20"
name="20" size="20">
<hr>
<img
src="C:\Users\Vinay\Pictures\cu_home_alma_mater.jp
g" width="100" height="100">
<input type="submit" value="Submit">
<input type="reset" value="Reset">
</body>
</html>
```

Generated HTML Page in a Browser



3. Language Reference Manual

This section formally defines the Bridge programming language, its syntax and semantics so that users and developers can understand the basic elements and start to write programs in this language.

3.1 Execution

The Bridge language can be run by executing the bridge.byte executable. The second step is to type in the Bridge program itself. In the process, the interpreter scans the input line by line in the lexical analysis stage, which results in tokens explained later in this document. The tokens are then parsed to verify if the input is a valid, syntactically correct program. This stage is followed by a semantic analysis and the generation of the HTML code as an output which can then be viewed in any browser.

3.2 Lexical Conventions

A Bridge program is comprised of a single file written in ASCII character set. Following the convention of other common languages – comments, tabs and newlines as defined below are ignored. Whitespace is required to separate tokens and is used by the parser to identify the beginning and the end of a token. At the lexical analysis stage a Bridge program can be thought of as a single line program containing the tokens described below separated by whitespace. It is also important to note that Bridge is a single-typed language. Everything in Bridge is internally handled as a `String`.

3.2.1 ASCII

Includes all of the 128 characters defined in the USASCII code chart. Every single element of a Bridge program is made up of some combination of these characters which the parser determines to be a part of the language.

3.2.2 Whitespace

Whitespace is used to identify one token apart from another.

3.2.3 Identifiers

An identifier is defined as a combination of alphanumeric characters `[a-z][A-Z][0-9]` and must start with a lower case alphabet `[a-z]`.

3.2.4 Keywords

The following identifiers are reserved keywords and therefore may not be used in any other context:

```
declare
link=
form=
input=
image=
int=
header[1-6]
para
bold
line
button
open
close
insert
comment
```

3.3 Types

Bridge is a single typed language and at the most basic level everything is a `string`. As documented in the following keyword definitions, it is how a declaration is made which determines the usage of a given variable.

3.3.1 Comments

Comments in Bridge are identified by starting a line with `/*` which identifies the entire given line as a comment. The Bridge interpreter does not support nested comments. Multi-line comments must be prefixed with `/*` on each line.

```
comment: /* commentString
commentString: ASCII characters
```

Example:

```
/* This is a comment in Bridge language
```

3.3.2 Whitespace

Whitespace helps identify one token from another.

```
whitespace: ‘ ’+
```

3.3.3 declare

The `declare` keyword is used to make a declaration of a variable

```
declare: ['_']['a'-'z']['a'-'z' 'A'-'Z' '0'-'9']*
```

Example:

```
   declare x;
```

3.3.4 link=

The `link=` keyword is used to assign a link to a variable

```
link=: identifier link= url, caption
identifier: as defined in 3.2.3
url: ASCII characters
caption: ASCII characters
```

3.3.5 form=

The `form=` keyword is used to assign a form to a variable

```
form=: identifier form= method, action
identifier: as defined in 3.2.3
method: ASCII characters
action: ASCII characters
```

3.3.6 input=

The `input=` keyword is used to assign an input text box to a variable

```
input=: identifier input= label, maxLength/size, name
identifier: as defined in 3.2.3
maxLength/Size: ASCII characters
name: ASCII characters
```

3.3.7 image=

The `image=` keyword is used to assign an image to a variable

```
image=: identifier image= source, width, height
identifier: as defined in 3.2.3
width: ASCII characters
name: ASCII characters
```

3.3.8 int=

The `int=` keyword is used to assign an image to a variable

```
int=: identifier int= int
identifier: as defined in 3.2.3
int: [0-9]
```

3.3.9 header

The `header` keyword is used to create and insert headings in the generated HTML page

```
header: [header1 | header2 | header3 | header4 |
header5| header6] headerString
headerString: ASCII characters
```

3.3.10 para

The `para` keyword is used to create and insert HTML paragraphs in the generated HTML page

```
para: para paragraphString
paragraphString: ASCII characters
```

3.3.11 bold

The `bold` keyword is used to create and insert bold text in the generated HTML page

```
bold: bold boldString
boldString: ASCII characters
```

3.3.12 line

The `line` keyword is used to create and insert a horizontal line in the generated HTML page

```
line: insert(“line”)
```

3.3.13 button

The `button` keyword is used to create and insert a button in the generated HTML page

```
button: insert(button type, value)
type: ASCII characters
value: ASCII characters
```

3.3.14 open

The `open` keyword is used to generate the standard opening tags of a HTML page

```
open: open(“”)
```

3.3.15 close

The `close` keyword is used to generate the standard closing tags of a HTML page

```
close: close(“”)
```

3.3.16 insert

The `insert` keyword is used to insert a link, form, input text box, image and a horizontal line in the generated HTML page

```
insert: insert(id)
id: link, form, input, image, line
link: as defined in section 3.3.4
form: as defined in section 3.3.5
input: as defined in section 3.3.6
image: as defined in section 3.3.7
line: as defined in section 3.3.12
```

3.3.17 comment

The `comment` keyword is used to insert comments in the generated HTML page

```
comment: comment(“commentString”)
commentString: ASCII characters
```

3.4 Punctuations

```
/*
```
Used for adding comments in the program text

```
()
```
Used for passing arguments to a function

```
f(arg1, arg2, argn)
f: function
arg1–argn: arguments to the function
```

```
{}
```
Used for grouping a block of statements and associate it with a given function

```
{
  statement1;
  statement2;
  …
  statementn;
}
```

```
;
```
Used for terminating a statements

```
statement;
```

```
,
```
Used for separating arguments

```
arg1,arg2,… , argn
```

```
=
```
Used as an assignment operator

```
id = value
id: identifier
identifier: as defined in 3.2.3
value: ASCII characters
```

```
“
```
Used to identify a string

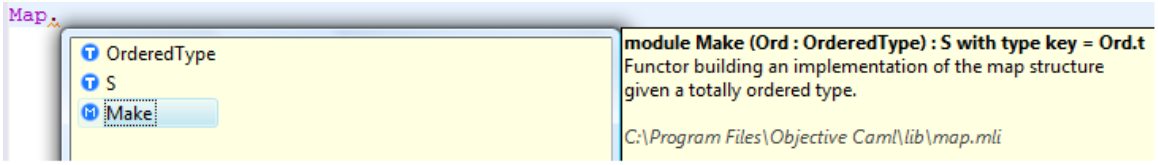
```
“string”
string: ASCII characters
```

4. Project Plan

Since the project for writing an interpreter included a steep learning curve with both a new language oCaml as well new concepts like scanning, parsing, lexical analysis, etc., it was essential to have a detailed yet practical project plan that would allow me, as a one-person team, to accomplish both the goals that were set for this class – 1. To understand "what" programming languages are, and 2. "How" to build compilers / interpreters for these languages.

I started off by first focusing on getting up to speed with oCaml. With Java being the only language I have used over the past four years, it was a challenge to think "functionally" in order to be able to write programs in oCaml. As a student totally new to oCaml, I realized that writing programs in a notepad text file was inefficient and very error-prone for a beginner, as other languages like Java have well developed IDEs like Eclipse which for example help you identify and therefore correct syntax errors which a beginner is bound to make numerous times, right at the time as you are typing the program.

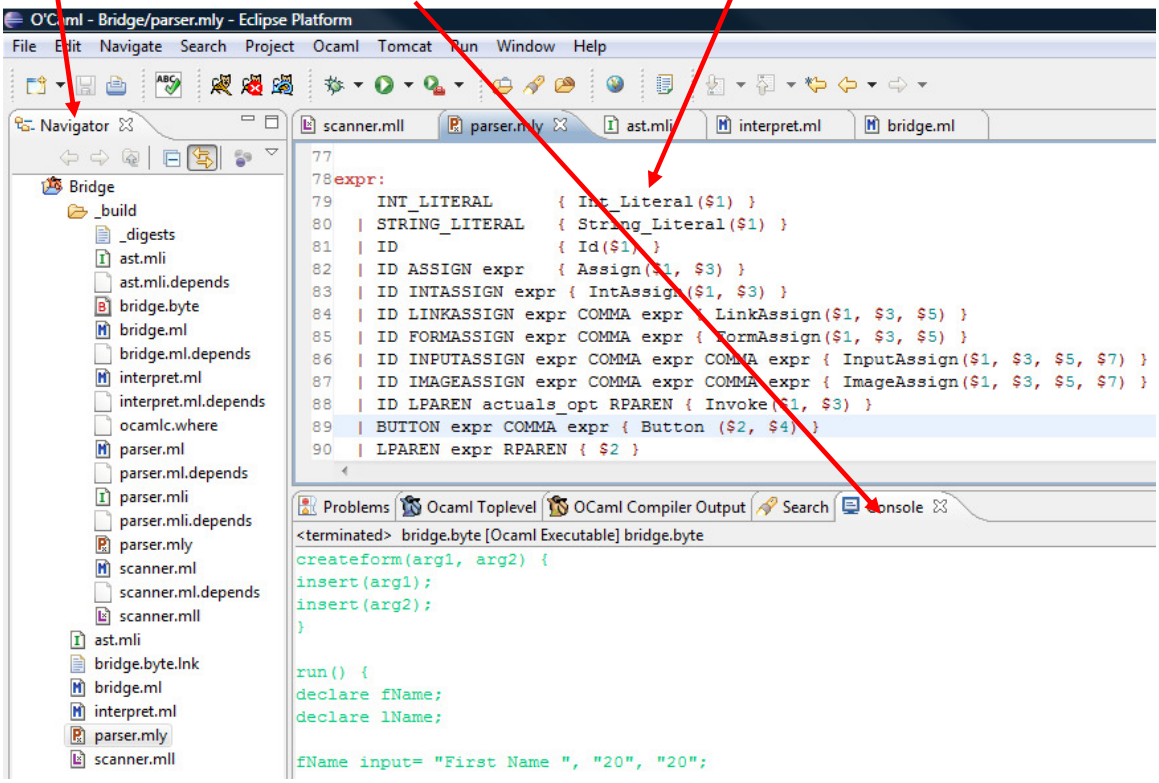
I therefore spent some time looking for IDEs that would assist in writing, compiling and running oCaml programs quickly and efficiently. I settled down with OcaIDE, available at http://ocaml.eclipse.ortsa.com:8480/ocaide/ which was also briefly discussed in one of the class lectures later on. I found this Eclipse plug-in for oCaml to be of great help. Features like auto-completion were very helpful as they present the available API and provide a brief description about each of the available options and then allow you to make a choice and proceed. In many cases, like the 'if then else', the IDE even provides one with a template to fill in the values with, much like the features available in Java. For example, using the `Map` for scope management, if one types in the keyword `Map` followed by a '.' the IDE presents the available options and a brief description as shown in the snapshot below.



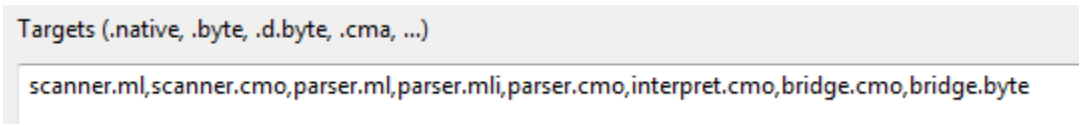
The above is of course possible by searching online as one is writing the program in a notepad text file, however from a beginners point of view, having features like this available all in one place while one is writing the program is a great help and over the

course, helps save a lot of time which can then be utilized for learning and implementing the concepts.

Using the OcaIDE also helped as it visually arranged all the source code in an organized manner as shown in this screenshot, with the source code file names in the Navigator pane on the left hand side, the source code file contents in the right hand side top panel and a convenient Console window to run Bridge programs –



This also fully automated the build process by simply configuring the IDE to use the source files for generating the bridge.byte executable -



4.1 Programming Style

With an IDE and the development environment all set up, my first goal was to have a small “Hello World” type of interpreter working, and even though looking back in the semester this now seems like a simple and easily attainable goal, I believe having this simple example working was my first major milestone as well as the most challenging milestone in the entire timeline of this project. It was the most challenging because even though it was an extremely basic interpreter, it still required all the different pieces like the scanner, parser, abstract syntax tree, the interpreter and the top level to fit in properly and work in harmony with each other. Everything else in the Bridge project is built upon this simple example, one piece at a time.

Working as a single-person team presented me with the privilege of managing everything by myself and therefore I chose to follow an iterative programming style. Under this mechanism, a project is developed in iterations and each iteration delivers a set of functionalities, which are then tested, documented before moving on two the next iteration. I deliberately chose this style of programming because of its following plus points –

1. At all times, the project is always functional meaning that after a particular iteration has been completed, then the project has a working, deliverable functionality that has been implemented as of that iteration.

2. The iterative style of programming helps divide the overall set of functionalities into smaller, more manageable chunks. This helps as it breaks one single deadline at the end of the semester into a number of deadlines, therefore giving the opportunity to make adjustments at the end of each iteration as compared to reaching the end of the semester and realizing there is a full set of important functionalities that cannot be completed in the remaining time.

3. Developing in iterations also helps as an efficient backup management. Since this was a single person project, I did not make use of source code control systems as all files were being edited and managed by just one person. Nevertheless, this does not reduce the need of having backups. Each successful iteration during the development this project also became a backup to revert to when necessary.

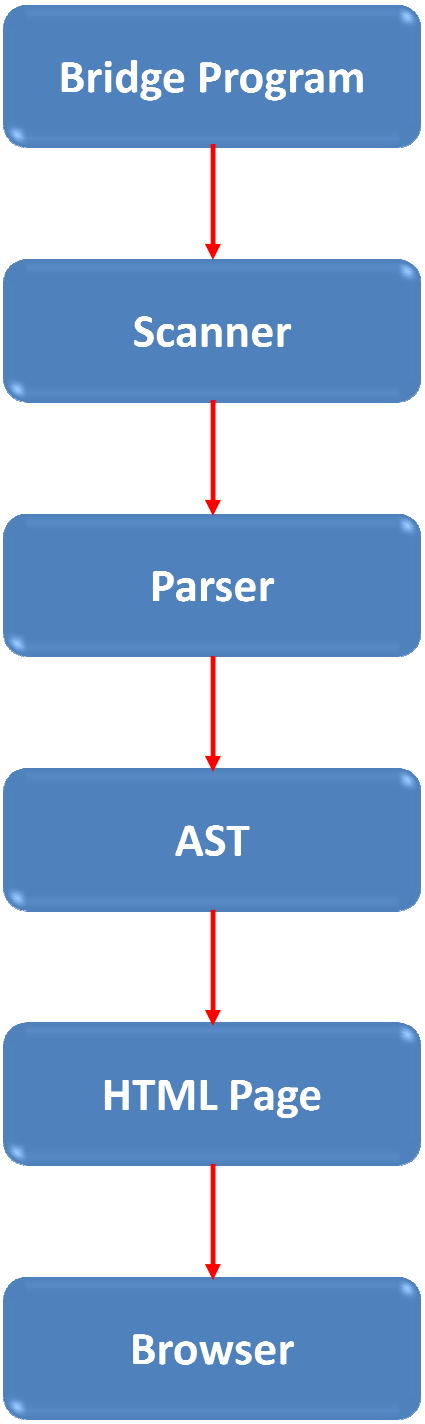
4. Each iteration has its own set of test cases which specifically test the functionality delivered in that particular iteration. This helps keep all

functionality tested throughout the iterations provided that after each iteration, the test cases developed in all the previous iterations are run to ensure no functionality is broken.

4.2 Project Timeline

Description	Functionalities	Date Finalized
Initial Project Proposal	N/A	February 10, 2009
Eclipse OcaIDE Dev Environment Setup	N/A	February 18, 2009
Iteration One	“Hello World” interpreter	March 8, 2009
Language Reference Manual	N/A	March 10, 2009
Iteration Two	Scope Management	April 3, 2009
Iteration Three	HTML links, input text boxes generation	April 10, 2009
Iteration Four	HTML forms, image setup generation	April 19, 2009
Iteration Five	General HTML tags generation	April 26, 2009
Iteration Six	Finalizing test cases developed in all iterations	May 9, 2009
Final Report	N/A	May 14, 2009

5. Architectural Design



6. Test Plan

Since Bridge is a non-mathematical language and generates HTML pages intended to be viewed in a browser, the testing had to be a manual effort and required opening each generated HTML file in a browser and inspecting its results. To maintain functionality throughout all the software development iterations, a separate folder was kept for each of the functionality being tested and was run after each iteration. The following table provides a list of all the test cases and a brief description of the functionality they test –

Test Name	Functionality Tested
HelloWorld	The first and the most basic Bridge program – generates an HTML page with the text "Hello World" printed in header1 font
Headers	Validates header1, header2, header3, header4, header5 and header6 HTML tags
Paragraphs	Generates an HTML page with three paragraphs
Links	Generates an HTML page with three HTML links
InputTextBoxes	Validates the generation of input text boxes
Images	Allows the insertion of images in an HTML page
Buttons	Generates an HTML page with 'Submit' and 'Reset' buttons
Forms	Generates an HTML POST form with a user's first and last name as the two input fields. Also included are 'Submit' and 'Reset' buttons.
Lines	Validates the usage of a horizontal line generally used to divide different sections of a form
Bold	Validates the generation of text in bold font in the HTML page
Comments	Allows a user to insert comments in the generated HTML page
FunctionCall	Tests the functionality of being able to invoke functionA() from within the body of functionB()
FunctionArgs	Tests the functionality of passing in arguments to functionA(arg1, arg2) which then uses arg1 and arg2 for the relevant HTML task from within the body of functionB()
UserInfoForm	A realistic user information HTML form

The above test cases were chosen with two considerations – 1. To be able to use the Bridge language to generate the most commonly used HTML pages, 2. To be able to

demonstrate the usage of the compiler / interpreter concepts learned in the class. The following few test cases provide an example of these considerations which were taken into account throughout software development iterations –

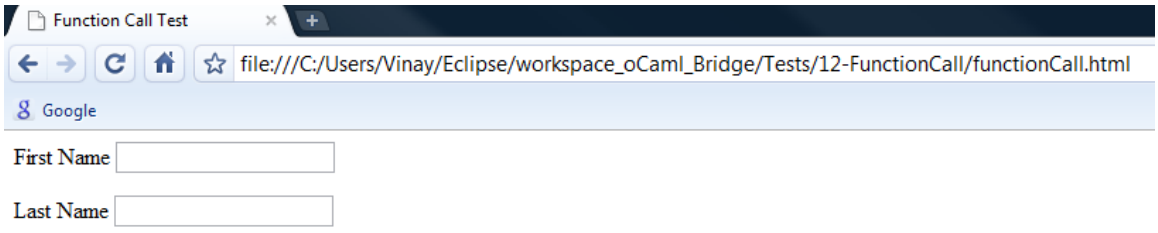
- Function Call Bridge Program

```
userName() {
declare fName;
declare lName;
fName input= "First Name ", "20", "20";
lName input= "Last Name ", "20", "20";
insert(fName);
insert(lName);
}

run() {
open("");
title("Function Call Test");
userName();
close("");
}
```

- Generated HTML page

```
<html>
<body>
<title>Function Call Test</title>
<p>First Name  <input type="text" maxlength="20"
name="20" size="20">
<p>Last Name  <input type="text" maxlength="20"
name="20" size="20">
</body>
</html>
```

- HTML page in a browser



- Function Call with Arguments Bridge Program

```
createform(arg1, arg2) {
insert(arg1);
insert(arg2);
}

run() {
declare fName;
declare lName;

fName input= "First Name ", "20", "20";
lName input= "Last Name ", "20", "20";

open("");
title("Function Argument Test");
createform(fName, lName);
close("");
}
```

- Generated HTML page

```
<html>
<body>
<title>Function Argument Test</title>
<p>Last Name  <input type="text" maxlength="20"
name="20" size="20">
<p>First Name  <input type="text" maxlength="20"
name="20" size="20">
</body>
</html>
```

7. Lessons Learned

I think the three biggest lessons I learned in this class were –

1. To have an understanding of how programming languages operate. Before this class, Java has been the primary language that I have been using for the most part. And any other language seemed to be a completely different approach to solving a problem, largely due to the difference in the syntax. However after this class, having an understanding of the scanning process, converting the input stream into a set of tokens, the parsers and the abstract syntax trees, it became apparent that under the covers most language operate the same way and differ only in the way they present their syntax to the user. I think learning the above concept will prove very important as it changes the way one approaches a new programming language. When I am confronted with a new language now, there will obviously be a learning curve with the syntax, however besides that I will have an understanding that under the covers this new language is very likely operating the same way as one of the languages that I already know of.

2. The second most important lesson I learned in this class was to have a better understanding of compilers. By implementing a basic compiler / interpreter provided an opportunity to understand some of the many complexities that go on in building a compiler. Being exposed to some of these complexities during the term of the semester also made me learn to appreciate other well established languages and have a better understanding of the amount of effort it takes under the covers to make software development easier – for example, by providing as user friendly errors as possible and indicating the source of the problem as accurately as possible.

3. The third most important lesson I learned in this class was obviously to have an opportunity to learn a new programming language – oCaml, which is a language much different from other common languages like Java, C++ and C, per se. Learning oCaml required thinking differently. While in the beginning it seemed ‘unintuitive’, with enough practice it started to make sense and in the end it brings the confidence of being able to learn a new language as well as write an interpreter using it.

8. Appendix

- scanner.mll

```
{ open Parser }

rule token = parse
  [' ' '\t' '\r' '\n'] { token lexbuf }
| "/*"      { comment lexbuf }
| '('       { LPAREN }
| ')'       { RPAREN }
| '{'       { LBRACE }
| '}'       { RBRACE }
| ';'       { SEMI }
| ','       { COMMA }
| '='       { ASSIGN }
| "int="    { INTASSIGN }
| "link="   { LINKASSIGN }
| "form="   { FORMASSIGN}
| "input=" { INPUTASSIGN }
| "image=" { IMAGEASSIGN }
| "button" { BUTTON }
| "return" { RETURN }
| "declare"     { DECLARE }
| ['0'-'9']+ as lxm { INT_LITERAL(lxm) }
| '"'[^'"']*'"' as lxm { STRING_LITERAL(lxm) }
| ['a'-'z' 'A'-'Z']['a'-'z' 'A'-'Z' '0'-'9']* as lxm {
ID(lxm) }
| eof { EOF }
| _ as char { raise (Failure("illegal character " ^
Char.escaped char)) }

and comment = parse
  "*/" { token lexbuf }
| _    { comment lexbuf }
```

- parser.mly

```
%{ open Ast %}

%token SEMI
%token LPAREN
%token RPAREN
%token LBRACE
%token RBRACE
%token COMMA
%token QUOT
%token ASSIGN
%token INTASSIGN
%token LINKASSIGN
%token FORMASSIGN
%token INPUTASSIGN
%token IMAGEASSIGN
%token DECLARE
%token BUTTON
%token RETURN
%token <string> INT_LITERAL
%token <string> STRING_LITERAL
%token <string> ID
%token EOF

%left ASSIGN
%left INTASSIGN
%left LINKASSIGN
%left TITLEASSIGN
%left FORMASSIGN
%left INPUTASSIGN
%left IMAGEASSIGN

%start program
%type <Ast.program> program

%%

program:
   /* nothing */ { [], [] }
 | program vdecl { ($2 :: fst $1), snd $1 }
 | program fdecl { fst $1, ($2 :: snd $1) }

fdecl:
  ID LPAREN formals_opt RPAREN LBRACE vdecl_list stmt_list
RBRACE
   { {
       fname = $1;
       formals = $3;
       locals = List.rev $6;
       body = List.rev $7 } }
```

- parser.mly contd.

```
formals_opt:
    /* nothing */ { [] }
  | formal_list   { List.rev $1 }

formal_list:
    ID                   { [$1] }
  | formal_list COMMA ID { $3 :: $1 }

vdecl_list:
    /* nothing */    { [] }
  | vdecl_list vdecl { $2 :: $1 }

vdecl:
    DECLARE ID SEMI { $2 }

stmt_list:
    /* nothing */  { [] }
  | stmt_list stmt { $2 :: $1 }

stmt:
    expr SEMI { Expr($1) }
  | RETURN expr SEMI { Return($2) }
  | LBRACE stmt_list RBRACE { Block(List.rev $2) }

expr_opt:
    /* nothing */ { Noexpr }
  | expr          { $1 }

expr:
    INT_LITERAL      { Int_Literal($1) }
      | STRING_LITERAL   { String_Literal($1) }
  | ID               { Id($1) }
  | ID ASSIGN expr   { Assign($1, $3) }
      | ID INTASSIGN expr { IntAssign($1, $3) }
      | ID LINKASSIGN expr COMMA expr { LinkAssign($1, $3,
$5) }
      | ID FORMASSIGN expr COMMA expr { FormAssign($1, $3,
$5) }
      | ID INPUTASSIGN expr COMMA expr COMMA expr {
InputAssign($1, $3, $5, $7) }
      | ID IMAGEASSIGN expr COMMA expr COMMA expr {
ImageAssign($1, $3, $5, $7) }
  | ID LPAREN actuals_opt RPAREN { Invoke($1, $3) }
      | BUTTON expr COMMA expr { Button ($2, $4) }
  | LPAREN expr RPAREN { $2 }

actuals_opt:
    /* nothing */ { [] }
  | actuals_list  { List.rev $1 }
```

- parser.mly contd.

```
actuals_list:
    expr                      { [$1] }
  | actuals_list COMMA expr { $3 :: $1 }
```

- ast.mli

```
type expr =
    Int_Literal of string
      | String_Literal of string
  | Id of string
  | Assign of string * expr
      | IntAssign of string * expr
      | LinkAssign of string * expr * expr
      | FormAssign of string * expr * expr
      | InputAssign of string * expr * expr * expr
      | ImageAssign of string * expr * expr * expr
      | Button of expr * expr
  | Invoke of string * expr list
  | Noexpr

type stmt =
    Block of stmt list
  | Expr of expr
  | Return of expr

type func_decl = {
      fname : string;
  formals : string list;
  locals : string list;
  body : stmt list;
}

type program = string list * func_decl list
```

- interpret.ml

```
open Ast

module NameMap = Map.Make(struct
  type t = string
  let compare x y = Pervasives.compare x y
end)

exception ReturnException of string * string NameMap.t

let run (vars, funcs) =
  let func_decls = List.fold_left
      (fun funcs fdecl -> NameMap.add fdecl.fname fdecl
funcs)
      NameMap.empty funcs
  in
      let rec trimQuote string =
      let l = String.length string in
      if string.[0]='"' then
      trimQuote (String.sub string 1 (l-1))
      else if string.[l-1]='"' then
      trimQuote (String.sub string 0 (l-1))
      else string

      in

  let rec invoke fdecl actuals globals =
    let rec eval env = function
                        Int_Literal(i) -> i, env
                  | String_Literal(i) -> i, env
      | Noexpr -> "1", env
      | Id(var) ->
                  let locals, globals = env in
                  if NameMap.mem var locals then
            (NameMap.find var locals), env
                  else if NameMap.mem var globals then
            (NameMap.find var globals), env
                  else raise (Failure ("undeclared
identifier in Id " ^ var))
      | Assign(var, e) ->
                        let v, (locals, globals) = eval env
e in
                        if NameMap.mem var locals then
                  v, (NameMap.add var v locals, globals)
                        else if NameMap.mem var globals then
                  v, (locals, NameMap.add var v globals)
                        else raise (Failure ("undeclared
identifier in Assign " ^ var))
```

- interpreter.ml contd.

```
                    | IntAssign(var, e) ->
                          let v, (locals, globals) = eval env
e in
                          if NameMap.mem var locals then
                    v, (NameMap.add var v locals, globals)
                          else if NameMap.mem var globals then
                    v, (locals, NameMap.add var v globals)
                          else raise (Failure ("undeclared
identifier in Assign " ^ var))
                    | LinkAssign(var, e, e2) ->
                          let v, (locals, globals) = eval env
e in
                                let v2, (locals, globals) =
eval env e2 in
                                let trimV2 = trimQuote v2 in
                          if NameMap.mem var locals then
                    v, (NameMap.add var ("<a href=" ^ v ^ ">"
^ trimV2 ^ "</a><br>") locals, globals)
                          else if NameMap.mem var globals then
                    v, (locals, NameMap.add var ("<a href=" ^
v ^ ">" ^ trimV2 ^ "</a><br>") globals)
                          else raise (Failure ("undeclared
identifier in LinkAssign " ^ var))
                    | FormAssign(var, methodName, action) ->
                            let v, (locals, globals) = eval
env methodName in
                                let v2,(locals, globals) =
eval env action in
                          if NameMap.mem var locals then
                    v, (NameMap.add var ("<form
onsubmit=\"return true\" method=" ^ v
                                 ^ " action=" ^ v2 ^ ">")
locals, globals)
                          else if NameMap.mem var globals then
                    v, (locals, NameMap.add var ("<a href=" ^
v ^ "dotcom") globals)
                          else raise (Failure ("undeclared
identifier in LinkAssign " ^ var))
               | InputAssign(var, label, size, name) ->
                            let labelStr, (locals, globals) =
eval env label in
                                      let trimmedLabelStr =
trimQuote labelStr in
                                let sizeStr,(locals, globals)
= eval env size in
                                let nameStr,(locals, globals)
= eval env name in
                          if NameMap.mem var locals then
                    trimmedLabelStr, (NameMap.add var ("<p>" ^
trimmedLabelStr
```

- interpreter.ml contd.

```
                                ^ " <input type=\"text\"
maxlength=" ^ sizeStr ^ " name="
                                ^ nameStr ^ " size=" ^
sizeStr ^ ">") locals, globals)
                        else if NameMap.mem var globals then
                    trimmedLabelStr, (locals, NameMap.add var
("<a href=" ^ trimmedLabelStr ^ "dotcom") globals)
                        else raise (Failure ("undeclared
identifier in LinkAssign " ^ var))
                  | ImageAssign(var, src, width, height) ->
                        let srcStr, (locals, globals) = eval
env src in
                                let widthStr,(locals, globals)
= eval env width in
                                let heightStr,(locals,
globals) = eval env height in
                        if NameMap.mem var locals then
                    srcStr, (NameMap.add var ("<img src=" ^
srcStr
                                ^ " width=" ^ widthStr ^ "
height="
                                ^ heightStr ^ ">") locals,
globals)
                        else if NameMap.mem var globals then
                    srcStr, (locals, NameMap.add var ("<img
src=" ^ srcStr
                                ^ " width=" ^ widthStr ^ "
height="
                                ^ heightStr ^ ">") globals)
                        else raise (Failure ("undeclared
identifier in LinkAssign " ^ var))
                  | Invoke ("bold", [e]) ->
                         let v, env = eval env e in
                         let vStr = trimQuote v in
                         print_endline("<b>" ^ vStr ^
"</b><br>");
                         "0", env
                  | Button (bType, value) ->
                        let bTypeStr, (locals, globals) =
eval env bType in
                        let valueStr, (locals, globals) =
eval env value in
                        "<input type=" ^ bTypeStr ^ "
value=" ^ valueStr ^ ">", (NameMap.add "dummyKey" ("")
locals, globals)
                  | Invoke ("close", [e]) ->
                        let v, env = eval env e in
                        print_endline("</body>\n</html>");
                        "0", env
```

- interpreter.ml contd.

```
                    | Invoke ("open", [e]) ->
                          let v, env = eval env e in
                          print_endline("<html>\n<body>");
                          "0", env
                    | Invoke ("header1", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<h1>" ^ vTrim ^
"</h1>");
                          "0", env
                    | Invoke ("header2", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<h2>" ^ vTrim ^
"</h2>");
                          "0", env
                    | Invoke ("header3", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<h3>" ^ vTrim ^
"</h3>");
                          "0", env
                    | Invoke ("header4", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<h4>" ^ vTrim ^
"</h4>");
                          "0", env
                    | Invoke ("header5", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<h5>" ^ vTrim ^
"</h5>");
                          "0", env
                    | Invoke ("header6", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<h6>" ^ vTrim ^
"</h6>");
                          "0", env
                    | Invoke ("para", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<p>" ^ vTrim ^
"</p>");
                          "0", env
```

- interpreter.ml contd.

```
                    | Invoke ("text", [e]) ->
                          let v, env = eval env e in
                          print_endline("<br>" ^ v ^ "</br>");
                          "0", env
                    | Invoke ("comment", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<!--" ^ vTrim ^ "--
>");
                          "0", env
                    | Invoke ("title", [e]) ->
                          let v, env = eval env e in
                          let vTrim = trimQuote v in
                          print_endline("<title>" ^ vTrim ^
"</title>");
                          "0", env
              | Invoke ("insert", [e]) ->
                          let v, env = eval env e in
                          if (v = "\"line\"") then
                                print_endline("<hr>")
                          else
                          print_endline (v);
                          "0", env
          | Invoke (f, actuals) ->
                          let fdecl =
                  try NameMap.find f func_decls
                  with Not_found -> raise (Failure ("undefined
function " ^ f))
                          in
                          let actuals, env = List.fold_left
                  (fun (actuals, env) actual ->
                          let v, env = eval env actual in v ::
actuals, env)
                  ([], env) actuals
                          in
                          let (locals, globals) = env in
                          try
                          let globals = invoke fdecl actuals
globals in "0", (locals, globals)
                                  with ReturnException(v,
globals) -> v, (locals, globals)
                          in
       let rec exec env = function
                          Block(stmts) -> List.fold_left exec
env stmts
          | Expr(e) -> let _, env = eval env e in env
          | Return(e) ->
                          let v, (locals, globals) = eval env e in
                          raise (ReturnException(v, globals))
                  in
```

- interpreter.ml contd.

```
                let locals =
              try List.fold_left2
                    (fun locals formal actual -> NameMap.add
   formal actual locals)
                   NameMap.empty fdecl.formals actuals
              with Invalid_argument(_) ->
                          raise (Failure ("wrong number of
   arguments passed to " ^ fdecl.fname))
              in
              (* Initialize local variables to 0 *)
                let locals = List.fold_left
                          (fun locals local -> NameMap.add
   local "0" locals) locals fdecl.locals
              in
              (* Execute each statement in sequence, return
   updated global symbol table *)
              snd (List.fold_left exec (locals, globals)
   fdecl.body)

                   (* Run a program: initialize global
   variables to 0, find and run "page" *)
                   in let globals = List.fold_left
              (fun globals vdecl1 -> NameMap.add vdecl1 "0"
   globals) NameMap.empty vars
                   in try
              invoke (NameMap.find "run" func_decls) []
   globals
                   with Not_found -> raise (Failure ("did not
   find the run() function"))
```

- bridge.ml

```
let insert = false

let _ =
  let lexbuf = Lexing.from_channel stdin in
  let program = Parser.program Scanner.token lexbuf in
  ignore (Interpret.run program)
```