The WIG language
Uses of the World Wide Web:

- static documents
  (supported by HTML);

- dynamic documents
  (supported by CGI, ASP, Ruby on Rails,
  various HTML extensions, ...); and

- interactive services
  (supported by <bigwig> and MAWL).
Static documents:

- there are too many documents;
- the documents are rarely updated; and
- the documents are not customized.

Dynamic documents:

- there are fewer documents;
- the documents are always updated;
- the documents are customized.
Standard interaction:

Client → Server

URL

static document

Server

HTML

Common Gateway Interface:

Client → Server

URL

fill-out form

form data

dynamic document

Server

HTML

script
Fill-out forms are HTML elements.

The \texttt{<form ...>} tag contains:

- the transmission method (\texttt{POST} or \texttt{GET});
- the URL of the script; and
- a query string.

Extra tags for input fields:

- simple text fields;
- radio buttons;
- menus; and
- submit buttons.
A simple fill-out form:

Your name: 

Your quest:  to find the Holy Grail

Your favorite color:  red green blue I don’t know

Answer
HTML source for the fill-out form:

```html
<form
   method="POST"
   action="http://www.brics.dk/cgi-mis/Python?Questions"
>
   Your name:
   <input name="name" type="text" size=20>.
<p>
   Your quest:
   <select name="quest">
   <option value="grail">to find the Holy Grail
   <option value="wig">to write a WIG compiler
   </select>
<p>
   Your favorite color:
   <input name="color" type="radio" value="red">red
   <input name="color" type="radio" value="green">green
   <input name="color" type="radio" value="blue">blue
   <input name="color" type="radio" value="argh">I don’t know
<p>
   <input name="submit" type="submit" value="Answer">
</form>
```
After filling out the form and clicking on the submit button, your browser sends the following text to the web server:

POST /cgi-mis/Python?Questions HTTP/1.0
Accept: www/source
Accept: text/html

......
User-Agent: ...
From: ...
Content-type: application/x-www-form-urlencoded
Content-length: 47

name=Michael
&quest=wig
&color=blue
&submit=Answer
The web server parses the data from the client (e.g., a browser), sets environment variables and input, and invokes CGI scripts.

Additional information is available in several UNIX environment variables. Consider the following simple query

http://www.cs.mcgill.ca/~hendren/cgi-bin/myenv.cgi?foo:

```
QUERY_STRING = foo
SERVER_ADDR = 132.206.51.10
HTTP_ACCEPT_LANGUAGE = en-us,en;q=0.5
SERVER_PROTOCO= HTTP/1.1
HTTP_CONNECTION = keep-alive
REMOTE_PORT = 35406
HTTP_USER_AGENT =
    Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.4)
    Gecko/20030624
HTTP_ACCEPT = text/xml,application/xml,application/xhtml+xml,
    text/html;q=0.9,text/plain;q=0.8,video/x-mng,
    image/png,image/jpeg,image/gif;q=0.2,*/*;q=0.1
GATEWAY_INTERFACE = CGI/1.1
HTTP_HOST = www.cs.mcgill.ca
SERVER_ADMIN = help@cs.mcgill.ca
SERVER_SOFTWARE = Apache/2.0.43 (Unix) PHP/4.3.0RC2
SCRIPT_URI =
    http://www.cs.mcgill.ca/~hendren/cgi-bin/myenv.cgi
REMOTE_ADDR = 132.206.3.136
SCRIPT_NAME = /~hendren/cgi-bin/myenv.cgi
```
SCRIPT_URL = ~/hendren/cgi-bin/myenv.cgi
HTTP_ACCEPT_ENCODING = gzip, deflate
SERVER_NAME = www.cs.mcgill.ca
DOCUMENT_ROOT = /usr/local/www/data
REQUEST_URI = ~/hendren/cgi-bin/myenv.cgi?Questions
HTTP_ACCEPT_CHARSET = ISO-8859-1, utf-8; q=0.7, *; q=0.7
REQUEST_METHOD = GET
SCRIPT_FILENAME =
   /u0/prof/hendren/public_html/cgi-bin/myenv.cgi
HTTP_KEEP_ALIVE = 300
PATH = /usr/local/bin:/usr/local/bin:/usr/bin:/bin
SERVER_PORT = 80
The script may be written in any programming or scripting language.

The form data appears on standard input as:

name=Michael&quest=wig&color=blue&submit=Answer

but must first be decoded:

- change ‘+’ into a space character; and
- replace %xy by the ASCII character with hex value xy.

In this example, ‘=’ and ‘&’ must be encoded.

For more on URL encoding see:

http://www.w3schools.com/HTML/html_urlencode.asp
The dynamic document is supplied by the script on standard output:

Content-type: text/html

Hello Michael,
<p>
Good luck on writing a blue WIG compiler!

or may be redirected from a different document:

Location: http://some.absolute/url
Content-type: text/html

How do we know it is really HTML?
CGI is a state-less protocol:

- each exchange happens in isolation;
- no information remains on the server; and
- different users cannot communicate.

We would like to have:

- global state;
- sessions;
- concurrent threads; and
- local state.
Interacting with a service:

Please guess a number between 0 and 99: 51

That is not correct. Try a higher number: 75

continue

That is not correct. Try a higher number: 87

continue

That is not correct. Try a lower number: 90

continue

That makes you the new record holder, beating the old record of 10 guesses.

Please enter your name for the hi-score list: Michael

continue

Thanks for playing this exciting game.
The WIG language provides:

- global state;
- safe, dynamic documents;
- sequential sessions;
- multiple threads; and
- local state.

A WIG specification is compiled into a self-contained CGI-script.
The (once) ubiquitous counter:

```
const html Nikolaj = <html> <body>
   <img src="http://www.brics.dk/~mis/babybath.jpg">
   <p>
   <i>You are visitor number <![no]]</i>
   </body> </html>;

int counter;

session Access() {
   counter = counter + 1;
   exit plug Nikolaj[no = counter];
}
```
A one-player guessing game:

```java
service {
    const html GetSeed = <html> <body> ... </body> </html>;
    const html GameSeeded = <html> <body> ... </body> </html>;
    const html Init = <html> <body> ... </body> </html>;
    const html Retry = <html> <body> ... </body> </html>;
    const html Again = <html> <body> ... </body> </html>;
    const html Done = <html> <body> ... </body> </html>;
    const html Record = <html> <body> ... </body> </html>;
    const html Finish = <html> <body> ... </body> </html>;
    const html List = <html> <body> ... </body> </html>;

    int plays, record;
    int seed;
    string holder;

    int nextRandom() {
        int current;

        seed = (25173 * seed + 13849) % 65536;
        return(seed);
    }

    session Seed() {
        show GetSeed receive[seed = seed];
        exit GameSeeded;
    }

    ...
}
```
session Play() {
    int number, guesses, guess;
    string localholder;

    number = nextRandom() % 100;
    plays = plays + 1;
    guesses = 1;
    show Init receive[guess = guess];
    while (guess > 99) show Retry receive[guess = guess];
    while (guess != number) {
        guesses = guesses + 1;
        if (guess > number)
            show plug Again[correction = "lower"]
            receive[guess = guess];
        else
            show plug Again[correction = "higher"]
            receive[guess = guess];
        while (guess > 99) show Retry receive[guess = guess];
    }
    show plug Done[trys = guesses];
    if (record == 0 || record > guesses) {
        show plug Record[old = record]
        receive [localholder = name];
        holder = localholder;
        record = guesses;
    }
    exit Finish;
}

session HiScore() {
    exit plug List[plays = plays,
        holder = holder, record = record];
}
const html GetSeed = <html> <body>
  Please enter an integer seed for the random
  number generator:
  <input name="seed" type="text" size=5>
</body> </html>;

const html GameSeeded = <html> <body>
  Ok, now the game can proceed, the generator is seeded.
</body> </html>;

const html Init = <html> <body>
  Please guess a number between 0 and 99:
  <input name="guess" type="text" size=2>
</body> </html>;

const html Retry = <html> <body>
  That number is too large!
  <p>
  Please keep your guess between 0 and 99:
  <input name="guess" type="text" size=2>
</body> </html>;

const html Again = <html> <body>
  That is not correct. Try a <corr> number:
  <input name="guess" type="text" size=2>
</body> </html>;
const html Again = <html> <body>
    That is not correct. Try a <[correction]> number:
    <input name="guess" type="text" size=2>
</body> </html>;

const html Done = <html> <body>
    You got it, using <[trys]> guesses.
</body> </html>;

const html Record = <html> <body>
    That makes you the new record holder,
    beating the old record of <[old]> guesses.
    <p>
    Please enter your name for the hi-score list
    <input name="name" type="text" size=20>
</body> </html>;

const html Finish = <html> <body>
    Thanks for playing this exciting game.
</body> </html>;

const html List = <html> <body>
    In <[plays]> plays of this game, the record
    holder is <[holder]> with <[record]> guesses.
</body> </html>;

Syntax for WIG html:

htmls : html | htmls html ;
html : "const" "html" identifier "="
     "<html>" htmlbodies "</html>" ;

htmlbodies : /* empty */ | nehtmlbodies;
nehtmlbodies : htmlbody | nehtmlbodies htmlbody;
htmlbody : "<" identifier attributes ">
          | "</" identifier ">
          | "<![" identifier "]>
          | whatever
          | meta
          | "<" "input" inputattrs ">
          | "<" "select" inputattrs ">
          htmlbodies "</" "select" ";

inputattrs : inputattr | inputattrs inputattr;
inputattr : "name" "=" attr
          | "type" "=" inputtype
          | attribute;
inputtype : "text" | "radio";

attributes : /* empty */ | neattributes;
neattributes : attribute | neattributes attribute;
attribute : attr | attr "=" attr;
attr : identifier | stringconst;
Comments on WIG html:

- documents are implicitly forms;
- the \(<[\text{foo}]>\) tag defines gaps to be filled in dynamically;
- \(<\text{input}...>\) and \(<\text{select}...>\) tags are explicitly recognized; and
- all other tags and plain text are permitted but ignored.
Syntax for WIG statements:

stms : /* empty */ | nestms;

;  
nestms : stm | nestms stm

;

stm : ";"

| "show" document receive ";"

| "exit" document ";"

| "return" ";"

| "return" exp ";"

| "if" "(" exp ")" stm

| "if" "(" exp ")" stm "else" stm

| "while" "(" exp ")" stm

| compoundstm

| exp ";"

;

document : identifier

| "plug" identifier "[" plugs "]";

receive : /* empty */

| "receive" "[" inputs "]";

compoundstm : "{" variables stms "}";

plugs : plug | plugs "," plug;

plug : identifier = exp;

inputs : /* empty */ | neinputs;

neinputs : input | neinputs "," input;

input : lvalue = identifier;
Syntax for WIG expressions:

\[
\begin{align*}
\text{exp} & : \text{lvalue} \\
& \mid \text{lvalue} \ "=" \ \text{exp} \\
& \mid \text{exp} \ "==" \ \text{exp} \\
& \mid \text{exp} \ "!=" \ \text{exp} \\
& \mid \text{exp} \ "<" \ \text{exp} \\
& \mid \text{exp} \ ">" \ \text{exp} \\
& \mid \text{exp} \ "<=" \ \text{exp} \\
& \mid \text{exp} \ ">=" \ \text{exp} \\
& \mid \ "!" \ \text{exp} \\
& \mid \ "-" \ \text{exp} \\
& \mid \ \text{exp} \ "+" \ \text{exp} \\
& \mid \ \text{exp} \ "-" \ \text{exp} \\
& \mid \ \text{exp} \ "*" \ \text{exp} \\
& \mid \ \text{exp} \ "/" \ \text{exp} \\
& \mid \ \text{exp} \ "/\" \ \text{exp} \\
& \mid \ \text{exp} \ "\&\&" \ \text{exp} \\
& \mid \ \text{exp} \ "\|\|" \ \text{exp} \\
& \mid \ \text{exp} \ "<<" \ \text{exp} \\
& \mid \ \text{exp} \ "\<<\" \ \text{identifiers} \\
& \mid \ \text{exp} \ "\+-\" \ \text{identifiers} \\
& \mid \ \text{exp} \ "\+-\" \ \text{identifiers} \\
& \mid \ \text{identifier} \ "(" \ \text{exp} \ ")" \\
& \mid \ \text{intconst} \\
& \mid \ "true" \\
& \mid \ "false" \\
& \mid \ \text{stringconst} \\
& \mid \ "tuple" \ \{" \ \text{fieldvalues} \ \}" \\
& \mid \ "(" \ \text{exp} \ ")" \\
\end{align*}
\]
Syntax for WIG expressions (cont.):

exps : /* empty */ | neexps;
neexps : exp | neexps "," exp;

lvalue : identifier | identifier "." identifier;

fieldvalues : /* empty */ | nefieldvalues;
nefieldvalues : fieldvalue | fieldvalues "," fieldvalue;
fieldvalue : identifier "=" exp;
Syntax for WIG schemas, types and functions:

schemas: /* empty */ | neschemas;
neschemas: schema | neschemas schema;
schema : "schema" identifier ";"
fields: /* empty */ | nefields;
nefields: field | nefields field;
field: simpletype identifier ";"

simpletype: "int" | "bool" | "string" | "void";
type: simpletype | "tuple" identifier;

functions: /* empty */ | nefunctions;
nefunctions: function | nefunctions function;
function: type identifier "(" arguments ")" compoundstm;

arguments: /* empty */ | nearguments;
nearguments: argument | nearguments "," argument;
argument: type identifier;
Syntax for WIG sessions, variables, and services:

sessions : session | sessions session;
session : "session" identifier "(" ")" compoundstm;

variables : /* empty */ | nevariables ;
nevariables : variable | nevariables variable ;
variable : type identifiers ";" ;
identifiers : identifier | identifiers "," identifier ;

service : "service" "{" htmls schemas
        variables functions sessions "}" ;

Compare our initial attempt at a grammar with a proper yacc/bison grammar with all conflicts resolved:

$ diff -u wiggrammar.txt wiggrammar_bison.txt
Some open questions on WIG semantics:

• what happens if not all gaps are plugged?
• what happens if a gap is plugged twice?
• must all form inputs be received?
• what are the allowed operations on tuples?
• what are the type rules?
• are global variables safe for concurrent threads?

There are many such questions to ponder.
A simple chat room:

```wigm
service {
    const html Logon = <html> <body>
        <h1>Welcome to The Chat Room</h1>
        Please enter your on-line name:
        <input name="name" type="text" size=25>
    </body> </html>;

    const html Update = <html> <body>
        <h1>The Chat Room Service</h1> <hr>
        <b>Messages so far:</b> <p>
        <hr>
        <b>Your new message:</b> <p>
        <p>
        <input name="msg" type="text" size=40>
        <p>
        <hr>
        <p>
        <input name="quit" type="radio" value="yes"> Quit now
    </body> </html>;

    const html ByeBye = <html> <body>
        <h1>Thanks for using The Chat Room</h1>
        You made <[conns]> connections
        and wrote <[msgs]> messages.
    </body> </html>;

    string msg0,msg1,msg2,msg3,msg4,msg5;
}
A simple chat room (cont.):

```wigi
session Chat() {
    string name, msg, quit;
    int connections, written;

    show Logon receive [name = name];
    while (quit != "yes") {
        show plug Update[msg0 = msg0,
                        msg1 = msg1,
                        msg2 = msg2,
                        msg3 = msg3,
                        msg4 = msg4,
                        msg5 = msg5]
        receive[msg = msg, quit = quit];
        connections = connections + 1;
        if (msg != ") {
            written = written + 1;
            msg0 = msg1;
            msg1 = msg2;
            msg2 = msg3;
            msg3 = msg4;
            msg4 = msg5;
            msg5 = name + " > " + msg;
        }
    }
    exit plug ByeBye[conns = connections,
                     msgs = written];
}
```
A sample chat:

The Chat Room Service

Messages so far:

Mads> What do I do now?
Anders> Any hot babes on the line?
Niels> Linux rulez!
Anders> I have an Amiga...
Mads> How do I get out of this room?
Niels> Linux rulez!

Your new message:

[Input field]

◇ Quit now

[Submit button]
Concurrent threads in a service:

- Global data
- Session A
- Session B
- Session C
Maintaining global and local state:

- global variables reside in shared files;
- local variables reside in program variables inside each thread.

Emulating a sequential thread:

- each `show` causes the CGI-thread to save the local state and stop;
- each form submission causes the CGI-thread to resume and restore the local state.
A WIG session thread:
Corresponding CGI-threads:

Client

Server

init

save local state and stop

restore local state and resume

save local state and stop

restore local state and resume

save local state and stop

restore local state and resume

stop
Some synchronization issues and solutions:

- exclusive updates of global data: 
  \textit{global file locking};
- critical sections: 
  \textit{mutex semaphores}.

Some security issues and solutions:

- tampering with the state: 
  \textit{keep all state on the server};
- hijacking a session: 
  \textit{use random keys in session id};
- rolling back a thread: 
  \textit{the server has the program counter}. 
A tiny WIG service:

```wig
service {
    const html Welcome = <html> <body>
        Welcome!
    </body> </html>;

    const html Pledge = <html> <body>
        How much do you want to contribute?
        <input name="contribution" type="text" size=4>
    </body> </html>;

    const html Total = <html> <body>
        The total is now [[total]].
    </body> </html>;

    int amount;

    session Contribute() {
        int i;
        i = 87;
        show Welcome;
        show Pledge receive[i = contribution];
        amount = amount + i;
        exit plug Total[total = amount];
    }
}
```
Generated C-based CGI source code:

```c
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <time.h>
#include "runwig.h"

char *url;
char *sessionid;
int pc;
FILE *f;

void output_Welcome()
{ printf("Welcome!\n");
}

void output_Pledge()
{ printf("How much do you want to contribute?\n");
    printf("<input name="contribution"
    type="text" size=4>\n");
}

void output_Total(char *total)
{ printf("The total is now %s.\n",total);
}

int local_Contribute_i;
```
int main() {

    /* initialize pseudorandom generator */
    srand48(time((time_t *)0));
    /* get form fields from CGI input */
    parseFields();
    /* assign the url of this service */
    url = "http://dovs-www.daimi.aau.dk/cgi-mis/tiny";
    /* find current sessionid from environment */
    sessionid = getenv("QUERY_STRING");

    /* do we start a new thread? */
    if (strcmp(sessionid,"Contribute")==0)
        goto start_Contribute;
    /* do we resume an old thread? */
    if (strncmp(sessionid,"Contribute$",11)==0)
        goto restart_Contribute;
    /* otherwise report an error */
    printf("Content-type: text/html\n\n");
    printf("<title>Illegal Request</title>\n");
    printf("<h1>Illegal request: %s</h1>\n",sessionid);
    exit(1);
/* start up a new thread */
start_Contribute:
/* initialize local variables */
local_Contribute_i = 87;
/* assign a random sessionid */
sessionid = randomString("Contribute",20);

/* show Welcome; */
printf("Content-type: text/html\n\n");
printf("<form method="POST" action="%s?%s">\n", url,sessionid);
output_Welcome();
printf("<p><input type="submit" value="continue">\n");
printf("</form>\n");
/* save local state */
f = fopen(sessionid,"w");
fprintf(f,"1\n");
fprintf(f,"%i\n",local_Contribute_i);
fclose(f);
/* terminate thread */
exit(0);
/* and resume from here */
Contribute_1:
/* show Pledge... */
printf("Content-type: text/html\n\n");
printf("<form method="POST" action="%s?%s">\n",
    url, sessionid);
output_Pledge();
printf("<p><input type="submit" value="continue">")
printf("</form>\n");

/* save local state */
f = fopen(sessionid, "w");
fprintf(f, "2\n");
fprintf(f, "%i\n", local_Contribute_i);
fclose(f);
 /* terminate thread */
exit(0);
 /* and resume from here */
Contribute_2:

/* ...receive[i = contribution]; */
local_Contribute_i = atoi(getField("contribution"));
/* amount = amount + i; */
putGlobalInt("global_tiny_amount",
    getGlobalInt("global_tiny_amount")
    +local_Contribute_i);
/* exit plug Total[total = amount]; */
printf("Content-type: text/html\n\n");
output_Total(itoa(getGlobalInt("global_tiny_amount")));
exit(0);
/* restart a thread */
restart_Contribute:
/* restore local state */
f = fopen(sessionid,"r");
fscanf(f,"%i\n",&pc);
fscanf(f,"%i\n",&local_Contribute_i);
/* jump to current pc */
if (pc==1) goto Contribute_1;
if (pc==2) goto Contribute_2;

} /* end of main () */
The library `runwig.h` implements:

```c
void parseFields();
char *getField(char *name);

char *randomString(char *name, int size);

int getGlobalInt(char *name);
void putGlobalInt(char *name, int value);

char *itoa(int i);
```
The service can be installed by a script:

```sh
#!/bin/sh
gcc tiny.c /path/to/wig4/runwig.c -o tiny4.cgi
cp tiny4.cgi ~/public_html/cgi-bin
chmod 755 ~/public_html/cgi-bin/tiny4.cgi
```

and invoked by:

```
```

Are we having fun yet?