15-213

"The course that gives CMU its Zip!"

Web services
Nov 29, 2001

Topics

- HTTP
- Serving static content
- Serving dynamic content

`class27.ppt`

Web history

1945:

- **Vannevar Bush, “As we may think”, Atlantic Monthly, July, 1945.**
  - **Describes the idea of a distributed hypertext system.**
  - **a “memex” that mimics the “web of trails” in our minds.**

1989:

- **Tim Berners-Lee (CERN) writes internal proposal to develop a distributed hypertext system.**
  - **connects “a web of notes with links”.**
  - **intended to help CERN physicists in large projects share and manage information**

1990:

- **Tim BL writes a graphical browser for Next machines.**

Web history (cont)

1992

- NCSA server released
- 26 WWW servers worldwide

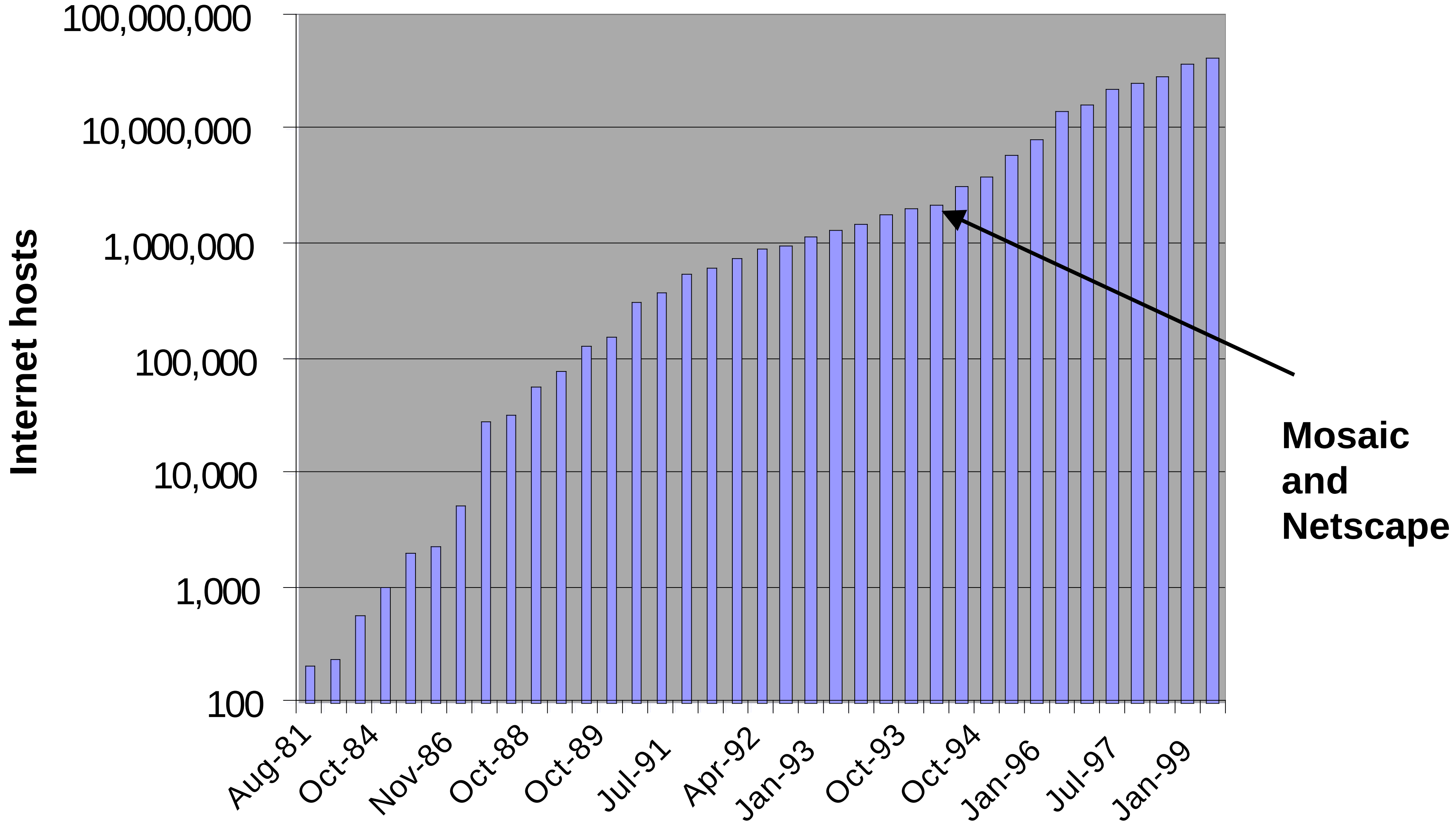
1993

- Marc Andreessen releases first version of NCSA Mosaic browser
- Mosaic version released for (Windows, Mac, Unix).
- Web (port 80) traffic at 1% of NSFNET backbone traffic.
- Over 200 WWW servers worldwide.

1994

- Andreessen and colleagues leave NCSA to form "Mosaic Communications Corp" (now Netscape).

Internet Domain Survey (www.isc.org)



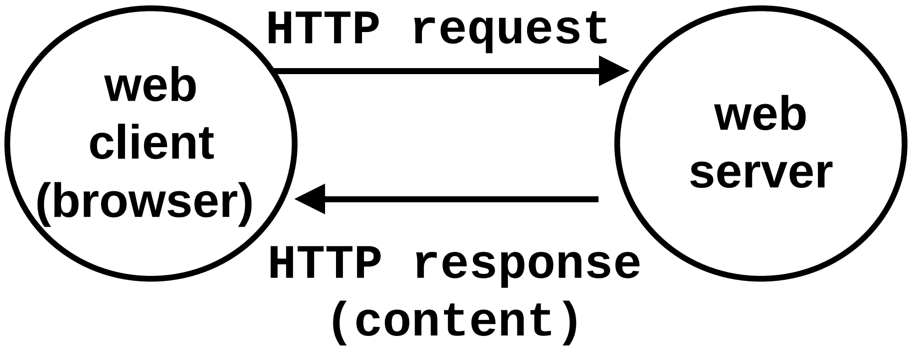
Web servers

Clients and servers communicate using the HyperText Transfer Protocol (HTTP)

- **client and server establish TCP connection**
- **Client requests content**
- **Server responds with requested content**
- **client and server close connection (usually)**

Current version is HTTP/1.1

- **RFC 2616, June, 1999.**



Web content

Web servers return *content* to clients

- ***content:*** **a sequence of bytes with an associated MIME (Multipurpose Internet Mail Extensions) type**

Example MIME types

`text/html`	HTML page
`text/plain`	Unformatted text
`application/postscript`	Postcript document
`image/gif`	Binary image encoded in GIF format
`image/jpg`	Binary image encoded in JPG format

Static and dynamic content

The content returned in HTTP responses can be either static or dynamic.

- Static content: content stored in files and retrieved in response to an HTTP request
  - Examples: HTML files, images, audio clips.
- Dynamic content: content produced on-the-fly in response to an HTTP request
  - Example: content produced by a program executed by the server on behalf of the client.

Bottom line: all content is associated with a file managed by the server.

URLs

Each file managed by a server has a unique name called a URL (Universal Resource Locator)

URLs for static content:

- `http://www.cs.cmu.edu:80/index.html`
- `http://www.cs.cmu.edu/index.html`
- `http://www.cs.cmu.edu`
  - identifies a file called `index.html`, managed by a Web server at `www.cs.cmu.edu` that is listening on port 80.

URLs for dynamic content:

- `http://www.cs.cmu.edu:8000/cgi-bin/adder?15000&213`
  - identifies an executable file called `adder`, managed by a Web server at `www.cs.cmu.edu` that is listening on port 8000, that should be called with two argument strings: `15000` and `213`.

How clients and servers use URLs

Example URL: `http://www.aol.com:80/index.html`

Clients use *prefix* (`http://www.aol.com:80`) to infer:

- **What kind of server to contact (Web server)**
- **Where the server is (www.aol.com)**
- **What port it is listening on (80)**

Servers use *suffix* (`/index.html`) to:

- **Determine if request is for static or dynamic content.**
  - **No hard and fast rules for this.**
  - **Convention: executables reside in `cgi-bin` directory**
- **Find file on filesystem.**
  - **Initial "/" in suffix denotes home directory for requested content.**
  - **Minimal suffix is "/", which all servers expand to some default home page (e.g., `index.html`).**

Anatomy of an HTTP transaction

```
unix> telnet www.aol.com 80           Client: open connection to server
Trying 205.188.146.23...              Telnet prints 3 lines to the terminal
Connected to aol.com.
Escape character is '^]'.
GET / HTTP/1.1                        Client: request line
host: www.aol.com                     Client: required HTTP/1.1 HOST header
                                      Client: empty line terminates headers.
HTTP/1.0 200 OK                       Server: response line
MIME-Version: 1.0                     Server: followed by five response headers
Date: Mon, 08 Jan 2001 04:59:42 GMT
Server: NaviServer/2.0 AOLserver/2.3.3
Content-Type: text/html               Server: expect HTML in the response body
Content-Length: 42092                 Server: expect 42,092 bytes in the resp body
                                      Server: empty line ("\r\n") terminates hdrs
<html>                                Server: first HTML line in response body
...                                   Server: 766 lines of HTML not shown.
</html>                               Server: last HTML line in response body
Connection closed by foreign host.    Server: closes connection
unix>                                 Client: closes connection and terminatesM
```

HTTP requests

HTTP request is a *request line*, followed by zero or more request *headers*

request line: `<method> <uri> <version>`

- **`<version>` is HTTP version of request (`HTTP/1.0` or `HTTP/1.1`)**
- **`<uri>` is typically URL for proxies, URL suffix for servers.**
- **`<method>` is either `GET`, `POST`, `OPTIONS`, `HEAD`, `PUT`, `DELETE`, or `TRACE`.**

HTTP requests (cont)

HTTP methods:

- `GET`: retrieve static or dynamic content
  - arguments for dynamic content are in URI
  - workhorse method (99% of requests)
- `POST`: retrieve dynamic content
  - arguments for dynamic content are in the request body
- `OPTIONS`: get server or file attributes
- `HEAD`: like `GET` but no data in response body
- `PUT`: write a file to the server!
- `DELETE`: delete a file on the server!
- `TRACE`: echo request in response body
  - useful for debugging.

HTTP requests (cont)

Request headers: `<header name>: <header data>`

- **Provide additional information to the server.**

Major differences between HTTP/1.1 and HTTP/1.0

- **HTTP/1.0 uses a new connection for each transaction.**
- **HTTP/1.1 also supports *persistent connections***
  - **multiple transactions over the same connection**
  - `Connection: Keep-Alive`
- **HTTP/1.1 requires `HOST` header**

HTTP Responses

HTTP response is a *response line* followed by zero or more *response headers*.

Response line:

`<version> <status code> <status msg>`

- **<version> is HTTP version of the response.**
- **<status code> is numeric status.**
- **<status msg> is corresponding English text.**

– 200	OK	Request was handled without error
– 403	Forbidden	Server lacks permission to access file
– 404	Not found	Server couldn't find the file.

Response headers: `<header name>: <header data>`

- **provide additional information about response**
- **`Content-Type:` MIME type of content in response body.**
- **`Content-Length:` Length of content in response body.**

GET request to Apache server from IE browser

```
GET /test.html HTTP/1.1
Accept: */*
Accept-Language: en-us
Accept-Encoding: gzip, deflate
User-Agent: Mozilla/4.0 (compatible; MSIE 4.01; Windows 98)
Host: euro.ecom.cmu.edu
Connection: Keep-Alive
CRLF
```

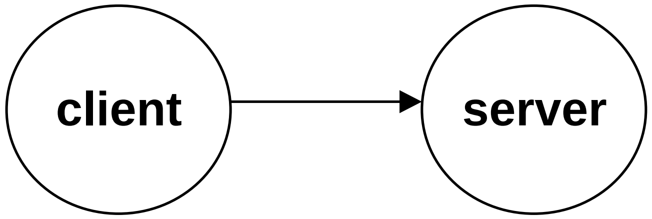
GET response from Apache

```
HTTP/1.1 200 OK
Date: Thu, 22 Jul 1999 04:02:15 GMT
Server: Apache/1.3.3 Ben-SSL/1.28 (Unix)
Last-Modified: Thu, 22 Jul 1999 03:33:21 GMT
ETag: "48bb2-4f-37969101"
Accept-Ranges: bytes
Content-Length: 79
Keep-Alive: timeout=15, max=100
Connection: Keep-Alive
Content-Type: text/html
CRLF
<html>
<head><title>Test page</title></head>
<body>
<h1>Test page</h1>
</html>
```

Serving dynamic content

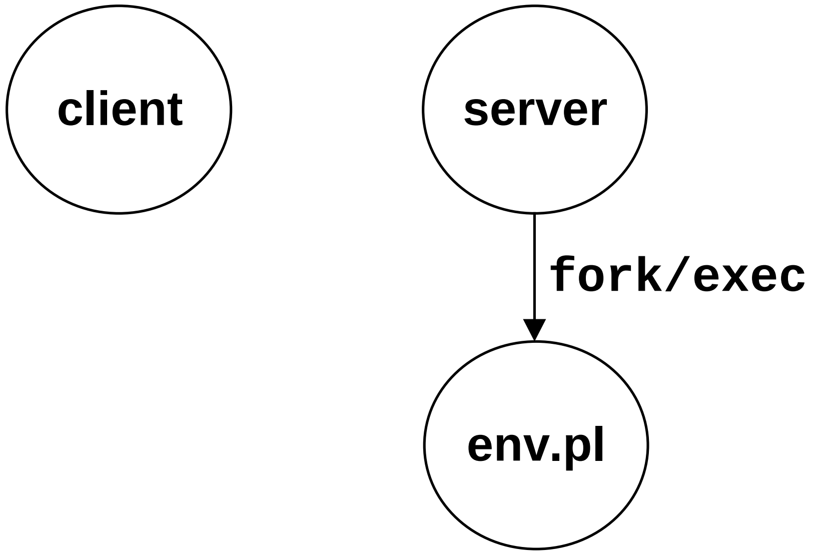
- **Client sends request to server.**
- **If request URI contains the string “`/cgi-bin`”, then the server assumes that the request is for dynamic content.**

```
GET /cgi-bin/env.pl HTTP/1.1
```



Serving dynamic content

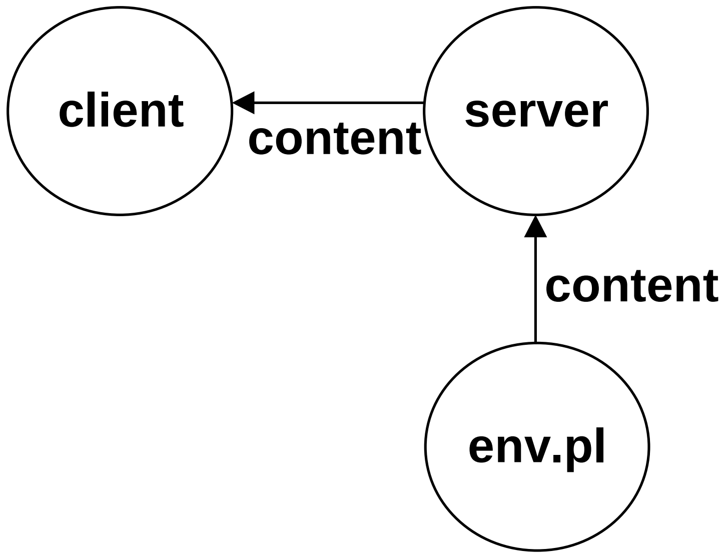
The server creates a child process and runs the program identified by the URI in that process



Serving dynamic content

The child runs and generates the dynamic content.

The server captures the content of the child and forwards it without modification to the client



Issues in serving dynamic content

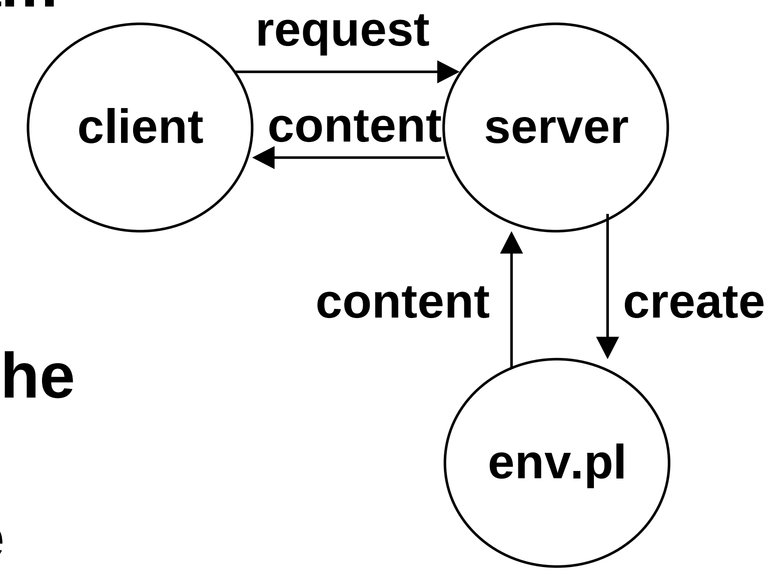
How does the client pass program arguments to the server?

How does the server pass these arguments to the child?

How does the server pass other info relevant to the request to the child?

How does the server capture the content produced by the child?

These issues are addressed by the Common Gateway Interface (CGI) specification.



CGI

Because the children are written according to the CGI spec, they are often called CGI programs.

Because many CGI programs are written in Perl, they are often called CGI scripts.

However, CGI really defines a simple standard for transferring information between the client (browser), the server, and the child process.

add.com:
THE Internet addition portal!

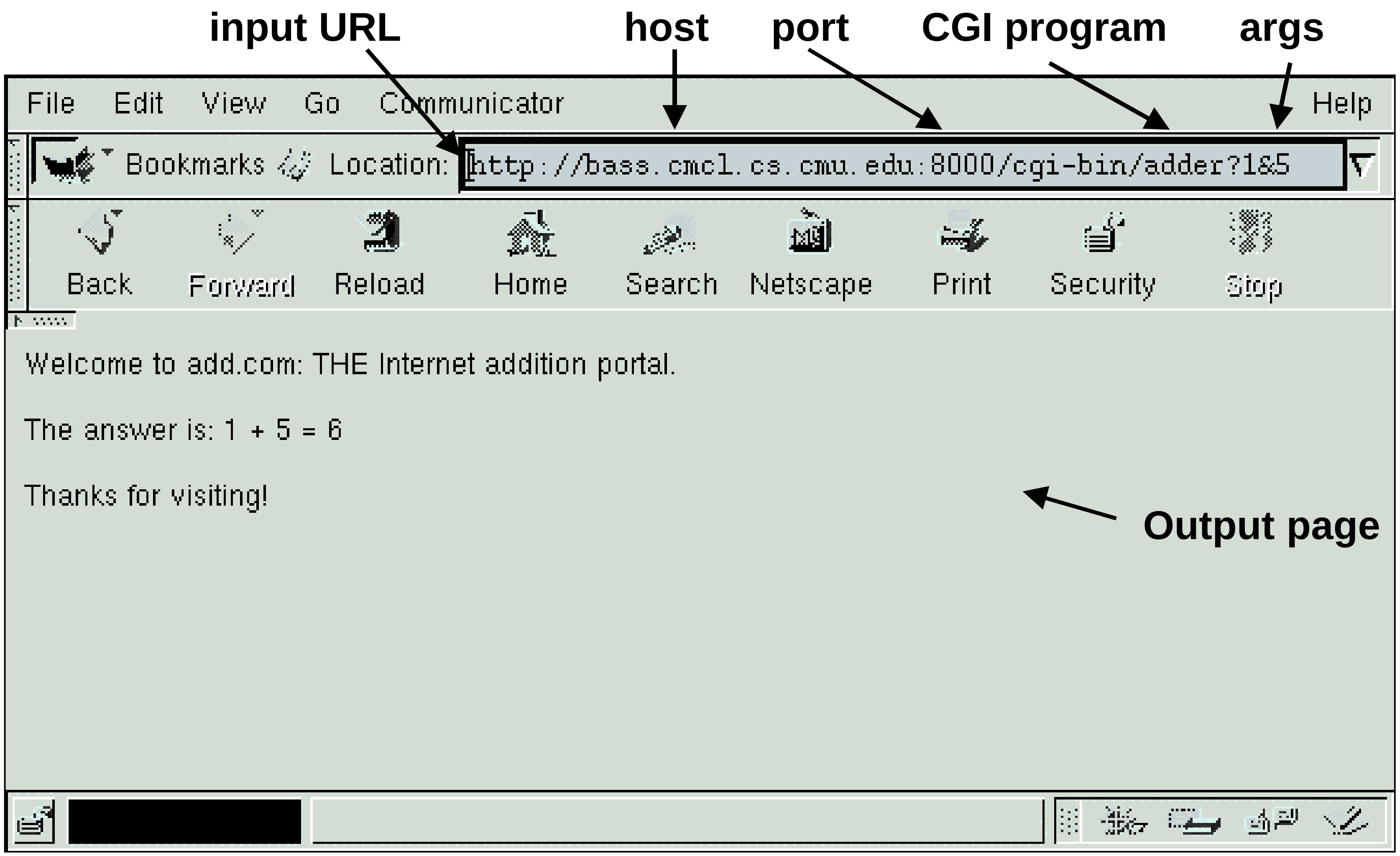
Ever need to add two numbers together and you just can't find your calculator?

Try Dr. Dave's addition service at add.com: THE Internet addition portal!

- Takes as input the two numbers you want to add together.
- Returns their sum in a tasteful personalized message.

After the IPO we'll expand to multiplication!

The add.com experience


input URL
host
port
CGI program
args
File Edit View Go Communicator Help
Bookmarks Location:
Back Forward Reload Home Search Netscape Print Security Stop
Output page

```
http://bass.cmcl.cs.cmu.edu:8000/cgi-bin/adder?1&5
```

Welcome to add.com: THE Internet addition portal.

The answer is: 1 + 5 = 6

Thanks for visiting!

Serving dynamic content with GET

Question: How does the client pass arguments to the server?

Answer: The arguments are appended to the URI

Can be encoded directly in a URL typed to a browser or a URL in an HTML link

- `http://add.com/cgi-bin/adder?1&2`
- `adder` is the CGI program on the server that will do the addition.
- argument list starts with “?”
- arguments separated by “&”
- spaces represented by `“+” or “%20”`

Can also be generated by an HTML form

```
<form method=get action="http://add.com/cgi-bin/postadder">
```

Serving dynamic content with GET

URL:

- `http://add.com/cgi-bin/adder?1&2`

Result displayed on browser:

```
Welcome to add.com: THE Internet addition portal.

The answer is: 1 + 2 = 3

Thanks for visiting! Tell your friends.
```

Serving dynamic content with GET

Question: How does the server pass these arguments to the child?

Answer: In environment variable QUERY_STRING

- a single string containing everything after the “?”
- for add.com: `QUERY_STRING` = “1&2”

```
/* child code that accesses the argument list */
if ((buf = getenv("QUERY_STRING")) == NULL) {
  exit(1);
}

/* extract arg1 and arg2 from buf and convert */
...
n1 = atoi(arg1);
n2 = atoi(arg2);
```

Serving dynamic content with GET

Question: How does the server pass other info relevant to the request to the child?

Answer: in a collection of environment variables defined by the CGI spec.

Some CGI environment variables

General

- `SERVER_SOFTWARE`
- `SERVER_NAME`
- `GATEWAY_INTERFACE` (CGI version)

Request-specific

- `SERVER_PORT`
- `REQUEST_METHOD` (`GET`, `POST`, etc)
- `QUERY_STRING` (contains `GET` args)
- `REMOTE_HOST` (domain name of client)
- `REMOTE_ADDR` (IP address of client)
- `CONTENT_TYPE` (for `POST`, type of data in message body, e.g., `text/html`)
- `CONTENT_LENGTH` (length in bytes)

Some CGI environment variables

In addition, the value of each header of type *type* received from the client is placed in environment variable `HTTP_`*type*

- Examples:
  - `HTTP_ACCEPT`
  - `HTTP_HOST`
  - `HTTP_USER_AGENT` (any “-” is changed to “`_`”)

Serving dynamic content with GET

Question: How does the server capture the content produced by the child?

Answer: The child generates its output on `stdout`. Server uses dup2 to redirect `stdout` to its connected socket.

- Notice that only the child knows the type and size of the content. Thus the child (not the server) must generate the corresponding headers.

```
/* child generates the result string */
sprintf(content, "Welcome to add.com: THE Internet addition portal\
        <p>The answer is: %d + %d = %d\
        <p>Thanks for visiting!\r\n",
       n1, n2, n1+n2);

/* child generates the headers and dynamic content */
printf("Content-length: %d\r\n", strlen(content));
printf("Content-type: text/html\r\n");
printf("\r\n");
printf("%s", content);
```

Serving dynamic content with GET

```
bass> tiny 8000
GET /cgi-bin/adder?1&2 HTTP/1.1
Host: bass.cmcl.cs.cmu.edu:8000
<CRLF>
```

HTTP request received by Tiny Web server

```
kittyhawk> telnet bass 8000
Trying 128.2.222.85...
Connected to BASS.CMCL.CS.CMU.EDU.
Escape character is '^]'.
GET /cgi-bin/adder?1&2 HTTP/1.1
Host: bass.cmcl.cs.cmu.edu:8000
<CRLF>
```

HTTP request sent by client

```
HTTP/1.1 200 OK
Server: Tiny Web Server
```

HTTP response generated by the server

```
Content-length: 102
Content-type: text/html
<CRLF>
Welcome to add.com: THE Internet addition portal.
<p>The answer is: 1 + 2 = 3
<p>Thanks for visiting!
```

HTTP response generated by the CGI program

```
Connection closed by foreign host.
kittyhawk>
```

For more information

See the Tiny Web server described in your text

- **Tiny is a sequential Web server.**
- **Serves static and dynamic content to real browsers.**
  - **text files, HTML files, GIF and JPG images.**
- **220 lines of commented, well structured C code.**
- **Also comes with an implementation of the CGI script for the add.com addition portal.**