Which concept has given you the most difficulty so far in the context of Homework 3?

A. Understanding the index file layout
B. C++ Classes & Inheritance
C. C++ STL
D. Query Processor Algorithm
E. Debugging/GDB
F. Style considerations
G. Prefer not to say
Hypertext Transfer Protocol
CSE 333 Winter 2023

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Relevant Course Information

- Midterm grades have been released
  - Regrades are open until Wednesday (3/1)

- Exercise 10 due Wednesday (3/1)
  - Client-side programming

- Exercise 11 due Friday (3/3)
  - Server-side programming
  - Can use ex10 client solution to send messages to ex11 server

- Homework 4 due next Thursday (3/09)
  - Can still use 2 late days for hw4 (hard deadline of 3/12)
  - Part of section this week will cover tools for debugging hw4
Homework 4 Summary

- Build a Multithreaded Web Server (333gle)
  - You will host the querying service that you built in your previous homework on a web server

- Running your server
  - `./http333d <port> <static files> <unit indices>`
  - Static files are the files on disk corresponding to our index files
  - You (and others) can access it on any browser now!

- Implementation
  - Using network protocols to communicate between client/server
  - Handling some additional security flaws
  - Note: Multithreading is already implemented for you
Client and Server Communication

- Lecture 20 (Client-side and Server-side Networking) has already shown how to do this in C/C++
  - `sendreceive.cc` and `server_accept_rw_close.cc`

- This is what actually happens on the web!
  - Clients establish a stable TCP connection the server
  - Lots of bytes are interchanged/processed between each other

“I’d like `index.html`”

“Found it, here it is: (`index.html`)”
Case Study of Protocols: HTTP

- A protocol defines a set of rules governing the **format** and **exchange** of messages in a computing system
  - Syntax: The formatting or grammar of the system
  - Semantics: What messages are being exchanged
  - Allows everyone be on the same page of communication

- Hyper**t**ext Transfer **P**rotocol: Request/Response Protocol
  - HTTP defines how we should send information between a client and a server
  - A **request** will send a message to the server (about anything)
  - A **response** will process and respond to that message
  - And it’s human readable!
Requests: Client Sending Messages

- A client wants to talk to a server about something
  - Initiates a conversation (establish or using existing connection)
  - Generally, this is for retrieving a resource, using **Uniform Resource Identifier (URI)**

- Standard Syntax:
  - `[METHOD] [request-uri] HTTP/[version]\r\n    [headerfield1]: [fieldvalue1]\r\n    [headerfield2]: [fieldvalue2]\r\n    [...]\n    [headerfieldN]: [fieldvalueN]\r\n    \r\n    [request body, if any]`
HTTP Methods

- There are three commonly-used HTTP methods:
  - **GET**: “Please send me the named resource”
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    - Doesn’t send resource; often to check if cached copy is still valid
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  - **GET**: “Please send me the named resource”
  - **POST**: “I’d like to submit data to you” (e.g. file upload)
  - **HEAD**: “Send me the headers for the named resource”
    - Doesn’t send resource; often to check if cached copy is still valid

- Other methods exist, but are much less common:
  - **PUT, DELETE, TRACE, OPTIONS, CONNECT, PATCH, ...**
    - For instance: **TRACE** – “show any proxies or caches in between me and the server”
Client Headers

- The client can provide one or more request “headers”
  - These provide information to the server or modify how the server should process the request

- You’ll encounter many in practice
  - **Host**: the DNS name of the server
  - **User-Agent**: an identifying string naming the browser
  - **Accept**: the content types the client prefers or can accept
  - **Cookie**: an HTTP cookie previously set by the server
  - [https://www.rfc-editor.org/rfc/rfc2616.html#section-5.3](https://www.rfc-editor.org/rfc/rfc2616.html#section-5.3)
A Real Request

```
GET / HTTP/1.1
Host: attu.cs.washington.edu:3333
Connection: keep-alive
Upgrade-Insecure-Requests: 1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64)
AppleWebKit/537.36 (KHTML, like Gecko)
Chrome/66.0.3359.181 Safari/537.36
Cookie:
SESS0c8e598bbe17200b27e1d0a18f9a42bb=5c18d7ed6d369d56b69ac0aa441d
...```

- Demo: use `nc` to see a real HTTP request
Response: Server Responding

- A server parses and sends a response to a user
  - Indicate how the server processed the request (accepted or not)
  - Send requested resource back to the client

- General form:
  - HTTP/[version] [status code] [reason]\r\n    [headerfield1]: [fieldvalue1]\r\n    [headerfield2]: [fieldvalue2]\r\n    [...]
    [headerfieldN]: [fieldvalueN]\r\n    \r\n    [response body, if any]
Status Codes and Reason

- **Code**: numeric outcome of the request – easy for computers to interpret
  - A 3-digit integer with the 1st digit indicating a response category
    - 1xx: Informational message
    - 2xx: Success
    - 3xx: Redirect to a different URL
    - 4xx: Error in the client’s request
    - 5xx: Error experienced by the server

- **Reason**: human-readable explanation
  - *e.g.* “OK” or “Moved Temporarily”
Common Statuses

- **HTTP/1.1 200 OK**
  - The request succeeded and the requested object is sent

- **HTTP/1.1 404 Not Found**
  - The requested object was not found

- **HTTP/1.1 301 Moved Permanently**
  - The object exists, but its name has changed
    - The new URL is given as the “Location:” header value

- **HTTP/1.1 500 Server Error**
  - The server had some kind of unexpected error
Server Headers

- The server can provide zero or more response “headers”
  - These provide information to the client or modify how the client should process the response

- You’ll encounter many in practice
  - **Server**: a string identifying the server software
  - **Content-Type**: the type of the requested object
  - **Content-Length**: size of requested object
  - **Last-Modified**: a date indicating the last time the request object was modified

A Real Response

HTTP/1.1 200 OK
Date: Mon, 21 May 2018 07:58:46 GMT
Server: Apache/2.2.32 (Unix) mod_ssl/2.2.32
OpenSSL/1.0.1e-fips mod_pubcookie/3.3.4a mod_uwa/3.2.1
Phusion_Passenger/3.0.11
Last-Modified: Mon, 21 May 2018 07:58:05 GMT
Content-Length: 82
Content-Type: text/html

...<html><body>
<font color="chartreuse" size="18pt">Awesome!!</font>
</body></html>

- Demo: Use telnet to see real HTTP responses
Which statement is FALSE about the HTTP/1.1 Protocol?

A. HTTP is a standard communication protocol for the web
B. A client always sends a message first before the server
C. An HTTP Request can only request one resource at a time
D. An HTTP Response needs to have a response body
E. I’m not really sure...
HTTP/1.1 Protocol

- HTTP / 1.1 (1997) – The protocols accepted by all current browsers and servers
  - Built after HTTP/0.9 (1991) and HTTP/1.0 (1996)
  - Better performance, richer caching features, better support for multihomed servers, and much more
- “Chunked Transfer-Encoding” – Send responses in multiple pieces (Transfer-Encoding: chunked)
- Persistent Connections: TCP connections can handle multiple requests (Connection: keep-alive)
Improvements: HTTP/2 and HTTP/3

- Human-readable text protocols can only go so far

- HTTP/2 (2015) was a push to optimize HTTP/1.1
  - Built off Google Project SPDY which aimed to reduce latency
  - Compressed headers and message body
  - Many larger companies quickly transitioned
  - [https://en.wikipedia.org/wiki/HTTP/2](https://en.wikipedia.org/wiki/HTTP/2)

- HTTP/3 (2022) builds even more on HTTP/2
  - Mainly using UDP-based protocol called QUIC (holds a standard connection like TCP)
Slow to Change: HTTP Protocols

- HTTP/1.1 is still used today (1996 – Present)
  - [https://almanac.httparchive.org/en/2022/http#fig-1](https://almanac.httparchive.org/en/2022/http#fig-1)
  - ~20% of requests still use HTTP/1.1
  - Down from ~50% of requests 4 years ago

- Why is the transition taking so long?
  - Lack of knowledge about HTTP/2+
  - A good portion of web servers are still using HTTP/1.1
  - It takes engineering work to support a new HTTP protocol
  - HTTP/1.1 is human readable
  - Amongst more...
Probably want to restructure this slide a bit.
Thanks Everyone for Listening to my Lectures!

- Honestly super cool to be able to lecture to a bunch of students. Wish time permitted for more guest lectures!

- I will be the Summer Instructor for CSE 333 (23su), so if you are interested in working with me, please contact me:
  - Email: tzyang2@cs.uw.edu
  - I will probably send an Ed post in Spring quarter

- Best of luck with the rest of the quarter! You got this!
Extra Exercise #1

- Write a program that:
  - Creates a listening socket that accepts connections from clients
  - Reads a line of text from the client
  - Parses the line of text as a DNS name
  - Connects to that DNS name on port 80
  - Writes a valid HTTP request for “/”

```
GET / HTTP/1.1\r\nHost: <DNS name>\r\nConnection: close\r\n\r\n```

- Reads the reply and returns it to the client