

Lecture 17

408/508 *Computational Techniques for Linguists*

Today's Topics

- Homework 6 (Tic-Tac-Toe) Code Review

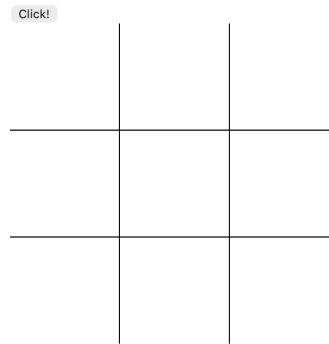
Today's Topics

- Creating a webserver (httpd)
 - install the Apache2 webserver
 - installed by default on macOS,
 - install using apt install on Ubuntu
 - how to start/stop service
 - DocumentRoot
 - User web files
- Homework 7 (heads-up):
 - *set up your own webserver*
 - *given out on Thursday*

Delay Issue Example

Why does it happen?

- single thread of execution
 - cell innerHTML write doesn't happen until after alert()



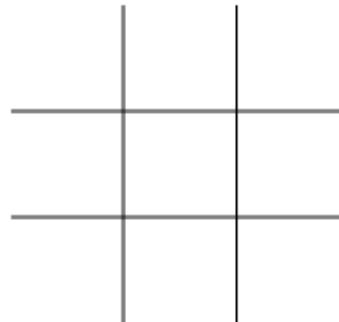
Example



Tic Tac Toe

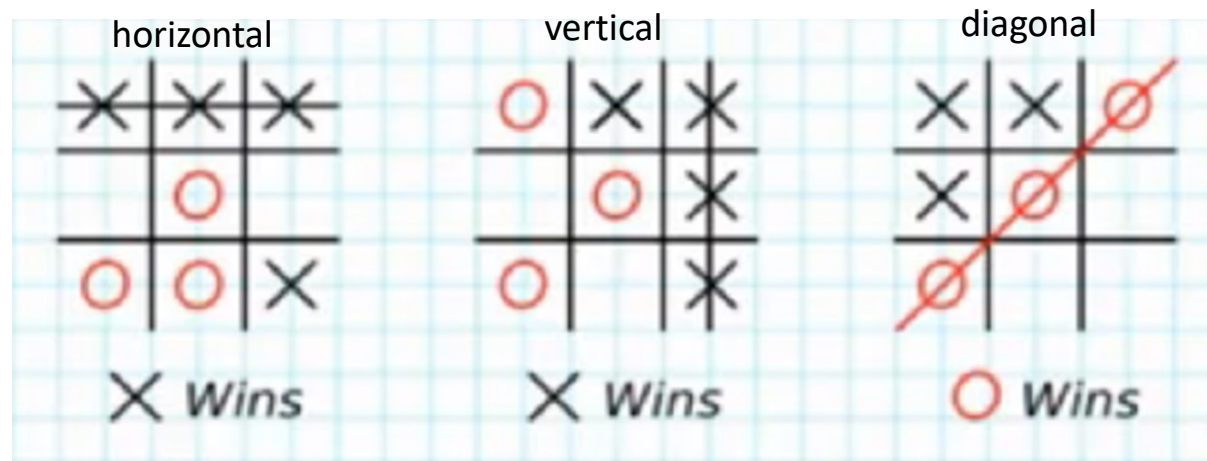
You're X, computer is O. Click on a square to place an X.

to let computer go first.



Last modified: Sun Sep 28 11:31:14 MST 2025

chk_win()



```
31 function win() {  
32     return (chk_win([1,2,3]) || chk_win([4,5,6]) || chk_win([7,8,9]) ||  
33             chk_win([1,4,7]) || chk_win([2,5,8]) || chk_win([3,6,9]) ||  
34             chk_win([1,5,9]) || chk_win([3,5,7]))  
35 }
```

```
36 function chk_win(l) {  
37     var win = ((document.getElementById(l[0]).innerHTML != "") &&  
38         (document.getElementById(l[0]).innerHTML ==  
39             document.getElementById(l[1]).innerHTML) &&  
40             (document.getElementById(l[1]).innerHTML ==  
41                 document.getElementById(l[2]).innerHTML));  
42     if (win) {  
43         for (const i of l) {  
44             document.getElementById(i).style.color = 'red'  
45         }  
46     }  
47     return win  
48 }
```

chk_win()

Generalize to
3D Tic Tac Toe



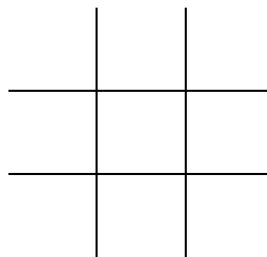
file:///Users/sandiway/Desktop/508/hv

3D Tic Tac Toe

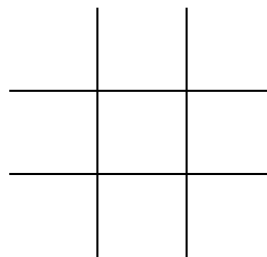
You're X, computer is O. Click on a square to place an X.

to let computer go first.

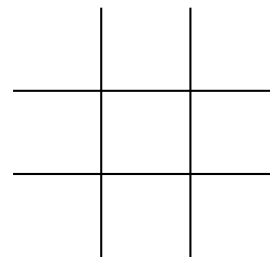
Top



Middle



Bottom



Last modified: Mon Sep 29 20:30:22 MST 2025

Generalize to 3D Tic Tac Toe

3D Tic Tac Toe

You're X, computer is O. Click on a square to place an X.

to let computer go first. game.

☐ Random ☐ Smart ☒ Smartest

Top	Middle	Bottom
	X	

Top	Middle	Bottom
	X	

Top	Middle	Bottom

top
middle
bottom

Game Over!

[Close](#)

Sandiway Fong, Univ
Last modified: Wed O

"Smart" 3D Tic Tac Toe

file:///Users/sandiway/Desktop/508/hw6plus3D.html

javascript acces...

3D Tic Tac Toe

You're X, computer is O. Click on a square to place an X.

to let computer go first.

☐ Random ☐ Smart ☒ Smartest

Top	Middle	Bottom
X	X	O
O		O
X	X	

Game Over!

Close

Last modified: Mon Sep 29 20:30:22 MST 2025

×

□

□

□

⊕

📺

!

🧩

Elements

Console

Sources

Network

Timelines

🔍

<

>

All

Evaluations

Errors

Warnings

Logs

☰

Console opened at 11:12:34 PM

📄 block layer 4

📄 block depth 19

📄 take 21 19,20,21

>

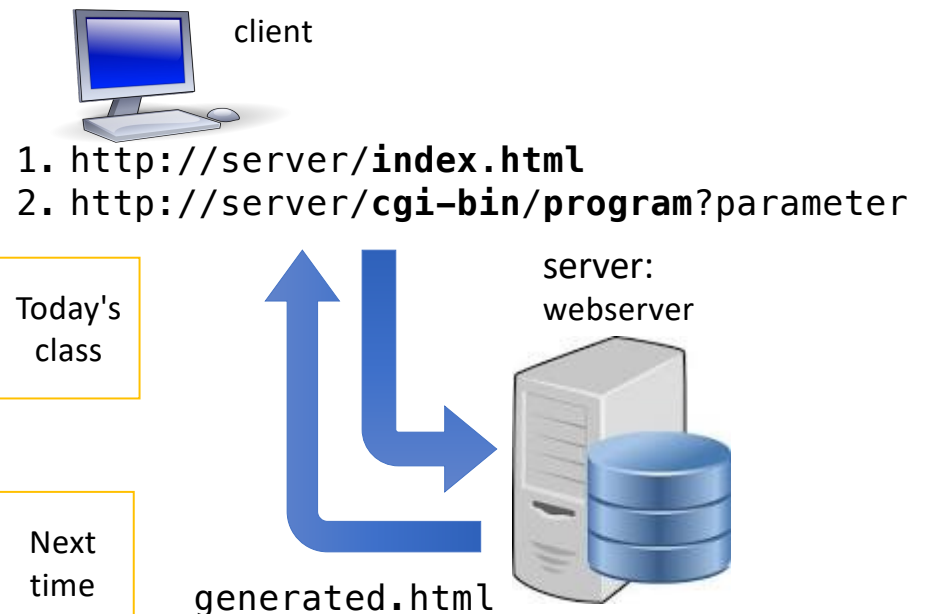
Building a Webserver

- We'll use `cgi-bin` and bash scripts initially ...
 - Apache2 is the most common webserver software
 - <https://httpd.apache.org>
 - has been around more than a quarter century
 - *unfortunately, configurations are similar but different on macOS and Ubuntu*
- (we will cover both today)

Common Gateway Interface (CGI)

- The glue between a webserver and programs that run on the computer (= server) hosting the webserver

1. Normally, a webserver sends out **static webpages** in response to (URL) requests from a client (your web browser).
2. Sometimes, we want the **request to run a program** (a script or binary) on the server that does some computation and generates some result to be displayed on the client (as a webpage).



httpd

- httpd is the Apache HyperText Transfer Protocol (HTTP) server program.
 - It is designed to be run as a standalone **daemon** process. When used like this it will create a pool of child processes or threads to handle requests.
 - "We fancifully began to use the word **daemon** to describe background processes that worked tirelessly to perform system chores". (Prof. Corbató, MIT)
 - In general, httpd should not be invoked directly, but rather should be invoked via `apachectl` on Unix-based systems

Apache Webserver on macOS

Commands to be entered at a Terminal

```
~$ which httpd  
/usr/sbin/httpd
```

- Apache version (macOS 26.7 *Tahoe*):

- ~\$ httpd -v
- Server version: Apache/2.4.67 (Unix)
- Server built: Aug 18 2026 19:55:09



Apache 2.4

- Apache version (macOS 14.0 *Sonoma*):

- ~\$ httpd -v
- Server version: Apache/2.4.56 (Unix)
- Server built: Aug 5 2023 06:30:16

- Apache version (OSX 10.13 *High Sierra*):

- ~\$ httpd -v
- Server version: Apache/2.4.33 (Unix)
- Server built: Apr 3 2018 17:54:07



Apache 2.4 released
in 2012

Apache Webserver on Ubuntu (on WSL)

- Ubuntu:
 - `sudo apt-get update`

```
sandiway@DESKTOP-VEPP64Q:~$ apachectl
```

```
Command 'apachectl' not found, but can be installed with:
```

```
sudo apt install apache2
```

```
sandiway@DESKTOP-VEPP64Q:~$ sudo apt install apache2
```

```
Reading package lists... Done
```

```
Building dependency tree
```

```
Enabling module alias.
```

```
Enabling module dir.
```

```
Enabling module autoindex.
```

```
Enabling module env.
```

```
Enabling module mime.
```

```
Enabling module negotiation.
```

```
Enabling module setenvif.
```

```
Enabling module filter.
```

```
Enabling module deflate.
```

```
Enabling module status.
```

```
Enabling module reqtimeout.
```

```
Enabling conf charset.
```

```
Enabling conf localized-error-pages.
```

```
Enabling conf other-vhosts-access-log.
```

```
Enabling conf security.
```

```
Enabling conf serve-cgi-bin.
```

```
Enabling site 000-default.
```

```
Created symlink /etc/systemd/system/multi-user.target.wants/apache2.service → /lib/systemd/system/apache2.service.
```

```
Created symlink /etc/systemd/system/multi-user.target.wants/apache-htcacheclean.service → /lib/systemd/system/apache-htcacheclean.service.
```

```
invoke-rc.d: could not determine current runlevel
```

Apache Webserver on Ubuntu

```
sandiway@DESKTOP-VEPP64:~$ sudo systemctl enable apache2
Enabling module dir.
Enabling module autoindex.
Enabling module env.
Enabling module mime.
Enabling module negotiation.
Enabling module ssl.
Enabling module filter.
Enabling module deflate.
Enabling module status.
Enabling module reqtimeout.
Enabling conf charset.
Enabling conf localized-error-pages.
Enabling conf other-vhosts-access-log.
Enabling conf security.
Enabling conf serve-cgi-bin.
Enabling site 000-default.
Created symlink /etc/systemd/system/multi-user.target.wants/apache2.service → /lib/systemd/system/apache2.service.
Created symlink /etc/systemd/system/multi-user.target.wants/apache-htcacheclean.service → /lib/systemd/system/apache-htcacheclean.service.
invoke-rc.d: could not determine current runlevel
Processing triggers for ufw (0.36-6ubuntu1.1) ...
Processing triggers for systemd (245.4-4ubuntu3.22) ...
Processing triggers for man-db (2.9.1-1) ...
Processing triggers for libc-bin (2.31-0ubuntu9.12) ...
/sbin/ldconfig.real: /usr/lib/wsl/lib/libcuda.so.1 is not a symbolic link

sandiway@DESKTOP-VEPP64:~$ which apache2ctl
/usr/sbin/apache2ctl
sandiway@DESKTOP-VEPP64:~$ which httpd
sandiway@DESKTOP-VEPP64:~$
```

Apache Webserver on macOS

Commands to be entered at a Terminal

- Apache webserver control:
 - ~\$ which apachectl
 - /usr/sbin/apachectl
 - sudo apachectl start
 - sudo apachectl stop
 - sudo apachectl -k restart (after configuration change)
 - apachectl configtest (check configuration)
 - Syntax OK
 - ps -ax | grep httpd (ps = process status)
 - sudo apachectl stop
 - ps -ax | grep httpd

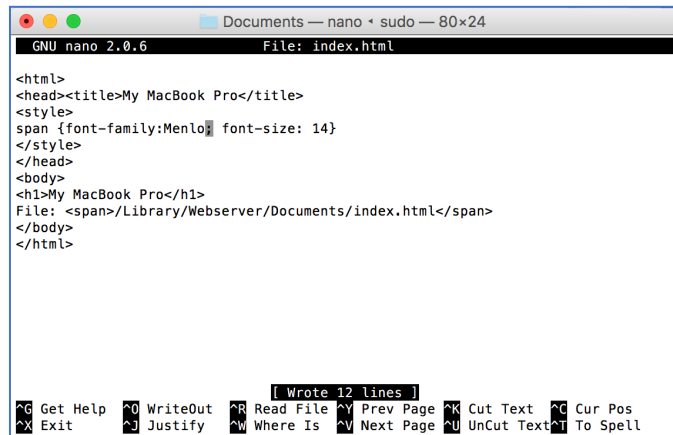
Apache Webserver on WSL2 (Ubuntu)

- From Windows Powershell:
 - `wsl`
- Default page (Document Root):
 - `/var/www/html/index.html`
 - owner of file is root, so use the sudo prefix to edit it
e.g. `sudo nano /var/www/html/index.html`
- Commands (or `apache2ctl`):
 - `sudo service apache2 start`
 - `sudo service apache2 stop`
 - `sudo service apache2 restart`

Apache Webserver on macOS

Default static webpage storage location:

- <http://localhost/>
- **/Library/WebServer/Documents/index.html.en~orig**
- Let's create **index.html** ourselves!
- **sudo nano /Library/Webserver/Documents/index.html.en~orig**



```
GNU nano 2.0.6 File: index.html

<html>
<head><title>My MacBook Pro</title>
<style>
span {font-family:Menlo font-size: 14}
</style>
</head>
<body>
<h1>My MacBook Pro</h1>
File: <span>/Library/Webserver/Documents/index.html</span>
</body>
</html>
```

nano is a simple text editor
^ means use the Control key
save file as
/Library/Webserver/Documents/index.html

Apache2 on Ubuntu

- Apache2 webserver (on VirtualBox or WSL2):

- `sudo apache2ctl start`
- `sudo apache2ctl stop`
- `sudo apache2ctl restart`

Note: macOS is different, uses `apachectl`

```
sandiway@sandiway-VirtualBox:~$ sudo apache2ctl start
Invoking 'systemctl start apache2'.
Use 'systemctl status apache2' for more info.
sandiway@sandiway-VirtualBox:~$ systemctl status apache2
● apache2.service - The Apache HTTP Server
   Loaded: loaded (/lib/systemd/system/apache2.service; enabled; vendor preset:
   Drop-In: /lib/systemd/system/apache2.service.d
            └─apache2-systemd.conf
   Active: active (running) since Wed 2018-10-24 20:43:13 MST; 4min 40s ago
   Main PID: 3488 (apache2)
     Tasks: 55 (limit: 4663)
    CGroup: /system.slice/apache2.service
            └─3488 /usr/sbin/apache2 -k start
               └─3490 /usr/sbin/apache2 -k start
                  └─3491 /usr/sbin/apache2 -k start

Oct 24 20:43:13 sandiway-VirtualBox systemd[1]: Starting The Apache HTTP Server.
Oct 24 20:43:13 sandiway-VirtualBox apachectl[3477]: AH00558: apache2: Could not
Oct 24 20:43:13 sandiway-VirtualBox systemd[1]: Started The Apache HTTP Server.
sandiway@sandiway-VirtualBox:~$
```

ps command

NAME

ps – process status

SYNOPSIS

ps [-AaCcEefhjlMmrSTvwXx] ...

DESCRIPTION

The **ps** utility displays a header line, followed by lines containing information about all of your processes that have controlling terminals.

- a** Display information about other users' processes as well as your own. This will skip any processes which do not have a controlling terminal, unless the **-x** option is also specified.
- x** When displaying processes matched by other options, include processes which do not have a controlling terminal.

grep command

NAME

grep, egrep, fgrep, rgrep, bzgrep, bzegrep, bzfgrep, zgrep, zegrep, zfgrep – file pattern searcher

SYNOPSIS

grep ... [pattern] [file ...]

DESCRIPTION

The **grep** utility searches any given input files, selecting lines that match one or more patterns. By default, a pattern matches an input line if the regular expression (RE) in the pattern matches the input line without its trailing newline. An empty expression matches every line. Each input line that matches at least one of the patterns is written to the standard output.

Apache Webserver on macOS

```
~$ ps -ax | grep httpd
  154 ??           0:19.63 /usr/sbin/httpd -D FOREGROUND
  517 ??           0:00.00 /usr/sbin/httpd -D FOREGROUND
17404 ttys001      0:00.00 grep httpd
~$ sudo apachectl stop
Password:
~$ ps -ax | grep httpd
17409 ttys001      0:00.00 grep httpd
(base) ~$ sudo apachectl start
(base) ~$ ps -ax | grep httpd
17414 ??           0:00.13 /usr/sbin/httpd -D FOREGROUND
17430 ??           0:00.00 /usr/sbin/httpd -D FOREGROUND
17432 ttys001      0:00.00 grep httpd
```

Apache Webserver on macOS

```
~$ sudo apachectl start
```

```
Password:
```

```
/System/Library/LaunchDaemons/org.apache.httpd.plist: service  
already loaded
```

```
Load failed: 37: Operation already in progress
```

```
~$ apachectl configtest
```

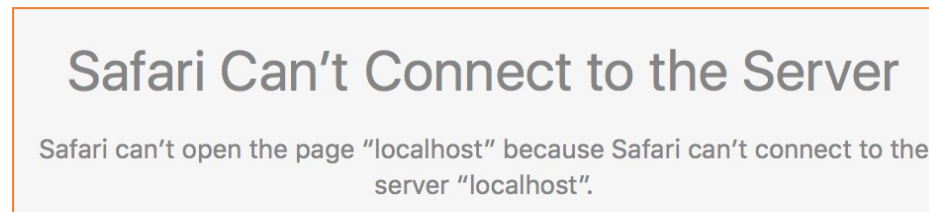
```
AH00558: httpd: Could not reliably determine the server's fully  
qualified domain name, using Sandiways-MacBook-4.local. Set the  
'ServerName' directive globally to suppress this message
```

```
Syntax OK
```

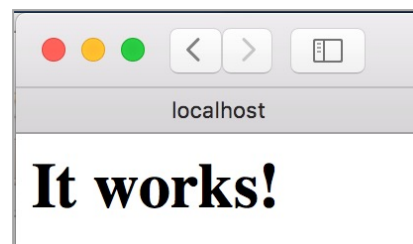
Apache Webserver on macOS

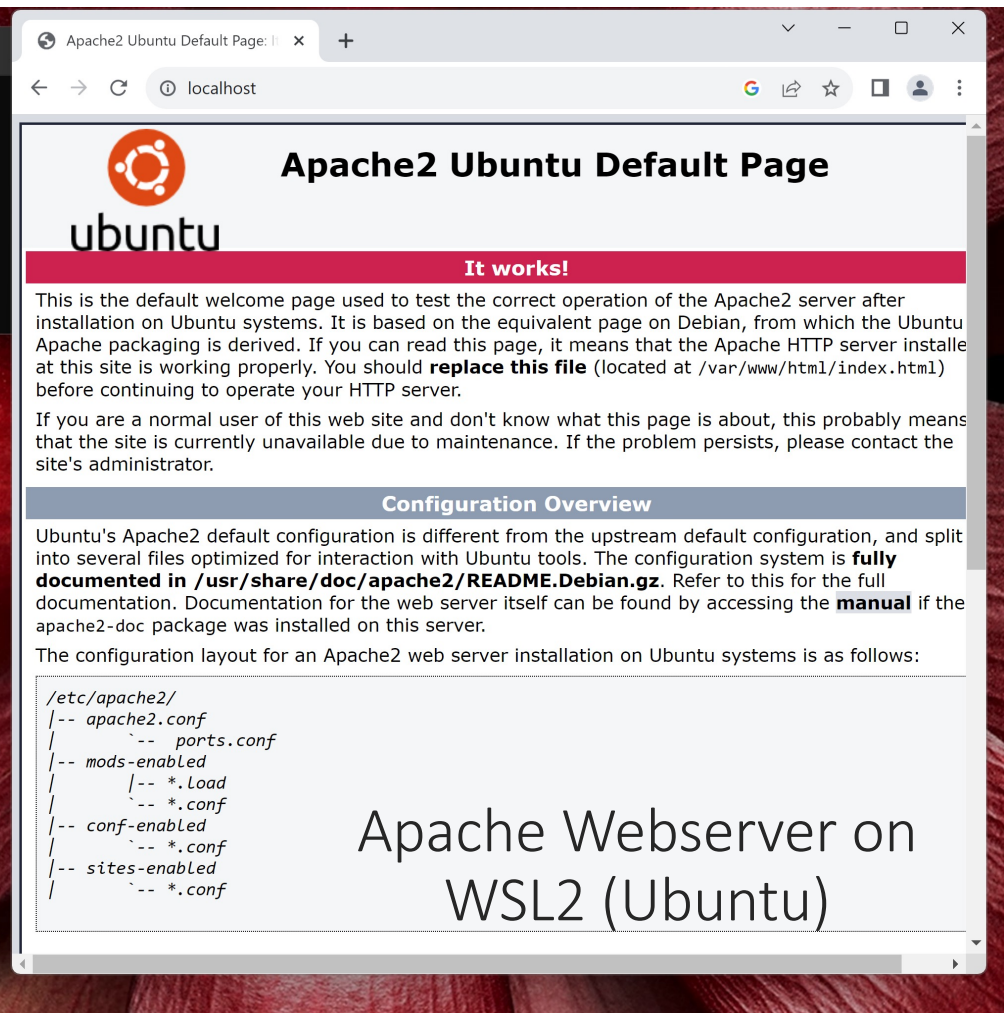
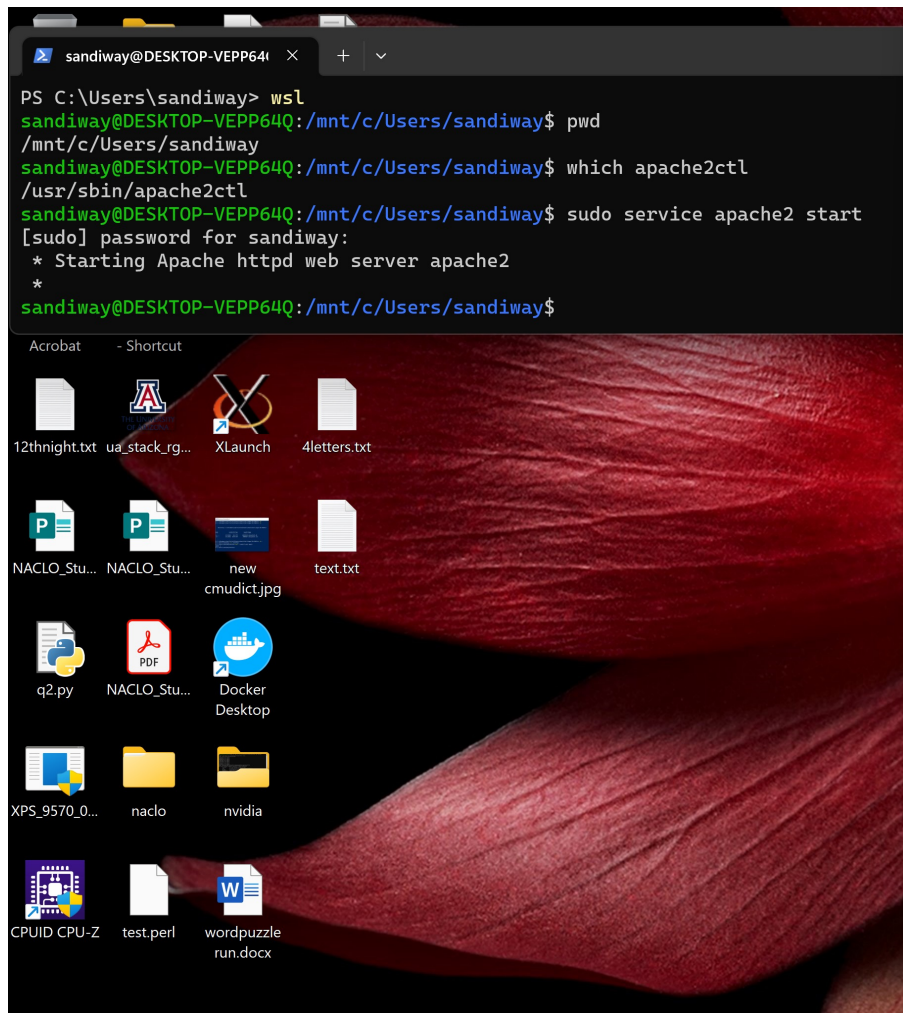
- `sudo apachectl start`
- On a browser, enter: <http://localhost/> this displays as default the file
 - `/Library/WebServer/Documents/index.html`

*not
running...*

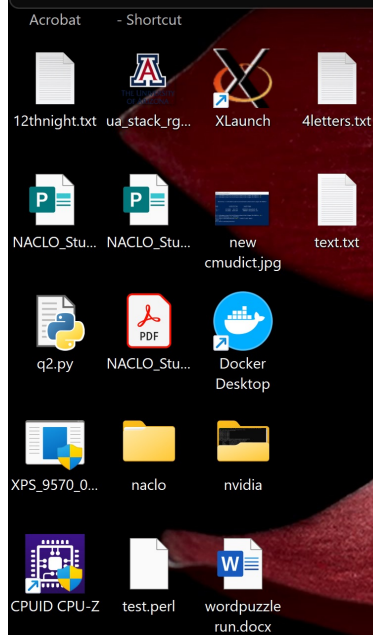


running





```
sandiway@DESKTOP-VEPP64: ~
Failed to connect to bus: Host is down
sandiway@DESKTOP-VEPP64Q:/mnt/c/Users/sandiway$ ls /var/www/html
index.html
sandiway@DESKTOP-VEPP64Q:/mnt/c/Users/sandiway$ ls /var/www/html/index.html
/var/www/html/index.html
sandiway@DESKTOP-VEPP64Q:/mnt/c/Users/sandiway$ less /var/www/html/index.html
sandiway@DESKTOP-VEPP64Q:/mnt/c/Users/sandiway$ sudo service apache2 stop
* Stopping Apache httpd web server apache2
*
sandiway@DESKTOP-VEPP64Q:/mnt/c/Users/sandiway$
```



localhost

localhost

This site can't be reached

localhost refused to connect.

Try:

- Checking the connection
- [Checking the proxy and the firewall](#)

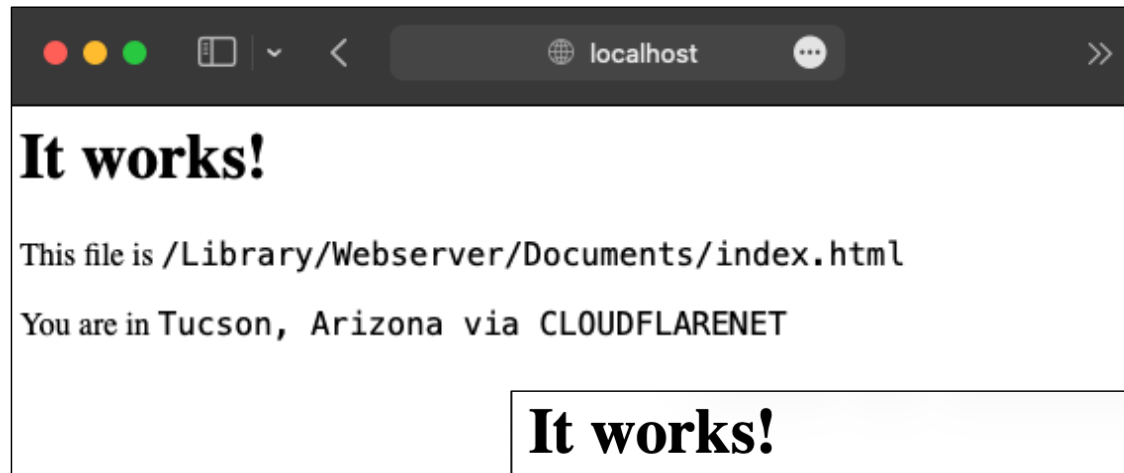
ERR_CONNECTION_REFUSED

Reload

Details

Apache Webserver on WSL2 (Ubuntu)

Apache Webserver on macOS



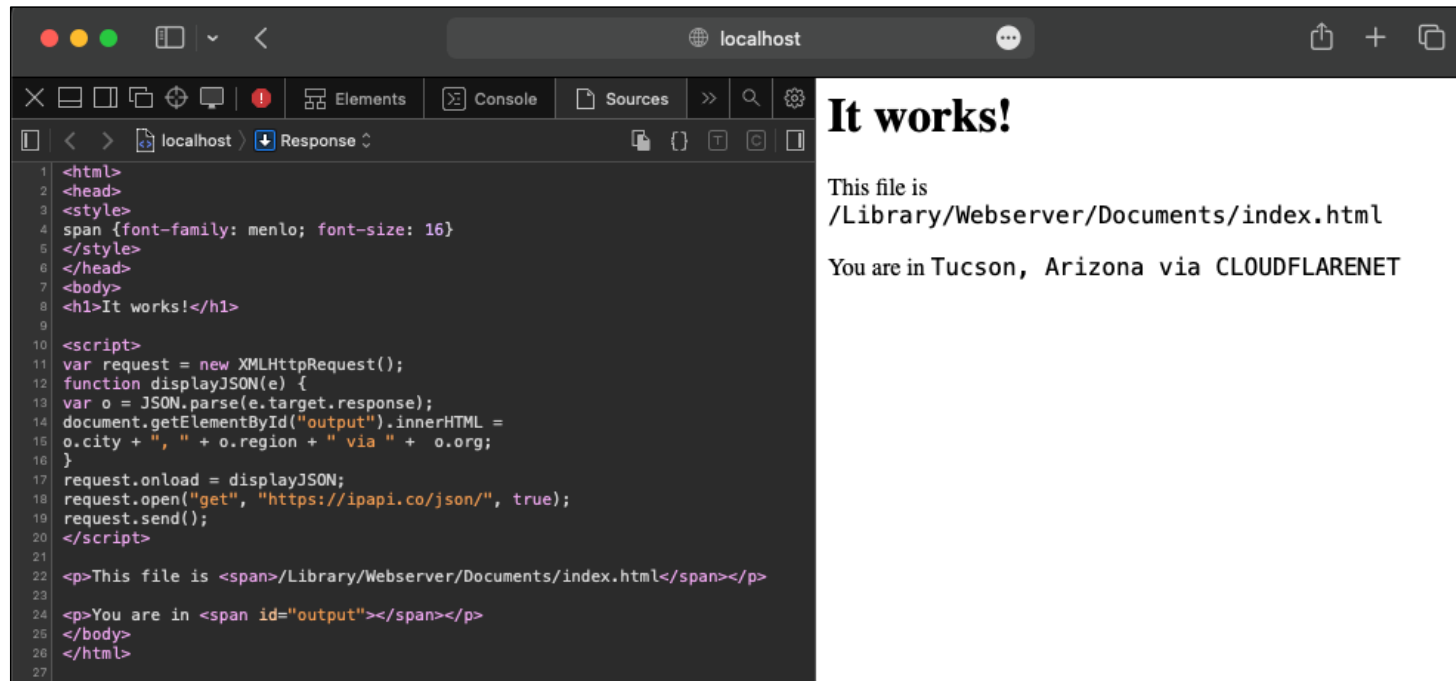
It works!

This file is /Library/Webserver/Documents/index.html

You are in Tucson, Arizona via The University of Arizona

Apache Webserver on macOS

- On macOS:



```
1 <html>
2 <head>
3 <style>
4   span {font-family: menlo; font-size: 16}
5 </style>
6 </head>
7 <body>
8   <h1>It works!</h1>
9
10  <script>
11    var request = new XMLHttpRequest();
12    function displayJSON(e) {
13      var o = JSON.parse(e.target.response);
14      document.getElementById("output").innerHTML =
15        o.city + ", " + o.region + " via " + o.org;
16    }
17    request.onload = displayJSON;
18    request.open("get", "https://ipapi.co/json/", true);
19    request.send();
20  </script>
21
22  <p>This file is <span>/Library/Webserver/Documents/index.html</span></p>
23
24  <p>You are in <span id="output"></span></p>
25 </body>
26 </html>
27
```

It works!

This file is
/Library/Webserver/Documents/index.html

You are in Tucson, Arizona via CLOUDFLARENET

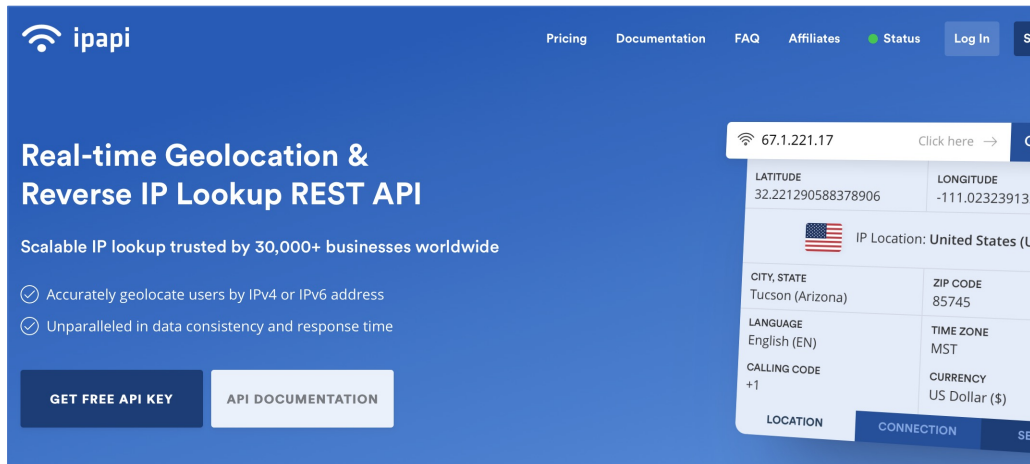
Sample Site webpage

- Normally, Javascript in the browser is sandboxed for security.
 - It has no access to your machine details, e.g. IP address or filesystem
- **So how did we do this?**
- File:
 - sample-index.html
 - I renamed it as index.html on my computer

```
1<html>␣
2<head>␣
3<style>␣
4span {font-family: menlo; font-size: 16}␣
5</style>␣
6</head>␣
7<body>␣
8<h1>It works!</h1>␣
9␣
10<script>␣
11var request = new XMLHttpRequest();␣
12function displayJSON(e) {␣
13var o = JSON.parse(e.target.response);␣
14document.getElementById("output").innerHTML = ␣
15o.city + ", " + o.region + " via " + o.org;␣
16}␣
17request.onload = displayJSON;␣
18request.open("get", "https://ipapi.co/json/", true);␣
19request.send();␣
20</script>␣
21␣
22<p>This file is <span>/Library/Webserver/Documents/index.html</span></p>␣
23␣
24<p>You are in <span id="output"></span></p>␣
25</body>␣
26</html>␣
```

Lookup

<https://ipapi.co/json/>



The screenshot shows the ipapi website interface. The header includes the ipapi logo and navigation links: Pricing, Documentation, FAQ, Affiliates, Status, and Log In. The main content area features the title "Real-time Geolocation & Reverse IP Lookup REST API" and a subheading "Scalable IP lookup trusted by 30,000+ businesses worldwide". Below this, there are two bullet points: "Accurately geolocate users by IPv4 or IPv6 address" and "Unparalleled in data consistency and response time". At the bottom, there are two buttons: "GET FREE API KEY" and "API DOCUMENTATION". On the right side, there is a search bar with the IP address "67.1.221.17" and a "Click here" link. Below the search bar, there is a table displaying geolocation data for the IP address.

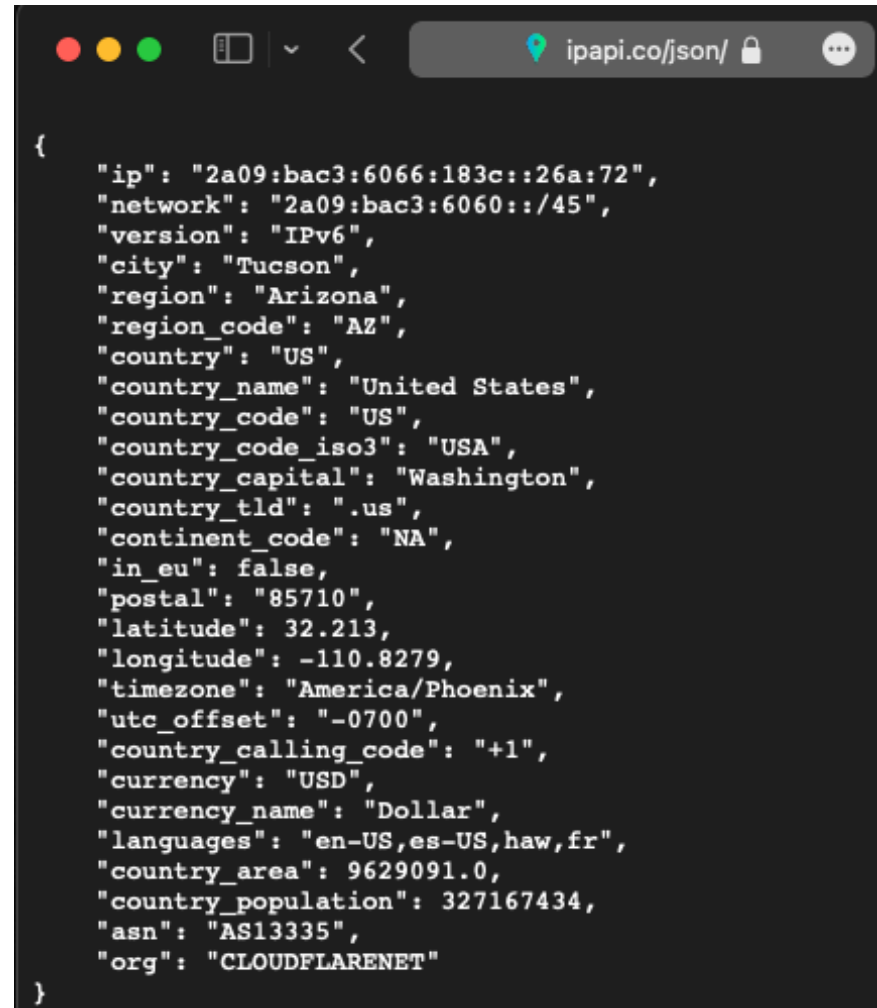
67.1.221.17	
LATITUDE	32.221290588378906
LONGITUDE	-111.023239135
IP Location: United States (U)	
CITY, STATE	Tucson (Arizona)
ZIP CODE	85745
LANGUAGE	English (EN)
TIME ZONE	MST
CALLING CODE	+1
CURRENCY	US Dollar (\$)

- Terminal:

```
~$ curl ifconfig.co/  
2a09:bac3:6066:296::42:3d
```

Lookup

- JSON = Javascript Object Notation
- IPv6 format
 - x:x:x:x:x:x:x:x
 - each x is 4 hex digits
 - total: 128 bits
- IPv4 format (*since 1983*)
 - x.x.x.x each x is 2 hex digits
 - total: 32 bits



```
{
  "ip": "2a09:bac3:6066:183c::26a:72",
  "network": "2a09:bac3:6060::/45",
  "version": "IPv6",
  "city": "Tucson",
  "region": "Arizona",
  "region_code": "AZ",
  "country": "US",
  "country_name": "United States",
  "country_code": "US",
  "country_code_iso3": "USA",
  "country_capital": "Washington",
  "country_tld": ".us",
  "continent_code": "NA",
  "in_eu": false,
  "postal": "85710",
  "latitude": 32.213,
  "longitude": -110.8279,
  "timezone": "America/Phoenix",
  "utc_offset": "-0700",
  "country_calling_code": "+1",
  "currency": "USD",
  "currency_name": "Dollar",
  "languages": "en-US,es-US,haw,fr",
  "country_area": 9629091.0,
  "country_population": 327167434,
  "asn": "AS13335",
  "org": "CLOUDFLARENET"
}
```