CS 444/544 OS II
Lab Tutorial #1

Lab Setup, Tools, and Debugging

Acknowledgement: Slides drawn heavily from Yeongjin Jiang

How Do We Run Lab Sessions?

Tutorial Video (30 ~ 45 minutes)

Follow the instructions (slides/video)

Exercise + Q&A

Do your lab exercises and ask questions to TAs (on Discord)

Lab instruction website:

Canvas → Labs

Lab Instructions

Getting Started with x86 assembly

If you are not already familiar with x86 assembly language, you will quickly become familiar with it during this course! The PC Assembly Language Book is an excellent place to start. Hopefully, the book contains mixture of new and old material for you.

Warning: Unfortunately the examples in the book are written for the NASM assembler, whereas we will be using the GNU assembler. NASM uses the so-called *Intel* syntax while GNU uses the *AT&T* syntax. While semantically equivalent, an assembly file will differ quite a lot, at least superficially, depending on which syntax is used. Luckily the conversion between the two is pretty simple, and is covered in Brennan's Guide to Inline Assembly.

Note

Exercise 1. Familiarize yourself with the assembly language materials available on the cs444 reference page. You don't have to read them now, but you'll almost certainly want to refer to some of this material when reading and writing x86 assembly.

We do recommend reading the section "The Syntax" in Brennan's Guide to Inline Assembly. It gives a good (and quite brief) description of the AT&T assembly syntax we'll be using with the GNU assembler in JOS.

Certainly the definitive reference for x86 assembly language programming is Intel's instruction set architecture reference, which you can find on the cs444/544 reference page in two flavors: an HTML edition of the old 80386 Programmer's Reference Manual, which is much shorter and easier to navigate than more recent manuals but describes all of the x86 processor features that we will make use of in cs444/544; and the full, latest and greatest IA-32 Intel Architecture Software Developer's Manuals from Intel, covering all the features of the most recent processors that we won't need in class but you may be interested in learning about. An equivalent (and often friendlier) set of manuals is available from AMD. Save the Intel/AMD architecture manuals for later or use

TA Availability – Lab Q&A (Discord)

- Course Discord: https://discord.gg/BJJTaWBHE
- Office hours: See Canvas Main page

JOS Lab (lab1-lab4, 70%)

Lab 1: Booting (10%)

Learn how an OS boots from BIOS to bootloader to the OS kernel

Lab 2: Virtual Memory (15%)

Learn how to manage physical/virtual memory space in an OS kernel

JOS Lab (1-4, 70%)

Lab 3: User Environment and System Call (20%)

Learn how user/kernel execution switch works and providing an isolated virtual memory space to a user process

Lab 4: Preemptive Multitasking (25%)

Learn how user/kernel execution switch works and providing an isolated virtual memory space to a user process

Extra Credit Labs

JOS Challenges (1% each from Lab 1,2,3, same due with the lab)

Solving a challenge would add +1% towards the entire course credits

Note

Challenge (Extra credit 1%). Enhance the console to allow text to be printed in different colors. The traditional way to do this is to make it interpret ANSI escape sequences embedded in the text strings printed to the console, but you may use any mechanism you like. There is plenty of information on the cs444/544 reference page and elsewhere on the web on programming the VGA display hardware. If you're feeling really adventurous, you could try switching the VGA hardware into a graphics mode and making the console draw text onto the graphical frame buffer.

To get 1% of credit, please create a command 'show' in the monitor and print a beautifule ASCII Art with 5 or more colors when the command is typed on the console.

Once you finish this, please create a file `.lab1-extra` at the root of your repository directory (under `jos/`). We will use that file as an indicator that you finished this extra-credit and then grade your work accordingly.

Today’s Tutorial

1. Lab environment setup
2. Commit your information on your own ‘jos’ repository
3. Run JOS with TMUX

ACTION: Setup the lab environment on OS servers

Connect to any of the following servers, with the –X flag to enable the X11 forwarding:

os2.engr.oregonstate.edu
oldos2.engr.oregonstate.edu
oldos1.engr.oregonstate.edu
os1.engr.oregonstate.edu

i.e., ssh –X your_username@os2.engr.oregonstate.edu

RUN (please copy-and-paste):

```
$ /nfs/farm/classes/eecs/spring2024/cs444-001/cs444-setup.py
```

This will setup BASH, VIM, GDB, QEMU, and TMUX

Running Script

Type ‘y’ if you wish to

use the default setup...

```
os2 ~ 166% /nfs/farm/classes/eecs/spring2021/cs444-001/cs444-setup.py
Cloning into '/nfs/stak/users/songyip/.cs444'...
remote: Enumerating objects: 19, done.
remote: Counting objects: 100% (19/19), done.
remote: Compressing objects: 100% (11/11), done.
remote: Total 432 (delta 7), reused 15 (delta 5), pack-reused 413
Receiving objects: 100% (432/432), 10.98 MiB | 0 bytes/s, done.
Resolving deltas: 100% (259/259), done.


Do you want to install peda to ~/.gdbinit (y/n) ?
n
Do you want to install cs444 custom tmux configuration (y/n) ?
n
Do you want to install .bashrc (y/n) ?
n
Do you want to install .vimrc and vim plugins (y/n) ?
n
```

ACTION: Generate Public Key (Step 1)

If you already have your ssh public/private key on our servers, you can use the same public key.

Otherwise, please create one by typing the following command:

```
$ ssh-keygen -t ecdsa
```

After that, please print your public key, and then copy the key to the clipboard

```
$ cat ~/.ssh/id_ecdsa.pub
```

```
ecdsa-sha2-nistp256 (THIS IS A SAMPLE PUBLIC KEY)
AAAAE2VjZHNhLXNoYTItbmlzdHAyNTYAAAAIbmlzdHAyNTYAAABBBFRxlq/fIouV7KflGVEwL04/yIprKdtf9KYO
Hk8gAbtIxocFFsAgBuEzRg4EtjQEYnitroSm2F14mHy2cz27+ho= songyip@os2.engr.oregonstate.edu
```

Generate Public/Private Key (Step 2)

Use your favorite command text editor (i.e., vim) to open up ~/.ssh/authorized_keys.

If it does not exist, creat it.

Paste the public key you copied in the last step

```
ecdsa-sha2-nistp256 (THIS IS A SAMPLE PUBLIC KEY)
AAAAE2VjZHNhLXNoYTItbmlzdHAyNTYAAAAIbmlzdHAyNTYAAABBBFRxlq/fIouV7KflGVEwL04/yIprKdt
f9KYOHk8gAbtIxocFFsAgBuEzRg4EtjQEYnitroSm2F14mHy2cz27+ho=
songyip@os2.engr.oregonstate.edu
```

You now need to set permissions on the file. Type

```
chmod 600 ~/.ssh/authorized_keys
```

ACTION: https://github.com/
Register your account! (in case you don’t have one!!)

Visit the website and register an account;

ACTION: Cloning jos-lab repository (step 1)

Logon to github classroom using your github account.
https://classroom.github.com/classrooms

Accept the JOS assignment using the invitation link:

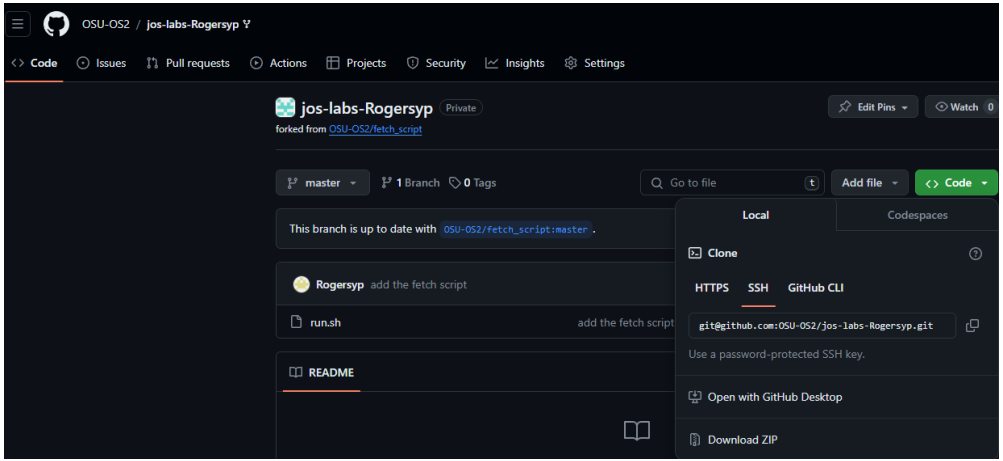
- https://classroom.github.com/a/6lknqiou

Note: you need to link your email address to your github account for the first time

Clone the repository by running the following command on flip:
HTTPS: $ git clone https://github.com/OSU-OS2/jos-labs-yourusername.git
SSH: $ git clone git@github.com:OSU-OS2/jos-labs-yourusername.git

ACTION: Cloning jos repository (step 2)

Note that this repo contains nothing but a setup script.



Since GitHub Classroom does not allow private fork all branches, in order to keep commit history of all branches in the starter code repo, you will have to run this script!

ACTION: Cloning jos repository (step 3)

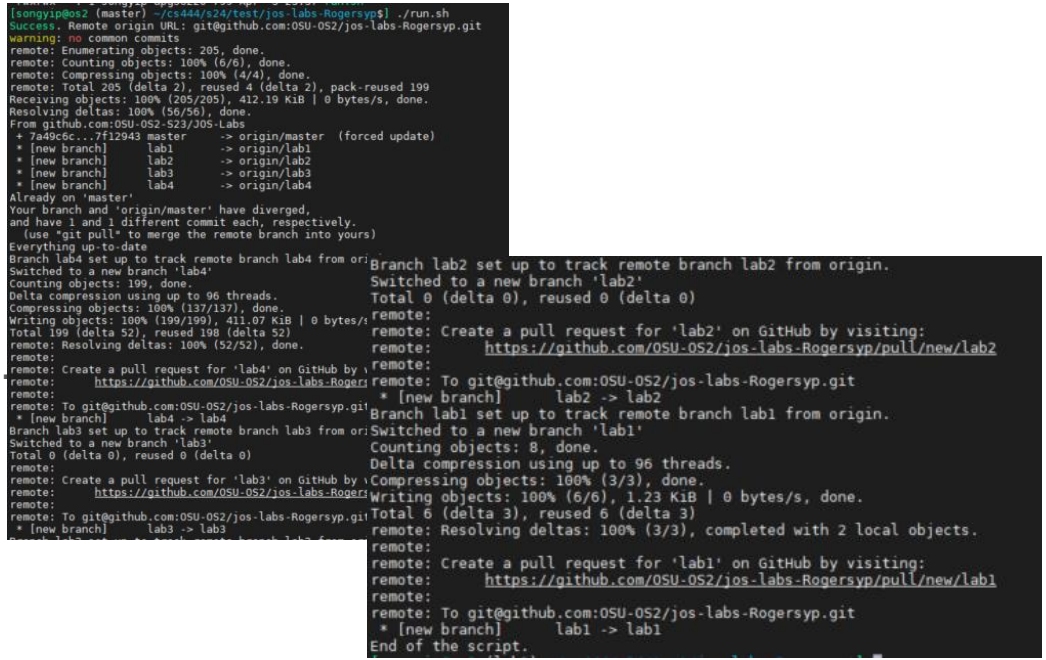
Make the script executable with the command

```
chmod +x run.sh
```

Then run it with the command

```
./run.sh
```

If it successfully runs, you will see…



Lastly, switch to lab1 branch by

```
git checkout lab1
```

ACTION: Test your jos

Run the following commands:

$ cd jos-labs-yourusername

$ make qemu-nox

You must see something like following:

You may quit qemu by pressing:

Ctrl+A, X

```
os2 ~/cs444/s21/os2-lab1-Rogersyp 162% make qemu-nox
+ as kern/entry.S
+ cc kern/entrypgdir.c
+ cc kern/init.c
+ cc kern/console.c
+ cc kern/monitor.c
+ cc kern/printf.c
+ cc kern/kdebug.c
+ cc lib/printfmt.c
+ cc lib/readline.c
+ cc lib/string.c
+ ld obj/kern/kernel
ld: warning: section `.bss' type changed to PROGBITS
+ as boot/boot.S
+ cc -Os boot/main.c
+ ld boot/boot
boot block is 380 bytes (max 510)
+ mk obj/kern/kernel.img
sed "s/localhost:1234/localhost:26220/" < .gdbinit.tmpl > .gdbinit
***
*** Use Ctrl-a x to exit qemu
***
qemu-system-i386 -nographic -drive file=obj/kern/kernel.img,index=
0,media=disk,format=raw -serial mon:stdio -gdb tcp::26220 -D qemu.
log
444544 decimal is XXX octal!
entering test_backtrace 5
entering test_backtrace 4
entering test_backtrace 3
entering test_backtrace 2
entering test_backtrace 1
entering test_backtrace 0
leaving test_backtrace 0
leaving test_backtrace 1
leaving test_backtrace 2
leaving test_backtrace 3
leaving test_backtrace 4
leaving test_backtrace 5
Welcome to the JOS kernel monitor!
Type 'help' for a list of commands.
K>
```

ACTION: Edit student.info and commit your change

Edit student.info via vim, emacs, nano, etc., e.g.,

$ vim student.info (press i to edit and ESC + :wq to write and quit)

$ nano student.info (stores and quit via pressing Ctrl-X)

$ emacs student.info

Type your information!

```
1 OSU  ID  (xxx-yyy-zzz)  : 933123456
2 ONID ID (e.g., songyip) : songyip
3 Name                    : Yipeng Song
4 CS 444/544 ?            : 444
5 Lab Class #             : Lab 1
```

ACTION: Commit your change

Run:

$ git add student.info

(short cut1: add all files: git add –A)

$ git commit

.. type commit message, e.g., edit student.info

(short cut2: git commit –m “your commit message here”)

(short cut3: add file and commit in one command:

git commit –am “your commit message here”)

$ git push

Commit result example

```
edit student.info
# Please enter the commit message for your changes. Lines starting
# with '#' will be ignored, and an empty message aborts the commit.
# On branch main
# Changes to be committed:
#   (use "git reset HEAD <file>..." to unstage)
#
#       modified:   student.info
#
```

```
os2 ~/cs444/s21/os2-lab1-Rogersyp 172% git push
warning: push.default is unset; its implicit value is changing in
Git 2.0 from 'matching' to 'simple'. To squelch this message
and maintain the current behavior after the default changes, use:

  git config --global push.default matching

To squelch this message and adopt the new behavior now, use:

  git config --global push.default simple

See 'git help config' and search for 'push.default' for further information.
(the 'simple' mode was introduced in Git 1.7.11. Use the similar mode
'current' instead of 'simple' if you sometimes use older versions of Git)

Username for 'https://github.com': Rogersyp
Password for 'https://Rogersyp@github.com':
Counting objects: 5, done.
Delta compression using up to 96 threads.
Compressing objects: 100% (3/3), done.
Writing objects: 100% (3/3), 298 bytes | 0 bytes/s, done.
Total 3 (delta 2), reused 0 (delta 0)
remote: Resolving deltas: 100% (2/2), completed with 2 local objects.
To https://github.com/OSU-CS444-S21/os2-lab1-Rogersyp.git
   f6e52cf..9ae64fa  main -> main
```

How to Start Labs?

Setup lab environment first (we will do this today!)

Read Lab description online

https://classes.engr.oregonstate.edu/eecs/spring2024/cs444-001/labs/Lab1.pdf

Finish all exercises, and run

```
$ make grade
```

Running GDB with JOS

Go to jos directory

Use the dual split-screen mode in tmux

Run make qemu-nox-gdb on the left side (must run a single instance of qemu..)

Port bind error could occur if you have another instance of qemu running..

Run gdb on the right side (must be under jos directory)

Otherwise, your gdb will never attach to jos qemu..

Attaching remote gdb to qemu to debug JOS kernel..

Left

```
os2 ~/cs444/s21/os2-lab1-Rogersyp 152% make qemu-nox-gdb
***
*** Now run 'gdb'.
***
qemu-system-i386 -nographic -drive file=obj/kern/kernel.img,index=0,media=disk,format=raw -se
rial mon:stdio -gdb tcp::26220 -D qemu.log  -S
```

Right

```
os2 ~/cs444/s21/os2-lab1-Rogersyp 156% gdb
```

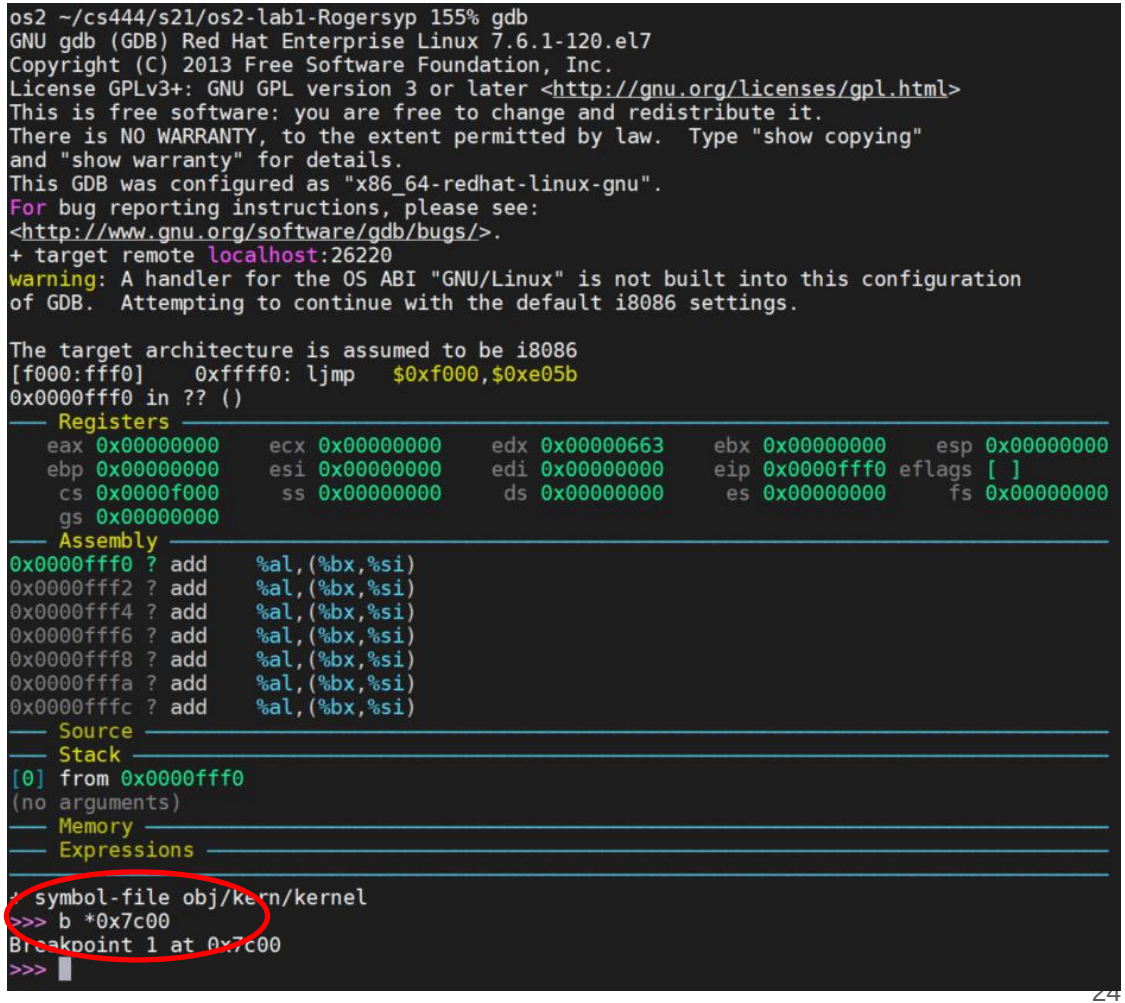
Result

Let’s set a breakpoint at the address 0x7c00.

b *0x7c00

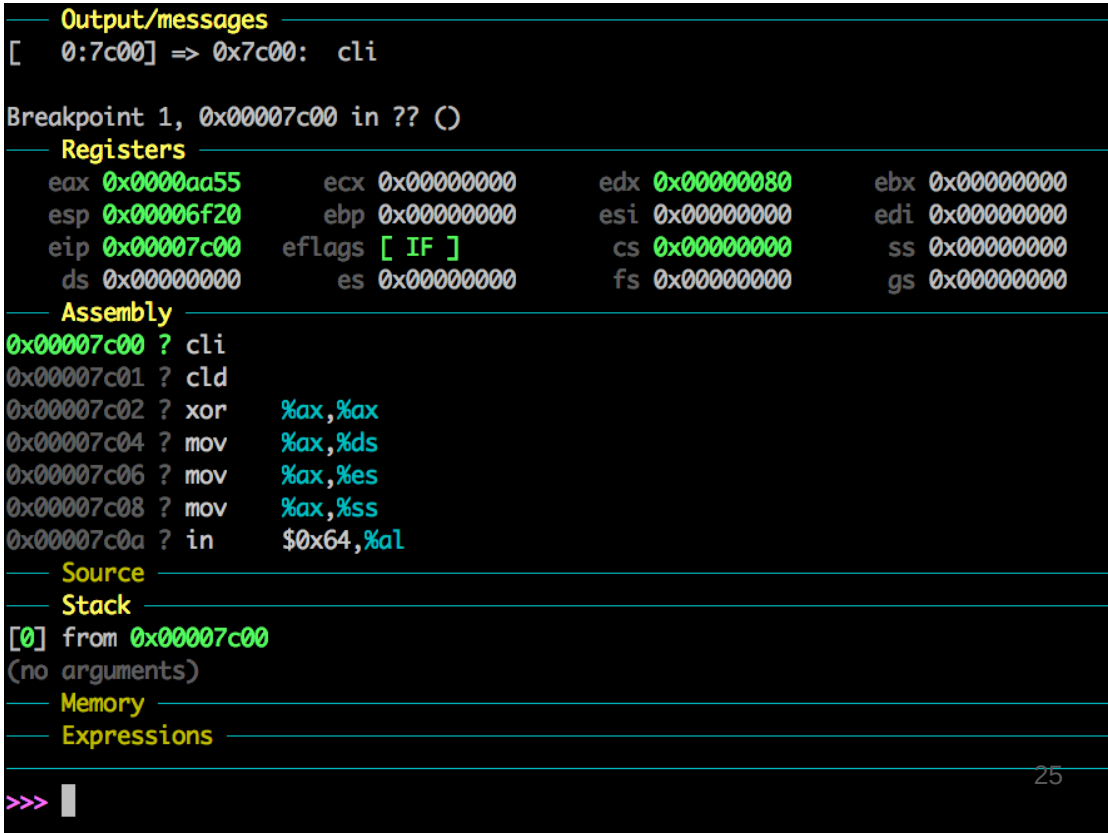
Then, continue the execution via

c (meaning continue..)



You can start Exercise 3 of Lab 1!

Use ‘si’ to follow the function call..

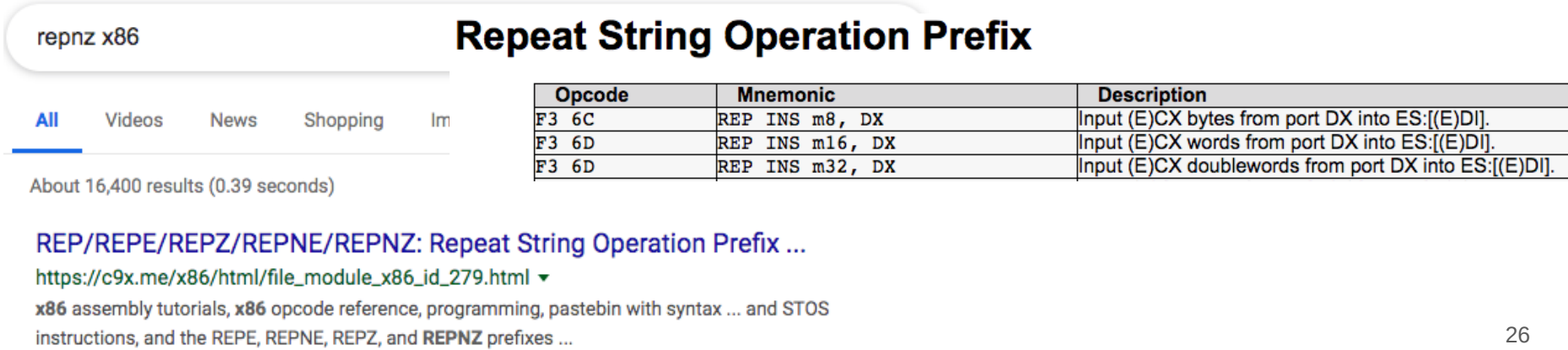


If you are curious about x86 assembly

X86 Assembly Guide: http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

Search instructions on Google

```
0x00007ccb ? repnz insl (%dx),%es:(%edi)
```



Grading Example

```
running JOS: make[1]: Warning: File `obj/.deps' has modification time 110 s in the future
make[1]: Warning: File `obj/.deps' has modification time 111 s in the future
make[1]: warning:  Clock skew detected.  Your build may be incomplete.
(0.9s)
  printf: OK
  backtrace count: OK
  backtrace arguments: OK
  backtrace symbols: OK
  backtrace lines: OK
Score: 50/50
make: warning:  Clock skew detected.  Your build may be incomplete.
```

Please ignore ‘Clock skew detected’ messages

Example of the correct output of Lab 1

```
qemu-system-i386 -nographic -drive file=obj/kern/kernel.img,index=0,media=disk,format=raw -serial mon:stdio -gdb tcp::26078 -D qemu.log
444544 decimal is 1544200 octal!
entering test_backtrace 5
entering test_backtrace 4
entering test_backtrace 3
entering test_backtrace 2
entering test_backtrace 1
entering test_backtrace 0
Stack backtrace:
  ebp f010ff18  eip f0100087  args 00000000 00000000 00000000 00000000 f01009db
    kern/init.c:19: test_backtrace+71
  ebp f010ff38  eip f0100069  args 00000000 00000001 f010ff78 00000000 f01009db
    kern/init.c:16: test_backtrace+41
  ebp f010ff58  eip f0100069  args 00000001 00000002 f010ff98 00000000 f01009db
    kern/init.c:16: test_backtrace+41
  ebp f010ff78  eip f0100069  args 00000002 00000003 f010ffb8 00000000 f01009db
    kern/init.c:16: test_backtrace+41
  ebp f010ff98  eip f0100069  args 00000003 00000004 00000000 00000000 00000000
    kern/init.c:16: test_backtrace+41
  ebp f010ffb8  eip f0100069  args 00000004 00000005 00000000 00010094 00010094
    kern/init.c:16: test_backtrace+41
  ebp f010ffd8  eip f01000ea  args 00000005 0006c880 00000640 00000000 00000000
    kern/init.c:43: i386_init+77
  ebp f010fff8  eip f010003e  args 00111021 00000000 00000000 00000000 00000000
    kern/entry.S:83: <unknown>+0
leaving test_backtrace 0
leaving test_backtrace 1
leaving test_backtrace 2
leaving test_backtrace 3
leaving test_backtrace 4
leaving test_backtrace 5
Welcome to the JOS kernel monitor!
Type 'help' for a list of commands.
K>
```

How to Submit Labs?

All lab submissions must be turn in via your lab repository on GitHub Classroom.

$ git add … (add files to git repo)

$ git commit (commit your changes)

After finishing the lab:

$ git tag lab1-final

$ git push

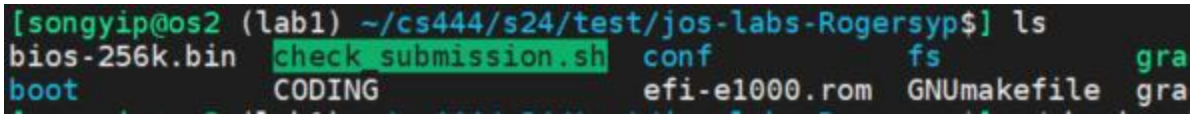
$ git push origin --tags

This will push lab1-final to the repository...

This completes the lab. In the `jos` directory, commit your changes with `git commit`, `git tag lab1-final`, `git push`, and `git push origin --tags` to submit your code. Please do not forget to create and include the file `.lab1-extra` in case if you finished extra-credit challenge.

How to Submit Labs?

Additionally, there is a check submission script to check if you have tagged and submitted correctly!

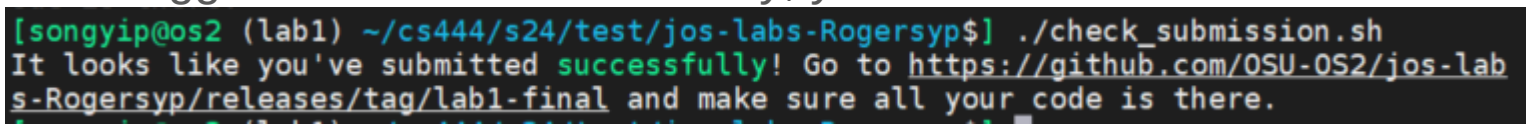


To run the script:

chmod +x check_submission.sh ← optional if it needs executable permission

./check_submission.sh

If it is tagged and submitted correctly, you should see:

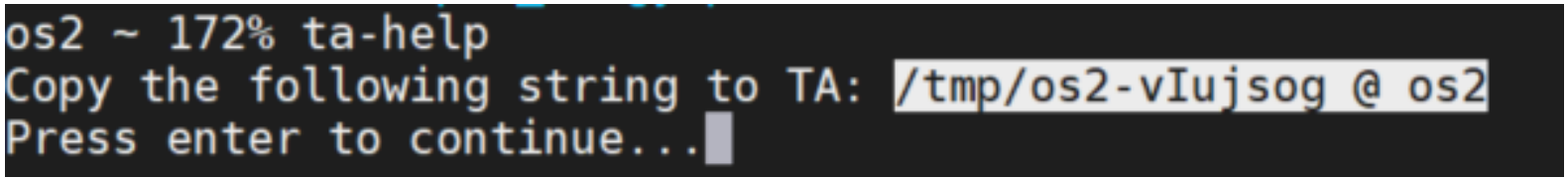


How to get help from TA?

- Get on the course Discord server
- Post your question on the each lab channel (JOS Lab1 ~ 4)
- Check TA availability, and then send a DM to a TA
    - Please do not bug our TAs much during their out-of-hour for the TA job. They could help you, but that’s all from their voluntary service. Please send many thanks to our TAs!
- How to code together with a TA?
    - Use the command TA-HELP

ta-help

- Sharing a tmux session with your TA (virtual finger-to-finger meeting with TA)



- Copy the tmp string, and send that to your TA via Discord Direct Message
- Press ENTER (you will see a regular tmux session).
- TA can share your tmux session and you two can code together

JOS Lab Setup

Tools:

- QEMU (Intel 32-bit x86 emulator)
- GIT (Source Code Version Control System)
- GDB (Debugger)
- BASH, TMUX, VIM, etc.

We will use GIT to checkout all code and submit your lab progress!

Read more at...

GIT cheat sheet: https://www.git-tower.com/blog/git-cheat-sheet

VIM cheat sheets: https://devhints.io/vim and https://vim.rtorr.com/

GDB cheat sheets: https://cs.brown.edu/courses/cs033/docs/guides/gdb.pdf

https://darkdust.net/files/GDB%20Cheat%20Sheet.pdf

TMUX cheat sheet:

https://gist.github.com/MohamedAlaa/2961058 (the prefix is ` in CS444 settings)