gem5 tutorial

References:

- https://github.com/gem5bootcamp

Environment

The steps outlined in this tutorial have been tested on the computers located in Delta 219. These computers are equipped with:

- CPU: 13th Gen Intel(R) Core(TM) i5-13500
- RAM: 16 GB
- SSD: 954 GB

Docker Desktop is pre-installed.

Installation on Your Own Computer

You may also install Docker on your own computer. Please ensure you have at least **10 GB** of disk space available.

Instructions for **Windows** and **macOS** are provided.

Install Docker Desktop on Windows

For Windows users:

1. Download the installer.
2. Double-click `Docker Desktop Installer.exe` to run the installer.
3. Follow the instructions in the installation wizard to authorize the installer and proceed with the installation.
4. Once the installation is complete, select **Close** to finish the process.

Install Docker Desktop on macOS

For macOS users:

1. Download the installer.
2. Double-click `Docker.dmg` to open the installer, then drag the Docker icon to the **Applications** folder.
3. Double-click `Docker.app` in the **Applications** folder to start Docker.
4. The Docker menu will display the Docker Subscription Service Agreement. Select **Accept** to continue.
5. In the installation window, select **Use recommended settings (Requires password)**.
6. Select **Finish**.

Back up files from `$HOME\workspaces\` to a flash drive

Delta 219 computers are configured to automatically revert to a previously saved system state (a restore point) without prior notice.

- Your files may be permanently deleted without warning at any time (unannounced data loss).
- You cannot predict when these reverts will occur, nor can you prevent them from happening (limited user control).

Temporary data storage:
Your files are temporarily stored in the `$HOME\workspaces\` directory. These files are deleted during the automatic system revert process.

Protecting your data:
To avoid data loss, regularly back up your data using external USB drives or cloud storage services.

Reason for automatic system reverts:
This feature is designed to maintain a consistent simulation environment for all users.

Open Docker Desktop on Windows

For Windows users:

1. Left-click on the **Start button** (or press the `Windows key`).
2. Select **Docker Desktop** (or type `Docker Desktop` and press `Enter`).

Expected outcome: Docker Desktop will open.

Open a terminal emulator on Windows

For Windows users:

1. Right-click on the **Start button** (or press the `Windows key` + `X`).
2. Select **Windows PowerShell** (or press `I`).

Expected outcome: A terminal emulator will open.

```
Windows PowerShell
Copyright (C) Microsoft Corporation. 著作權所有，並保留一切權利。

請嘗試新的跨平台 PowerShell https://aka.ms/pscore6

PS C:\Users\user>
```

Open a terminal emulator on macOS

For macOS users:

1. Click the **Launchpad** icon in the Dock.
2. Type `Terminal` in the search field.
3. Click **Terminal**.

Expected outcome: A terminal emulator will open.

Run a container in PowerShell

For PowerShell users, run this command:

```
docker container run `
--rm --interactive --tty `
--volume $HOME\workspaces\:/workspaces/ `
--workdir /workspaces/2024/ `
--hostname codespaces-ae14be `
ghcr.io/gem5/devcontainer:bootcamp-2024
```

Expected outcome: An interactive TTY will indicate its readiness to accept commands.

```
root@codespaces-ae14be:/workspaces/2024#
```

Alternative outcome: A newer image will be downloaded before the interactive TTY displays the username, hostname, and working directory.

```
PS C:\Users\user> docker container run `
>> --rm --interactive --tty `
>> --volume $HOME\workspaces\:/workspaces/ `
>> --workdir /workspaces/2024/ `
>> --hostname codespaces-ae14be `
>> ghcr.io/gem5/devcontainer:bootcamp-2024
Unable to find image 'ghcr.io/gem5/devcontainer:bootcamp-2024' locally
bootcamp-2024: Pulling from gem5/devcontainer
00d679a470c4: Pull complete
c782a11a41b6: Pull complete
4f6b9996da3d: Pull complete
bb60cbcef558: Pull complete
92c0abbbf0ee: Pull complete
865d1839a002: Pull complete
2ceb23f2c7bb: Pull complete
31825ae2d134: Pull complete
Digest: sha256:dc299b8bf11b324cbd89aab82bdbe31bf9ce71a33386f2a2153a590a803d2c71
Status: Downloaded newer image for ghcr.io/gem5/devcontainer:bootcamp-2024
root@codespaces-ae14be:/workspaces/2024#
```

Run a container on macOS

For macOS users, run this command:

```
docker container run \
--rm --interactive --tty \
--volume ~/workspaces/:/workspaces/ \
--workdir /workspaces/2024/ \
--hostname codespaces-ae14be \
ghcr.io/gem5/devcontainer:bootcamp-2024
```

Expected outcome: An interactive TTY will indicate its readiness to accept commands.

```
root@codespaces-ae14be:/workspaces/2024#
```

Get the source code of gem5

Run this command:

```
time git clone --recurse-submodules \
https://gitlab.larc-nthu.net/ee6455/public-gem5bootcamp-2024 /workspaces/2024/
```

Expected outcome: A repository will be cloned, including its submodules.

```
root@codespaces-ae14be:/workspaces/2024# time git clone --recurse-submodules \
> https://gitlab.larc-nthu.net/ee6455/public-gem5bootcamp-2024 /workspaces/2024/
Cloning into '/workspaces/2024'...
warning: redirecting to https://gitlab.larc-nthu.net/ee6455/public-gem5bootcamp-2024.git/
remote: Enumerating objects: 10982, done.
remote: Counting objects: 100% (6/6), done.
remote: Compressing objects: 100% (6/6), done.
remote: Total 10982 (delta 0), reused 0 (delta 0), pack-reused 10976
Receiving objects: 100% (10982/10982), 378.29 MiB | 28.30 MiB/s, done.
Resolving deltas: 100% (7432/7432), done.
Updating files: 100% (952/952), done.
Submodule 'gem5' (https://github.com/gem5/gem5) registered for path 'gem5'
Submodule 'gem5-resources' (https://github.com/gem5/gem5-resources) registered for path 'gem5-resources'
```

Run a simulation using gem5

Run this command:

```
time gem5-mesi --outdir=/workspaces/m5out/ \
/workspaces/2024/materials/01-Introduction/02-getting-started/completed/basic.py
```

Expected outcome: The `X86DemoBoard` will be simulated using `x86-ubuntu-24.04-img` as a workload.

```
root@codespaces-ae14be:/workspaces/2024# time gem5-mesi --outdir=/workspaces/m5out/ \
> /workspaces/2024/materials/01-Introduction/02-getting-started/completed/basic.py
gem5 Simulator System.  https://www.gem5.org
gem5 is copyrighted software; use the --copyright option for details.

gem5 version 24.0.0.0
gem5 compiled Jul 25 2024 18:47:27
gem5 started Sep  8 2024 12:45:46
gem5 executing on codespaces-ae14be, pid 13
command line: gem5-mesi --outdir=/workspaces/m5out/ /workspaces/2024/materials/01-Introduction/02-getting-started/completed/basic.py

warn: The X86DemoBoard is solely for demonstration purposes. This board is not known to be be representative of any real-world system. Use with caution.
info: Using default config
Resource 'x86-linux-kernel-5.4.0-105-generic' was not found locally. Downloading to '/root/.cache/gem5/x86-linux-kernel-5.4.0-105-generic'...
Finished downloading resource 'x86-linux-kernel-5.4.0-105-generic'.
Resource 'x86-ubuntu-24.04-img' was not found locally. Downloading to '/root/.cache/gem5/x86-ubuntu-24.04-img.gz'...
Finished downloading resource 'x86-ubuntu-24.04-img'.
Decompressing resource 'x86-ubuntu-24.04-img' ('/root/.cache/gem5/x86-ubuntu-24.04-img.gz')...
Finished decompressing resource 'x86-ubuntu-24.04-img'.
warn: Max ticks has already been set prior to setting it through the run call. In these cases the max ticks set through the `run` function is used
Global frequency set at 1000000000000 ticks per second
src/mem/dram_interface.cc:690: warn: DRAM device capacity (8192 Mbytes) does not match the address range assigned (2048 Mbytes)
src/sim/kernel_workload.cc:46: info: kernel located at: /root/.cache/gem5/x86-linux-kernel-5.4.0-105-generic
```

Retrieve the simulation statistics on Windows

For Windows users, open `$HOME\workspaces\m5out\stats.txt` using a text editor.

Expected outcome: The first few lines will resemble this:

```
---------- Begin Simulation Statistics ----------
simSeconds                                   0.020000                       # Number of seconds simulated (Second)
simTicks                                  20000000000                       # Number of ticks simulated (Tick)
finalTick                                 20000000000                       # Number of ticks from beginning of simulation (restored from checkpoints and never reset) (Tick)
simFreq                                 1000000000000                        # The number of ticks per simulated second ((Tick/Second))
hostSeconds                                    18.88                       # Real time elapsed on the host (Second)
hostTickRate                                1059100397                       # The number of ticks simulated per host second (ticks/s) ((Tick/Second))
hostMemory                                    2770924                       # Number of bytes of host memory used (Byte)
simInsts                                      7479814                       # Number of instructions simulated (Count)
simOps                                       34912342                       # Number of ops (including micro ops) simulated (Count)
hostInstRate                                   396059                       # Simulator instruction rate (inst/s) ((Count/Second))
hostOpRate                                     1848597                      # Simulator op (including micro ops) rate (op/s) ((Count/Second))
board.cache_hierarchy.ruby_system.delayHistogram::bucket_size            2                       # delay histogram for all message (Unspecified)
board.cache_hierarchy.ruby_system.delayHistogram::max_bucket           19                       # delay histogram for all message (Unspecified)
board.cache_hierarchy.ruby_system.delayHistogram::samples       735551                          # delay histogram for all message (Unspecified)
board.cache_hierarchy.ruby_system.delayHistogram::mean     1.036855                             # delay histogram for all message (Unspecified)
board.cache_hierarchy.ruby_system.delayHistogram::stdev     2.687016                            # delay histogram for all message (Unspecified)
```

Retrieve the simulation configuration on Windows

For Windows users, open `$HOME\workspaces\m5out\config.ini` using a text editor.

Expected outcome: The first few lines will resemble this:

```
[board]
type=System
children=cache_hierarchy clk_domain dvfs_handler iobus memory pc processor workload
auto_unlink_shared_backstore=false
cache_line_size=64
eventq_index=0
exit_on_work_items=true
init_param=0
m5ops_base=4294901760
mem_mode=timing
mem_ranges=0:2147483648 3221225472:3222274048
memories=board.memory.mem_ctrl.dram
mmap_using_noreserve=false
multi_thread=false
```