# CPEN 411: Assignment 1
# Instrumentation, Program Analysis, and Modelling

Prashant J. Nair

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# Contents

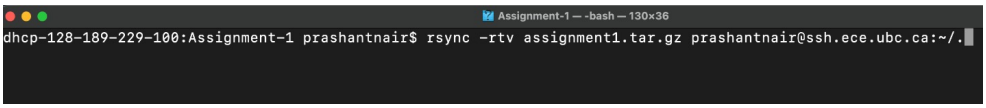
# Chapter 1

# Introduction and Setup [0 Points]

This assignment discusses program analysis using Pintool [1,2] and writing efficient searching algorithms. The assignment is divided into three parts. The first part looks to prepare you to start with this assignment. The second part looks at the assignment itself. The third part deals with the submission process. Please read this document very carefully and in detail!

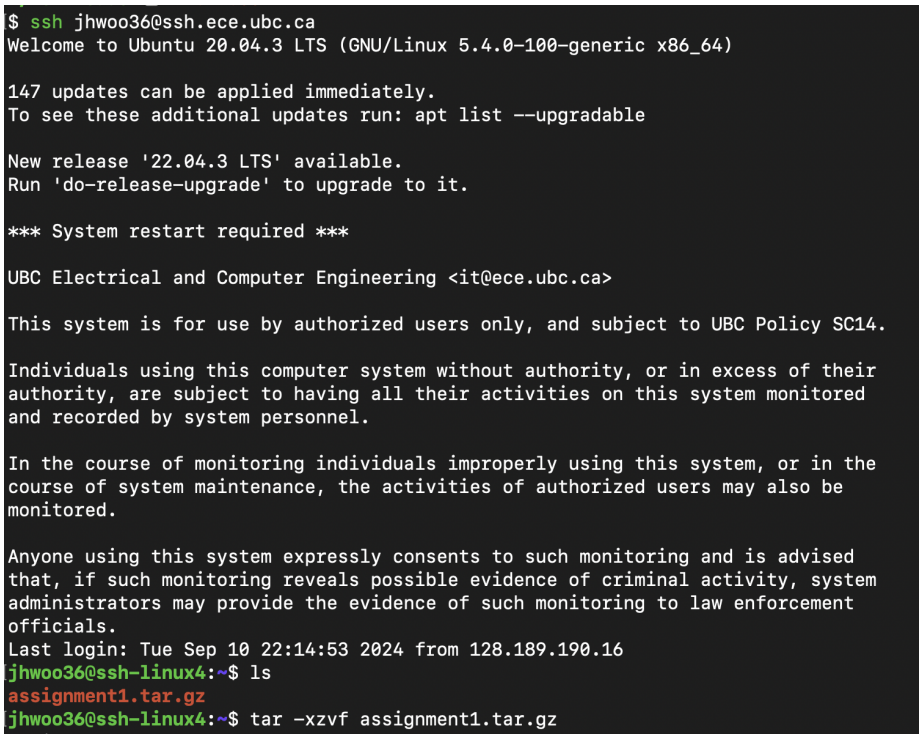
## 1.1. Preparatory Steps: Setup

1. Copy the **assignment1.tar.gz** to the **<username>@ssh.ece.ubc.ca** server.

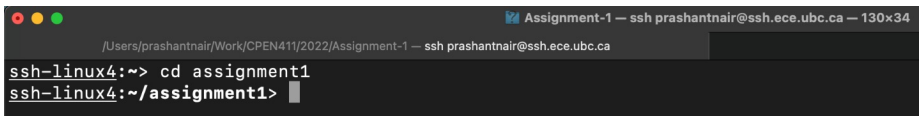



Suppose you do not have rsync (command) installed. You could try installing it. Alternatively, you can try using the scp command. For instance, Mac users can install these tools using Homebrew [3]. Windows and Mac users can use GUI tools like VSCode [4], CyberDuck [5], and MobaXterm [6] (**Windows Only**) to transfer files to remote servers. Linux users can use their *package manager* and install *rsync*, *scp*, or *sftp*.

2. untar **assignment1.tar.gz** in the ECE server.

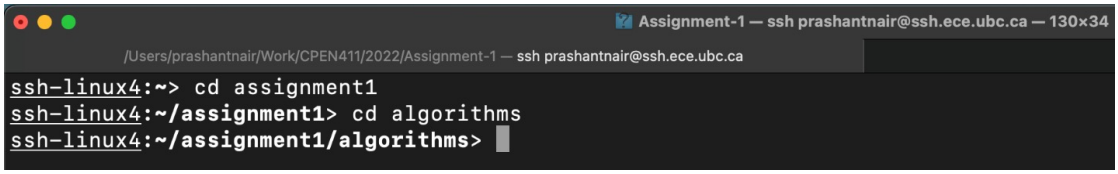



3. Change the directory into the **assignment1** folder.

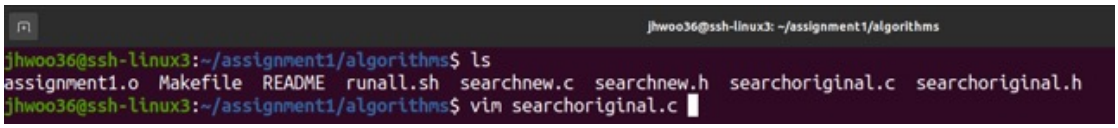


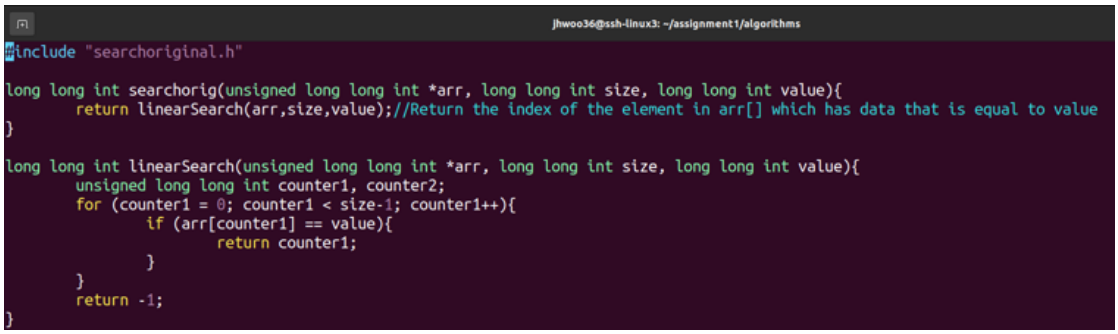
## 1.2. Preparatory Steps: Algorithm

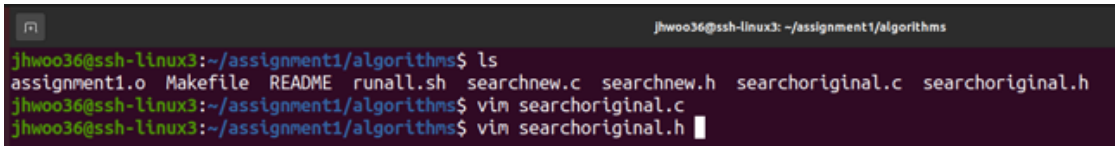
1. Change directory into **assignment1/algorithms** folder.




2. Understand the searching algorithm in **searchoriginal.c** and **searchoriginal.h**

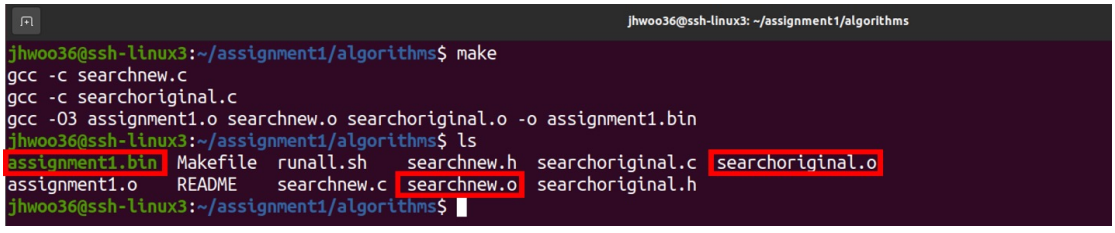


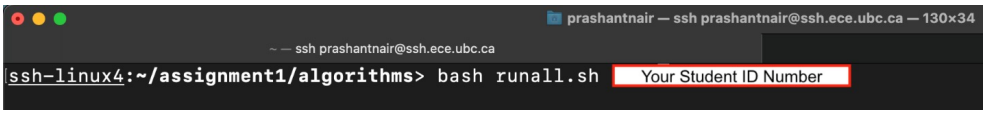





3. Compile the source files in the **assignment1/algorithms** folder.

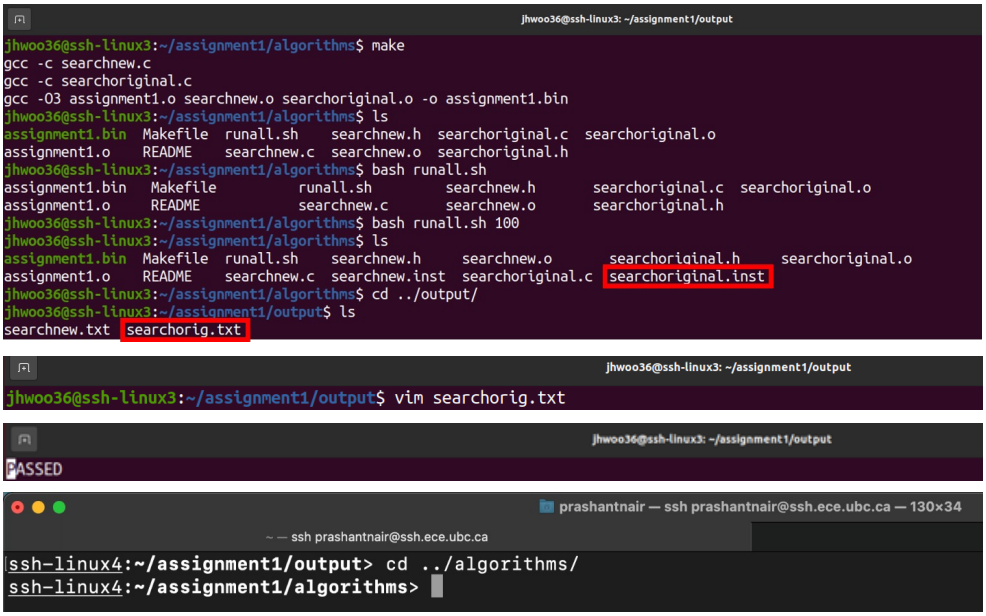



4. Execute your compiled code.



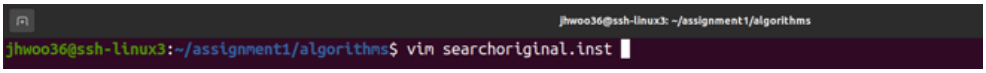

5. Change to the **assignment1/output**

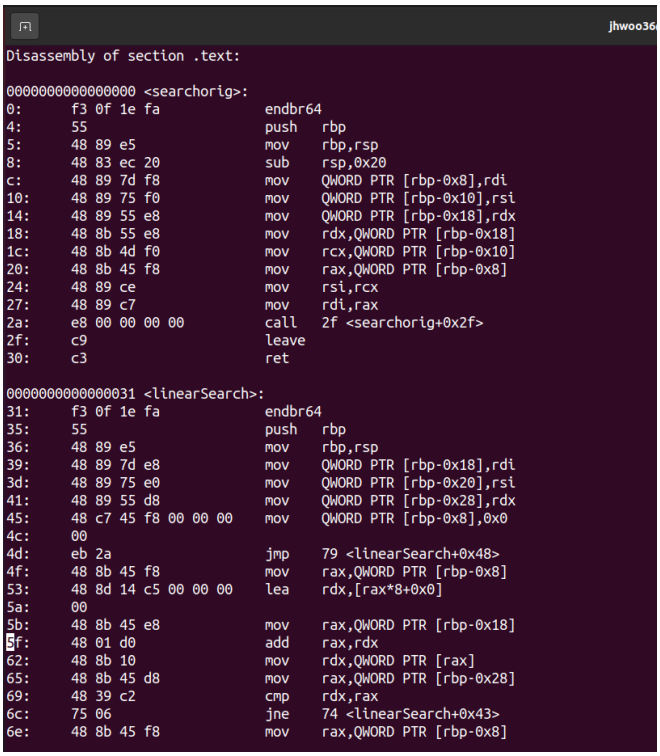
6. Make sure that **searchorig.txt** has `PASSED`.




7. Change to the **assignment1/algorithms**

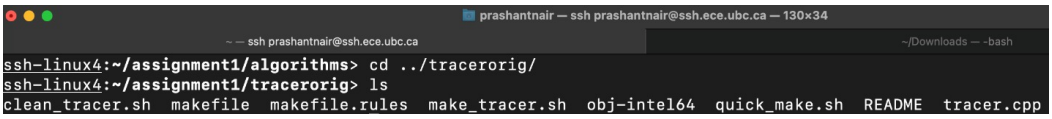
8. Understand the x86-ISA instructions used in the **Linear-Search** algorithm



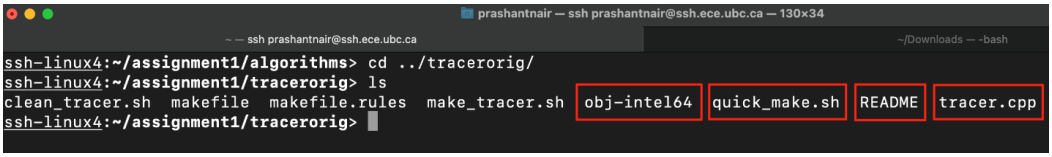



## 1.3. Preparatory Steps: Pintool

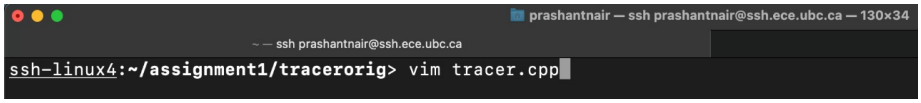
1. Change directory into **assignment1/tracerorig** folder

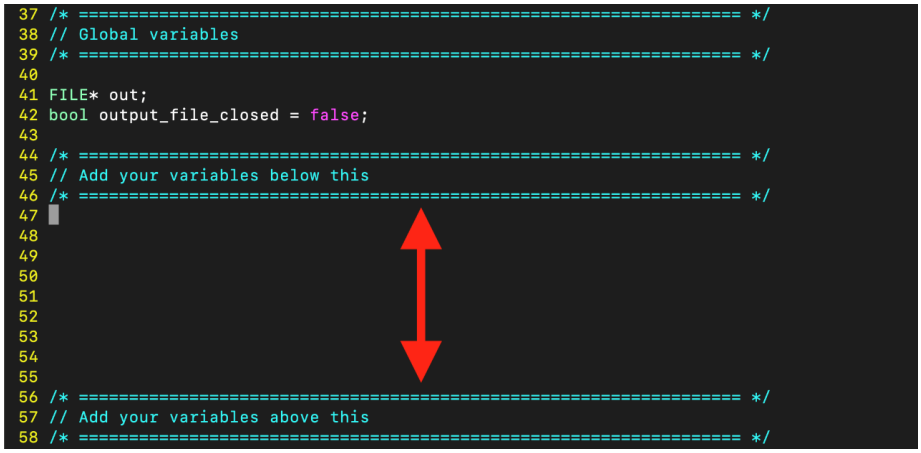


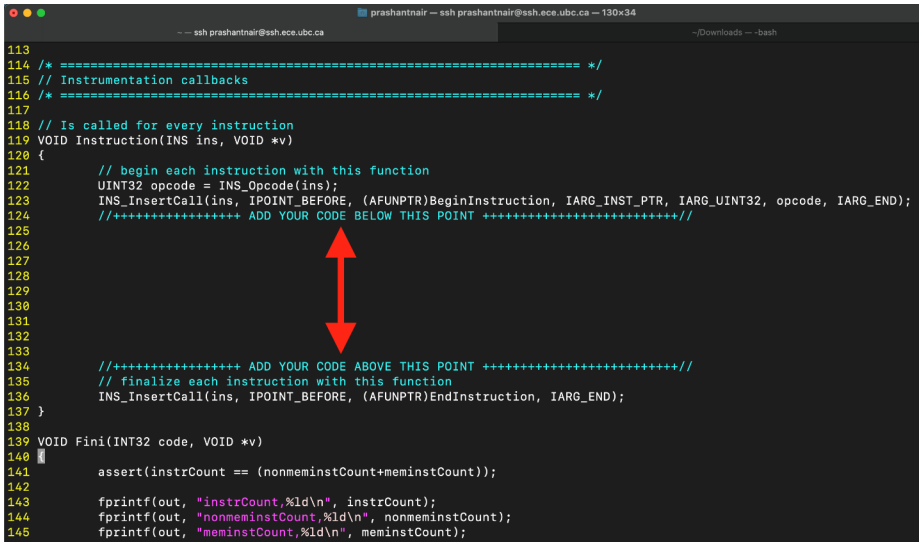

2. Understand the **assignment1/tracerorig** folder




3. Understand the **tracer.cpp** file and compile your code



```
80 }
81
82
83 /* ===================================================================== */
84 // Analysis routines
85 /* ===================================================================== */
86
87 void BeginInstruction(VOID *ip, UINT32 op_code, VOID *opstring){
88         instrCount++;
89         if(instrCount%1000000 == 0){
90                 std::cout << "." << std::flush;
91                 if(instrCount%10000000 == 0){
92                         std::cout << " -- " << instrCount/1000000 << " Million Instructions" << std::endl << std::flush;
93                 }
94         }
95 }
96
97 /* ++++++++++++++++ ADD YOUR FUNCTION (IF ANY) BELOW ++++++++++++++++++++ */
98
99
100
101
102
103
104
105
106 /* ++++++++++++++++ ADD YOUR FUNCTION (IF ANY) ABOVE ++++++++++++++++++++ */
107
108
109 void EndInstruction()
110 {
111
112 }
```

```
ssh-linux4:~/assignment1/tracerorig> bash quick_make.sh
g++ -Wall -Werror -Wno-unknown-pragmas -D__PIN__=1 -DPIN_CRT=1 -fno-stack-protector -fno-exceptions -funwind-tables -fasynchronous
-unwind-tables -fno-rtti -DTARGET_IA32E -DHOST_IA32E -fPIC -DTARGET_LINUX -fabi-version=2 -faligned-new  -I/ubc/ece/home/pnj/facul
ty/prashantnair/assignment1/pin-dir//source/include/pin -I/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//source/inclu
de/pin/gen -isystem /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir/extras/stlport/include -isystem /ubc/ece/home/pnj/f
aculty/prashantnair/assignment1/pin-dir/extras/libstdc++/include -isystem /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-d
ir/extras/crt/include -isystem /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir/extras/crt/include/arch-x86_64 -isystem
/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir/extras/crt/include/kernel/uapi -isystem /ubc/ece/home/pnj/faculty/prash
antnair/assignment1/pin-dir/extras/crt/include/kernel/uapi/asm-x86 -I/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//e
xtras/components/include -I/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//extras/xed-intel64/include/xed -I/ubc/ece/h
ome/pnj/faculty/prashantnair/assignment1/pin-dir//source/tools/Utils -I/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir/
/source/tools/InstLib -O3 -fomit-frame-pointer -fno-strict-aliasing   -c -o obj-intel64/tracer.o tracer.cpp
g++ -shared -Wl,--hash-style=sysv /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel64/runtime/pincrt/crtbeginS.o -
Wl,-Bsymbolic -Wl,--version-script=/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//source/include/pin/pintool.ver -fab
i-version=2    -o obj-intel64/tracer.so obj-intel64/tracer.o  -L/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel6
4/runtime/pincrt -L/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel64/lib -L/ubc/ece/home/pnj/faculty/prashantnai
r/assignment1/pin-dir//intel64/lib-ext -L/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//extras/xed-intel64/lib -lpin
-lxed /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel64/runtime/pincrt/crtendS.o -lpin3dwarf  -ldl-dynamic -nost
dlib -lstlport-dynamic -lm-dynamic -lc-dynamic -lunwind-dynamic
ssh-linux4:~/assignment1/tracerorig>
```

4. Refer to Pintool [1] website to write/understand/explore some example Pintools. You have a folder called **examples**, implement Pintools there and compile them.

```
ssh-linux4:~/assignment1/tracerorig> cd ../example/
ssh-linux4:~/assignment1/example> ls
clean_example.sh  example.cpp  make_example.sh  makefile  makefile.rules  obj-intel64  pintool.log  quick_make.sh  README
ssh-linux4:~/assignment1/example>
```

5. Execute your Pintool to "instrument" **assignment1/algorithms/assignment1.bin**. Note that the first parameter after assignment1.bin is "0" → Indicating Linear-Search

```
jhwoo36@gattaca:~/ta/cpen411/2023/assignment1_test/tracerorig$ ../pin-dir/pin -t obj-intel64/tracer.so -m 0 -- ../algorithms/assignment1.bin 0
......... -- 10 Million Instructions
......... -- 20 Million Instructions
......... -- 30 Million Instructions
......... -- 40 Million Instructions
......... -- 50 Million Instructions
......... -- 60 Million Instructions
......... -- 70 Million Instructions
......... -- 80 Million Instructions
......... -- 90 Million Instructions
......... -- 100 Million Instructions
......... -- 110 Million Instructions
```

Your Student #

```
ssh-linux4:~/assignment1/tracerorig> cd ../output/
ssh-linux4:~/assignment1/output> vim tracerorig.out
```

```
instrCount,115515776
nonmeminstCount,0
meminstCount,0
branchCount,0
MEMDELAY,2000
NONMEMDELAT,1000
CYCLEVAL-SERIAL,0
CYCLEVAL-HIDEMEM,0
CHANGE,0
OPT-MEMDELAY,2000
OPT-NONMEMDELAT,1000
OPT-CYCLEVAL-SERIAL,0
OPT-CYCLEVAL-HIDEMEM,0
SPEEDUP,nan
SPEEDUP-HIDEMEM,nan
```

6. Add a constant delay = NONMEMDELAY to the CYCLEVALS counter after each instruction. In this example, we do not know which instructions are memory instructions and we assume every instruction to be a non-memory instruction.

```
prashantnair — ssh prashantnair@ssh.ece.ubc.ca — 130×34
~ — ssh prashantnair@ssh.ece.ubc.ca    ~/Downloads — -bash
INT32 Usage()
{
        cerr << "This tool creates helps instrument instructions" << endl << "Percentage Change in Non-Memory Instruction Latency:
 From -90 to +90 with -o" << endl;
        cerr << KNOB_BASE::StringKnobSummary() << endl;
        return -1;
}


/* ===================================================================== */
// Analysis routines
/* ===================================================================== */

void BeginInstruction(VOID *ip, UINT32 op_code, VOID *opstring){
        instrCount++;
        //This is an example, and this is an incorrect assumption
        CYCLEVALS = CYCLEVALS + NONMEMDELAY;

        if(instrCount%1000000 == 0){
                std::cout << "." << std::flush;
                if(instrCount%10000000 == 0){
                        std::cout << " -- " << instrCount/1000000 << " Million Instructions" << std::endl << std::flush;
                }
        }
}

/* ++++++++++++++++ ADD YOUR FUNCTION (IF ANY) BELOW +++++++++++++++++++ */
```

```
prashantnair — ssh prashantnair@ssh.ece.ubc.ca — 130×34
~ — ssh prashantnair@ssh.ece.ubc.ca    ~/Downloads — -bash
ssh-linux4:~/assignment1/tracerorig> bash quick_make.sh
g++ -Wall -Werror -Wno-unknown-pragmas -D__PIN__=1 -DPIN_CRT=1 -fno-stack-protector -fno-exceptions -funwind-tables -fasynchronous
-unwind-tables -fno-rtti -DTARGET_IA32E -DHOST_IA32E -fPIC -DTARGET_LINUX -fabi-version=2 -faligned-new  -I/ubc/ece/home/pnj/facul
ty/prashantnair/assignment1/pin-dir//source/include/pin -I/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//source/inclu
de/pin/gen -isystem /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir/extras/stlport/include -isystem /ubc/ece/home/pnj/f
aculty/prashantnair/assignment1/pin-dir/extras/libstdc++/include -isystem /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-d
ir/extras/crt/include -isystem /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir/extras/crt/include/arch-x86_64 -isystem
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ome/pnj/faculty/prashantnair/assignment1/pin-dir//source/tools/Utils -I/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir/
/source/tools/InstLib -O3 -fomit-frame-pointer -fno-strict-aliasing   -c -o obj-intel64/tracer.o tracer.cpp
g++ -shared -Wl,--hash-style=sysv /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel64/runtime/pincrt/crtbeginS.o -
Wl,-Bsymbolic -Wl,--version-script=/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//source/include/pin/pintool.ver -fab
i-version=2    -o obj-intel64/tracer.so obj-intel64/tracer.o  -L/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel6
4/runtime/pincrt -L/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel64/lib -L/ubc/ece/home/pnj/faculty/prashantnai
r/assignment1/pin-dir//intel64/lib-ext -L/ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//extras/xed-intel64/lib -lpin
-lxed /ubc/ece/home/pnj/faculty/prashantnair/assignment1/pin-dir//intel64/runtime/pincrt/crtendS.o -lpin3dwarf  -ldl-dynamic -nost
dlib -lstlport-dynamic -lm-dynamic -lc-dynamic -lunwind-dynamic
ssh-linux4:~/assignment1/tracerorig>
```
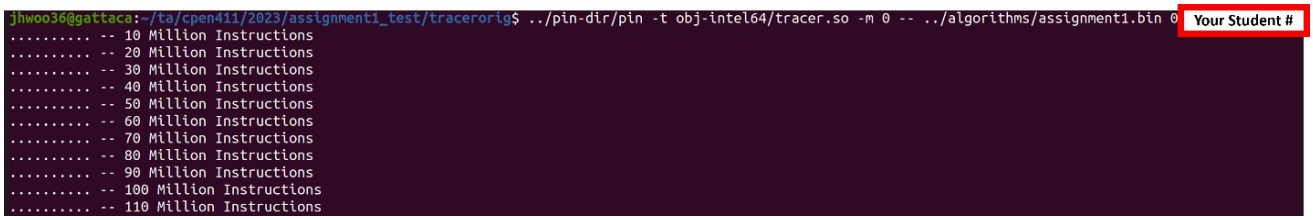
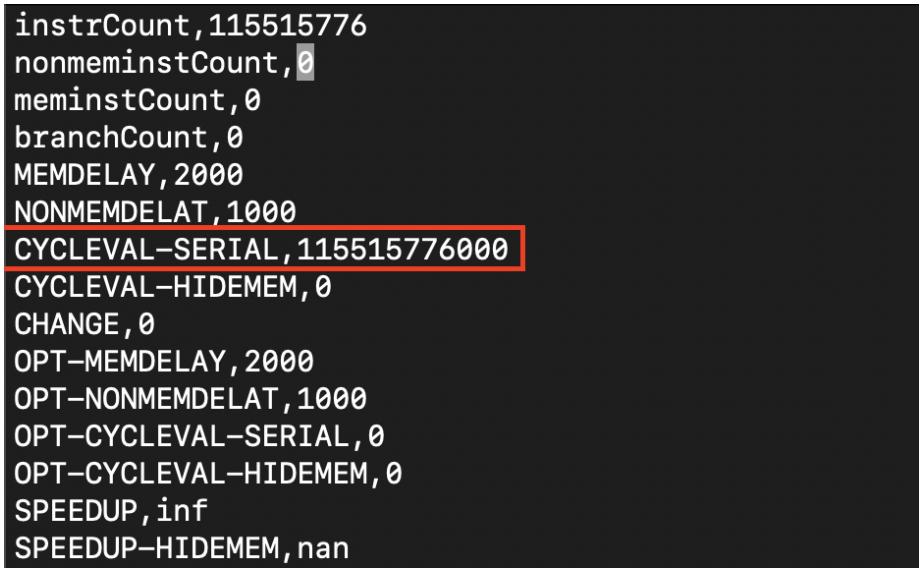








7. Remove any modification to tracer.c and proceed to the next step. Essentially remove the line CYCLEVALS = CYCLEVALS + NONMEMDELAY.

**Note**: **Your Pintool should not execute longer than 5 mins on the server. If it takes longer to execute, we will give you 0 marks. Please write efficient programs and Pintools**.

# Chapter 2

# Evaluation: Algorithm & Pintool [5 Points]

1. **[0.5 Points]** Write a Pintool in **assignment1/traceorig/** to count the number of instructions in **assignment1/algorithms/assignment1.bin** for Linear Search (This should already be implemented in the preparatory example).

2. **[1 Point]** Add a function in this Pintool to count the number of memory and non-memory instructions in **assignment1/algorithms/assignment1.bin** for Linear Search.

- "**meminstCount**" and "**nonmeminstCount**" variables must be repeatedly updated.
- **Note**: There is an assertion and if **(meminstCount + nonmeminstCount) != instrCount**, your program will fail. It is non-trivial to count memory instructions. You will need to understand the functions **INS_IsMemoryRead()** and **INS_IsMemoryWrite()** for this. These functions are described here: Memory Read and Write Functions.
- Additionally, please refer to an example here: Memory Traces.

3. **[0.5 Points]** Add a function in this Pintool to count the number of **branch instructions** in **assignment1/algorithms/assignment1.bin** for Linear Search.

- The "**branchCount**" variable needs to be updated in this example.
- **Note**: You must understand the functions **INS_IsBranch()** for this. These functions are described here: Branch Count Function.

4. **[0.5 Points]** Assuming all instructions are executed one after another with their own delays, compute the **total execution time** required to execute **assignment1/algorithms/assignment1.bin** for Linear Search. For this exercise, the Pintool is pre-filled with delays (CPI) for memory and nonmemory instructions.

- Your **CYCLEVALS** variable needs to be repeatedly updated in this example. This needs to be done by using the values of **MEMDELAY** for memory instructions and **NONMEMDELAY** for non-memory instructions.
- The output file, tracerorig.out will reflect this number.

5. **[0.5 Points]** Assuming all memory instructions do not show any latency or block any other instructions (perhaps due to some computer architecture optimization), compute the **total execution time** required to execute **assignment1/algorithms/assignment1.bin** for Linear Search. For this exercise, the Pintool is pre-filled with delays (CPI) for memory and non-memory instructions. **Note**: Your **CYCLEVALP** variable needs to be repeatedly updated in this example.

6. **[0.5 Points]** You can change the latency (CPI) of non-memory instructions by +90% to -90%. Repeat steps 4 and 5. On canvas, enter this value (such as 10%, 20%, -50%, etc.) wherein the speedup as compared to step 4 **just crosses 1.2**. **This value must be entered as a comment on Canvas**. This has trade-offs, a 50% increase in non-memory instruction CPI causes a 50% decrease in memory instruction CPI.

- Your **OPTCYCLEVALP** and **OPTCYCLEVALS** variables need to be repeatedly updated in this example. This needs to be done by using the values of **MEMDELAY** for memory instructions and **NONMEMDELAY** for non-memory instructions.

```
ssh-linux4:~/assignment1/traceorig> ../pin-dir/pin -t obj-intel64/tracer.so -m -20 -- ../algorithms/assignment1.bin 0 Your Student #
```

- The input parameter to your pintool "-m" is used to pass the change in latency.
- Remember, you need to report the value used when your SPEEDUP in your output file just surpasses 1.2.
- This value needs to reflect in the output file **../output/traceorig.out**. The entry "**CHANGE**" should show this value. Make sure you do not change this value after you converge on the right value. If you change "**-m**" and run your experiment again, your "**CHANGE**" value in the output folder would be overwritten.

7. **[0.5 Points]** Change the directory into assignment1/algorithms folder and implement your searching algorithm – in **searchnew.c** and **searchnew.h**.

- You can only edit these files, and you can add any number of additional functions in **searchnew.h** and **searchnew.c**
- This algorithm needs to **PASS**. After you execute bash runall.sh in this folder, check the **../output/searchnew.txt**

8. **[0.5 Points]** Change directory into assignment1/tracernew folder. Write a Pintool in its trace.cpp to count the number of instructions in assignment1/algorithms/assignment1.bin for <your searching algorithm>.

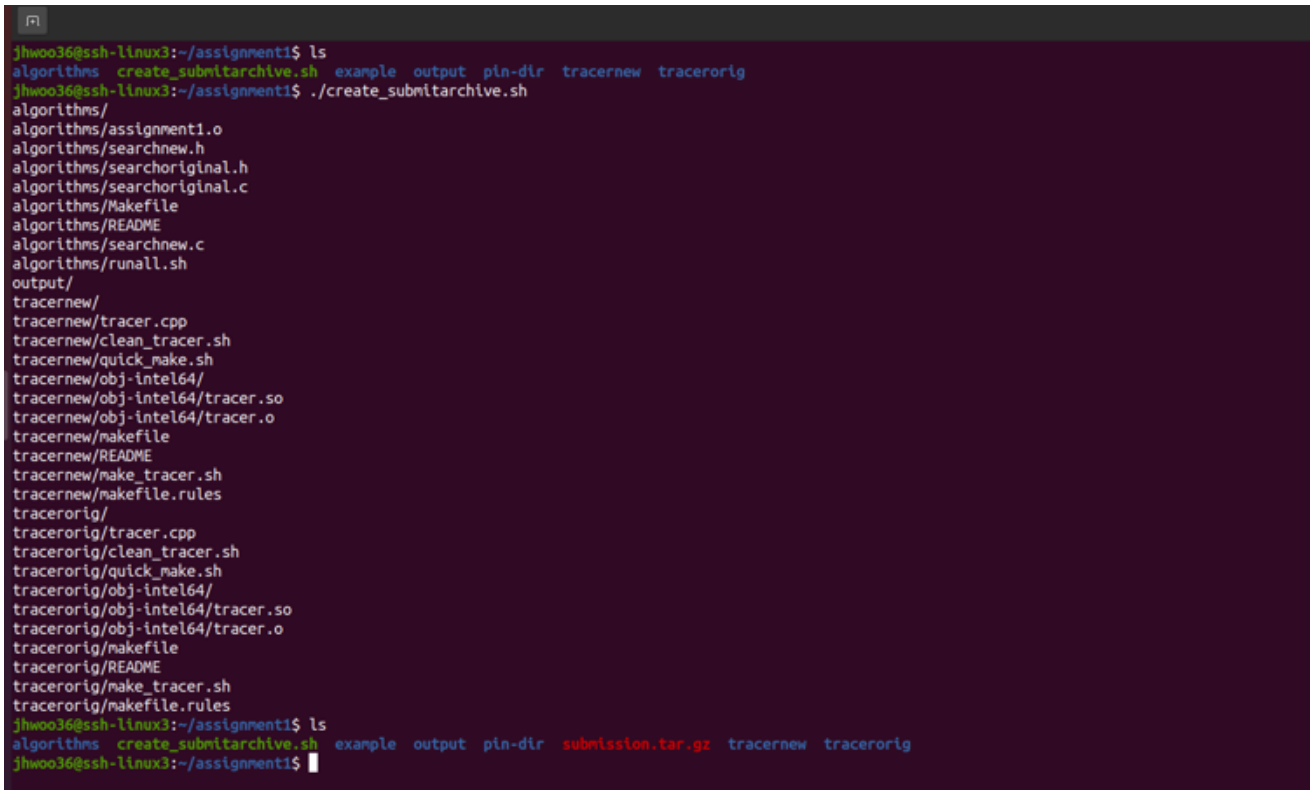
```
ssh-linux4:~/assignment1> cd tracernew/
ssh-linux4:~/assignment1/tracernew> vim tracer.cpp
ssh-linux4:~/assignment1/tracernew> ../pin-dir/pin -t obj-intel64/tracer.so -m 0 -- ../algorithms/assignment1.bin 1 Your Student #
```

9. **[0.5 Points]** Ensure that **<your searching algorithm>** executes **at least 20x lower total instructions** as compared to your original Linear-Search. You can check the output folder/tracernew.out file for the total instructions executed.

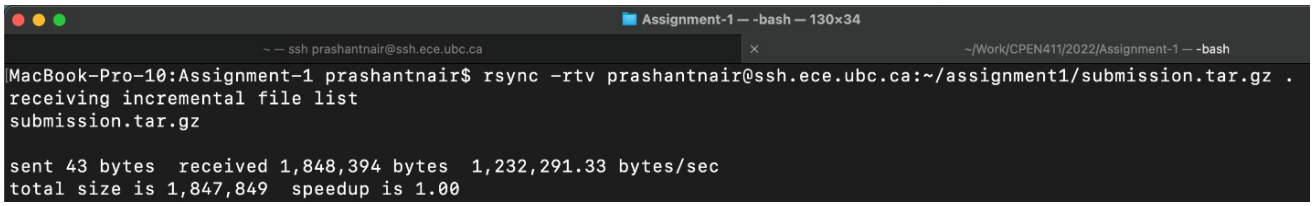
# Chapter 3

# Submission Instructions

1. To submit, please execute the following command within assignment1 folder.




2. You can then run **rsync** from your local computer and download the submission file.




3. Please upload **ONLY** the **submission.tar.gz** on Canvas. **Make sure it has the updated algorithms, tracer.cpp, and output files**. **If we find stale files and execute those, you can get "0" points for this assignment**.

Thus, be extremely careful and double check if your outputs, source files, etc. are the right ones! We have 80 students in this course, and we will not re-evaluate your Assignment if you submit incorrect or stale work.

# Bibliography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