

HW 3: All-Pairs Shortest Path (CPU)

Deadline: 2 Dec 2020, 18:00

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Goal

This homework helps you understand the all-pairs shortest path problem.

Requirements

In this assignment, you are asked to:

1. **Implement a program that solves the all-pairs shortest path problem.**
 - You are required to use **threading** to parallelize the computation in your program.
 - You can choose any threading library or framework you like (pthread, std::thread, OpenMP, Intel TBB, etc).
 - You can choose any algorithm to solve the problem.
 - You must implement the shortest path algorithm yourself. (Do not use libraries to solve the problem. Ask TA if unsure).
2. **Create your input test case.**

Command line specification

```
srun -N1 -n1 -cCPUS ./hw3 INPUTFILE OUTPUT
```

- CPUS: Number of CPUs, specified by TA.
- INPUTFILE: The pathname of the input file. Your program should read the input graph from this file.
- OUTPUTFILE: The pathname of the output file. Your program should output the shortest path distances to this file.

Input specification

- The input is a directed graph with non-negative edge distances.
- The input file is a binary file containing 32-bit integers. You can use the `int` type in C/C++.
- The first two integers are *the number of vertices (V)* and *the number of edges (E)*.
- Then, there are E edges. Each edge consists of 3 integers:
 1. *source vertex id* (src_i)
 2. *destination vertex id* (dst_i)
 3. *edge weight* (w_i)

- The values of vertex indexes & edge indexes start at 0.
- The ranges for the input are:
 - $2 \leq V \leq 6000$
 - $0 \leq E \leq V \times (V - 1)$
 - $0 \leq \text{src}_i, \text{dst}_i < V$
 - $\text{src}_i \neq \text{dst}_i$
 - if $\text{src}_i = \text{src}_j$ then $\text{dst}_i \neq \text{dst}_j$ (there will not be repeated edges)
 - $0 \leq w_i \leq 1000$

Here's an example:

offset	type	decimal value	description
0000	32-bit integer	3	# vertices (V)
0004	32-bit integer	6	# edges (E)
0008	32-bit integer	0	src id for edge 0
0012	32-bit integer	1	dst id for edge 0
0016	32-bit integer	3	edge 0's distance
0020	32-bit integer		src id for edge 1
...
0076	32-bit integer		edge 5's distance

Output specification

- The output file is also in binary format.
- For an input file with V vertices, you should output an output file containing V^2 integers.
- The first V integers should be the shortest path distances for starting from edge 0: $\text{dist}(0, 0), \text{dist}(0, 1), \text{dist}(0, 2), \dots, \text{dist}(0, V - 1)$; then the following V integers would be the shortest path distances starting from edge 1: $\text{dist}(1, 0), \text{dist}(1, 1), \text{dist}(1, 2), \dots, \text{dist}(1, V - 1)$; and so on, totaling V^2 integers.
- $\text{dist}(i, j) = 0$ where $i = j$.
- If there is no valid path between $i \rightarrow j$, please output with: $\text{dist}(i, j) = 2^{30} - 1 = 1073741823$.

Example output file:

offset	type	decimal value	description
0000	32-bit integer	0	$\text{dist}(0, 0)$
0004	32-bit integer	?	$\text{dist}(0, 1)$
0008	32-bit integer	?	$\text{dist}(0, 2)$
...
$4V^2-8$	32-bit integer	?	$\text{dist}(V-1, V-2)$
$4V^2-4$	32-bit integer	0	$\text{dist}(V-1, V-1)$

Report

Answer the questions below. You are recommended to use the same section numbering as they are listed.

1. Implementation

- a. Which algorithm do you choose?

- b. Describe your implementation.
- c. What is the time complexity of your algorithm, in terms of number of vertices V , number of edges E , number of CPUs P ?
- d. How did you design & generate your test case?

2. Experiment & Analysis

a. System Spec

If you didn't use our `apollo` server for the experiments, please show the CPU, RAM, disk of the system.

b. Strong scalability

Perform strong scalability experiments, plot your experiment results.

Note:

You have to make sure that your execution time is long enough so that the results are meaningful.

c. Time profile

How much time is spent in input / computation / output.

Note:

You should not use the `clock()` function to measure execution time, because it measures *CPU time*. You can use either:

- `clock_gettime` with `CLOCK_MONOTONIC`
- `std::chrono::steady_clock`
- `omp_get_wtime`

3. Experience & conclusion

- a. What have you learned from this homework?
- b. Feedback (optional)

Grading

1. Correctness (30%)

An unknown number of test cases will be used to test your implementation. You get 30 points if you passed all the test cases, $\max(0, 30 - 2k)$ points if there are k failed test cases.

Time limit for each case: (960 seconds) / (number of CPU cores).

2. Performance (20%)

- We will use several different hidden test cases (denoted C) to run your code. Your performance score will be given by:

$$\sum S(C) \times \frac{T_{best}(C)}{T_{yours}(C)}$$

- C is a test case
- $S(C)$ is the score allocated to the test case.
- $T_{best}(C)$ is the shortest execution time of all students for the test case, excluding incorrect implementations.
- $T_{yours}(C)$ is your shortest execution time for the test case, excluding incorrect implementations.
- $\sum S(C) = 20$

3. Generated testcase (10%)

Your generated testcase should conform to the [Input specification](#). Points are given according to the **total time all other students finish your test case**. More time results in higher testcase score.

If someone cannot finish your case correctly, the time used for calculation will be: time limit \times 1.5.

Your code must pass your own testcase in order to get points on your generated testcase.

4. Demo (20%)

A demo session will be held in the Lab. You'll be asked questions about the homework.

5. Report (20%)

Grading based on your evaluation of the results, discussion and writing.

Must be a PDF document.

Submission

Upload these files to ILMS. Do not compress them.

- hw3.cc
- Makefile (optional)
- hw3_{student_ID}.pdf

Put your generated test case in `~/homework/hw3/mycase.in` on apollo before the deadline. We will copy the file locate there afterward.

Final Notes

- Type `hw3-judge` to run the test cases.
- Scoreboard: <https://apollo.cs.nthu.edu.tw/pp20/scoreboard/hw3/>
- Use the `hw3-cat` command to view the binary test cases in text format.
- Resources are provided under `/home/pp20/share/hw3/`:
 - `Makefile` - example Makefile
 - `validator.cc` - sample source code to validate an input testcase against the input specification
 - `cases/` - sample testcases
- Contact TA via pp@lsalab.cs.nthu.edu.tw or iLMS if you find any problems with the homework specification, judge scripts, example source code or the test cases.
- You are allowed to discuss and exchange ideas with others, but you are required to write the code on your own. You'll get **0 points** if we found you cheating.