CS 4000
Introduction to Distributed, Parallel, and Web-Centric Computing
Lecture #8: Parallel Performance Limits

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Parallel Performance

We have been talking about parallel performance throughout the semester. Let's make sure we all are on the same page.

On page 58 of the book, they define *speedup* of a parallel program is defined to be

$$S = T_{sequential} / T_{parallel},$$

that is, the ratio of the time taken by the original program and the time taken by the parallel version. This number, in general, should be bounded by the number of processors on the system.

The *efficiency* of the parallel execution is $E = S/p$, where p is the number of processors being used.

There are fundamental limits to S and to E that we will see next, both from a theoretical and experimental framework.

Parallel Performance Examples

Consider a program runs sequentially (1 thread) and takes 60 seconds...

- If it takes 30 seconds with 2 cores, what is the speedup? What is the efficiency?
  Speedup is 2 (or 200%), efficiency is 100%
- If it takes 30 seconds with 4 cores, what is the speedup? What is the efficiency?
  Speedup is 2 (or 200%), efficiency is 50%
- If it takes 15 seconds with 16 cores, what is the speedup? What is the efficiency?
  Speedup is 4 (or 400%), efficiency is 25%

Gene Amdahl

Gene Amdahl in the 1960's observed that, in any software system, part of that system must be executed sequentially due to dependency constraints, while other parts of a system may be executed in parallel.

Amdahl suggested a simple model where some percentage (S) of a software system must be executed sequentially. In those cases, the value of S limits the performance enhancements that can be made when applying multiple processors to the same system.

Amdahl's law, cont'd

The maximum speedup using N processors that can be achieved when S percent of a software system must be executed sequentially is

$$\frac{1}{S + \frac{1-S}{N}} \tag{1}$$

Amdahl's law - Fundamental Limit

What is the value as N approaches infinity?

$$\lim_{N \longrightarrow \infty} \frac{1}{S + \frac{1-S}{N}} = \frac{1}{S} \tag{2}$$

Amdahl's law - Sanity Check

What is the value if N is 1?

$$\frac{1}{S + \frac{1-S}{N}} \tag{3}$$

Amdahl's law - Sanity Check

What is the value if S is 0%?

$$\frac{1}{S + \frac{1-S}{N}} \tag{4}$$

Amdahl's law - Sanity Check

What is the value if S is 100%?

$$\frac{1}{S + \frac{1-S}{N}} \tag{5}$$

Applying Amdahl's law

So, if 50% of a program must be executed in parallel, then, even with 10 processors, we can expect at most a speed-up of 1.8181.
That maximum speedup (according to Amdahl's law) could never by more than 2.

Applying Amdahl’s law

My ./sharpen program has an overhead of about 57% (the portion that must be run sequentially) on my workstation

What is the maximum speedup?

Applying Amdahl's law

Answer: My ./sharpen program has an overhead of about 57% (the portion that must be run sequentially) on my workstation
What is the maximum speedup (with 10 cores)?

$$\frac{1}{0.57+\frac{1-0.57}{10}} = \frac{1}{0.57+\frac{0.43}{10}} = \frac{1}{0.57+0.043} = \frac{1}{0.613} = 1.63 \tag{6}$$

What about an infinite number of cores?