

Pollack's Rule

Justification for Heterogeneous Computing

Big picture

- Performance modeling: Estimating performance of a hypothetical system so system designer can compare different options
- Today: Consider different configurations of cores
 - Assumption: Total processor size (silicon area) is the same for all configurations

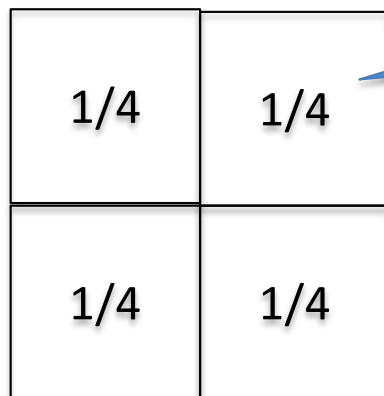
Pollack's rule

- The performance of a processing core is proportional to the square root of its area

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If a single core is replaced by 4 cores, each $\frac{1}{4}$ as large, what is the expected peak performance of the entire system? (i.e. the performance assuming all 4 could be kept perfectly busy)



Performance: $\text{sqrt}(1/4) = \frac{1}{2}$

Total performance: $4 \times \frac{1}{2} = 2$
(twice as much)

How does the running time change when a single core is replaced with 4 cores if only half the program can be parallelized?

- Parallel part:

$$\frac{1}{2} \text{ the work} / 2 \text{ the performance} = \frac{1}{4}$$

How does the running time change when a single core is replaced with 4 cores if only half the program can be parallelized?

- Parallel part:

$$\frac{1}{2} \text{ the work} / 2 \text{ the performance} = \frac{1}{4}$$

- Serial part:

$$\frac{1}{2} \text{ the work} / \frac{1}{2} \text{ the performance} = 1$$

Total time: 1.25 times as long

Recall: Amdahl's Law

$$T_p = \underbrace{\frac{T_1(1-B)}{p}}_{\text{Time for parallel part}} + \underbrace{T_1 B}_{\text{Time for serial part}}$$

T_p = processing time on p processors

T_1 = processing time on 1 processor

B = fraction of program that can run in parallel

By what factor does the running time of a program that can be 75% parallelized change on 4 equal-sized cores?

Serial part: $\text{work} / \text{performance} = 0.25 / 0.5 = 0.5$

Parallel part: $0.75 / 2 = 0.375$

Total time: 0.875 times as long

By what factor does the running time of a program that can be 90% parallelized change on 4 equal-sized cores?

Serial part: $\text{work} / \text{performance} = 0.1/0.5 = 0.2$

Parallel part: $0.90 / 2 = 0.45$

Total time: 0.65 times as long

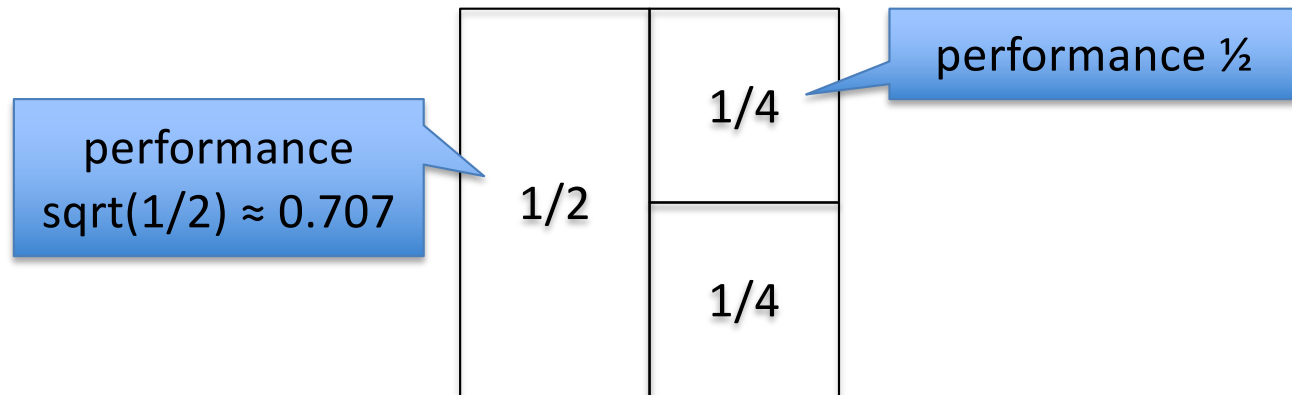
Factor by which running time changes for different programs

% of program that can be parallelized

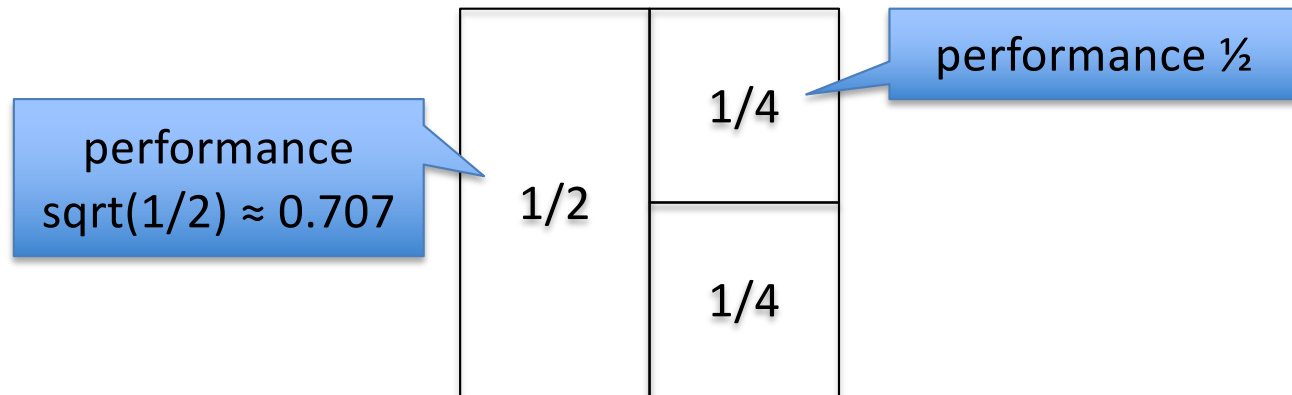
	75%	90%	95%
1 core	1	1	1
4 cores	0.875	0.65	0.575
9 cores	1	0.6	0.467
16 cores	1.1875	0.625	0.438
25 cores	1.4	0.68	0.44
36 cores	1.625	0.75	0.458

As the number of cores increases, highly parallelizable programs have improved performance, but less parallelizable programs suffer

What about unequal core sizes?



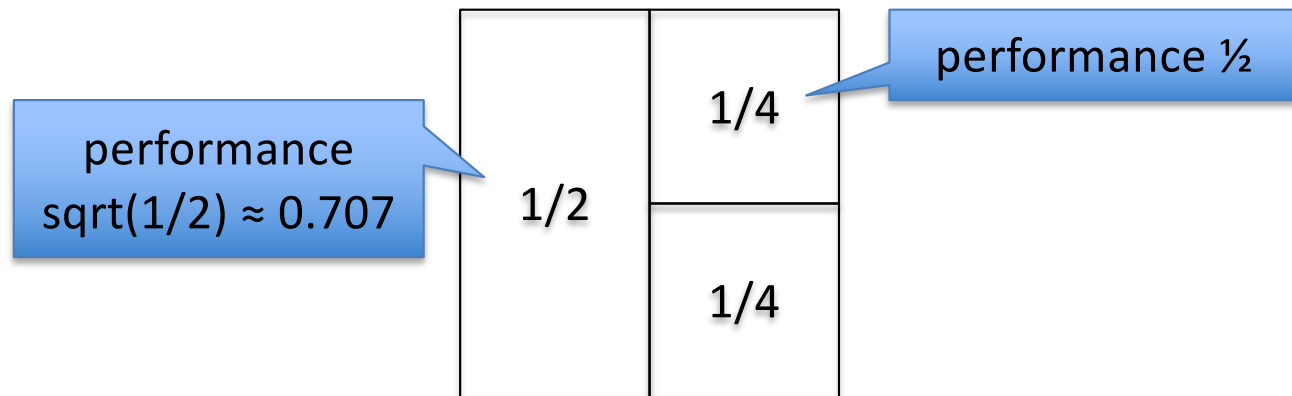
What about unequal core sizes?



By what factor does the peak performance of this system differ from a single core?

$$0.707 + 2 \times 0.5 = 1.707 \text{ times as much}$$

What about unequal core sizes?



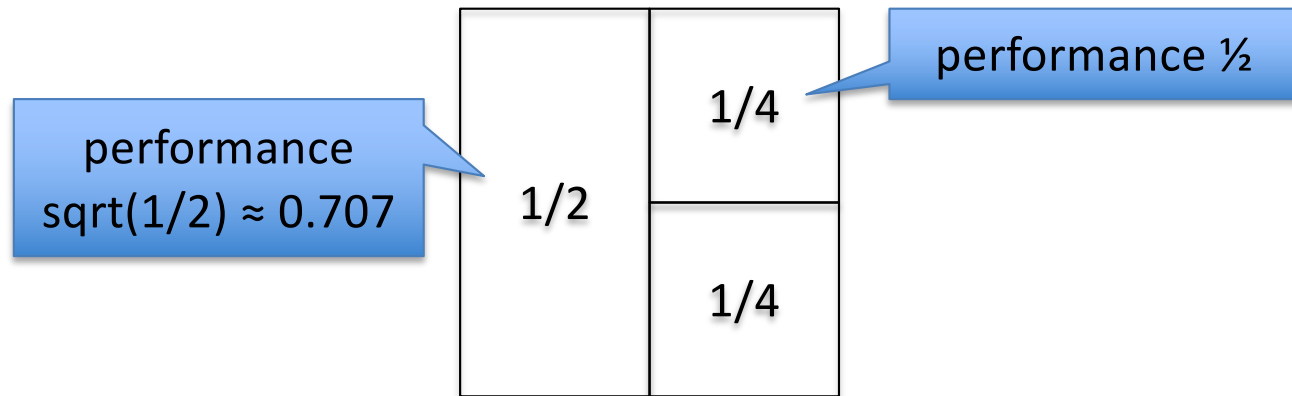
By what factor does the running time of a program that can be 75% parallelized change?

Serial part: $0.25 / 0.707 = 0.354$

Parallel part: $0.75 / 1.707 = 0.439$

Total time: 0.793 times as long

What about unequal core sizes?



By what factor does the running time of a program that cannot be parallelized change?

$$\text{Total time} = \text{serial time} = 1 / 0.707 = 1.414$$

Factor by which running time changes for different programs

	% of program that can be parallelized		
	50%	75%	90%
4 equal cores	1.25	0.88	0.65
Half-sized + 2 quarter-sized cores	1.00	0.79	0.66

Having different sized cores improves performance on less parallelizable programs at small cost on more highly parallelizable ones

Heterogeneity on a cell phone

The screenshot shows the 'Benchmarks' app interface. At the top, the status bar displays the time 9:56, signal strength, and 84% battery. The app's header is blue with a hamburger menu icon and the title 'Benchmarks'. Below the header, there are three tabs: 'CPU', 'COMPUTE', and 'BATTERY'. The 'CPU' tab is selected. The main content area is divided into two sections. The first section, titled 'YOUR DEVICE', lists the following specifications: Model (OnePlus 5T), OS (Android 9), and CPU (Qualcomm MSM8998 Snapdragon 835). Below this, a table with a green border lists the CPU clusters: Cluster 1 (4 Cores @ 1.90 GHz) and Cluster 2 (4 Cores @ 2.46 GHz). The second section, titled 'CPU BENCHMARK', contains a paragraph explaining that the benchmark measures CPU performance for everyday tasks and takes 2 to 20 minutes to complete. At the bottom of this section is a blue button labeled 'RUN CPU BENCHMARK'.

YOUR DEVICE	
Model	OnePlus 5T
OS	Android 9
CPU	Qualcomm MSM8998 Snapdragon 835
Cluster 1	4 Cores @ 1.90 GHz
Cluster 2	4 Cores @ 2.46 GHz

CPU BENCHMARK

CPU Benchmark measures the performance of CPUs at performing everyday tasks using tests designed to simulate real-world applications. This benchmark takes from 2 to 20 minutes to complete.

[RUN CPU BENCHMARK](#)

8 cores, 2 levels of performance