

# Pollack's Rule

Justification for Heterogeneous Computing

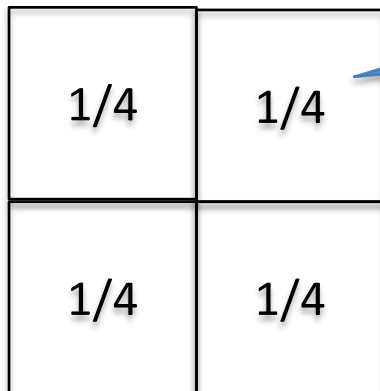
# Pollack's rule

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

# Pollack's rule

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

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

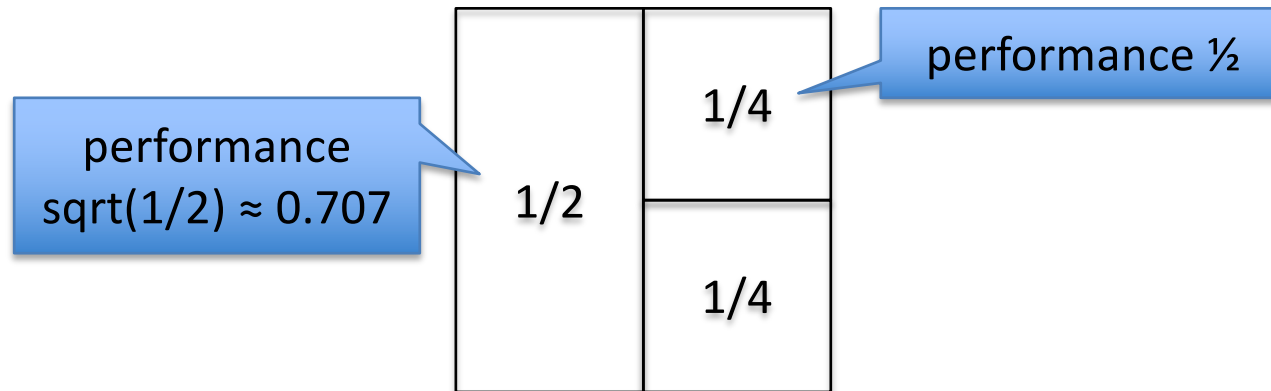


# Factor by which running time changes for different programs

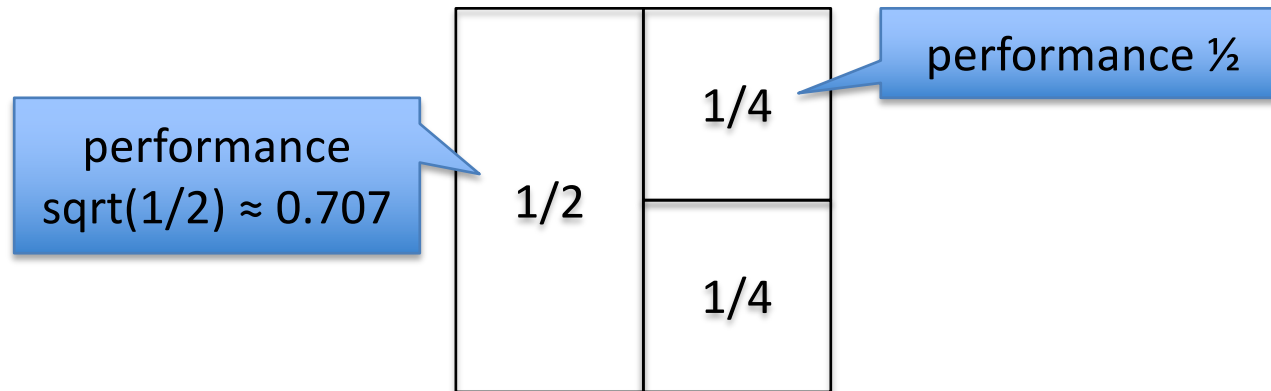
| % of program that<br>is parallelizable | 75%    | 90%   | 95%   |
|--|--------|-------|-------|
| 1 core                                 | 1      | 1     | 1     |
| 4 cores                                | 0.875  | 0.65  | 0.575 |
| 9 cores                                | 1      | 0.6   | 0.467 |
| 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?



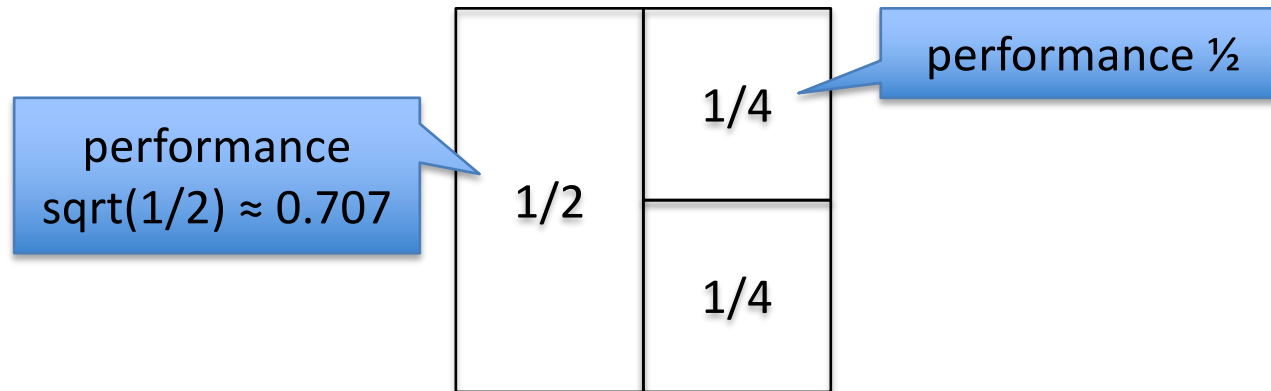
# What about unequal core sizes?



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?



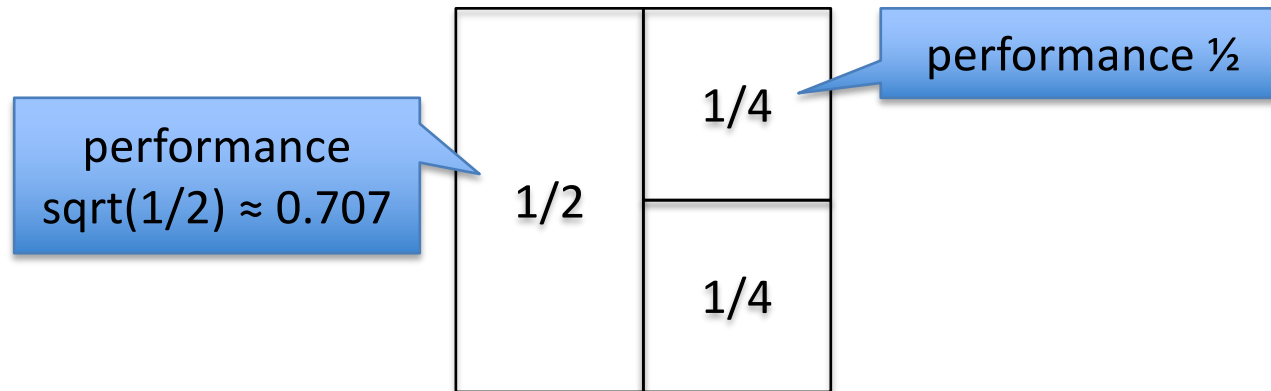
By what factor does the running time of a program that can be 75% parallelized change?

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<br>is parallelizable | 50%  | 75%  | 90%  |
|--|------|------|------|
| 4 equal cores                          | 1.25 | 0.88 | 0.65 |
| Half-sized + 2<br>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, there's a blue header with a menu icon and the title 'Benchmarks'. Below the header, there are three tabs: 'CPU', 'COMPUTE', and 'BATTERY'. The 'CPU' tab is selected. Under the 'YOUR DEVICE' section, the following information is displayed:

|           |                                    |
|-----------|------------------------------------|
| Model     | OnePlus 5T                         |
| OS        | Android 9                          |
| CPU       | Qualcomm MSM8998<br>Snapdragon 835 |
| Cluster 1 | 4 Cores @ 1.90 GHz                 |
| Cluster 2 | 4 Cores @ 2.46 GHz                 |

The last two rows, 'Cluster 1' and 'Cluster 2', are highlighted with a green border. Below this, the 'CPU BENCHMARK' section is visible, containing a description of the benchmark and a 'RUN CPU BENCHMARK' button.

8 cores, 2 levels of  
performance