FCDS – Lab

Summer Semester 2015

Your Advisors

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If you're stuck, have questions/issues, or want to have a consultation, write to one of us

Introduction

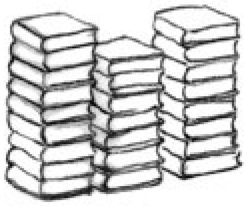
Single-threaded code

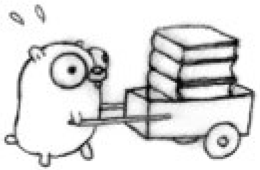
- Underutilized hardware
- Not scalable

Concurrent code

- low-level concurrency using threads & locks
- Higher level concurrency using fork/join model or actors
- Leverage multicore hardware

Explanation from Rob Pike

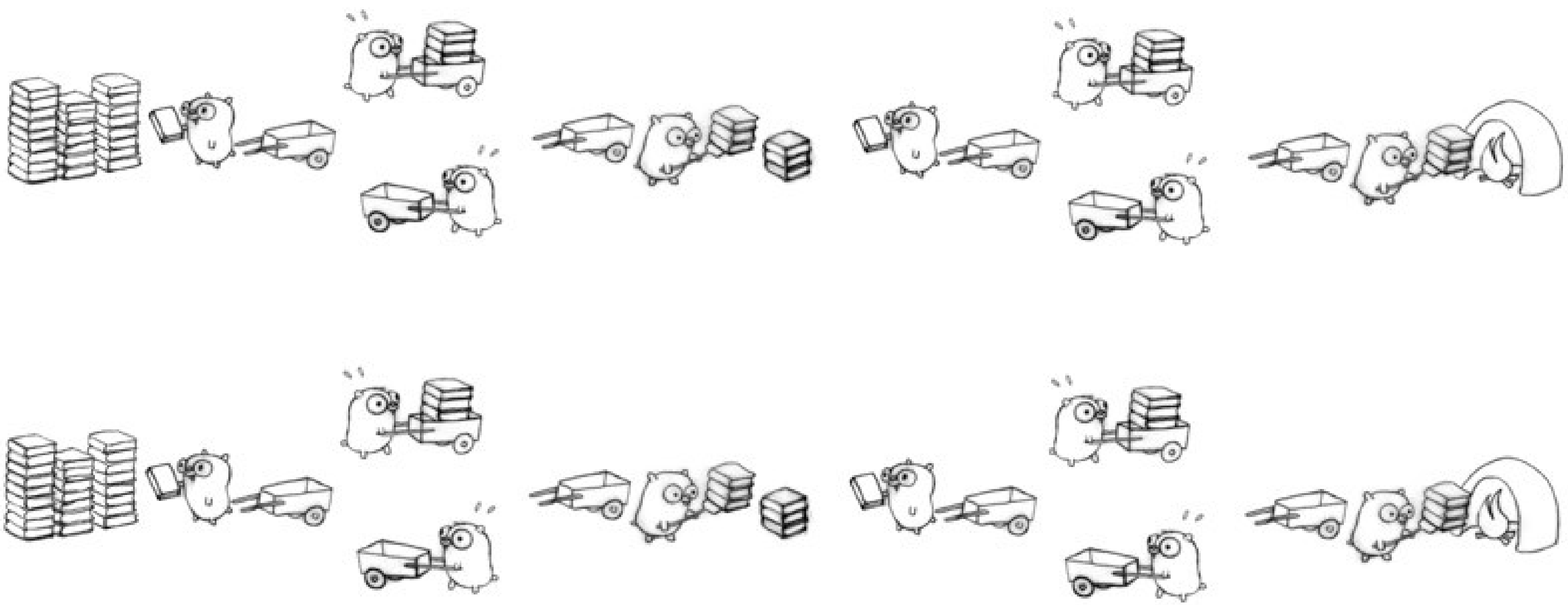




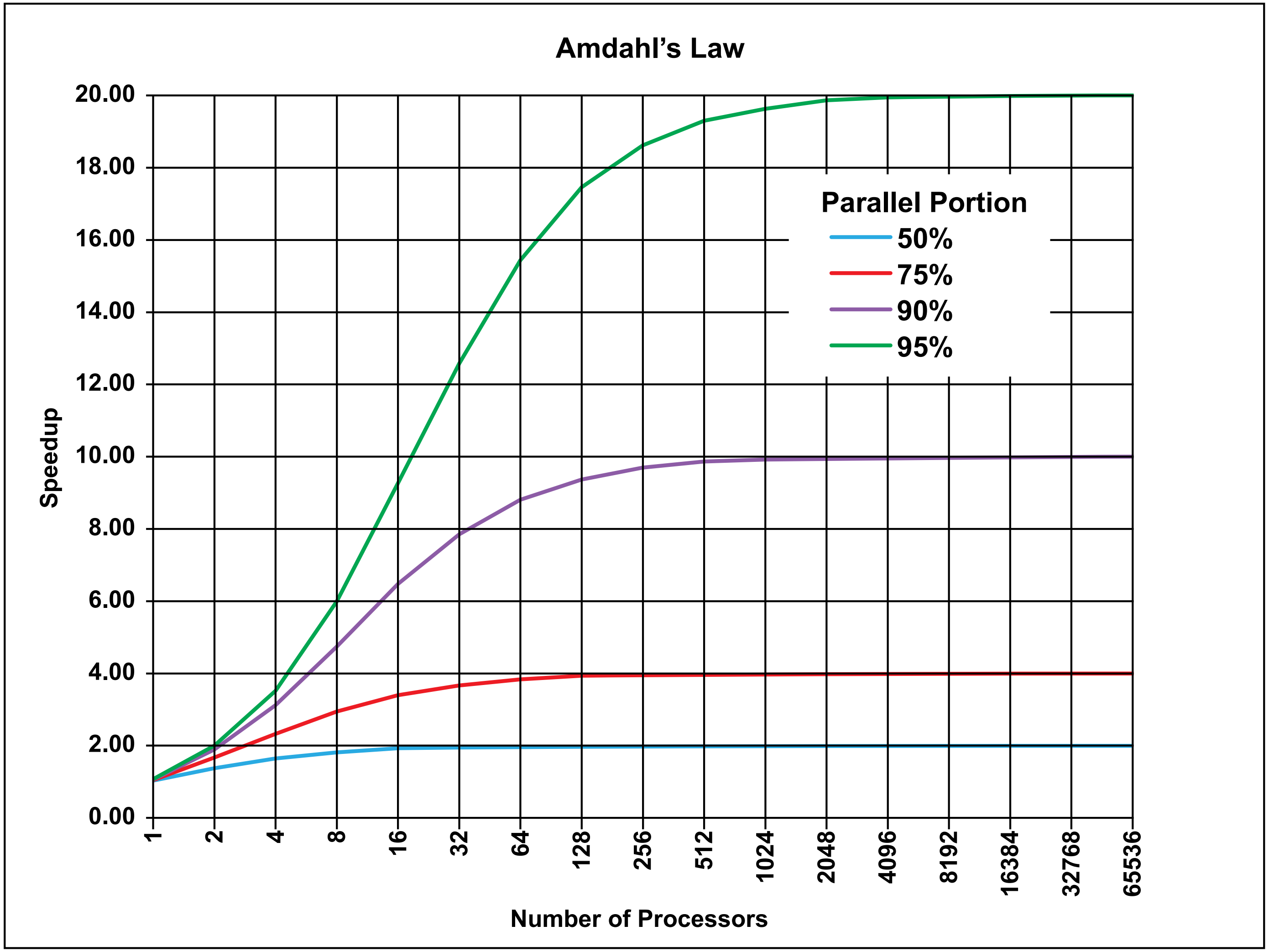
(Rob Pike, “Concurrency is not Parallelism”,

http://talks.golang.org/2012/waza.slide)

Explanation from Rob Pike



Amdahl's Law



Amdahl's Law
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Speedup
Parallel Portion
50%
75%
90%
95%
1
2
4
8
16
32
64
128
256
512
1024
2048
4096
8192
16384
32768
65536
Number of Processors

Goals

- Introduction to state-of-the-art concurrency technologies
- Hands-on experience in designing high-performance algorithms
- First experience in parallel programming
- Evaluation of different approaches

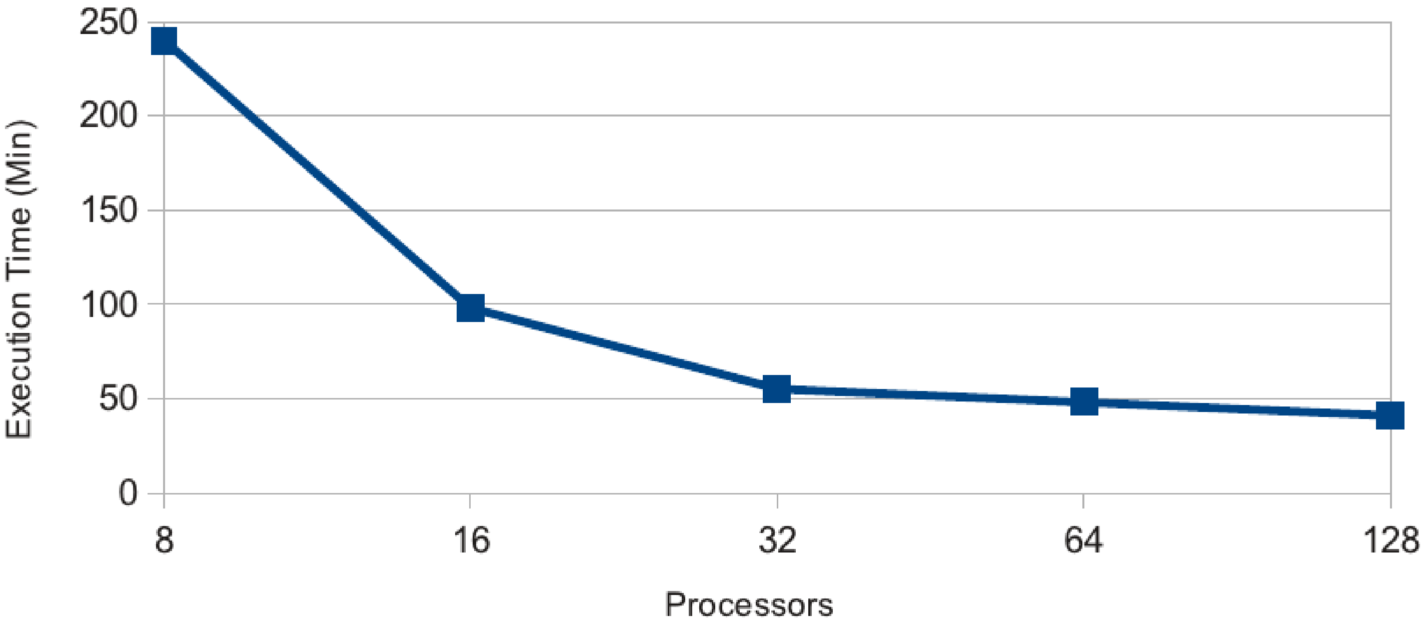
Submission

- **Intermediate presentation:**
  - Date: 15.6.2015 / 11:00 – 12:30 / room INF3105
  - Present the ideas/concepts at midterm

- **Final presentation:**
  - Date: 20.7.2015 / 11:00 – 12:30 / room INF3105
  - 5 tasks must be solved to pass the lab
  - Your program will be evaluated at the end of the lab
    - deliverables deadline: 13.7.2015 / 11:59 pm
  - Your presentation includes:
    - Program architecture
    - Experience gathered
    - Algorithm tricks

Required Measurements

- Total execution time for 1, 2, 4, 8 cores
- Show that your solution scales



Testing Machine

- ssh fcdsrl08.zih.tu-dresden.de
- 8 CPU machine
- accounts: (XX $\in$ {01, ... ,05})
  login: studentXX
  password: FCDstun_XX
- This is not a debugging machine!

Concurrency Concepts

- Thread Model
- Fork-Join Model
- Message Passing Model
- Actors Model

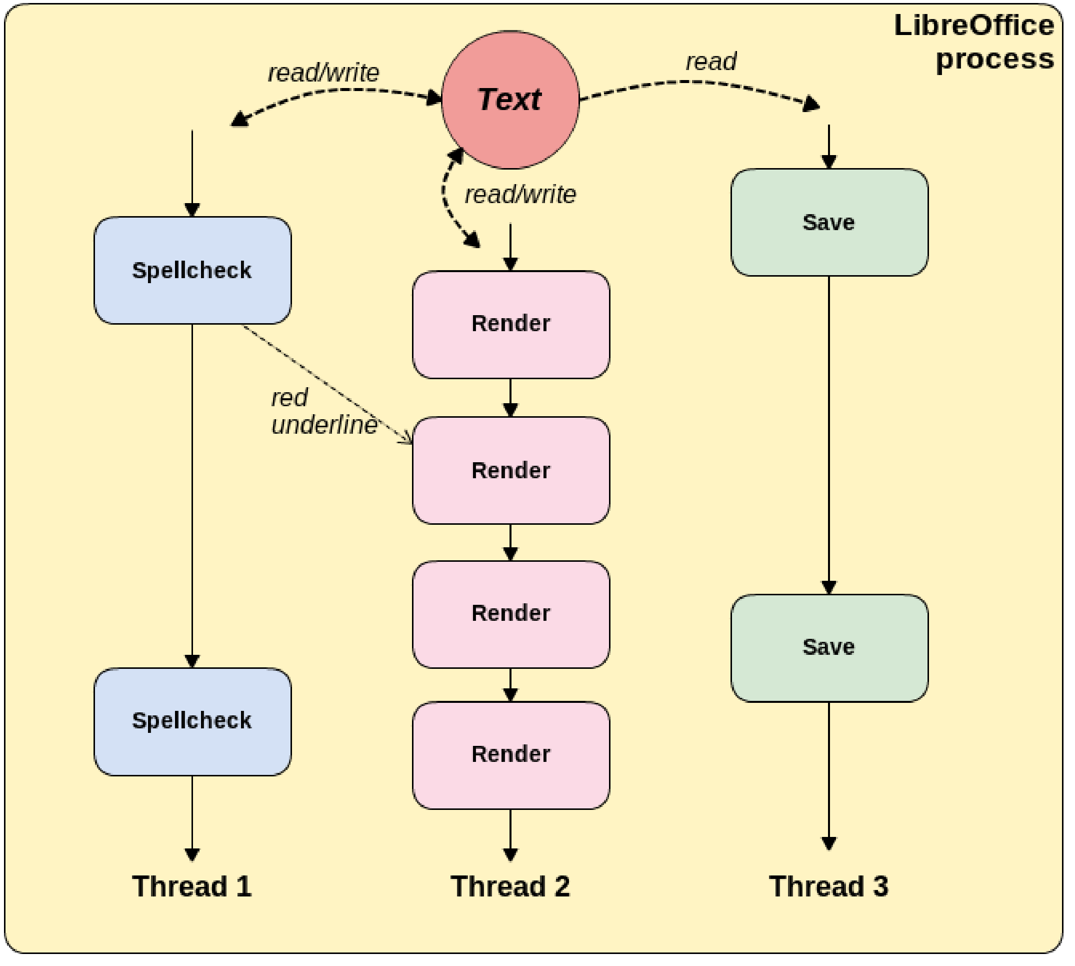
- Implementations: language/library

Thread Model

- Shared **memory model**
- **Single** "heavy weight" process has **multiple** "light weight", concurrent execution paths (threads)
- Threads communicate via shared variables (need to be careful: locks/semaphores) and/or sending signals
- Threads split the **tasks**
- Most control, least safety/comfort

- Implementations:
  - C (Pthreads)
  - C++ (Boost Threads)
  - Java (Thread/Runnable classes)
  - Python (threading module)

Threading Example

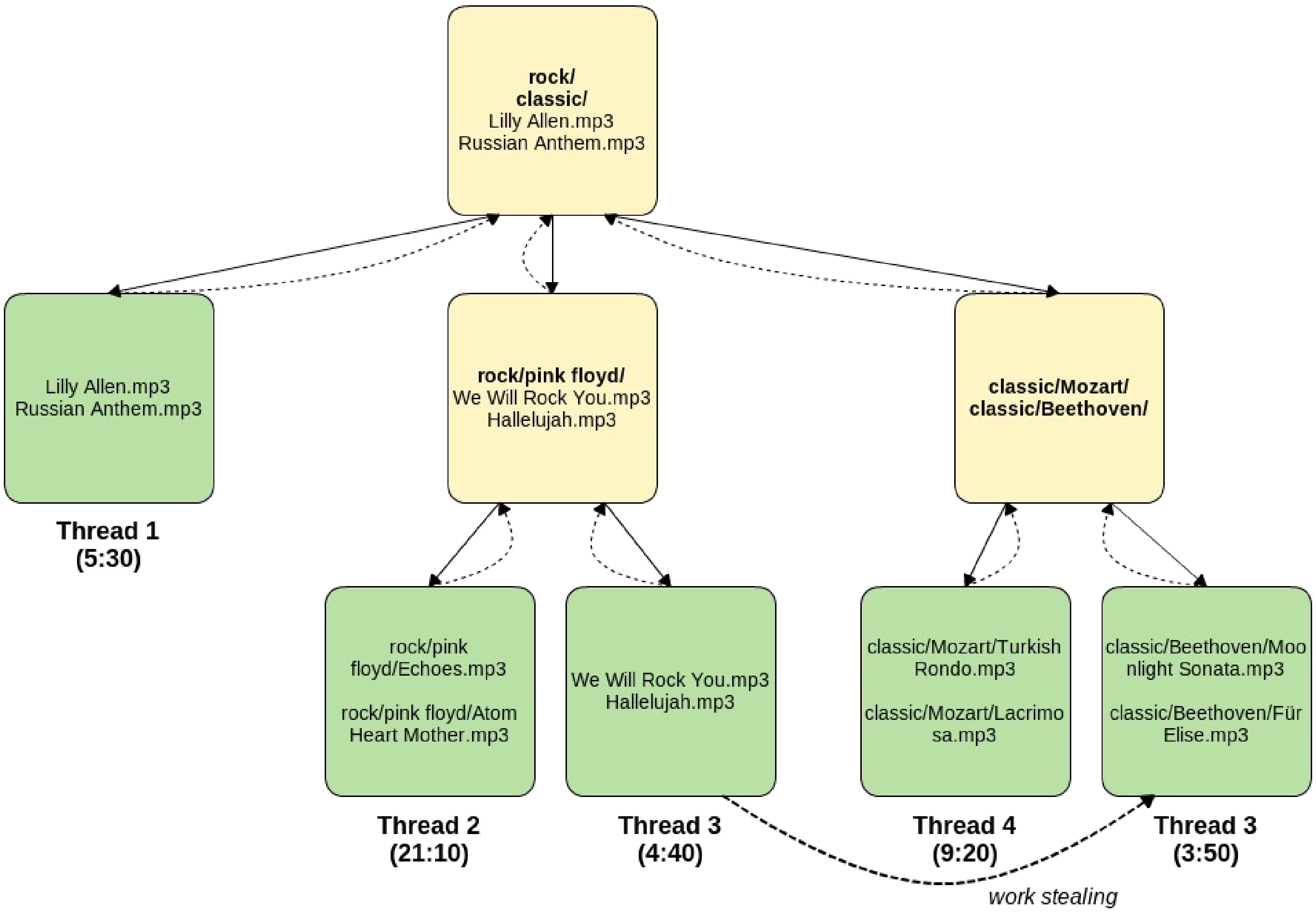


Fork-Join Model

- **Divide & Conquer** model to solve hierarchical problems
- Split a problem into smaller sub-problems and recursively apply the same algorithm to each sub-problem (**Fork**)
- Solutions of all sub-problems are combined to solve the initial problem (**Join**)
- Sub-problems do not share data: no locks, no races!

- Implementations:
  - Java (ForkJoinPool)
  - C OpenMP -- uses pragmas, gcc 4.3
  - Cilk Plus -- extension of C/C++, gcc 4.9

Fork-Join Example

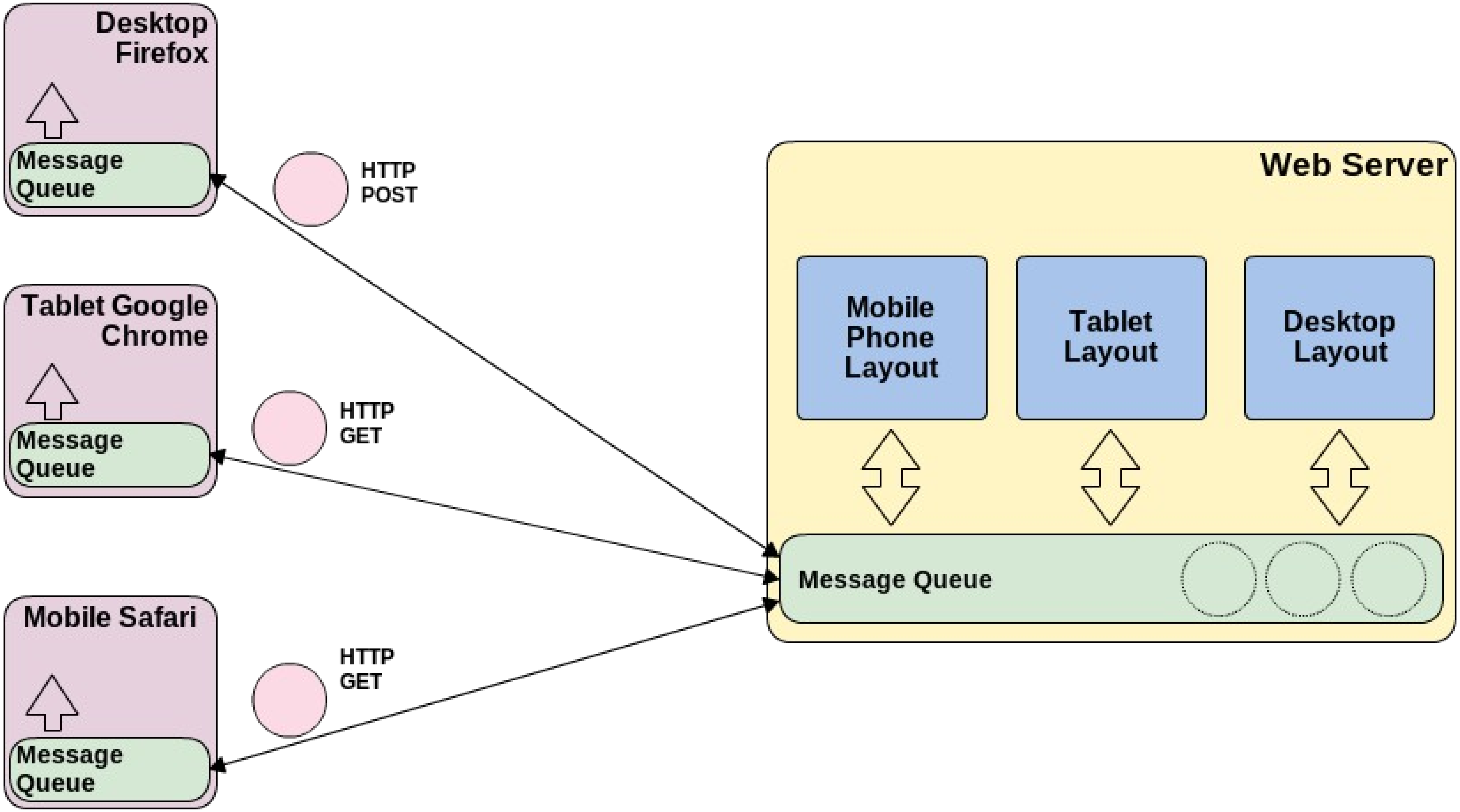


Message Passing Model

- Different **objects** (*actors*, *agents*) communicate only via sending and receiving messages
- No shared data – messages contain **full copies**
- Need an infrastructure to communicate – **channels** (*message queues, pipes, sockets*)
- Synchronous or Asynchronous
- Great for distributed programming, useful for concurrent programming

- Implementations:
  - ZeroMQ (bindings to C, C++, Java, Python, PHP, Ruby)

Message Passing Example



Actor Model

- Specific implementation of message passing
- Actors are **independent isolated** objects
- Actors communicate only via **asynchronous** messages:
  - Actor can send message to itself → recursion
  - Actors can create new actors and send their addresses to other actors
- Actors reuse the same threads from thread pool
- Implementations:
  - Erlang
  - Rust / D / Google Go

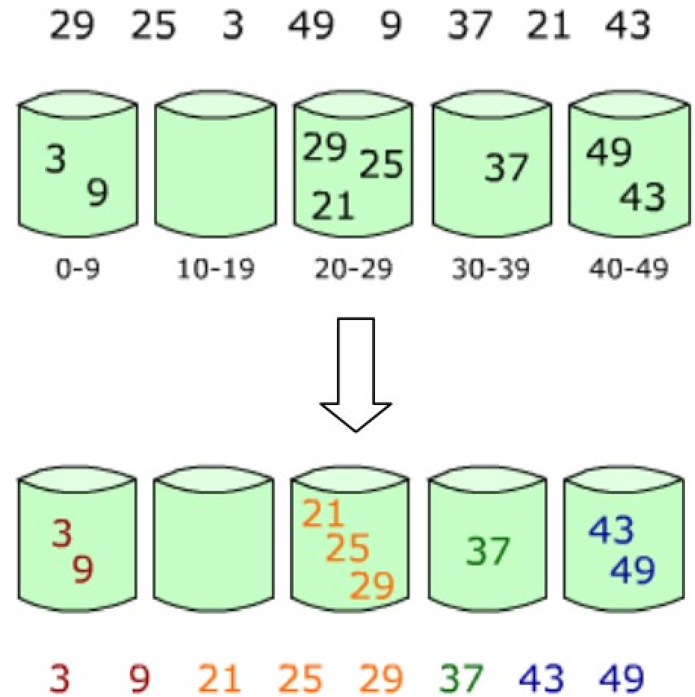
Tasks

- Tasks provided by the 7th Marathon of Parallel Programming 2012
  https://bitbucket.org/dimakuv/fcds-lab-2015

- Main requirements:
  - program correctness and concurrency
- 5 Tasks:
  - Bucketsort
  - Mutually Friendly Numbers
  - Haar Wavelets
  - Unbounded Knapsack Problem
  - 3SAT

Task 1: Bucketsort

1. Divide and Conquer algorithm
2. Partition input array into **buckets**
3. Sort each bucket **individually**



Task 2: Mutually Friendly Numbers

1. Two numbers are **mutually friendly**
   - if the ratio of the sum of all divisors of the number
   - and the number itself
   - is equal to the corresponding ratio of the other number
2. Find all pairs of numbers that are mutually friendly in specified range

$$\frac{1+2+3+5+6+10+15+30}{30}=\frac{72}{30}=\frac{12}{5}$$

$$\frac{1+2+4+5+7+10+14+20+28+35+70+140}{140}=\frac{336}{140}=\frac{12}{5}$$

Task 3: Haar Wavelets

1. Transformation to prepare images for compression
2. Input: matrix of ZxZ greyscale pixels
3. Each pass: calculate approximation and details coefficients
4. Next pass on smaller matrix

$t_0 = [\ 420\ \ 680\ \ 448\ \ 709\ \ 1420\ \ 1260\ \ 1600\ \ 1600\ ]$

$a_1 = (420+680) \div 2,\ d_1 = (420-680) \div 2$

$a_2 = (448+709) \div 2,\ d_2 = (448-709) \div 2$

$a_3 = (1420+1260) \div 2,\ d_3 = (1420-1260) \div 2$

$a_4 = (1600+1600) \div 2,\ d_4 = (1600-1600) \div 2,\ \therefore$

$t_1 = [\ 550\ \ 578\ \ 1340\ \ 1600\ \ -130\ \ -130\ \ 80\ \ 0\ ]$

$a_1 = (550+578) \div 2,\ d_1 = (550-578) \div 2$

$a_2 = (1340+1600) \div 2,\ d_2 = (1340-1600) \div 2$

$t_2 = [564\ \ 1470\ \ -14\ \ -130\ \ -130\ \ -130\ \ 80\ \ 0\ ]$

$a_1 = (564+1470) \div 2,\ d_1 = (564-1470) \div 2$

$t_3 = [1017\ \ -453\ \ -14\ \ -130\ \ -130\ \ -130\ \ 80\ \ 0\ ]$

Task 4: Unbounded Knapsack Problem

1. Resource allocation problem
2. You have a knapsack with **weight capacity** *M*
3. You also have *n* **types of items** with their **weights** and **values**
4. Cram so many items in the knapsack that:
   - the **total value** is the **maximum possible** and
   - the **total weight** does not **exceed** *M*
5. *Unbounded* means as many copies of each type of item as you like!

Task 5:We're Back: 3SAT

1. 3-satisfiability, where each clause contains **exactly** 3 literals
2. Literal is a **variable** or a **negation of variable**
3. Input: amount of clauses, amount of variables
4. Prove satisfiability:
   - If **at least one assignment** of variables exists when formula becomes TRUE, then function is **satisfiable**
   - If **no such assignment** exists (formula is always FALSE), then function is **unsatisfiable**

Our Suggestions

- You always wanted to try that new language or library?
  - Try it for this lab, we're happy with new approaches
- You don't have any preferences?
  - Choose from one of our suggestions

Language	C with Pthreads	Java with Fork/Join	Python with ZeroMQ	Google Go with go-routines	Rust
Parallel model	Threads	Fork/Join	Message Passing	Actors	Actors