

Parallel programming

Introduction



Libor Bukata a Jan Dvořák





Web sites

- <https://cw.fel.cvut.cz/wiki/courses/b4m35pag/start>

[\[courses:b4m35pag:start\]](#) COURSE WARE

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Paralelní algoritmy (B4M35PAG)

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Cvičící: Jan Dvořák a Libor Bukata

Rychlé odkazy: Paralelní algoritmy - cvičení, Upload system, Diskusní Fórum, Kde najdete místnosti, Rozvrh předmětu, Casový plán akademického roku.

Proč paralelní algoritmy?

Table of Contents
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• Proč paralelní algoritmy?
• Novinky
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• Osnova přednášek
• Hdnocení a zkouška
• Literatura

Novinky



Vítáme Vás na stránkách nového předmětu věnovaného paralelním algoritmům. Věříme, že předmět bude pro Vás přínosem.





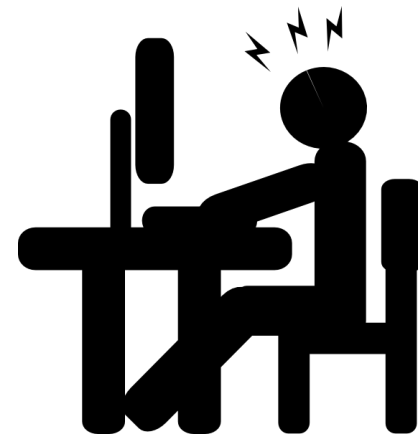
Academic calendar

1.	Introduction to Parallel programming
2.	C++11 threads – basic usage
3.	C++11 threads - advanced
4.	1. individual lab assignment (ILA), semestral work assignment
5.	Basics of OpenMP
6.	Advanced statements in OpenMP
7.	2. ILA, deadline for submission of 1. ILA
8.	<i>Consultation of the semestral work</i>
9.	OpenMPI
10.	3. ILA, deadline for submission of 2. ILA
11.	<i>Reserved</i>
12.	<i>Consultation of the semestral work</i>
13.	Presentation of results from semestral work
14.	Deadline for submission of 3. ILA



What is the aim of this lab?

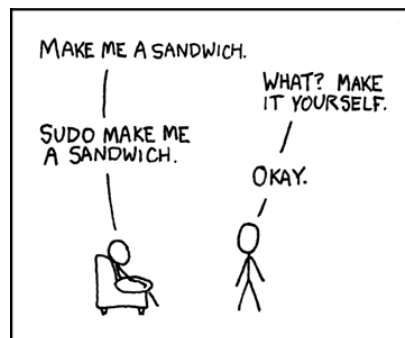
- To get the feel for parallel programming
 - 1) Understand what makes the parallelisation **complicated**
 - 2) Which **problems** can occur during the parallelisation
 - 3) What can be a **bottleneck**
 - 4) How to think about **algorithms** from the parallelisation point of view
- To get basic skills in common parallel programming frameworks
 - 1) for Multicore processors – C++11 threads, OpenMP
 - 2) for Computer clusters – OpenMPI



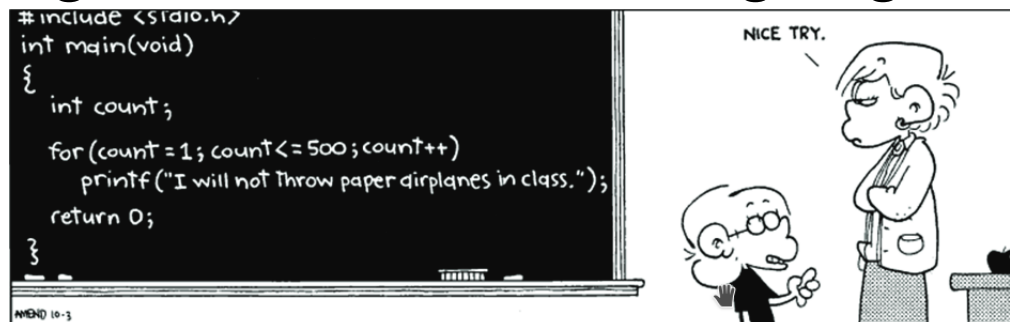


What this course requires?

- Basic skills with Linux – shell, ssh, etc.



- Knowledge of C and C++ language



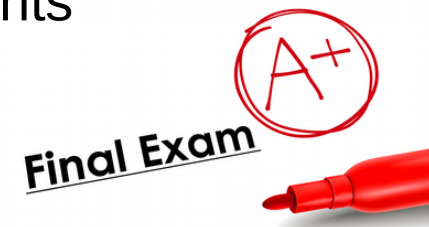
- Analytical thinking and opened mind





How will we evaluate you?

- Labs
 - Each Individual Lab Assignment – **7 points**
 - Semestral work – **14 points**
- Lectures
 - Teoretical test (optional) – **10 points**
- Final Exam
 - Written exam – **45 points**
 - Oral exam – **10 points**
- **Pass criteria:**
 - **Assignment:** Semestral work submitted + at least 25 points
 - **Exam:** At least 25 points from written exam





Parallel programming – the first cut

No questions?

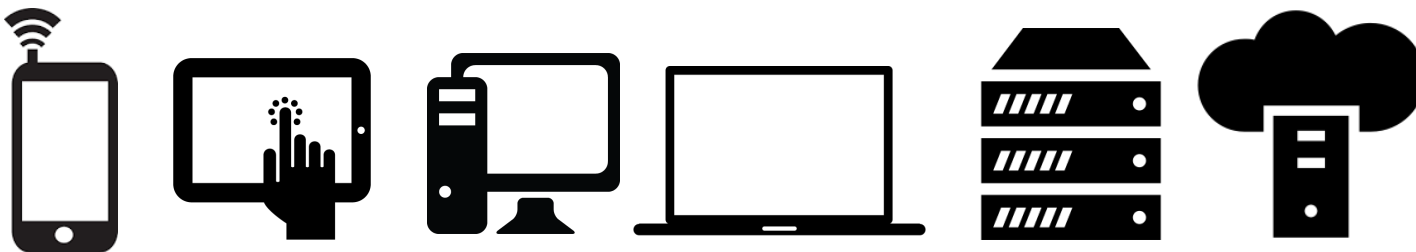
Let's start with our business!





Why should you care about it?

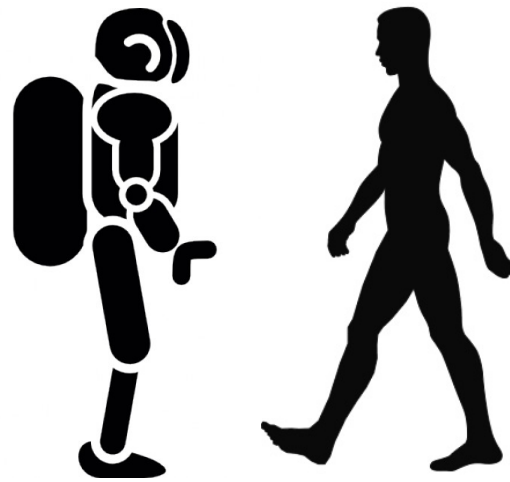
- Parallel computing is a dominant player in scientific and cluster computing. Why?
 - Moore law is reaching its limits
 - Increase in transistor density is limited
 - Memory access time has not been reduced at a rate comparable with processing speed
- How to get out of this trap?
 - Most promising approach is to have multiple cores on a single processor.
 - Parallel computing can be found at many devices today:





Ok; However, It should be task for compiler and not for me!!!

- Yes, compiler can help you, but without your guidance, it is not able pass all the way to the successful result.
 - Parallel programs often look very different than sequential ones.
 - An efficient parallel implementation of a serial program may not be obtained by simply parallelizing each step.
 - Rather, the best parallelization may be obtained by stepping back and devising an entirely new algorithm.

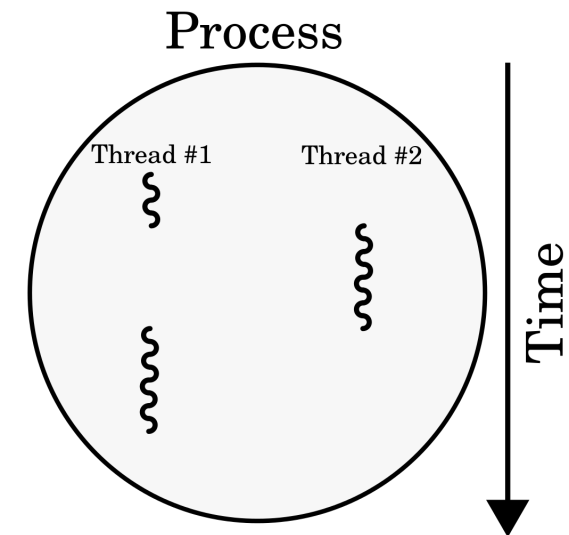


Basics of Parallel programming theory

Terms



- Program
 - Collection of instructions designed to perform a group of coordinated functions
- Process
 - Instance of a program that is being executed.
 - Multiple processes are typically independent
 - It has its own memory space.
- Thread
 - Sequence of instructions that is managed independently by system scheduler.
 - Subset of process
 - Multiple threads within process share the memory space.
- Task
 - Unit of execution

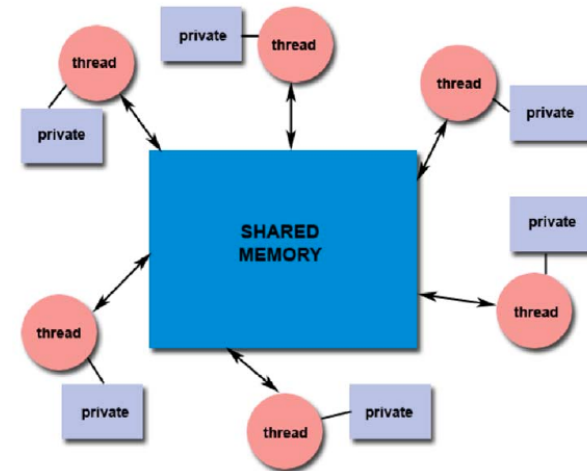


Basics of Parallel programming theory

Memory architectures

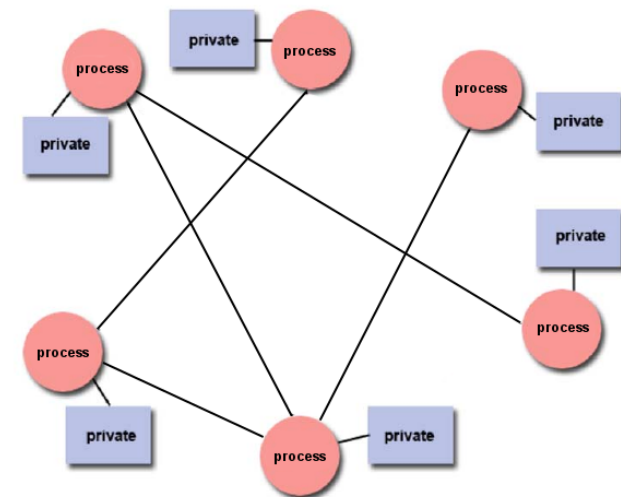
- **Shared memory**

- All functional units share the common memory space.
- When a functional unit share the value in the common memory space another functional unit can access this value.



- **Distributed memory**

- Each functional unit has its own private memory space.
- When two or more units need to share a value, they have to exchange this value by a message transmitted through the network.

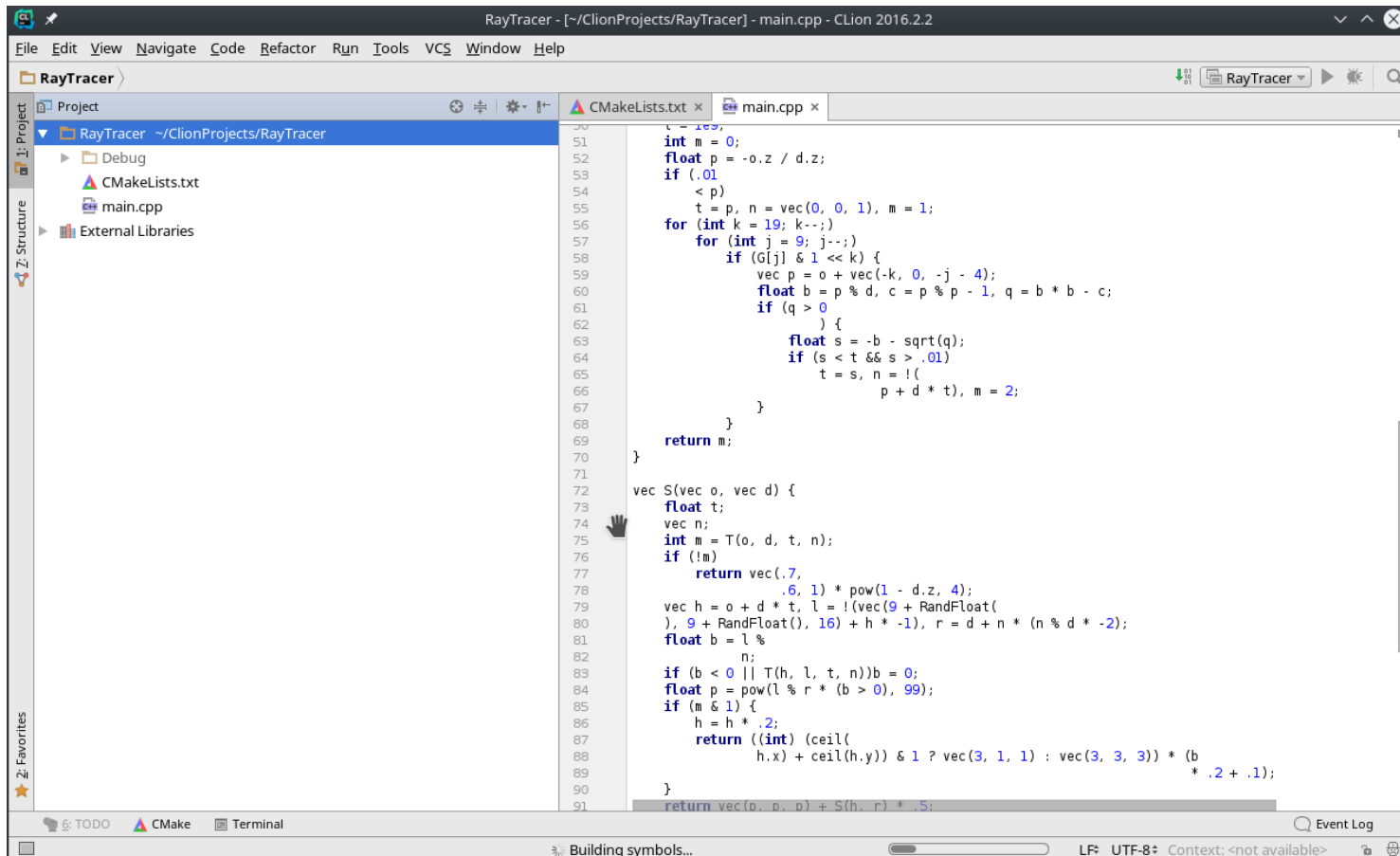




That was theory and now something practical!

Clion IDE

- Licence server - <https://turnkey.felk.cvut.cz/>



```
51 int m = 0;
52 float p = -o.z / d.z;
53 if (.01
54 < p)
55 t = p, n = vec(0, 0, 1), m = 1;
56 for (int k = 19; k--;)
57   for (int j = 9; j--;)
58     if (G[j] & 1 << k) {
59       vec p = o + vec(-k, 0, -j - 4);
60       float b = p % d, c = p % p - 1, q = b * b - c;
61       if (q > 0
62           ) {
63         float s = -b - sqrt(q);
64         if (s < t && s > .01)
65           t = s, n = !(
66             p + d * t), m = 2;
67       }
68     }
69   return m;
70 }
71
72 vec S(vec o, vec d) {
73   float t;
74   vec n;
75   int m = T(o, d, t, n);
76   if (!m)
77     return vec(.7,
78               .6, 1) * pow(1 - d.z, 4);
79   vec h = o + d * t, l = !(vec(9 + RandFloat(
80     ), 9 + RandFloat(), 16) + h * -1), r = d + n * (n % d * -2);
81   float b = l %
82     n;
83   if (b < 0 || T(h, l, t, n)) b = 0;
84   float p = pow(l % r * (b > 0), 99);
85   if (m & 1) {
86     h = h * .2;
87     return ((int) (ceil(
88       h.x) + ceil(h.y)) & 1 ? vec(3, 1, 1) : vec(3, 3, 3)) * (b
89       * .2 + .1);
90   }
91   return vec(b, p, p) + S(h, r) * .5;
```



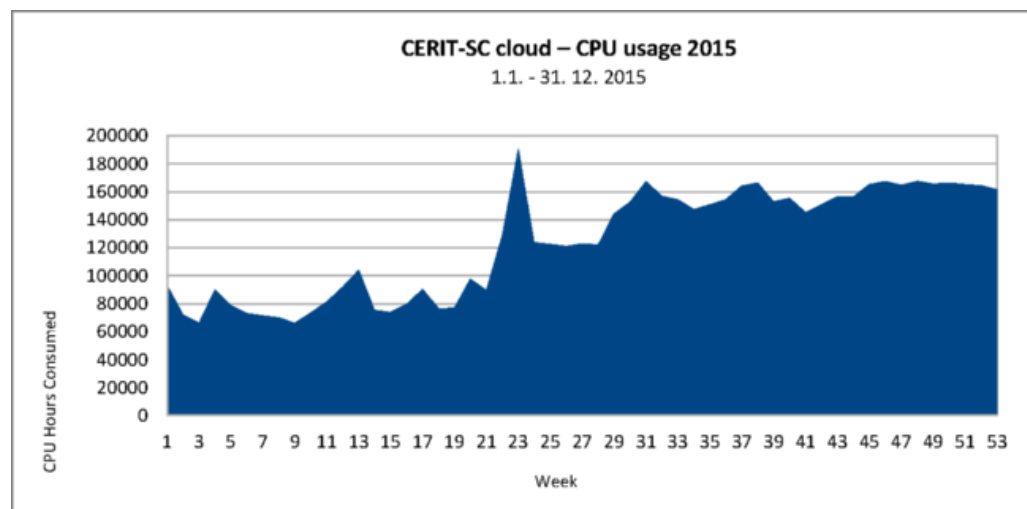
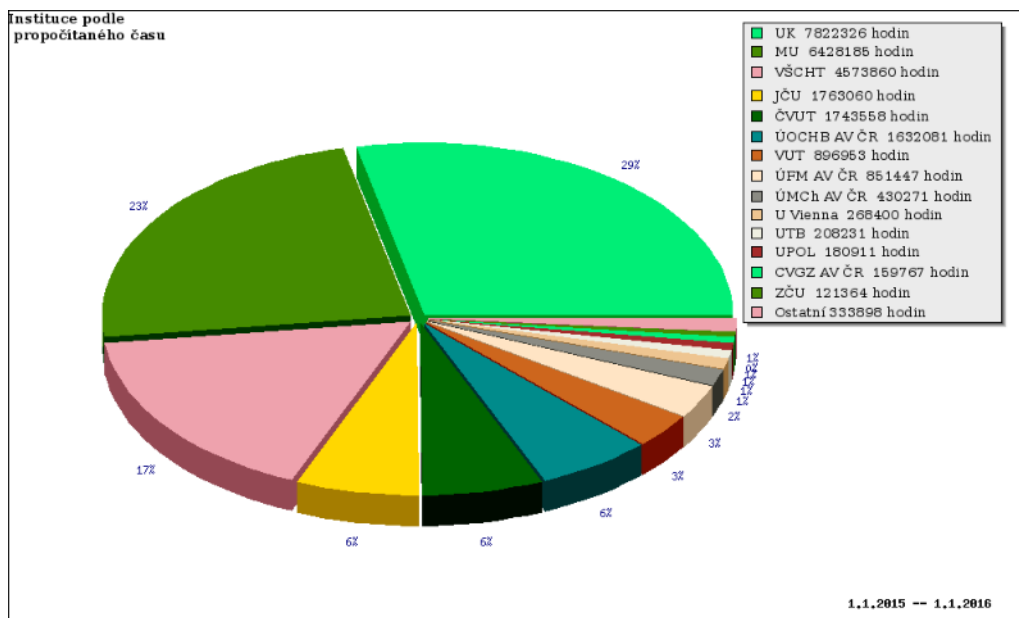
Hello world for free

- Live example and walk-through
 - Create project, Build code, Run code, Debug code,
 - Code profiling – valgrind, callgrind

```
1 seminar - Uvod [~/Seafile/PA_Library/Materials/Seminars/1. seminar - Uvod] - main.cpp - CLion 2016.2.2
File Edit View Navigate Code Refactor Run Tools VCS Window Help
1. seminar - Uvod
Project
1. seminar - Uvod ~/Seafile/PA_Library/Mate
External Libraries
Z: Structure
2: Favorites
1 #include <iostream>
2
3 int main() {
4     std::cout << "Hello, World!" << std::endl;
5     return 0;
6 }
LF UTF-8+ Context: BohatyProjekt [D]
```

Metacentrum system

- operates and manages **distributed computing** infrastructure consisting of computing and storage resources owned by **CESNET**
- MetaCentrum membership is free for researchers and students of academic institutions in the Czech Republic





MetaCentrum – Sign up

- How to sign up





Metacentrum – How to run code?

- Example of the execution of a program
 - qsub
 - module
 - \$SCRATCHDIR
 - \$PSB_O_WORKDIR
- Running jobs in MetaCentrum
 - https://wiki.metacentrum.cz/wiki/Running_jobs_in_scheduler
- Detailed description of the scheduling system
 - https://wiki.metacentrum.cz/wiki/Scheduling_system_-_detailed_description
- Application modules
 - https://wiki.metacentrum.cz/wiki/Application_modules



That was nice, wasn't it?

Thank you for your attention...

