Arhitecturi Paralele
Introducere

Lect. Dr. Ing. Cristian Chilipirea – cristian.chilipirea@mta.ro

Regulament

- Laboratoarele sunt obligatorii
  - Se pot prezenta cu o mică întârziere.
- Laboratoarele se rezolvă **individual** și vor fi verificate **anti-plagiat**
- Temele se rezolvă **individual** și vor fi verificate **anti-plagiat**

Indicații prevenire plagiat

Este **încurajată** folosirea Internetului. **Orice preluare trebuie corect citată**.

- **Laborator**
  - **NU** este permis mutat cod de la un student la altul.
  - Este permis uitat scurt unul peste codul celuilalt, arătat un detaliu mic.
  - Este **încurajată** discutarea problemelor.
- **Teme**
  - **NU** este permis copiat de cod (de pe net, de la coleg, de la terț).
  - **NU** este permis văzut codul unui coleg.
  - Se pot discuta probleme punctuale, dar **NU** spus explicit soluția.
- **Examen**
  - **NU** este permisă nici o interacțiune cu alte persoane.

Punctaje

6p Teme

- **Minim 50% punctaj pe fiecare temă pentru promovare**

2p Examen parțial

- **Minim 50% pentru promovare**

2p Examen final

- **Minim 50% pentru promovare**

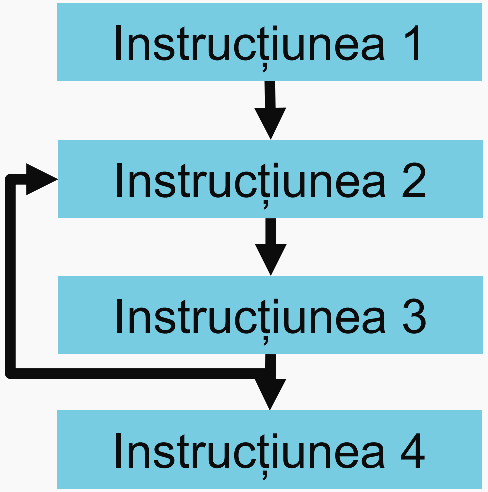
Obiective

Dezvoltarea abilităților pentru:

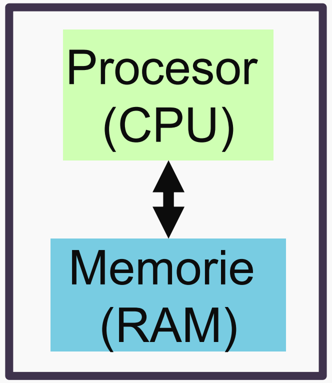
- Proiectarea și implementarea aplicațiilor multi-thread
- Proiectarea și implementarea aplicațiilor GPU
- Depanarea unor aplicații multi-thread și GPU
- Demonstrarea corectitudinii și scalabilității unui program multi-thread sau GPU
- Modelarea complexității unui algoritm multi-thread sau GPU
- Recunoașterea soluțiilor clasice de tip multi-thread sau GPU în probleme reale

Calcul Paralel vs Distribuit vs Secvențial

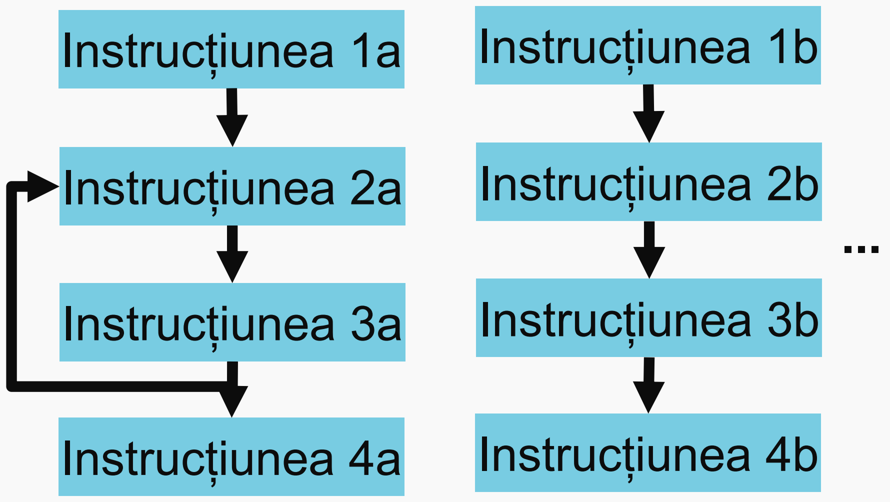
Calcul Secvențial

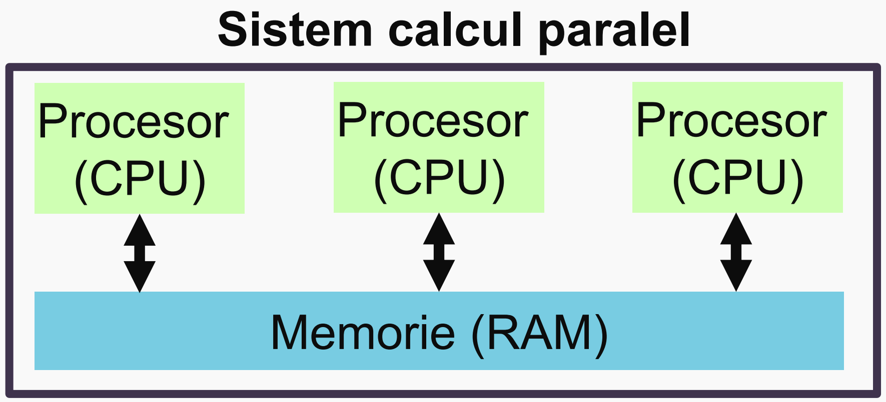


Sistem calcul secvențial

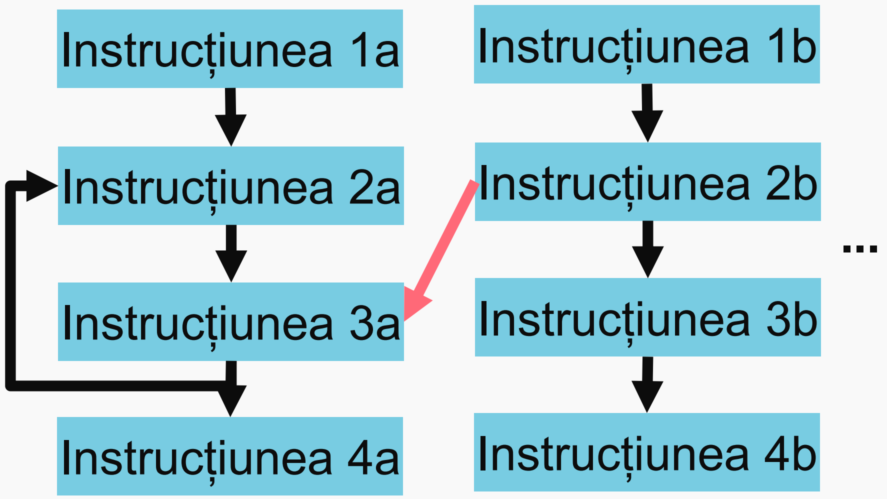


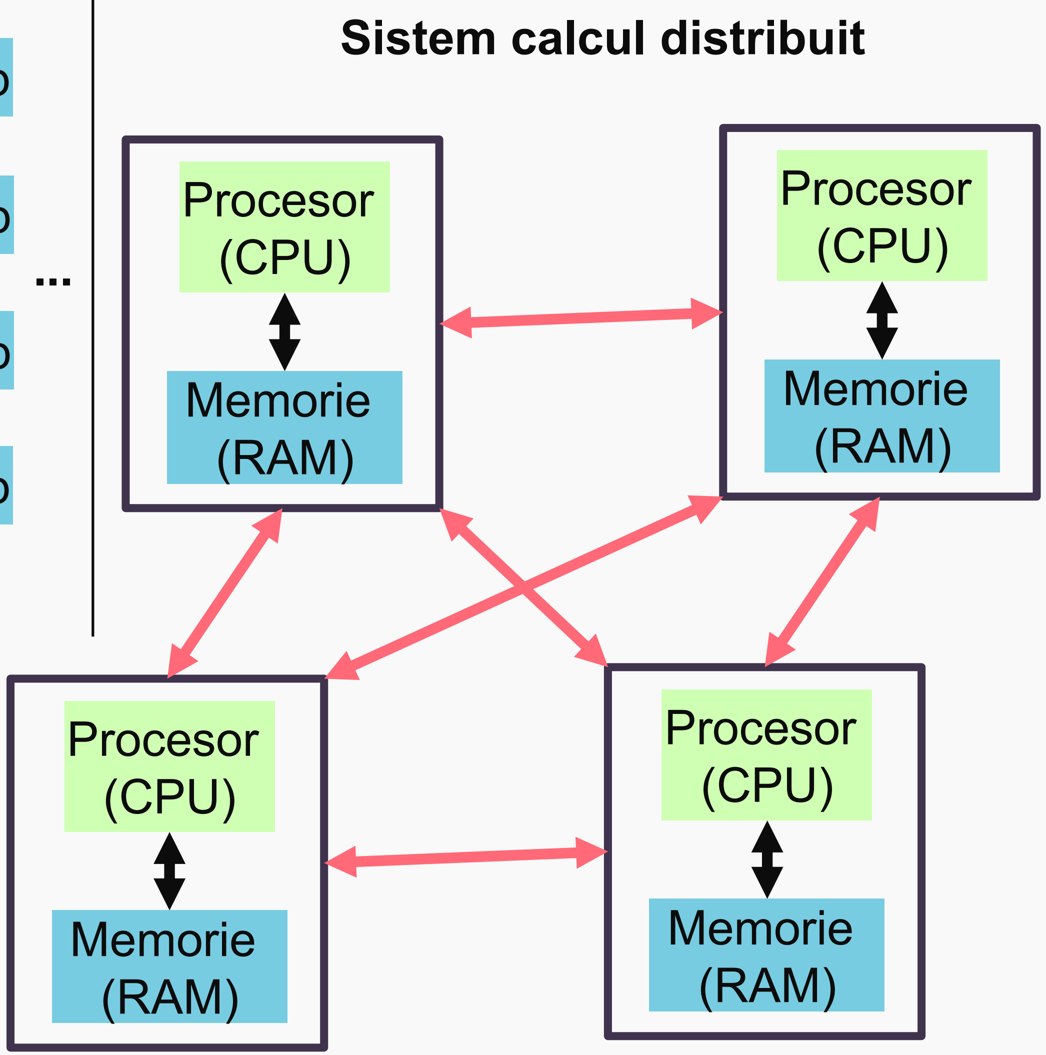
Calcul Paralel





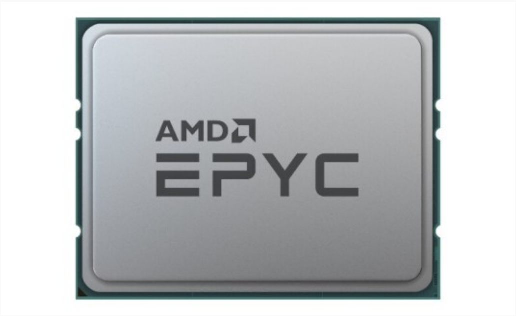
Calcul Distribuit



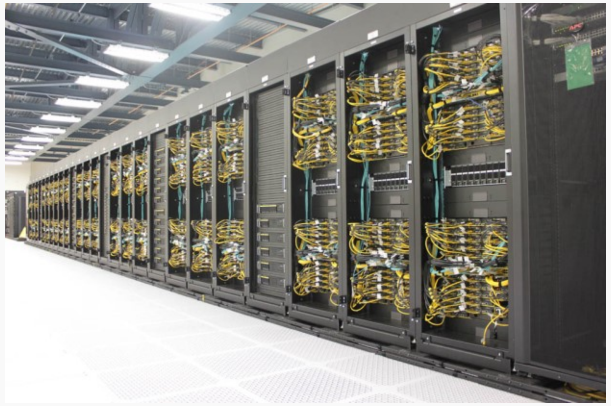


Resurse fizice

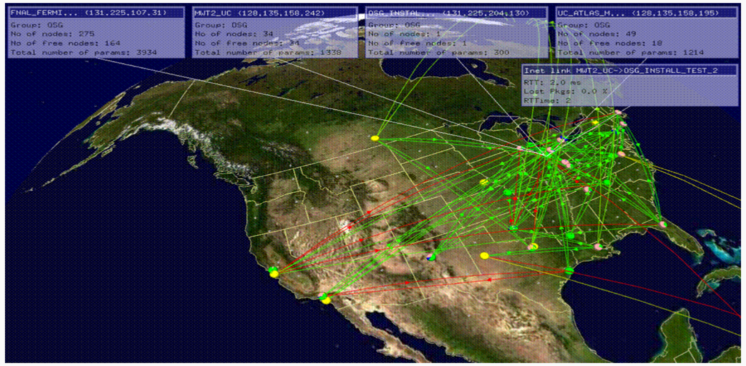
- Procesor – multi-core – 64 core-uri



- Cluster



- Grid/Cloud



Supercomputers

Rank	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	**Supercomputer Fugaku** - Supercomputer Fugaku, A64FX 48C 2.2GHz, Tofu interconnect D, Fujitsu RIKEN Center for Computational Science Japan	7,630,848	442,010.0	537,212.0	29,899
2	**Summit** - IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband, IBM DOE/SC/Oak Ridge National Laboratory United States	2,414,592	148,600.0	200,794.9	10,096
3	**Sierra** - IBM Power System AC922, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband, IBM / NVIDIA / Mellanox DOE/NNSA/LLNL United States	1,572,480	94,640.0	125,712.0	7,438
4	**Sunway TaihuLight** - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway, NRCPC National Supercomputing Center in Wuxi China	10,649,600	93,014.6	125,435.9	15,371
5	**Perlmutter** - HPE Cray EX235n, AMD EPYC 7763 64C 2.45GHz, NVIDIA A100 SXM4 40 GB, Slingshot-10, HPE DOE/SC/LBNL/NERSC United States	706,304	64,590.0	89,794.5	2,528

Fugaku

Summit

Sierra

Sunway TaihuLight

Perlmutter

BOINC computing power

Totals

24-hour average: 15.074 PetaFLOPS.

Active: 64,217 volunteers, 269,827 computers.

De ce calcul paralel?

- Timp de execuție mai scurt
- Permite abordarea problemelor de dimensiuni mari
- Reducerea costurilor
- Ascunderea timpilor de așteptare
- Scalabilitatea
- Scăderea timpului de răspuns

Limitele programării secvențiale?

Cramming More Components onto Integrated Circuits

GORDON E. MOORE, LIFE FELLOW, IEEE

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65 000 components on a single silicon chip.

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.

But the biggest potential lies in the production of large systems. In telephone communications, integrated circuits

Each approach
each borrowed te
believe the way
various approach

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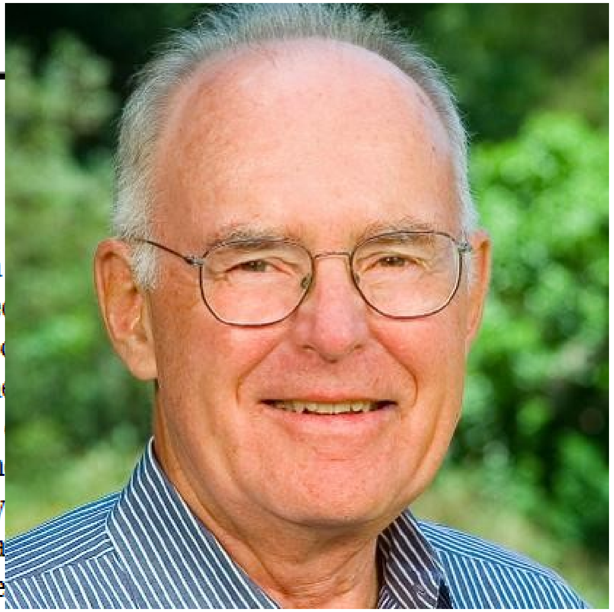
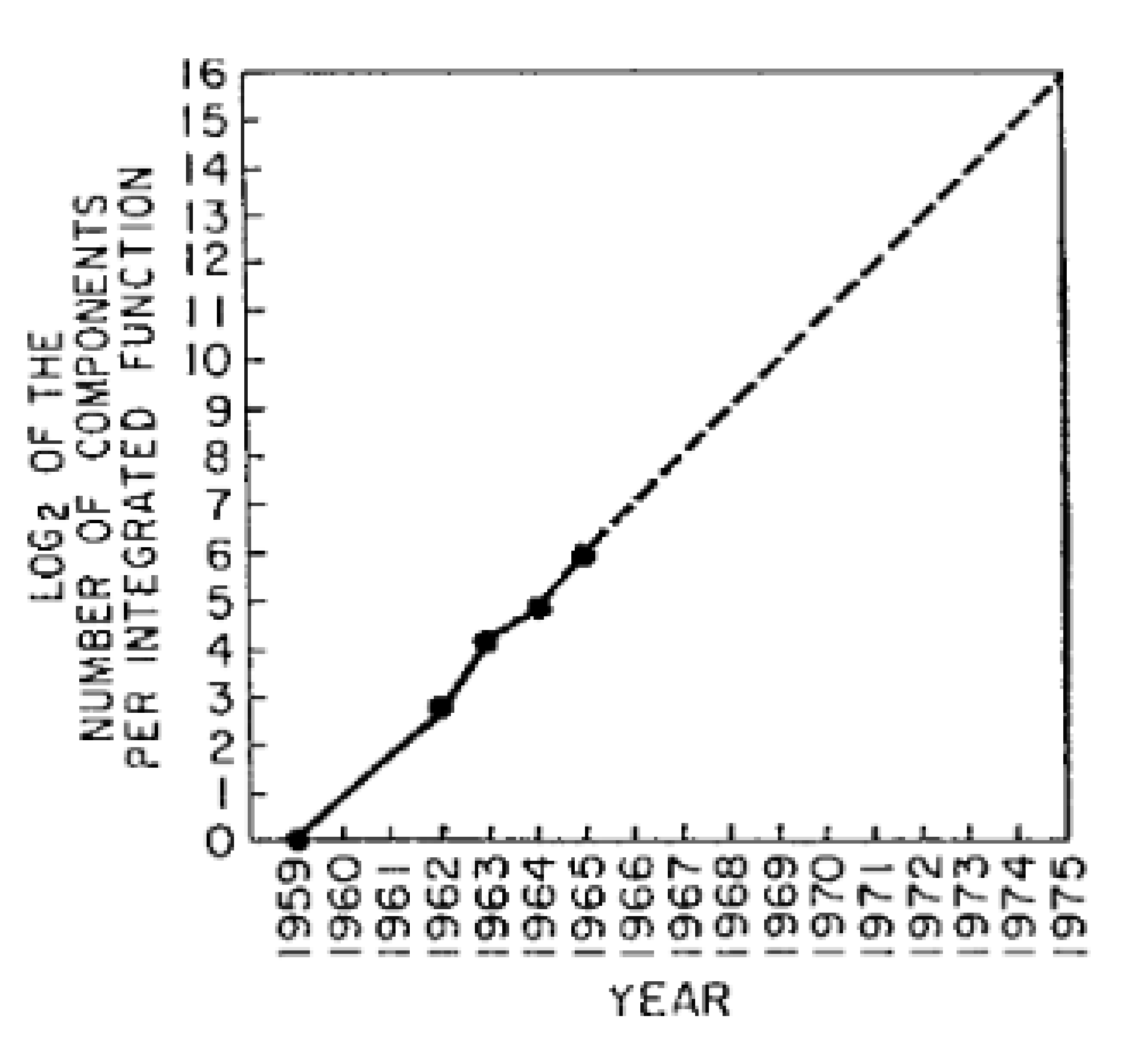
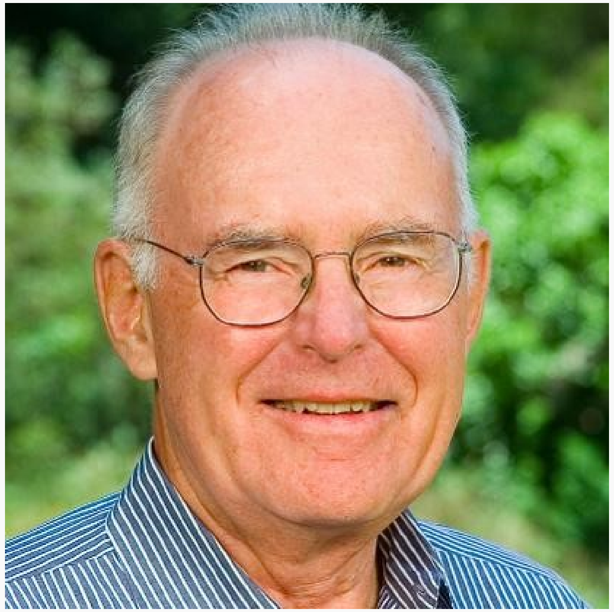
already using th
resistors by apply
conductor substra
upon films are de
attachment of active semiconductor devices to the passive film arrays.

Both approaches have worked well and are being used in equipment today.



Limitele programării secvențiale?





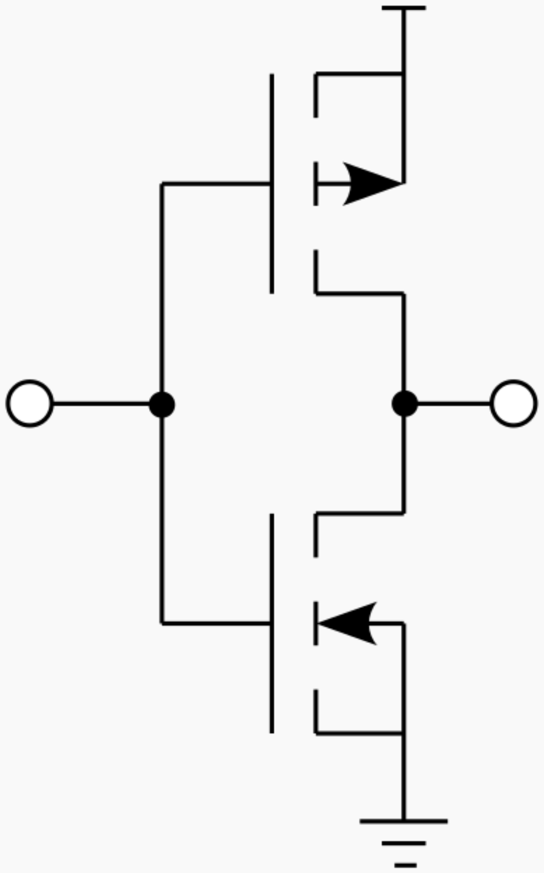
cofounded Intel

Limitele programării secvențiale

- Viteza de transmisie
  - **Maxim c – viteza luminii**
- Miniaturizare
  - **Tranzistor de mărimea unui atom**
- Economic
  - **Costuri enorme pentru cercetare și proiectarea unui nou timp de procesor**

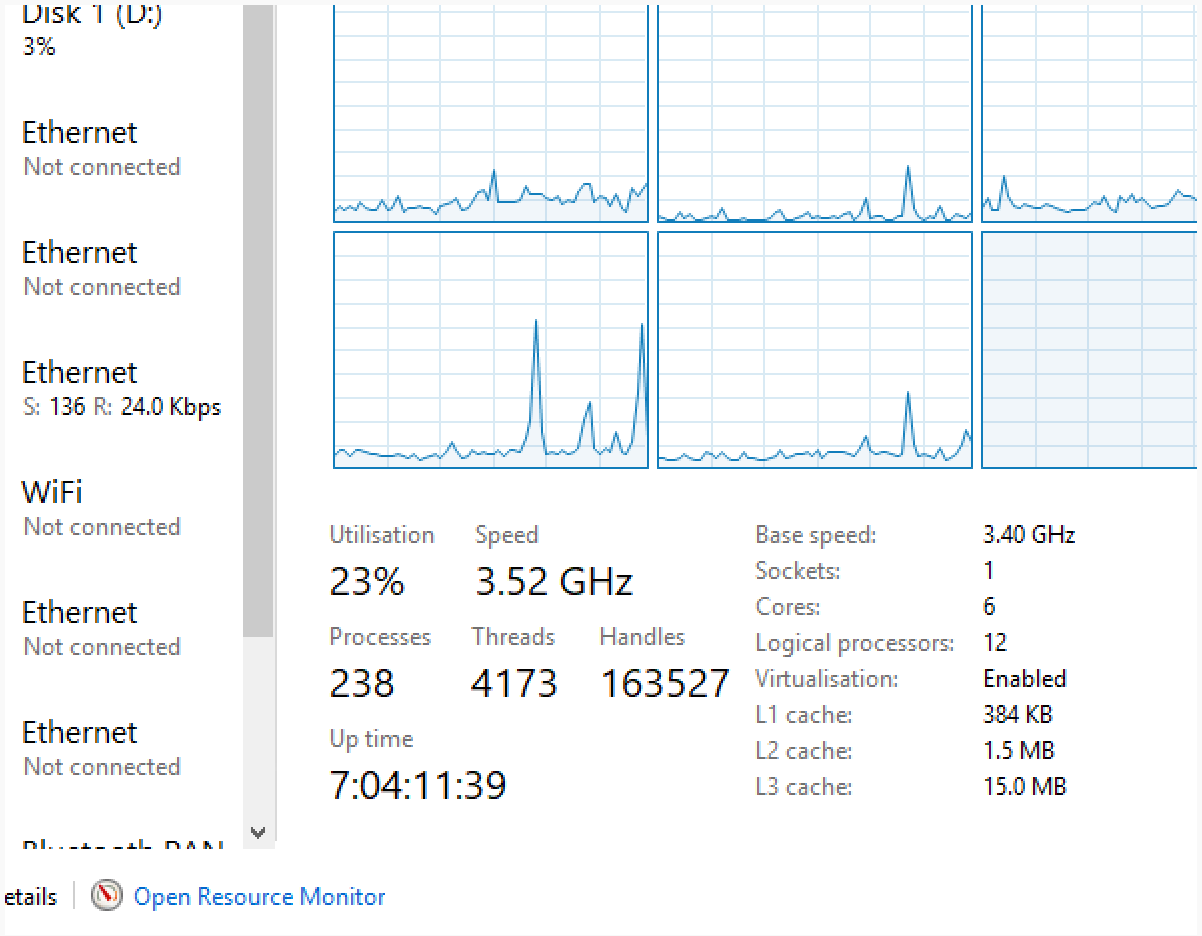
Limitele programării secvențiale

- CMOS

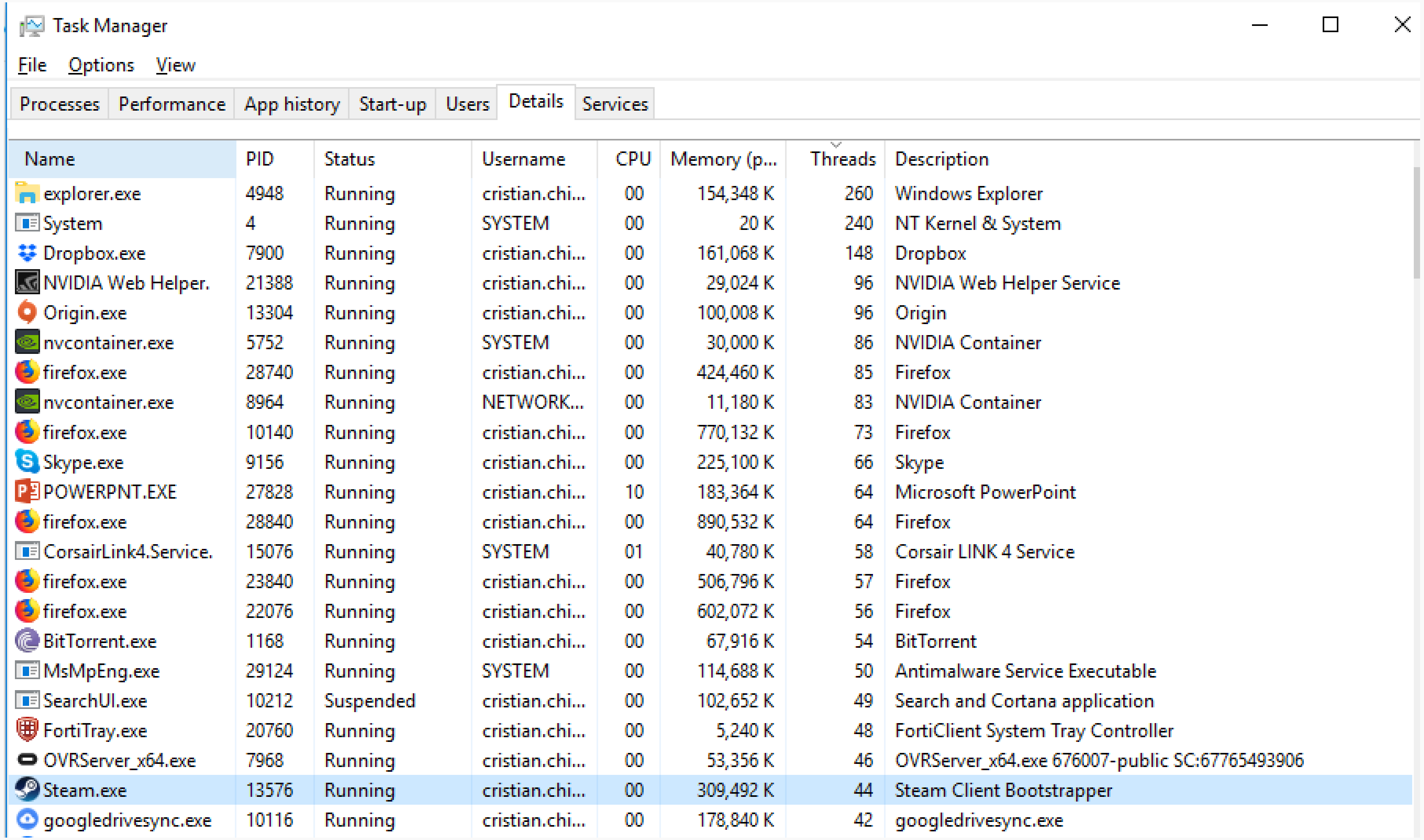


Importanța cursului

- Aproape toate aplicațiile au mai multe thread-uri



Importanța cursului



Task Manager

File Options View

Processes | Performance | App history | Start-up | Users | Details | Services

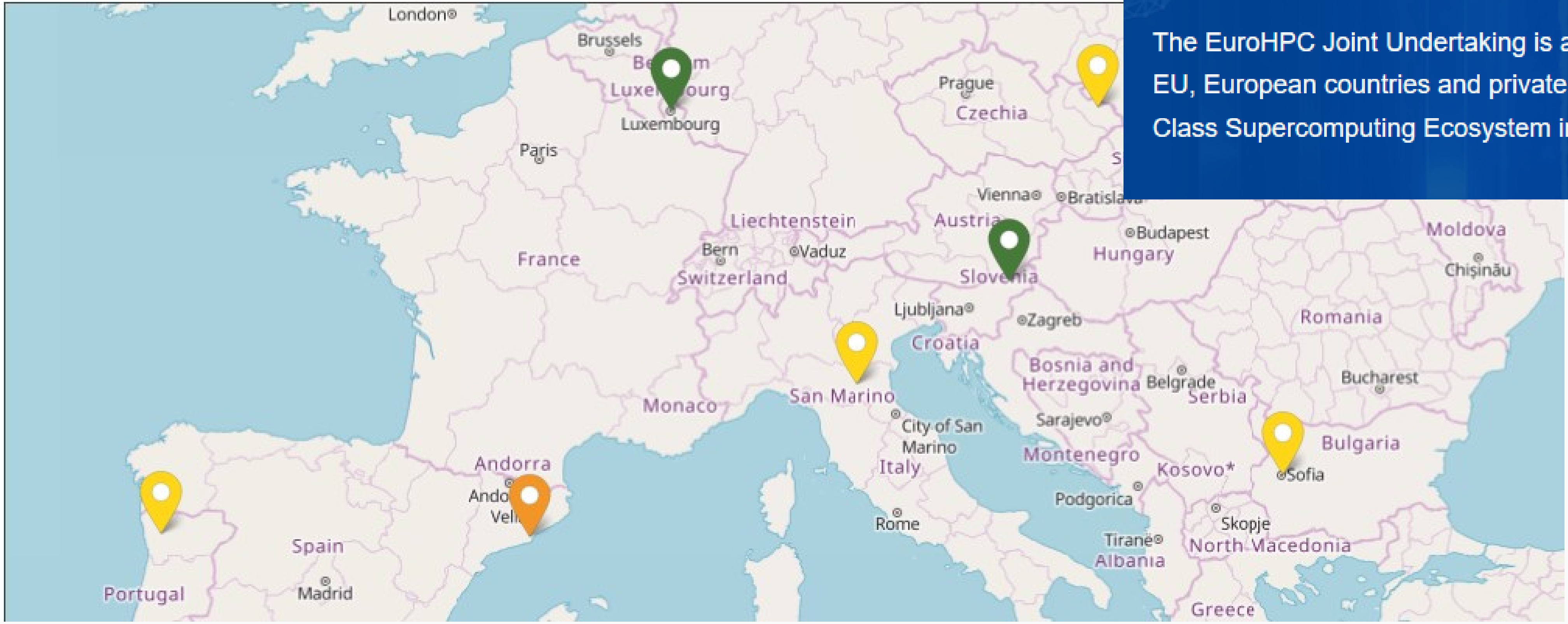
Name	PID	Status	Username	CPU	Memory (p...	Threads	Description
explorer.exe	4948	Running	cristian.chi...	00	154,348 K	260	Windows Explorer
System	4	Running	SYSTEM	00	20 K	240	NT Kernel & System
Dropbox.exe	7900	Running	cristian.chi...	00	161,068 K	148	Dropbox
NVIDIA Web Helper.	21388	Running	cristian.chi...	00	29,024 K	96	NVIDIA Web Helper Service
Origin.exe	13304	Running	cristian.chi...	00	100,008 K	96	Origin
nvcontainer.exe	5752	Running	SYSTEM	00	30,000 K	86	NVIDIA Container
firefox.exe	28740	Running	cristian.chi...	00	424,460 K	85	Firefox
nvcontainer.exe	8964	Running	NETWORK...	00	11,180 K	83	NVIDIA Container
firefox.exe	10140	Running	cristian.chi...	00	770,132 K	73	Firefox
Skype.exe	9156	Running	cristian.chi...	00	225,100 K	66	Skype
POWERPNT.EXE	27828	Running	cristian.chi...	10	183,364 K	64	Microsoft PowerPoint
firefox.exe	28840	Running	cristian.chi...	00	890,532 K	64	Firefox
CorsairLink4.Service.	15076	Running	SYSTEM	01	40,780 K	58	Corsair LINK 4 Service
firefox.exe	23840	Running	cristian.chi...	00	506,796 K	57	Firefox
firefox.exe	22076	Running	cristian.chi...	00	602,072 K	56	Firefox
BitTorrent.exe	1168	Running	cristian.chi...	00	67,916 K	54	BitTorrent
MsMpEng.exe	29124	Running	SYSTEM	00	114,688 K	50	Antimalware Service Executable
SearchUI.exe	10212	Suspended	cristian.chi...	00	102,652 K	49	Search and Cortana application
FortiTray.exe	20760	Running	cristian.chi...	00	5,240 K	48	FortiClient System Tray Controller
OVRServer_x64.exe	7968	Running	cristian.chi...	00	53,356 K	46	OVRServer_x64.exe 676007-public SC:67765493906
Steam.exe	13576	Running	cristian.chi...	00	309,492 K	44	Steam Client Bootstrapper
googledrivesync.exe	10116	Running	cristian.chi...	00	178,840 K	42	googledrivesync.exe

Importanța cursului

- Chiar și un procesor de ceas are mai multe core-uri
  - **TicWatch E3 – Snapdragon 4100**
    - Quad-Core
- Suport în noile IDE-uri
  - **Eclipse; Visual Studio**

Importanța cursului

EuroHPC supercomputers under deployment



EuroHPC
Leading the way in European Supercomputing

The EuroHPC Joint Undertaking is a joint initiative between the EU, European countries and private partners to develop a World Class Supercomputing Ecosystem in Europe.

Taxonomia Flynn

Some Computer Organizations and Their Effectiveness

MICHAEL J. FLYNN, MEMBER, IEEE

Abstract—A hierarchical model of computer organizations is developed, based on a tree model using request/service type resources as nodes. Two aspects of the model are distinguished: logical and physical.

General parallel- or multiple-stream organizations are examined as to type and effectiveness—especially regarding intrinsic logical difficulties.

The overlapped simplex processor (SISD) is limited by data dependencies. Branching has a particularly degenerative effect.

The parallel processors [single-instruction stream–multiple-data stream (SIMD)] are analyzed. In particular, a nesting type explanation is offered for Minsky's conjecture—the performance of a parallel processor increases as log M instead of M (the number of data stream processors).

Multiprocessors (MIMD) are subjected to a saturation syndrome based on general communications lockout. Simplified queuing models indicate that saturation develops when the fraction of task time spent locked out (L/E) approaches $1/n$, where n is the number of processors. Resources sharing in multiprocessors can be used to avoid

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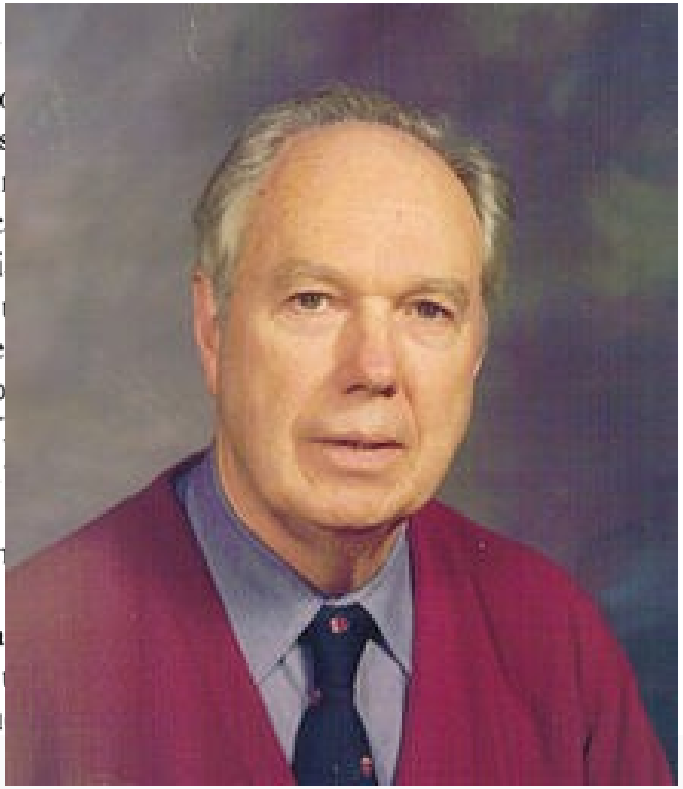
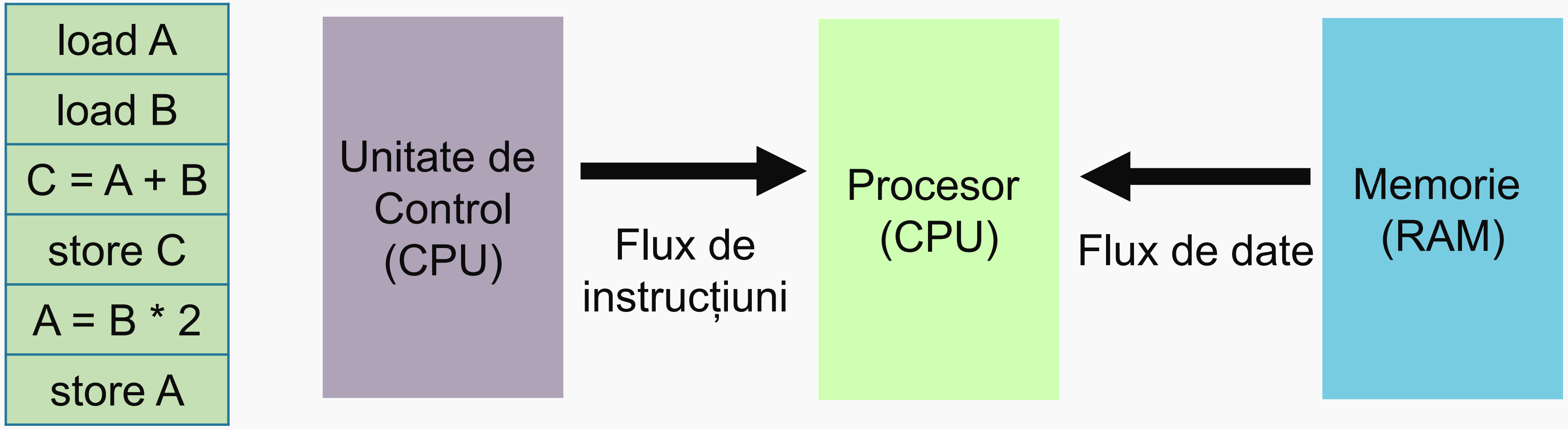


Taxonomia Flynn

- SISD
    - **Single Instruction Stream, Single Data Stream**
    - **Calculatorul “clasic” one-core**
- SIMD
    - **Single Instruction Stream, Multiple Data Streams**
    - **Suportul SSE; procesoare GPU**
- MISD
    - **Multiple Instruction Streams, Multiple Data Streams**
    - **Sisteme specializate**
- MIMD
    - **Multiple Instruction Streams, Multiple Data Streams**
    - **Procesoare actuale (ce aveți acasă și în buzunar)**

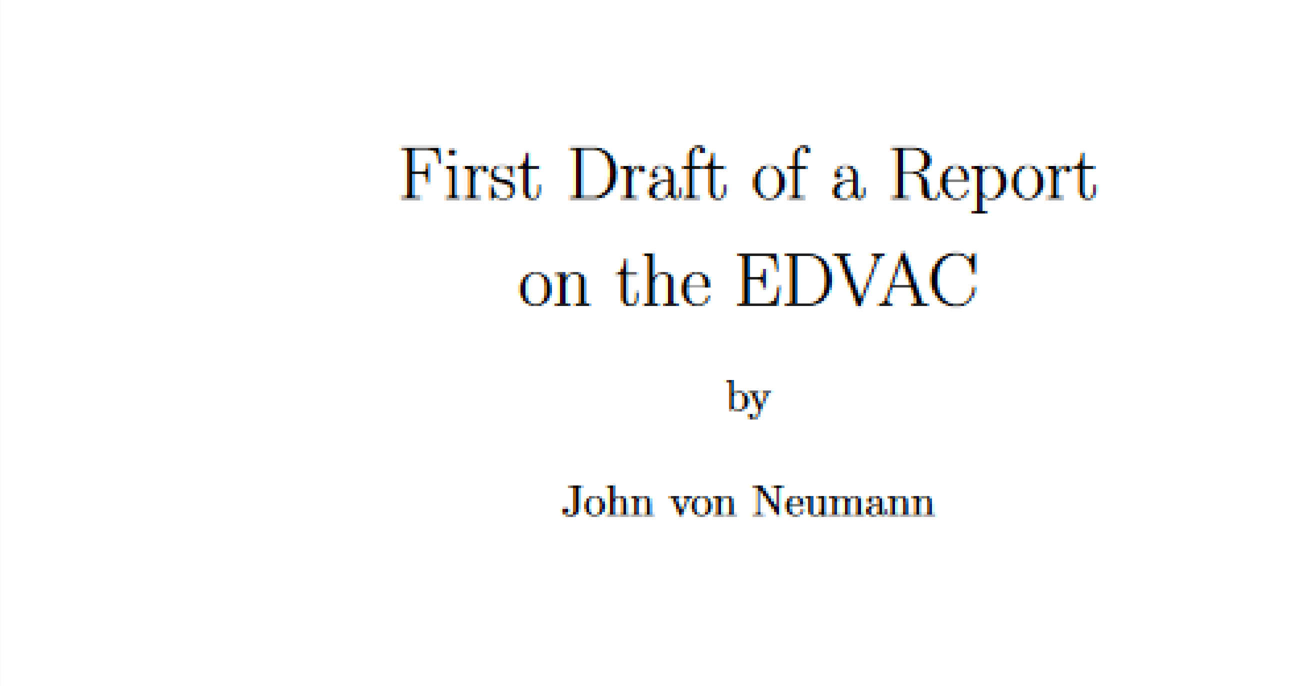
SISD

- Model clasic Arhitectura *von Neumann*



SISD

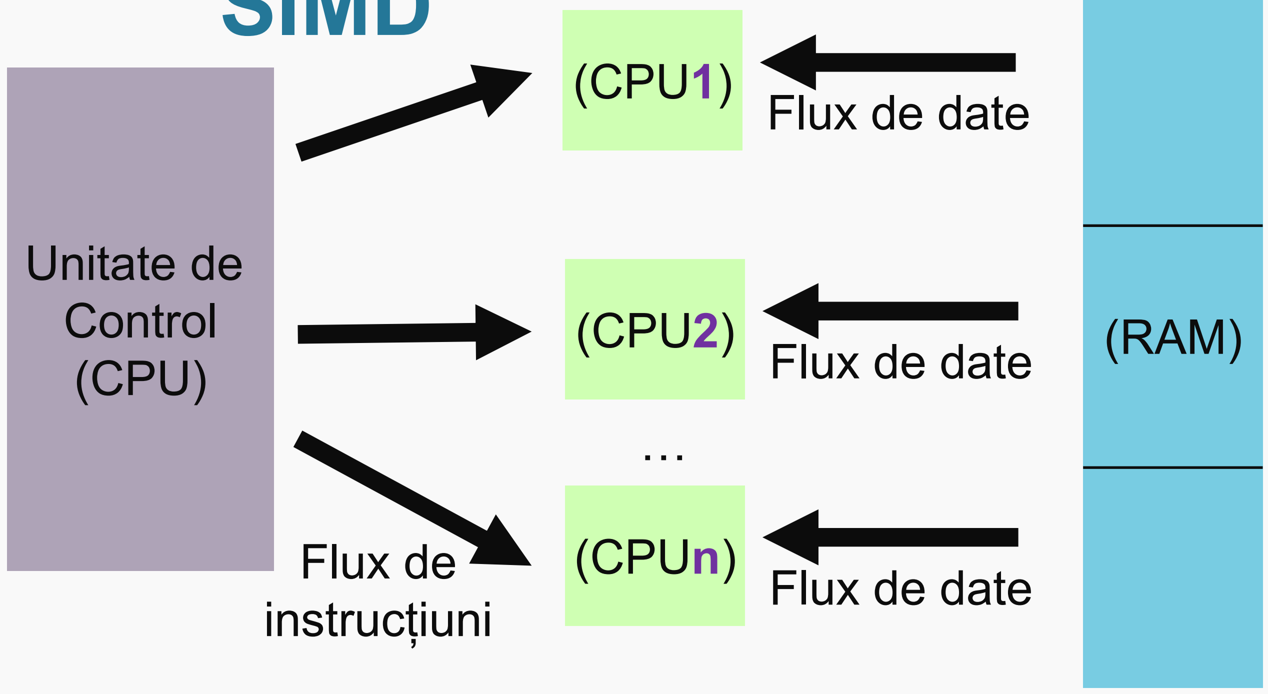
- Model clasic Arhitectura *von Neumann*


First Draft of a Report on the EDVAC

by

John von Neumann

SIMD



load A[1]	load A[2]		load A[n]
load B[1]	load B[2]	.	load B[n]
C[1] = A[1] + B[1]	C[2] = A[2] + B[2]	.	C[n] = A[n] + B[n]
store C[1]	store C[2]	.	store C[n]
A[1] = B[1] * 2	A[2] = B[2] * 2		A[n] = B[n] * 2
store A[1]	store A[2]		store A[n]

SIMD – Memorie Partajată

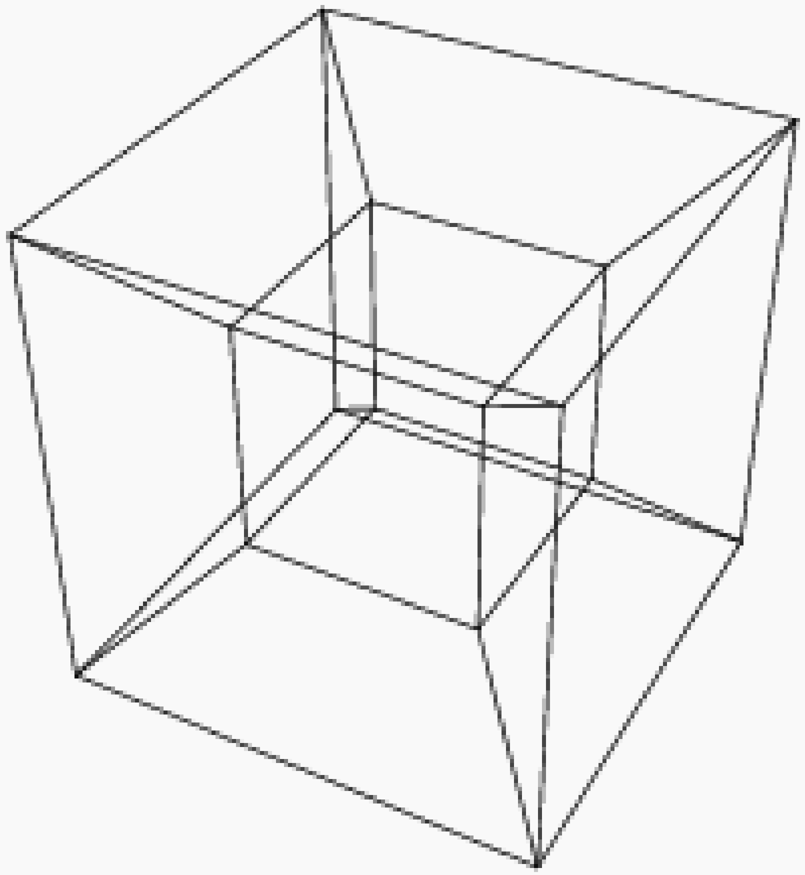
- Shared memory
  - **Parallel Random Access Memory**
  - **PRAM**

  - **EREW – Exclusive Read Exclusive Write**
  - **CREW – Concurrent Read Exclusive Write -- cel mai des întâlnit**
  - **ERCW – Exclusive Read Concurrent Write**
  - **CRCW – Concurrent Read Concurrent Write**

  - **O variabilă poate fi citiă într-un pas în model CR dar în log(N) în model ER.**

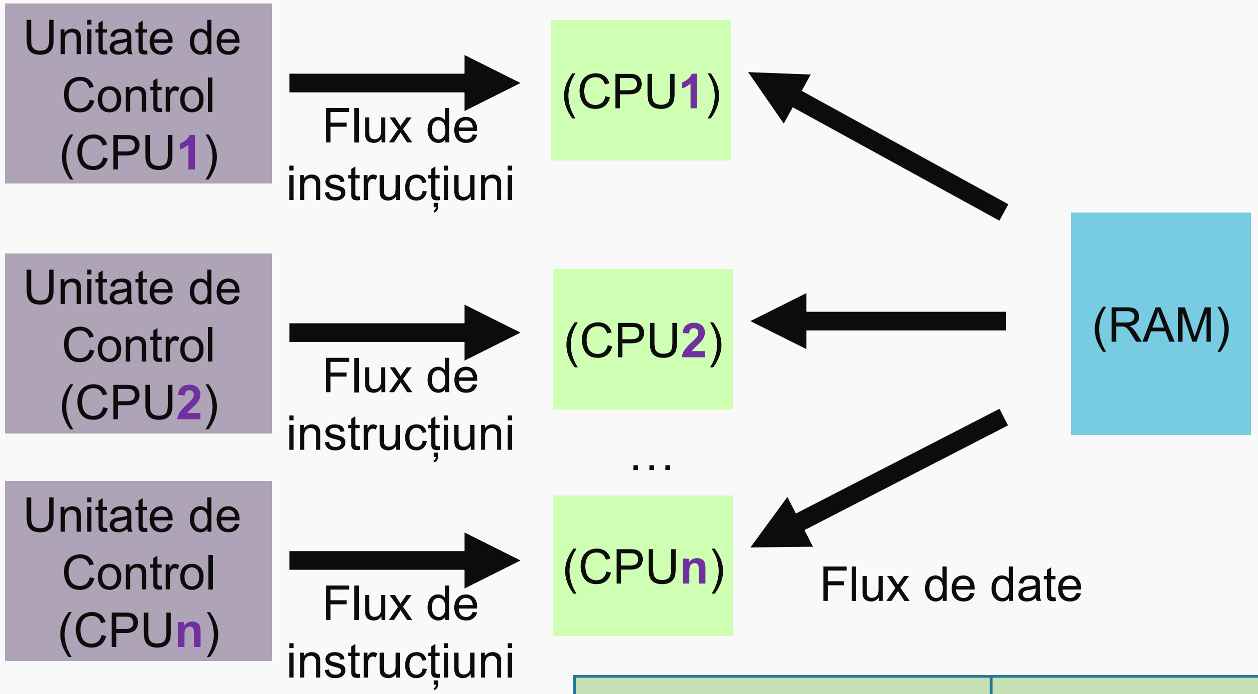
Rețele de configurare

- Topologii
  - **Tablou**
  - **Arbore**
  - **Cub**
  - **Hipercub**



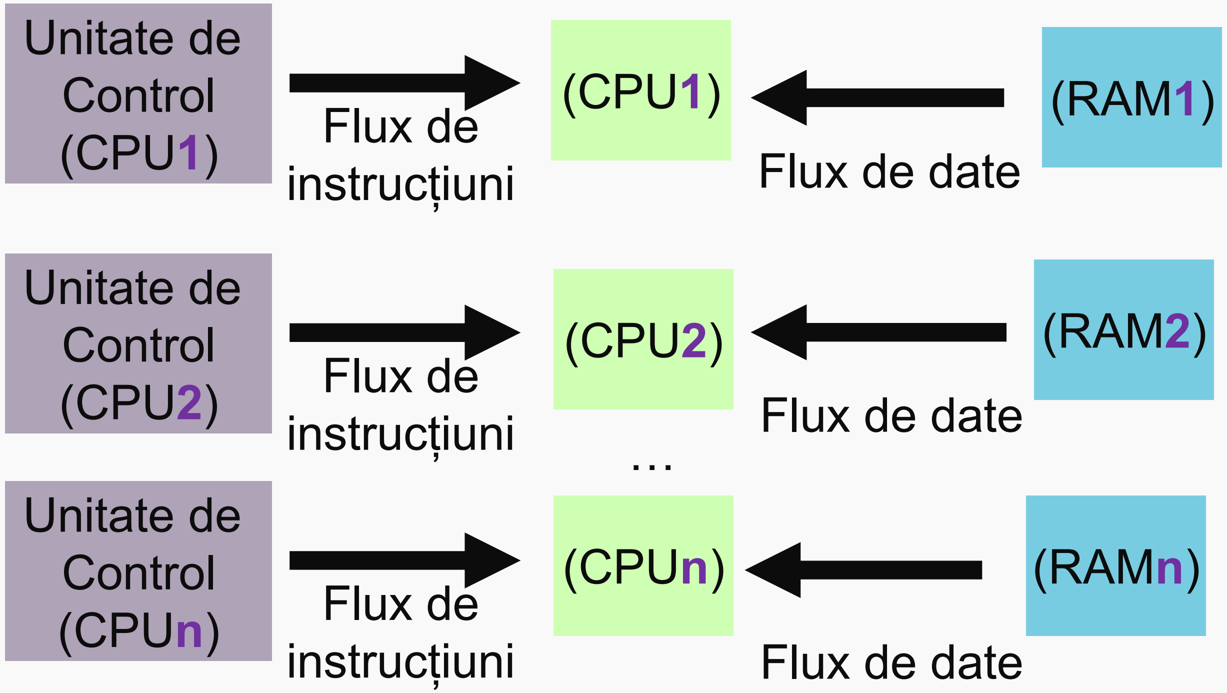
- Depinde de
  - **Aplicație**
  - **Performanțe dorite**
  - **Număr procesoare disponibile**
- Exemple: IBM 9000, Cray C90, Fujitsu VP

MISD



load A[1]	load A[1]		load A[1]
load B[1]	load B[1]	.	load B[1]
C[1] = A[1] + B[1]	C[1] = A[1] / B[1]	.	C[1] = A[1] * B[1]
store C[1]	store C[1]	.	store C[1]
A[1] = B[1] * 2	load D[1]		C[1] = A[1] + B[1]
store A[1]	A[1] = D[1]		store C[1]

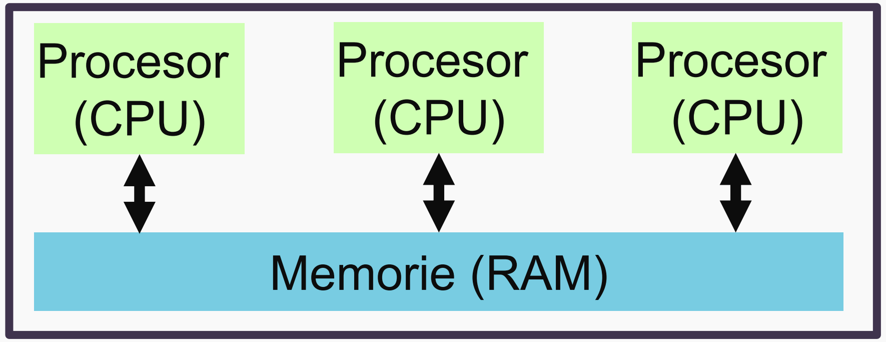
MIMD



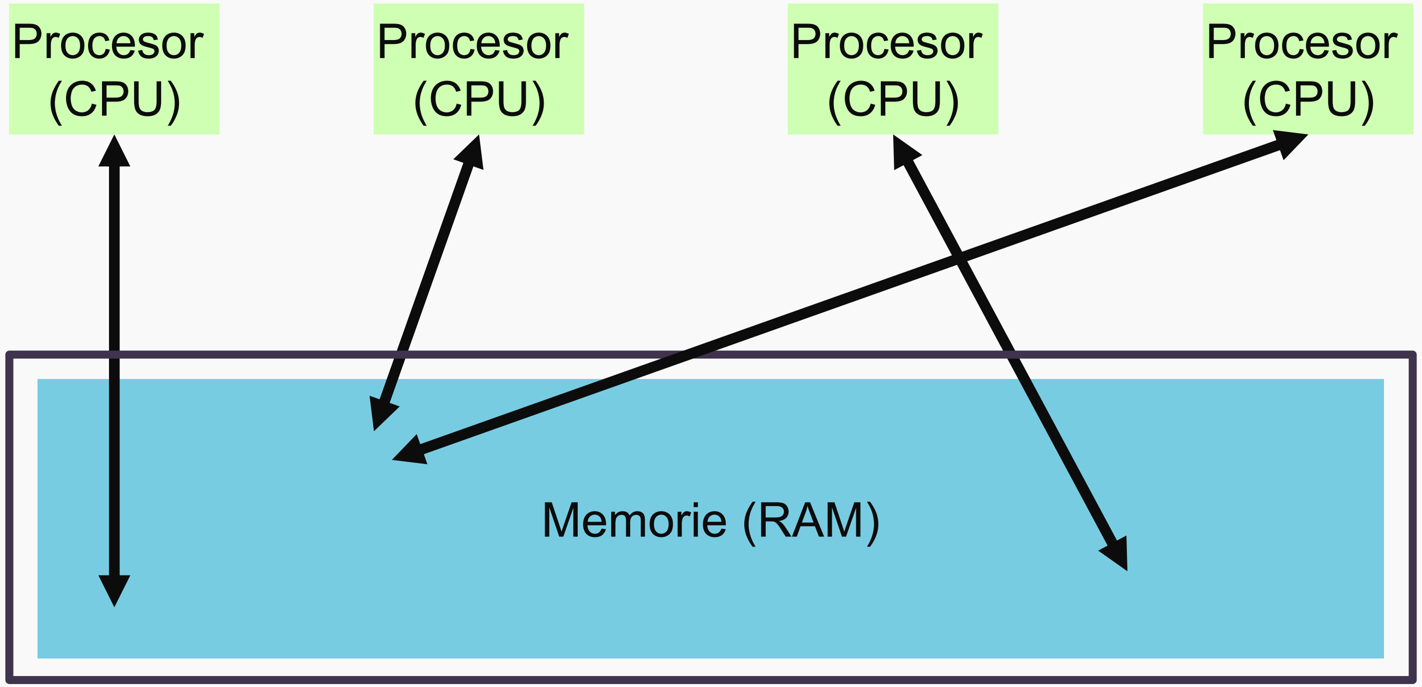
load A	load Z		A = B + C
D = A	store H	.	store A
load C	H=H*100	.	G[1] = G[2] + G[3]
load E	H++	.	store G[1]
load F	store H		G[4] = G[5] + G[6]

Memorie Partajată

- Uniform Memory Access **(UMA)**

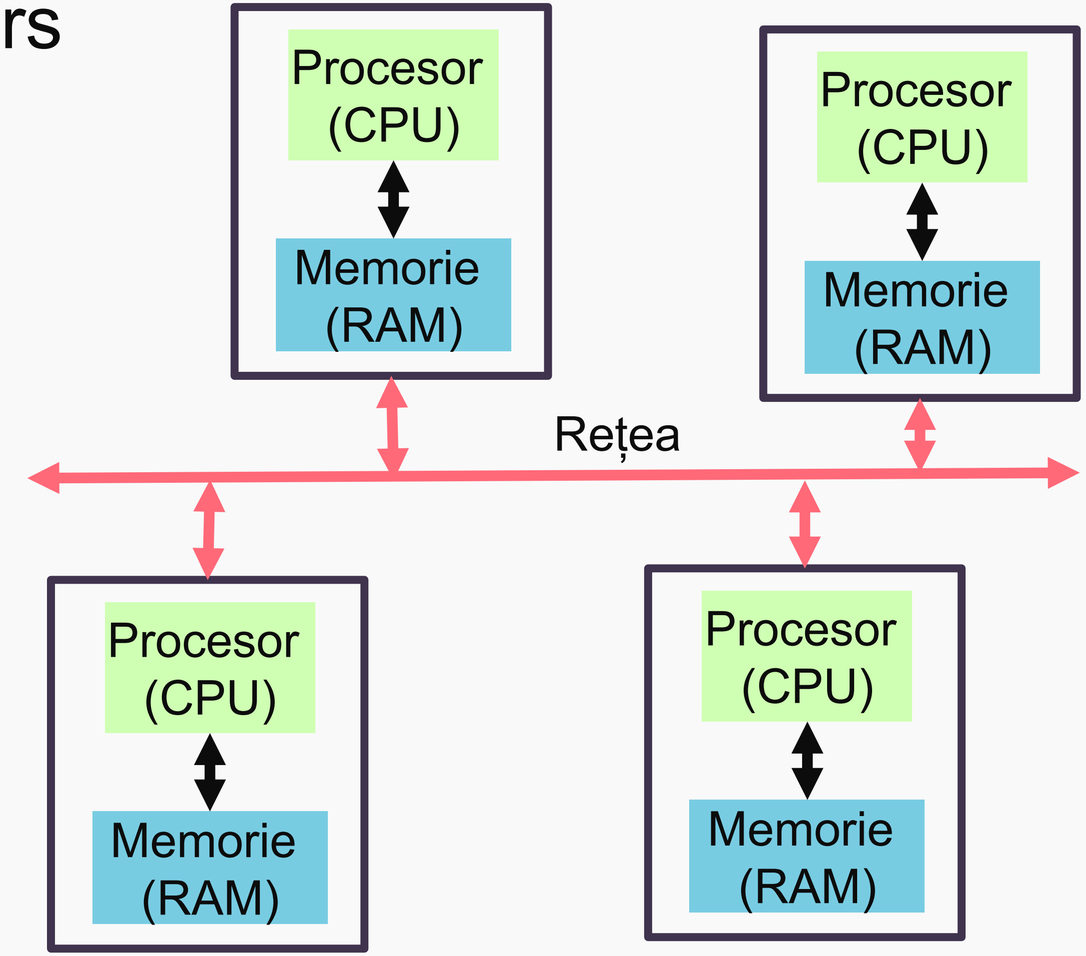


Memorie Partajată - Acces

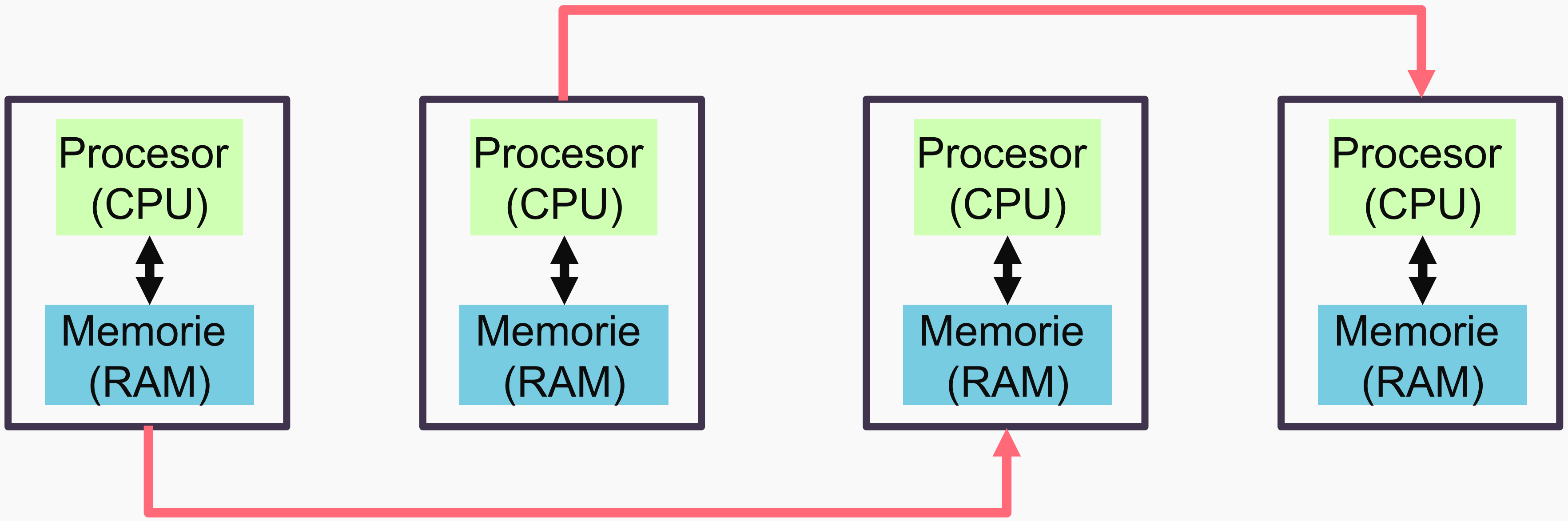


Memorie Distribuită

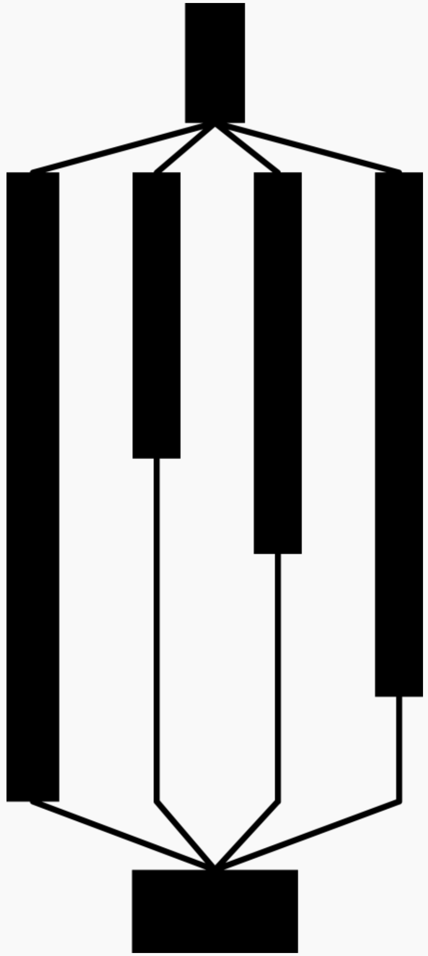
- Non-Uniform Memory Access **(NUMA)**
- Massively Parallel Processors
- Network of workstations

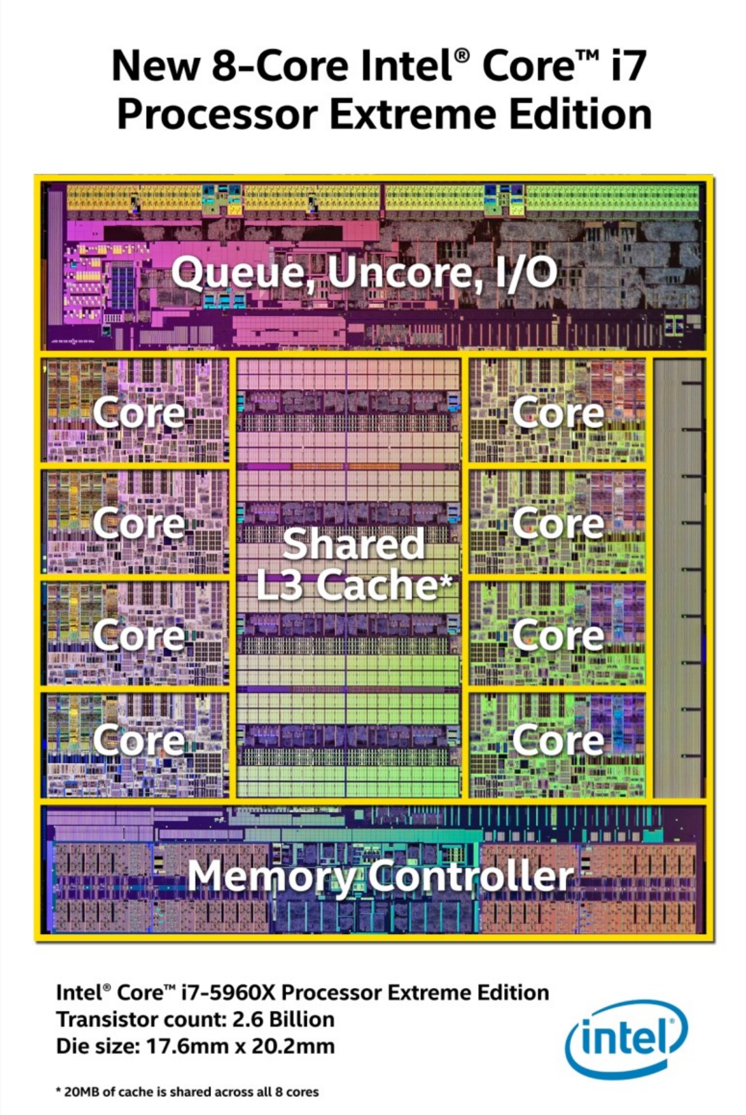


Memorie Distribuită - Acces



Threads vs cores

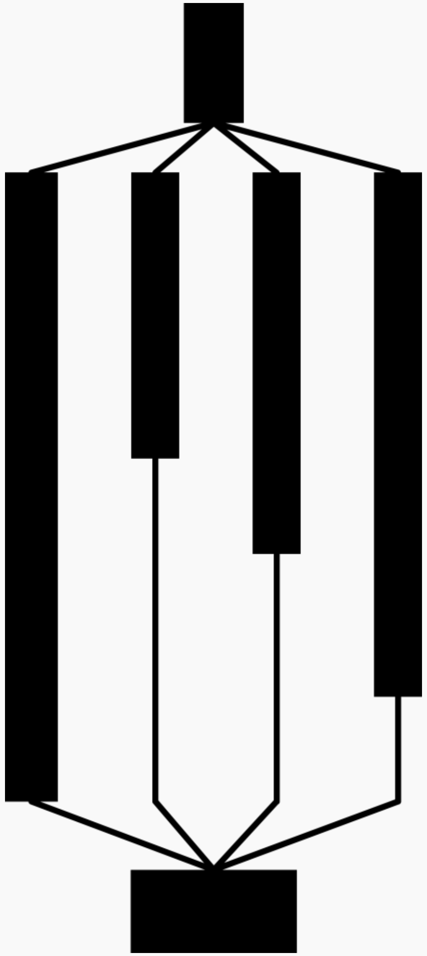


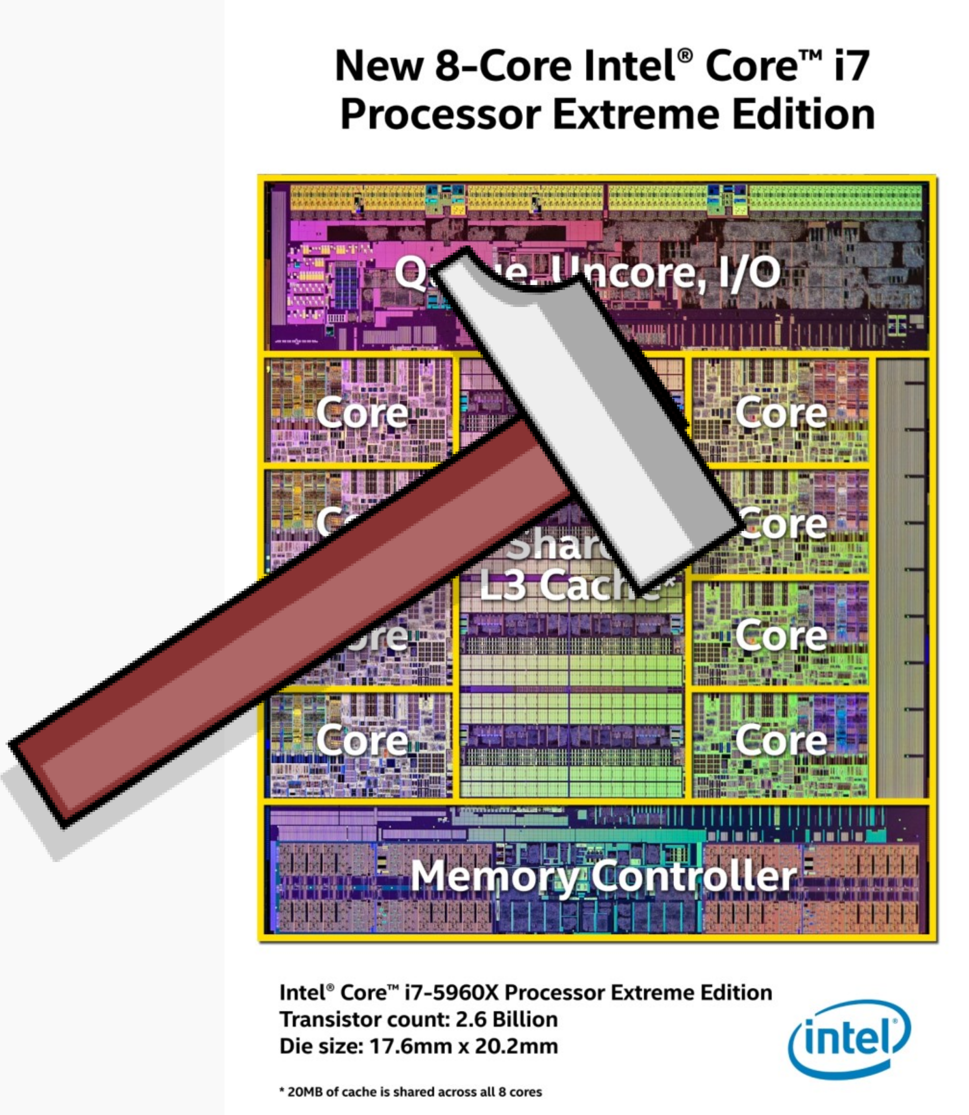


Hyperthreading – the confusion

Thank you intel

Hyperthreading – the confusion





Multi-tasking vs Multi-threading

Multi-tasking

Task 1

Task 2

Multi-tasking

Task 2

Task 1

Multi-tasking

Task 1

Task 2

Multi-tasking

Task 2

Task 1

Multi-threading

Multi-threading

Thread 2

Thread 3

Thread 4

Thread 1

Multi-threading

Thread 1

Thread 2

Thread 4

Thread 3

Multi-threading

Thread 1

Thread 2

Thread 4 Thread 3

Multi-threading

Thread 2

Thread 3

Thread 4

Thread 1

Multi-threading

Thread 1

Thread 4

Thread 2 Thread 3

Multi-tasking vs Multi-threading

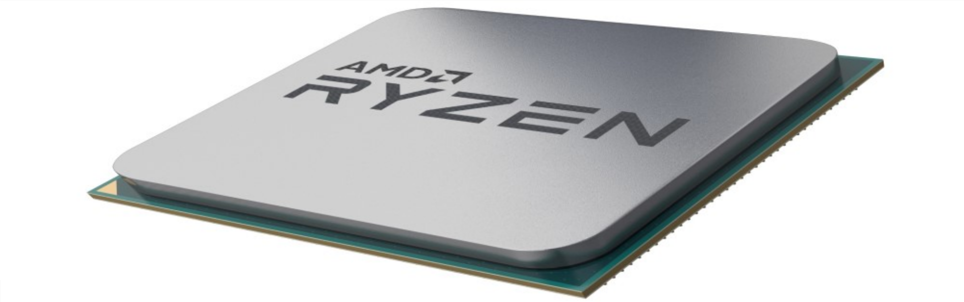
Folosesc același principiu, ba chiar și aceleași sisteme!

Multi-tasking vs Multi-threading

Deci care sunt diferențele?

Un proces are mai multe thread-uri

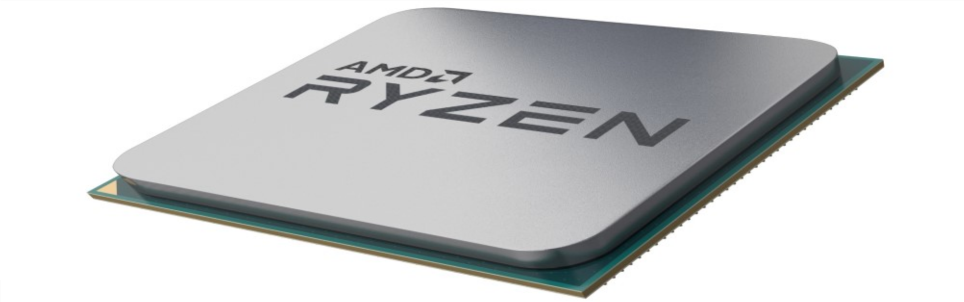
Thread-urile unui proces împart memoria



Multi-tasking vs Multi-threading

Poți avea multi-tasking pe mai multe core-uri?

Poți avea multi-thread-ing pe un singur core?



Multi-tasking vs Multi-threading

Poți avea multi-tasking pe mai multe core-uri? **DA**

Poți avea multi-thread-ing pe un singur core? **DA**