



Arhitecturi Paralele Introducere

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Curs susținut în parteneriat cu Prof. Florin Pop



FACULTATEA DE
**AUTOMATICĂ ȘI
CALCULATOARE**





Regulament

- Laboratoarele sunt obligatorii
- Temele se rezolvă **individual** și vor fi verificate **anti-plagiat**



Punctaje

6p Teme

- Minim 3p pentru promovare

2p Examen parțial

- Minim 1p pentru promovare

2p Examen final

- Minim 1p pentru promovare



Objective

Dezvoltarea abilităților pentru:

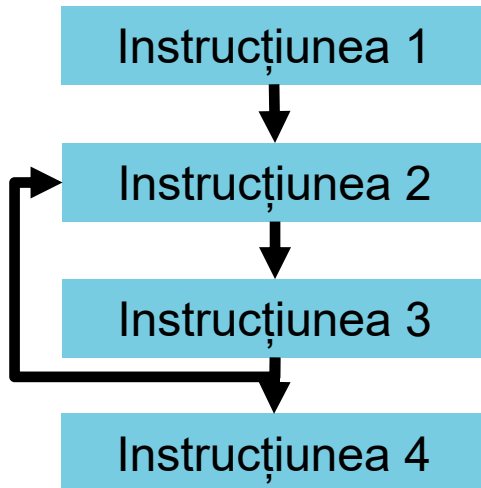
- Proiectarea și implementarea aplicațiilor multi-thread
- Proiectarea și implementarea aplicațiilor distribuite
- Depanarea unor aplicații multi-thread sau distribuite
- Demonstrarea corectitudinii și scalabilității unui program multi-thread sau distribuit
- Modelarea complexității unui algoritm multi-thread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



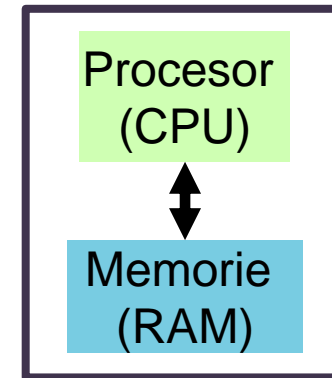
Calcul Paralel vs Distribuit vs Secvențial



Calcul Secvențial

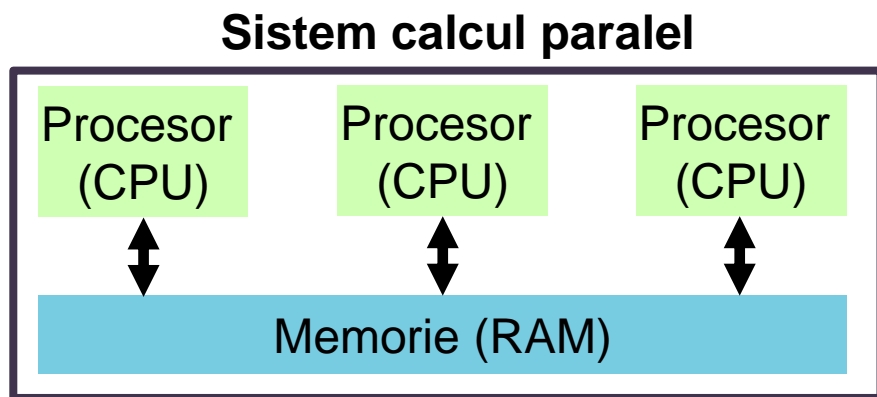
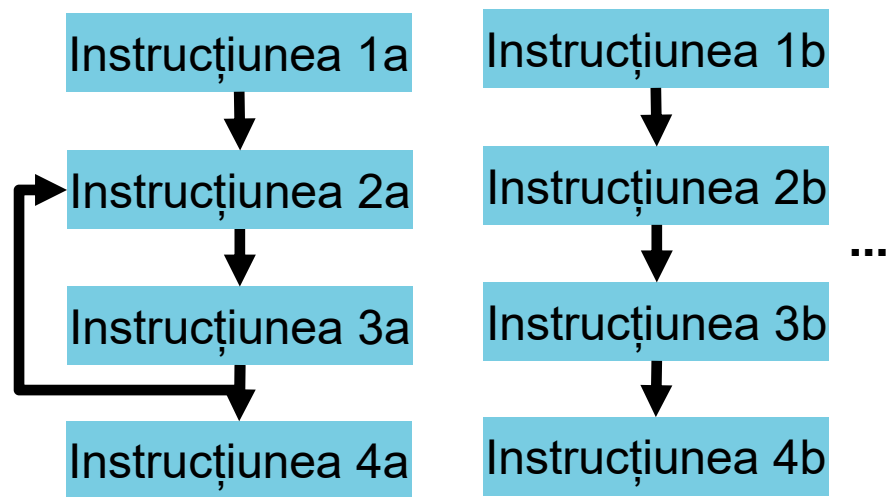


Sistem calcul secvențial



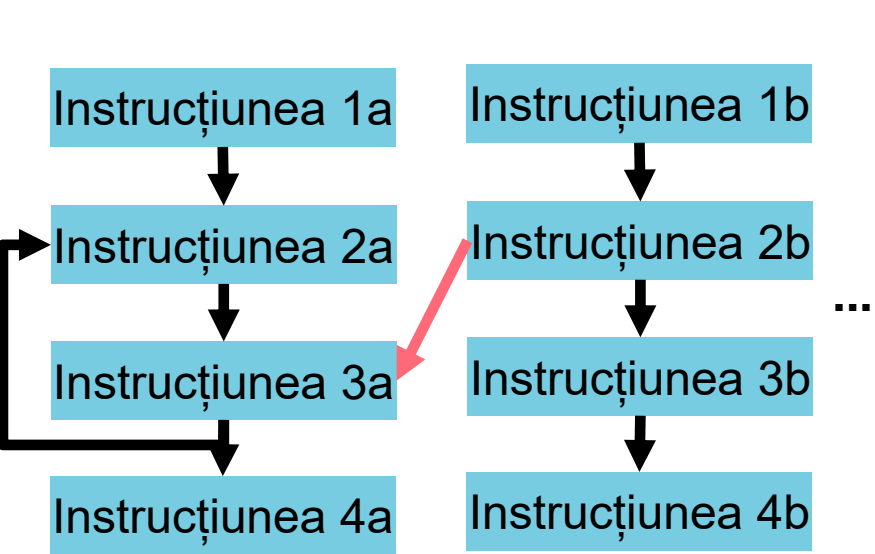


Calcul Paralel

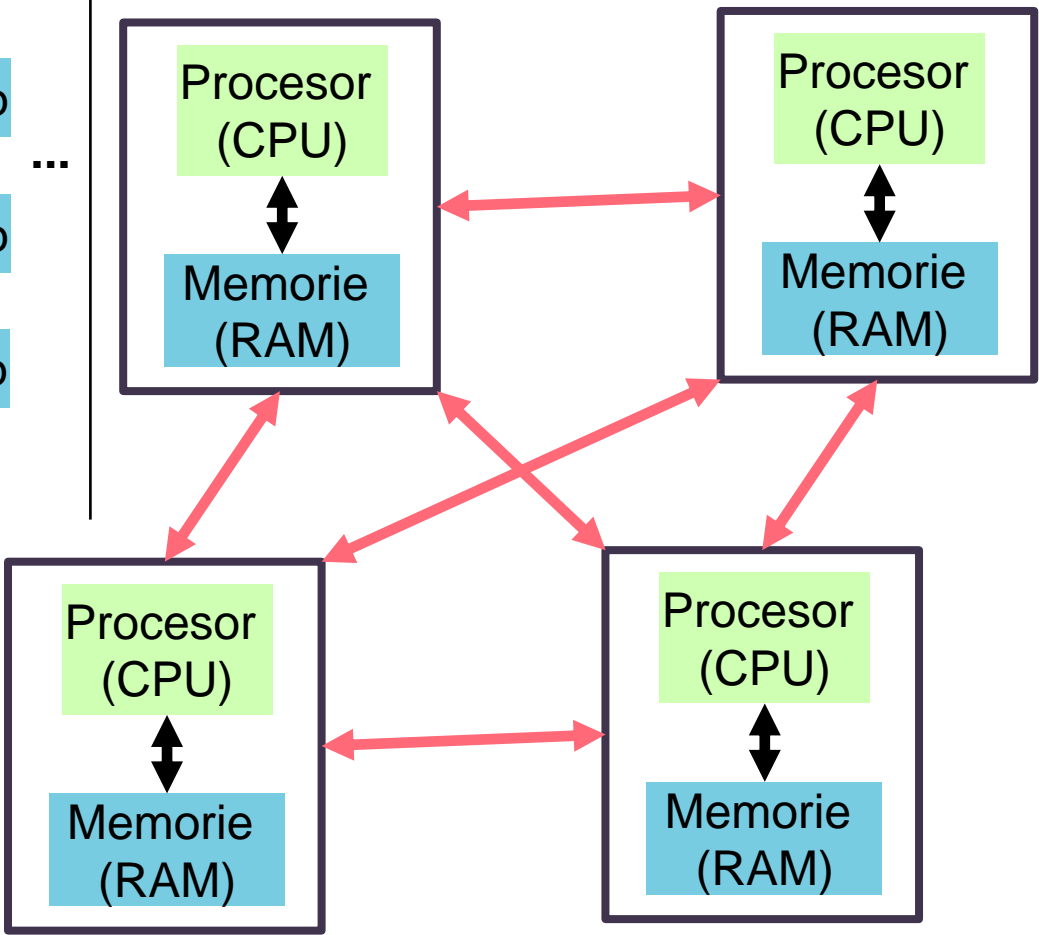




Calcul Distribuit



Sistem calcul distribuit





- 
- A close-up photograph of an Intel Core i9 X-series processor. The processor is a square, silver-colored integrated circuit with the Intel logo and "CORE i9 X-series" printed on its surface. It is mounted on a green printed circuit board (PCB) with visible gold-plated pins along the edges.

- 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	7,299,072	415,530.0	513,854.7	28,335
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, NRCP National Supercomputing Center in Wuxi China	10,649,600	93,014.6	125,435.9	15,371
5	Tianhe-2A - TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000, NUDT National Super Computer Center in Guangzhou China	4,981,760	61,444.5	100,678.7	18,482



Fugaku





Summit





Sierra





Sunway TaihuLight





HPC - 5





Computing power

24-hour average: 27.702 PetaFLOPS.
Active: 87,060 volunteers, 918,047 computers.



De ce calcul paralel și distribuit?

- Timp de execuție mai scurt
- Permite abordarea problemelor de dimensiuni mari
- Accesul resurselor aflate la distanță
- Reducerea costurilor
- Toleranța la defecte
- Ascunderea timpilor de așteptare
- Redundanța
- Scalabilitatea
- Scăderea timpului de răspuns
- Securitate



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.

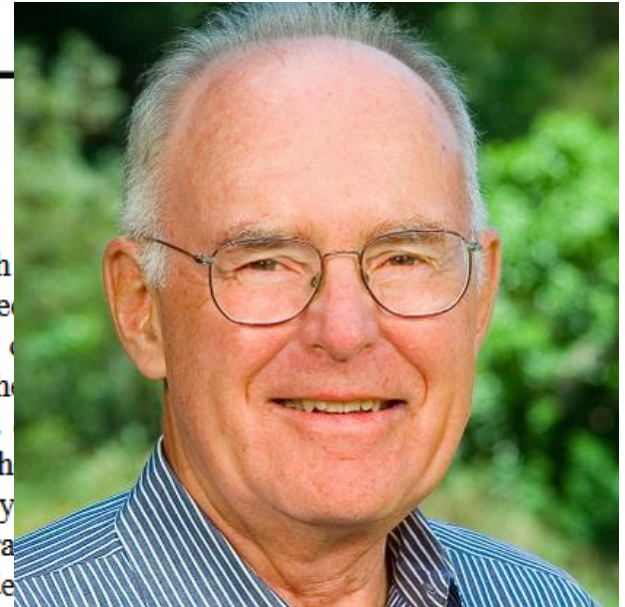
Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.

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

Each approach each borrowed technology believe the way of various approaches

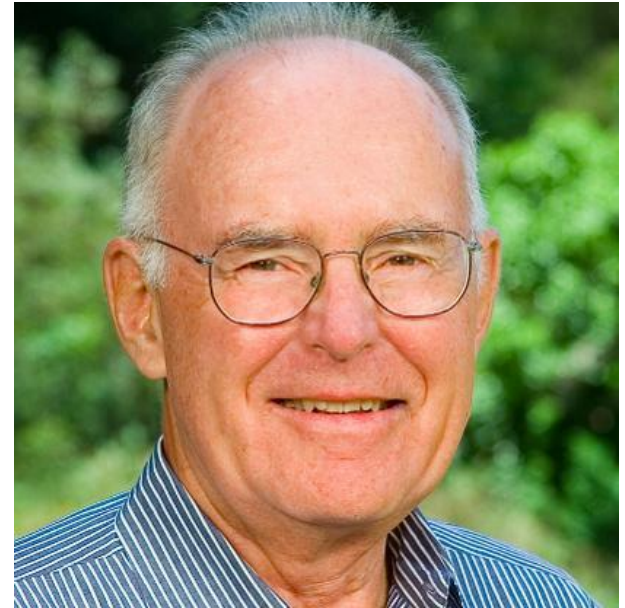
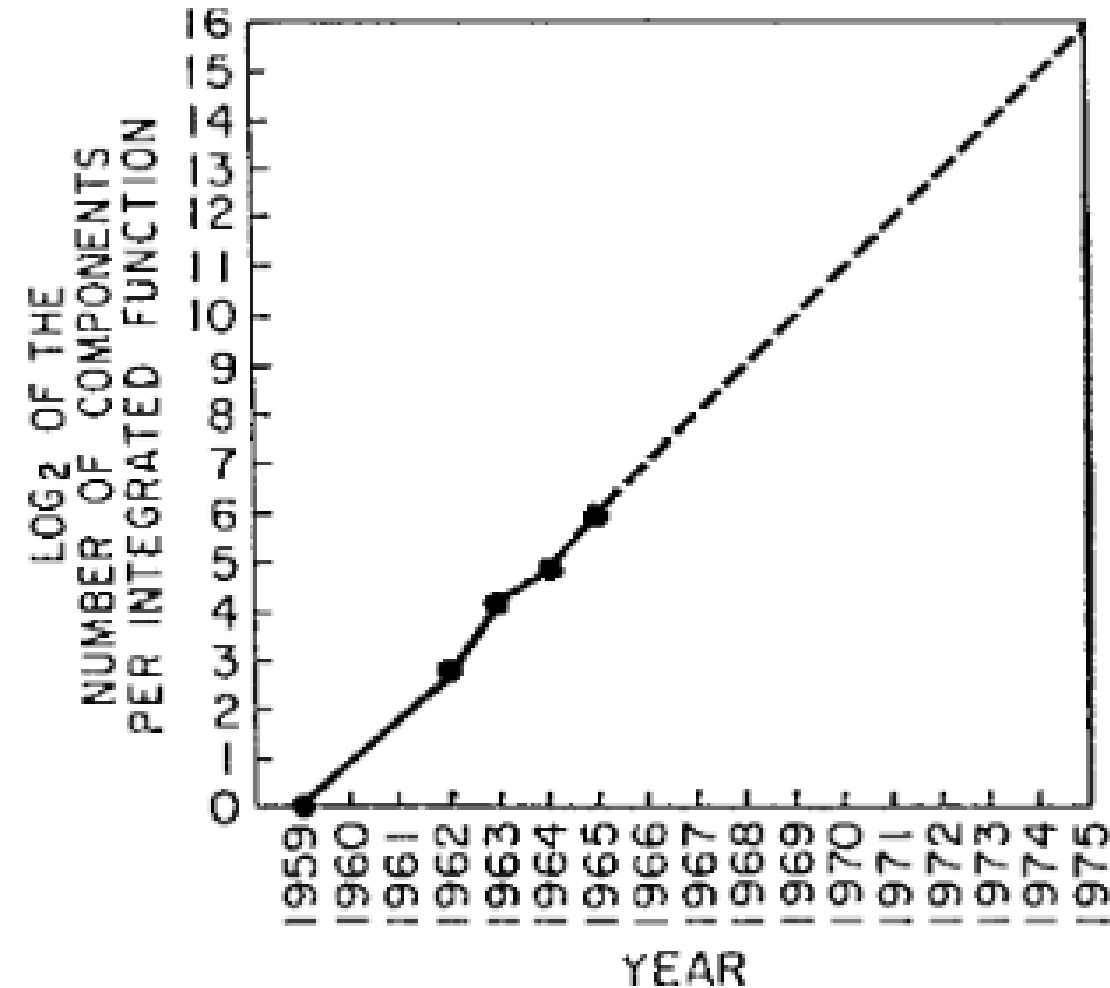
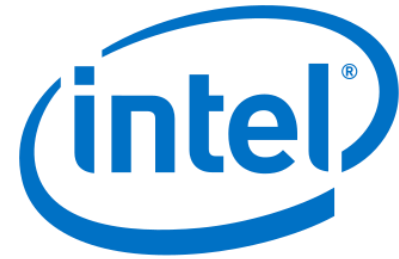
The advocates already using the resistors by applying conductor substrates upon films are developing attachment of active semiconductor devices to the passive film arrays.

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

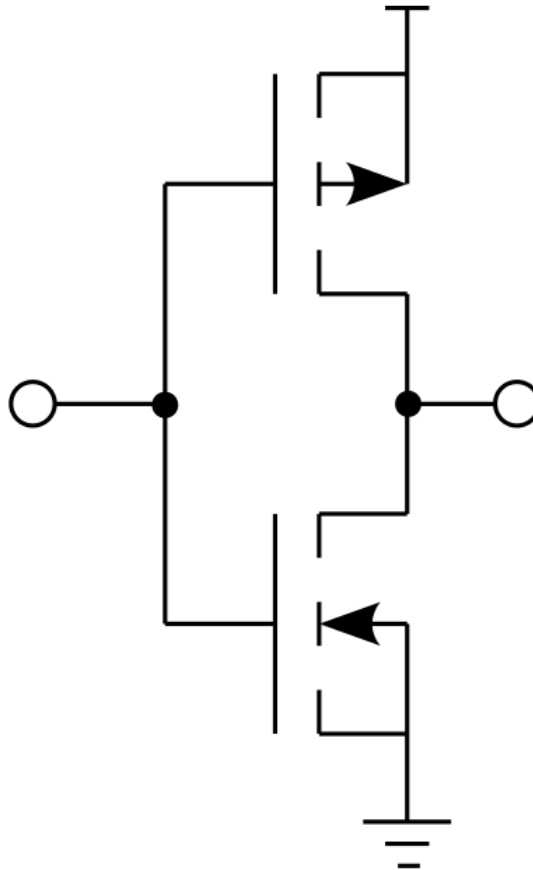
- Economic

- Costuri enorme pentru cercetare și proiectarea unui nou timp de procesor



Limitele programării secvențiale

- CMOS





Importanța cursului

- Apar tot mai multe tehnologii distribuite
 - Blockchain; Peer-to-Peer
- Chiar și un procesor de ceas are mai multe core-uri
 - LG Watch Sport - MSM8909w Processor
 - Quad-Core
- Suport în noile IDE-uri
 - Eclipse; Visual Studio
- Număr mare de aplicații distribuite
 - Dropbox; Spark; [Boinc](#)





Importanța cursului

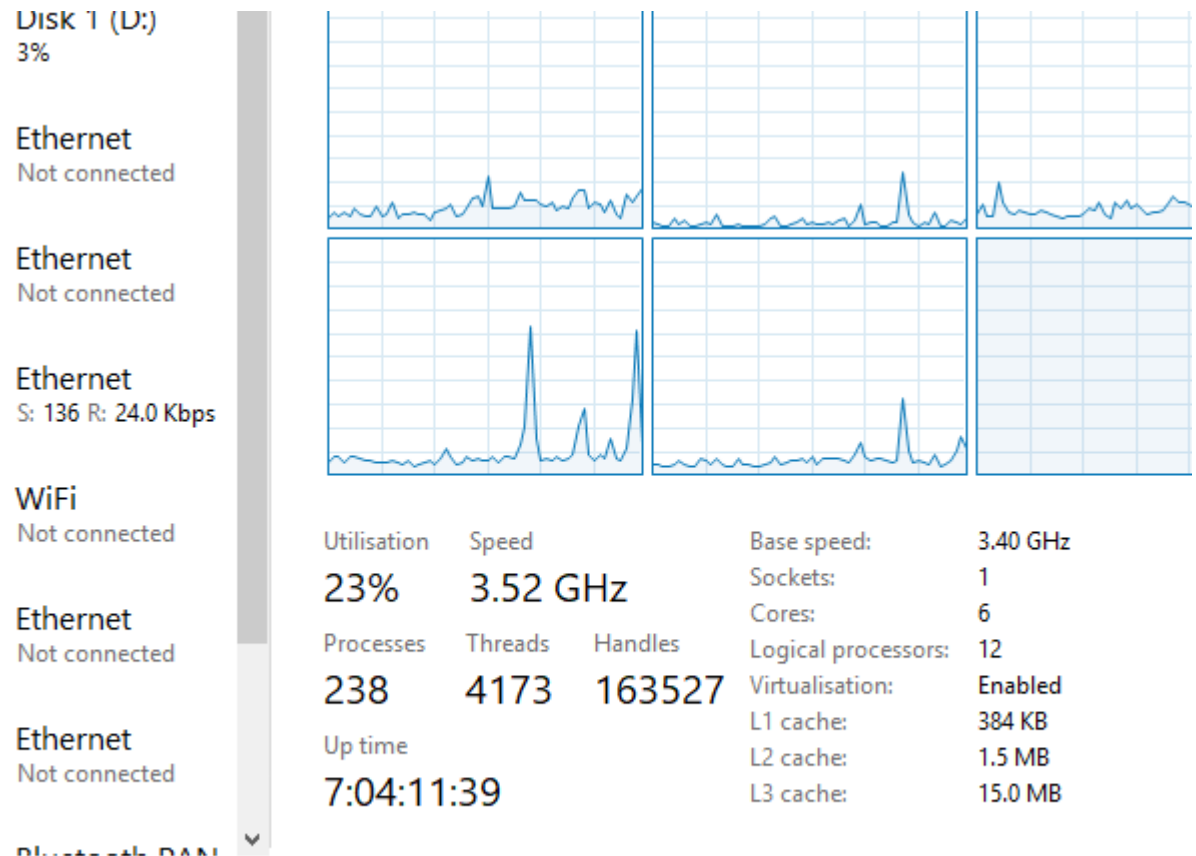
EuroHPC **Leading the way in European Supercomputing**

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.



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



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.

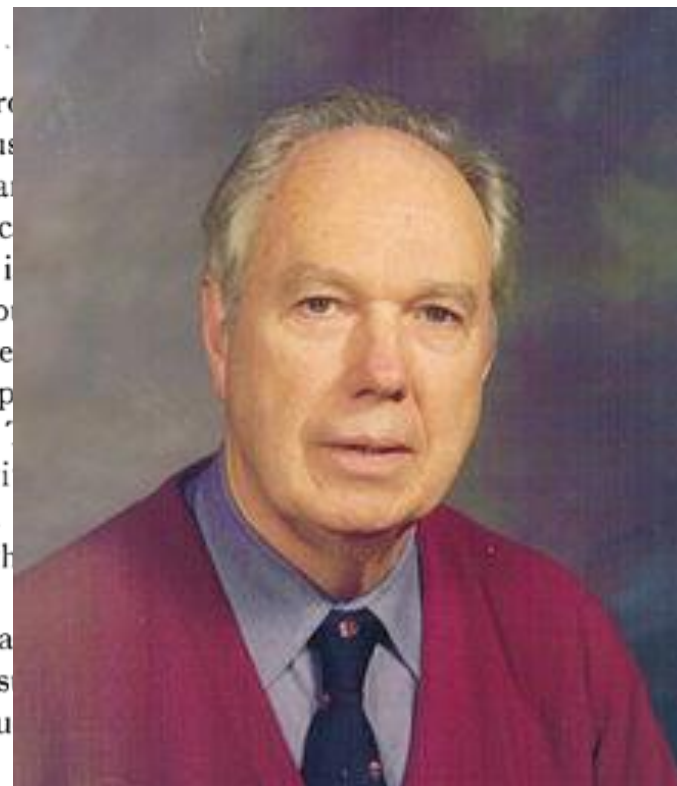
The parallel processors [single-instruction stream-multiple-data stream (SIMD)] are analyzed. In particular, a nesting type explanation is offered for Minsky's conjecture—the performance of a parallel processor increases as $\log M$ instead of M (the number of data stream processors).

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

more “macro” particular use must be shared more significantly.

1) There is a limiting resource. The best estimate will either be a limitation on the number of processors or on the number of instructions. The computer will be concerned with the potential, which is a consideration.

2) We make a set of instructions. It is assumed that a set of instructions





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

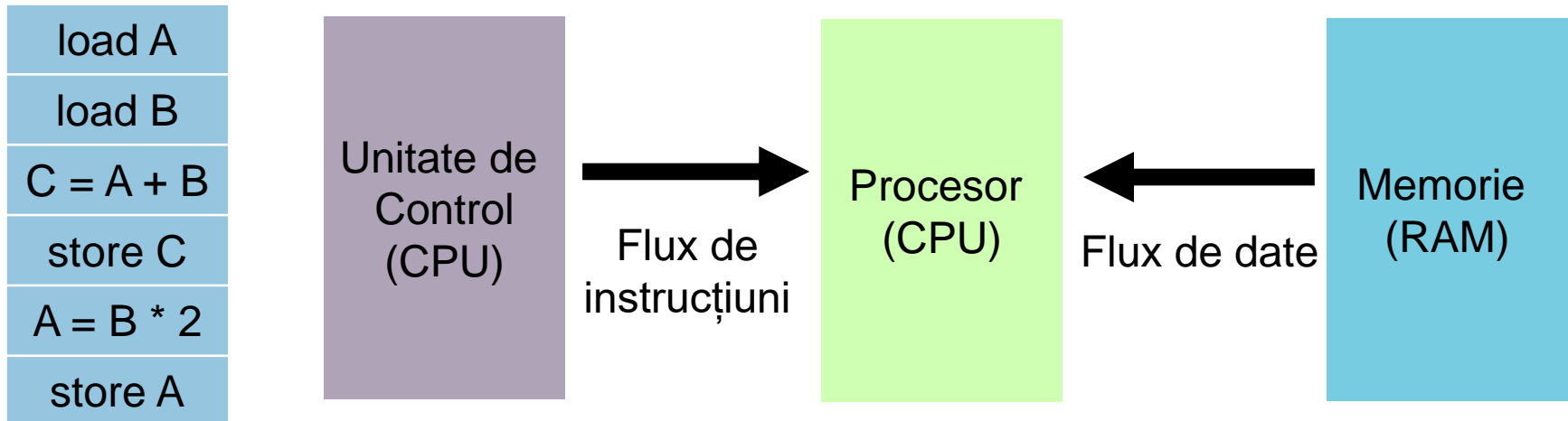
■ MIMD

- Multiple Instruction Streams, Multiple Data Streams
- Procesoare actuale (ce aveți acasă și în buzunar)



SISD

- Model clasic Arhitectura *von Neumann*





SISD

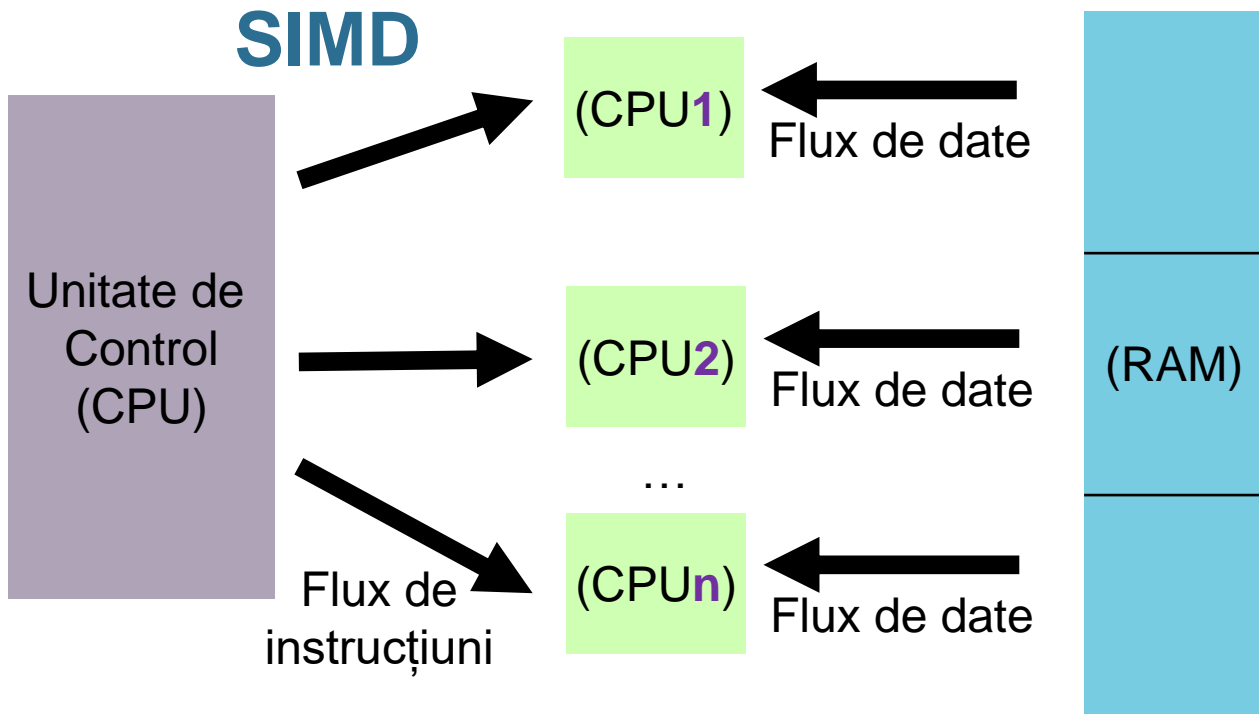
- Model clasic *Arhitectura von Neumann*

First Draft of a Report
on the EDVAC

by

John von Neumann





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 citită într-un pas în model **CR** dar în $\log(N)$ în model **ER**.



Rețele de configurare

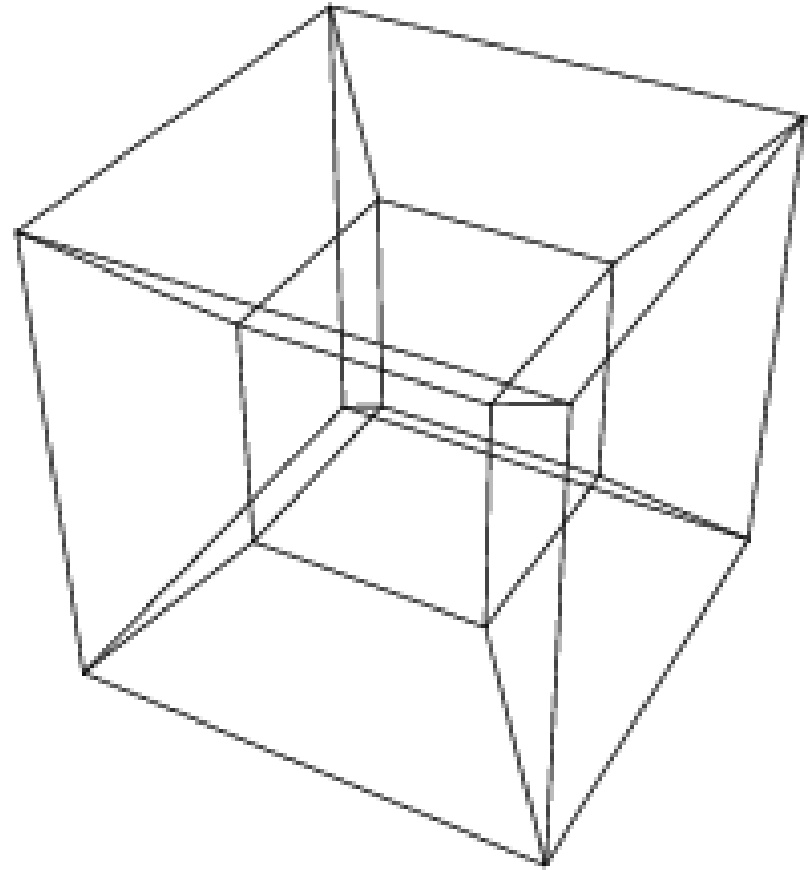
- Topologii

- Tablou
- Arbore
- Cub
- Hiper cub

- Depinde de

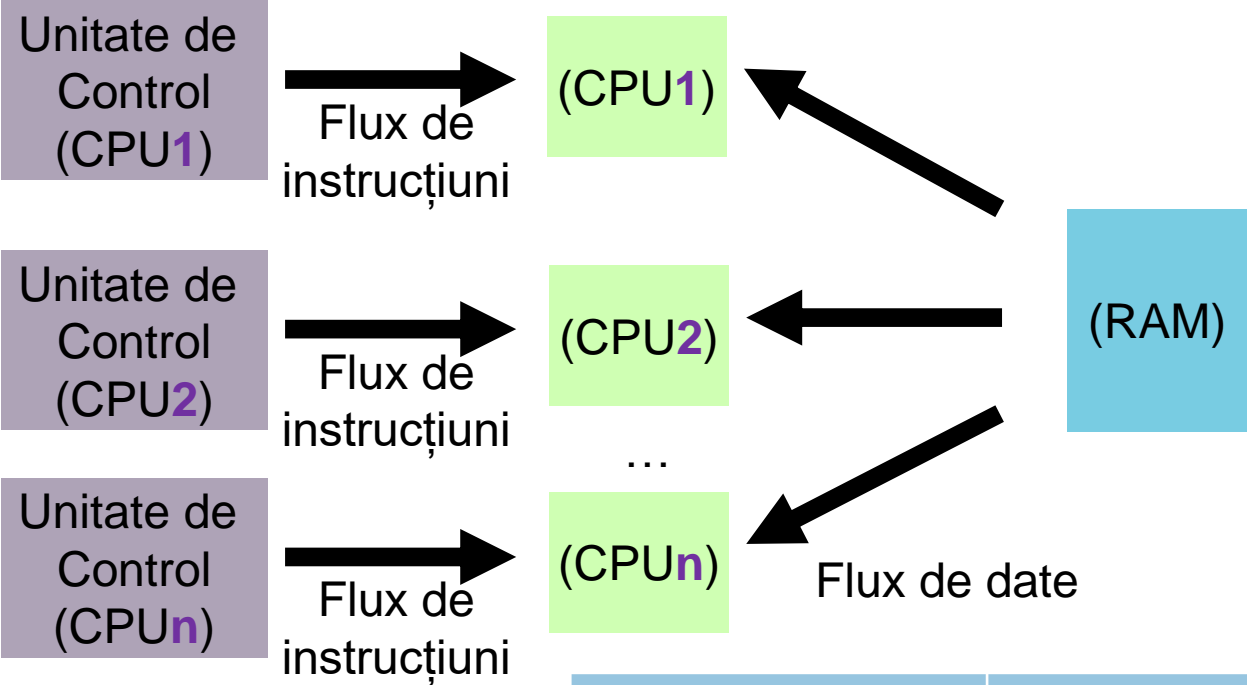
- Aplicație
- Performanțe dorite
- Număr procesoare disponibile

- Exemple: IBM 9000, Cray C90, Fujitsu VP





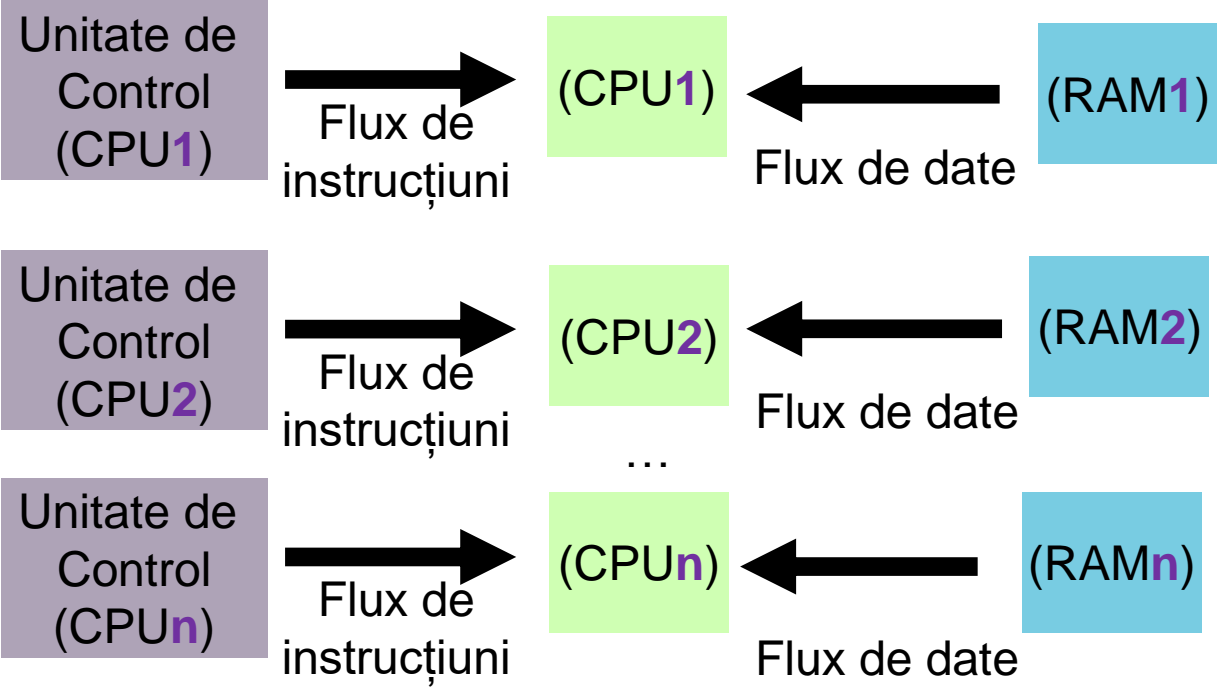
MISD



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

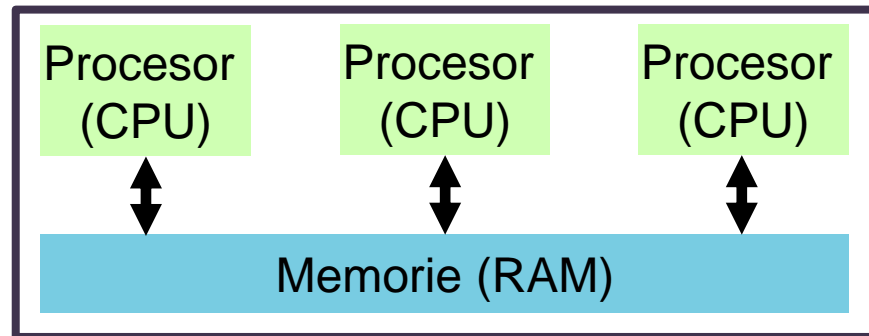


load A	load Z		A = B + C
D = A	store H	.	store A
load C	H=H*100	.	G[1] = G[2] + G[3]
load E	H++	.	store G[1]
load F	store H		G[4] = G[5] + G[6]



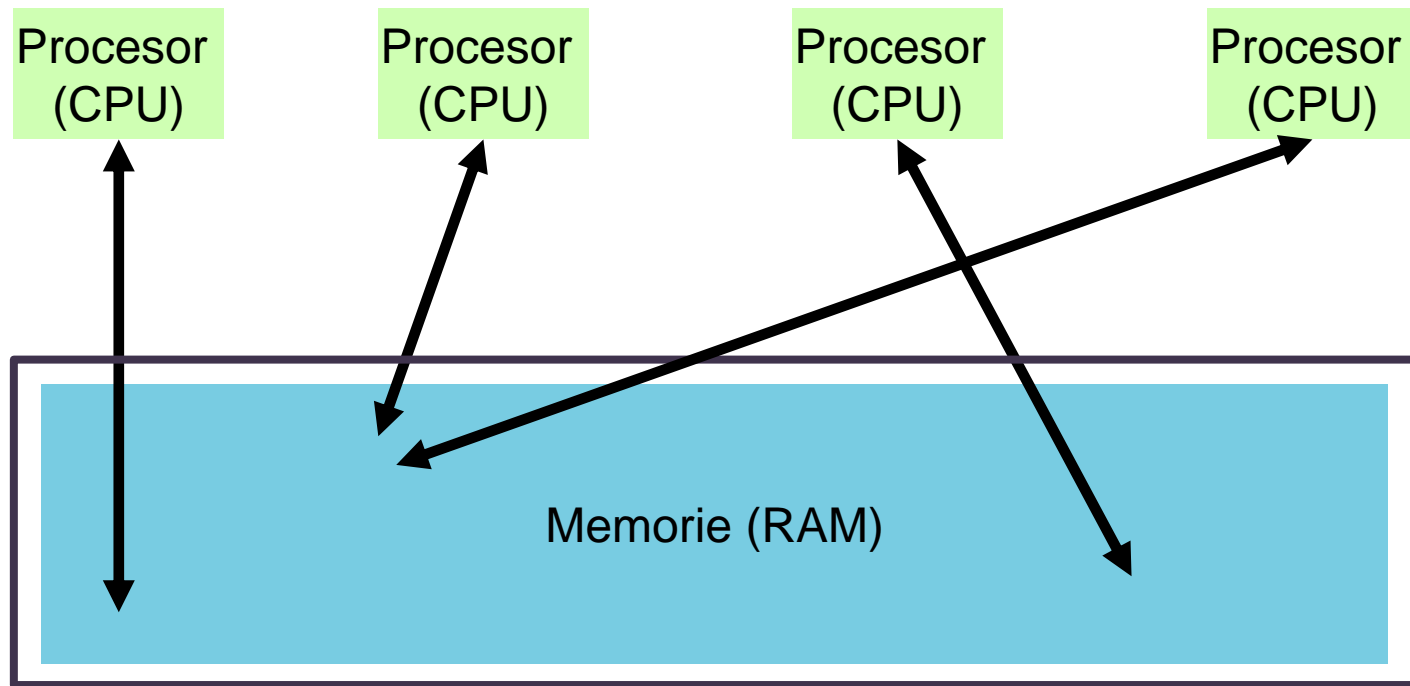
Memorie Partajată

- Uniform Memory Access (**UMA**)





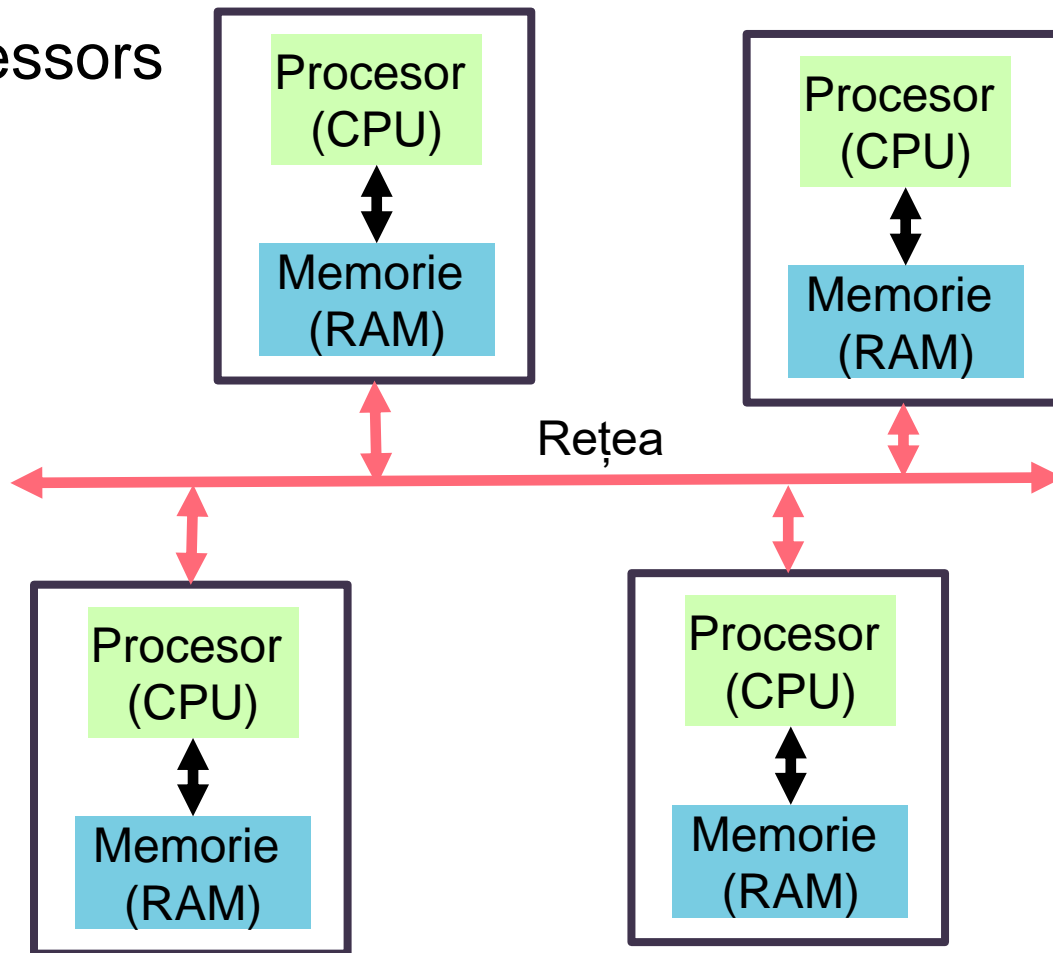
Memorie Partajată - Acces





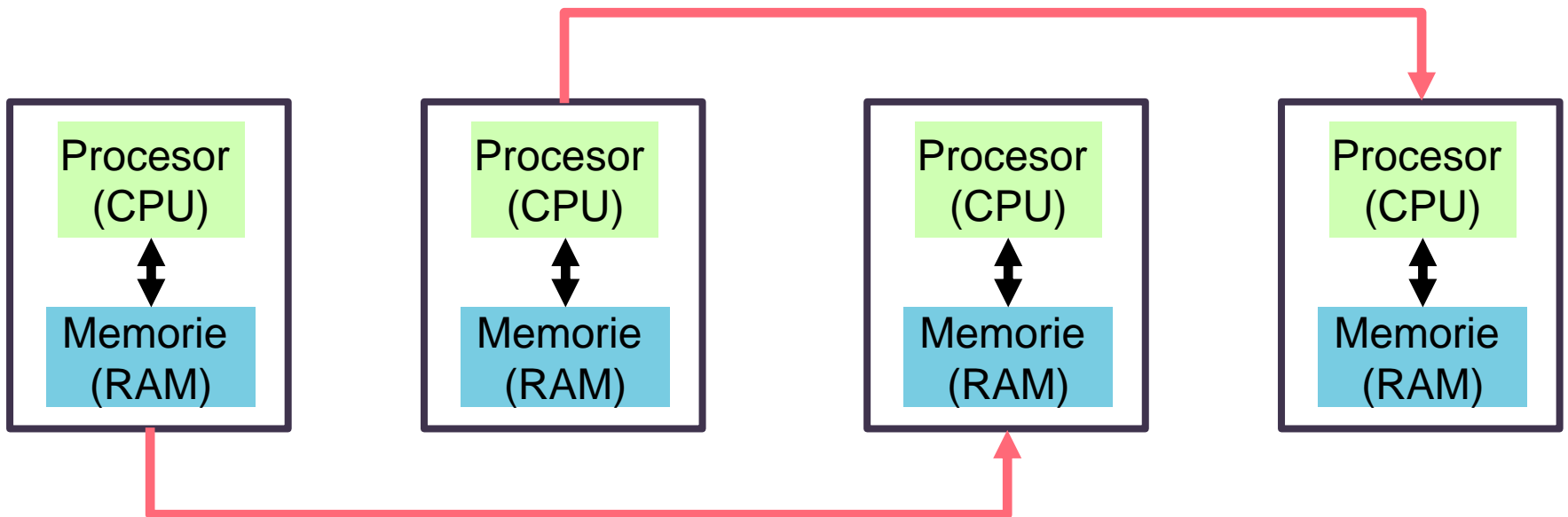
Memorie Distribuită

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



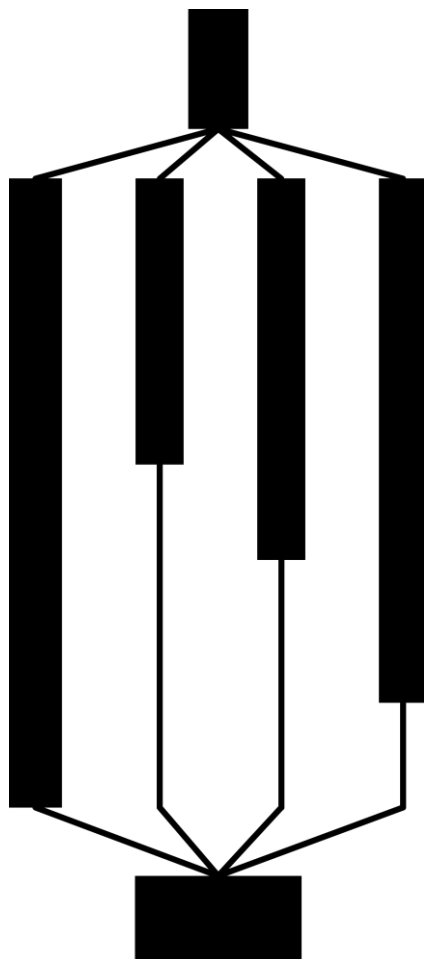


Memorie Distribuită - Acces

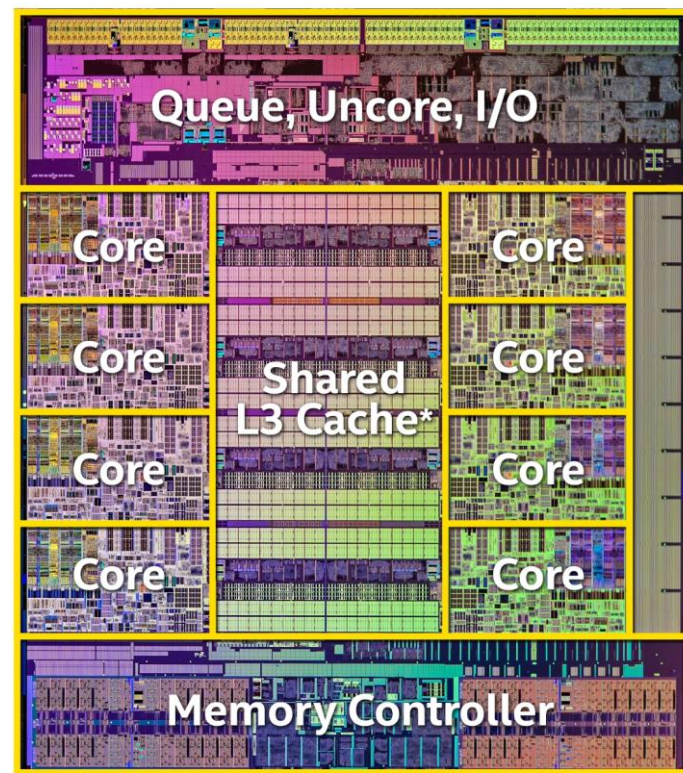




Threads vs cores



New 8-Core Intel® Core™ i7 Processor Extreme Edition



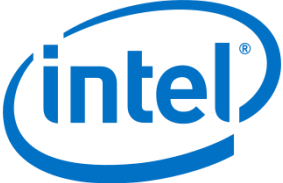
Intel® Core™ i7-5960X Processor Extreme Edition
Transistor count: 2.6 Billion
Die size: 17.6mm x 20.2mm

* 20MB of cache is shared across all 8 cores



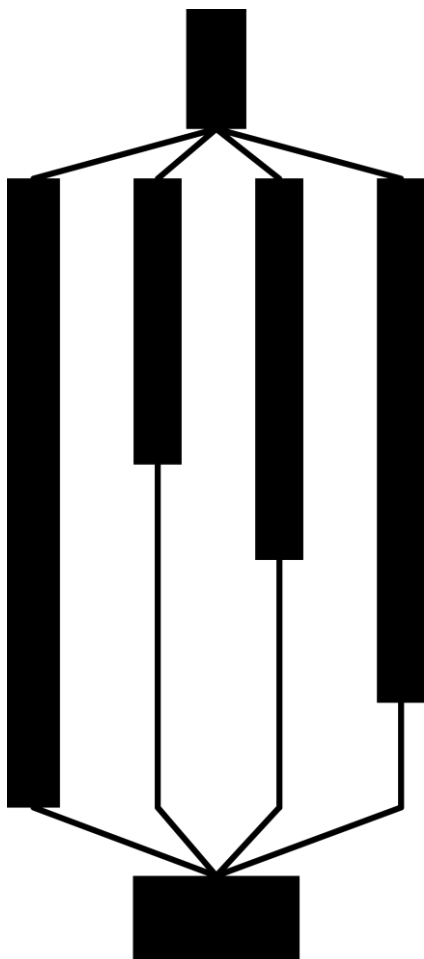


Hyperthreading – the confusion

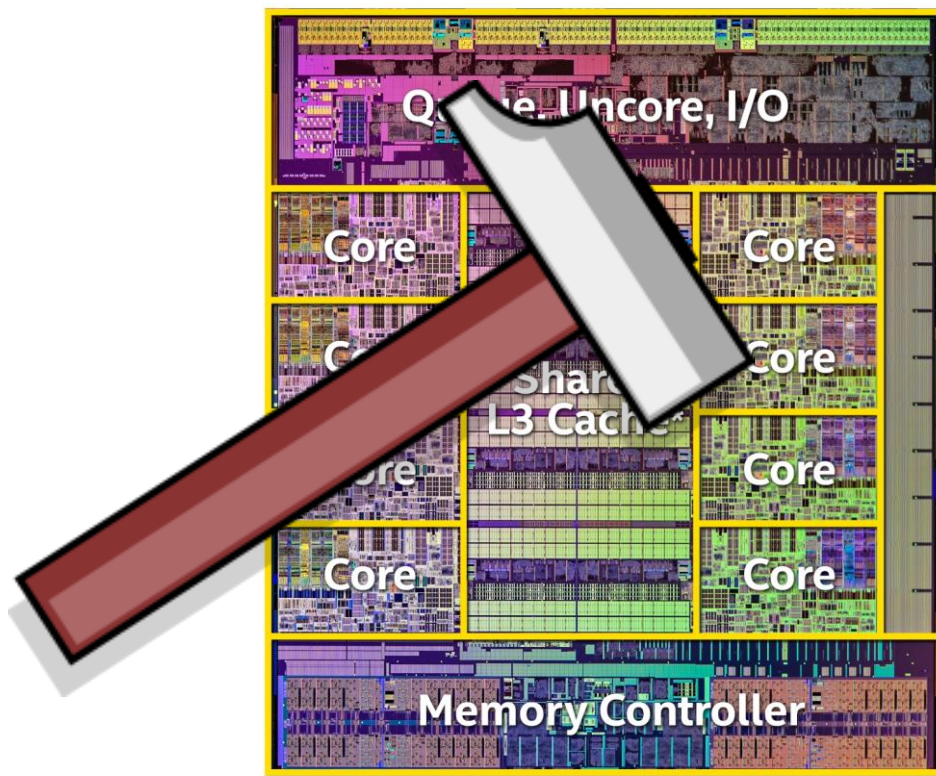
Thank you 



Hyperthreading – the confusion



New 8-Core Intel® Core™ i7 Processor Extreme Edition



Intel® Core™ i7-5960X Processor Extreme Edition
Transistor count: 2.6 Billion
Die size: 17.6mm x 20.2mm

* 20MB of cache is shared across all 8 cores





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**



