Arquiteturas de Computadores Paralelos

ELC139 - Programação Paralela

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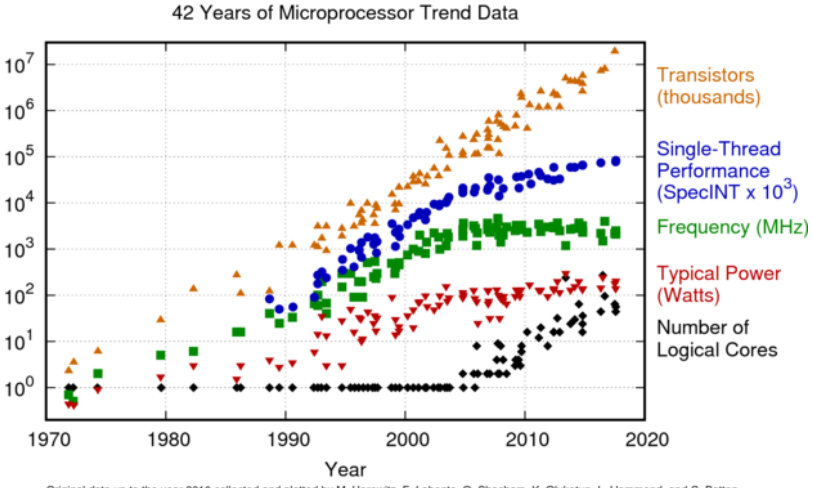
2023/1

Outline

Outline

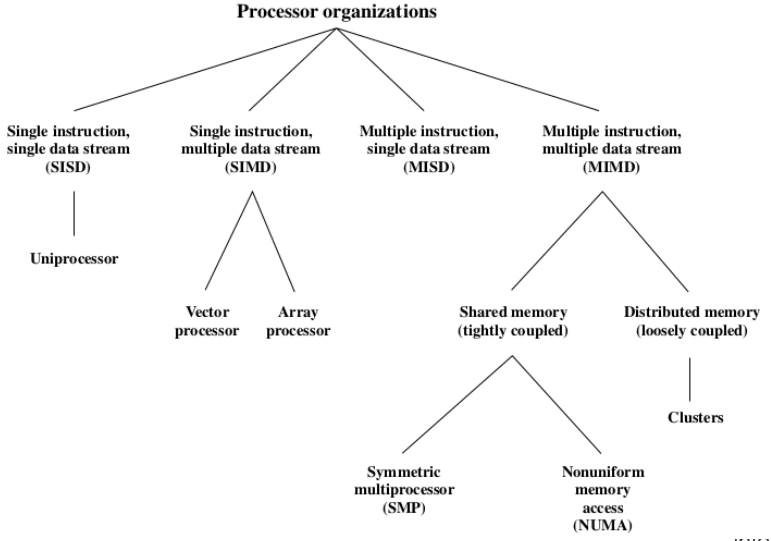
Evolução dos processadores



https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data/

Outline

Taxonomia de Flynn



Stallings, W. Computer Organization and Architecture. 2017.

Single instruction, single data (SISD)

- Uma instrução opera sobre um dado de cada vez.
- Arquitetura Von Neumann.

Single instruction, multiple data (SIMD)

- O processador executa um conjunto de operações **simultaneamente** sobre múltiplos dados (matrizes ou vetores)
- Muito usada em HPC
- Exemplos de arquiteturas
  - NEC SX-Aurora TSUBASA
  - GPUs como Single Instruction Multiple Threads (SIMT)

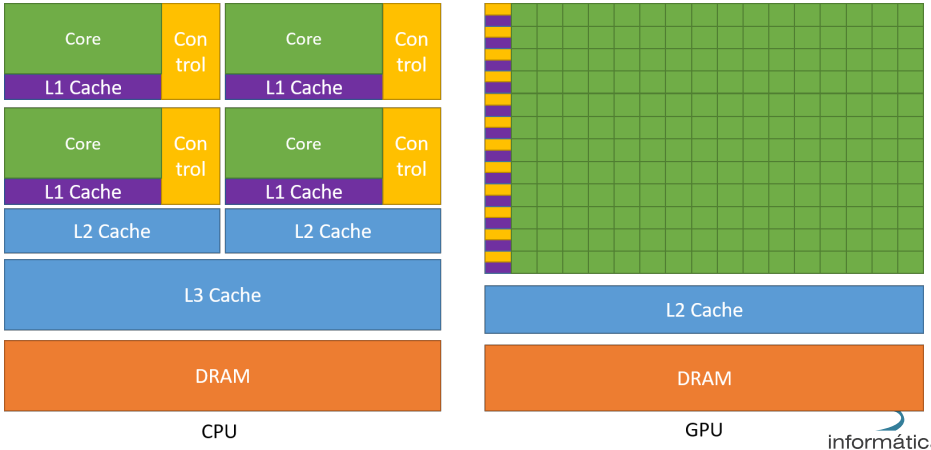
NEC SX-Aurora TSUBASA

- Cada Vector Engine Processor pode ter até 16x cores.
- FMA - Fused multiply-add `a*b + c`

https://www.nec.com/en/global/solutions/hpc/sx/architecture.html

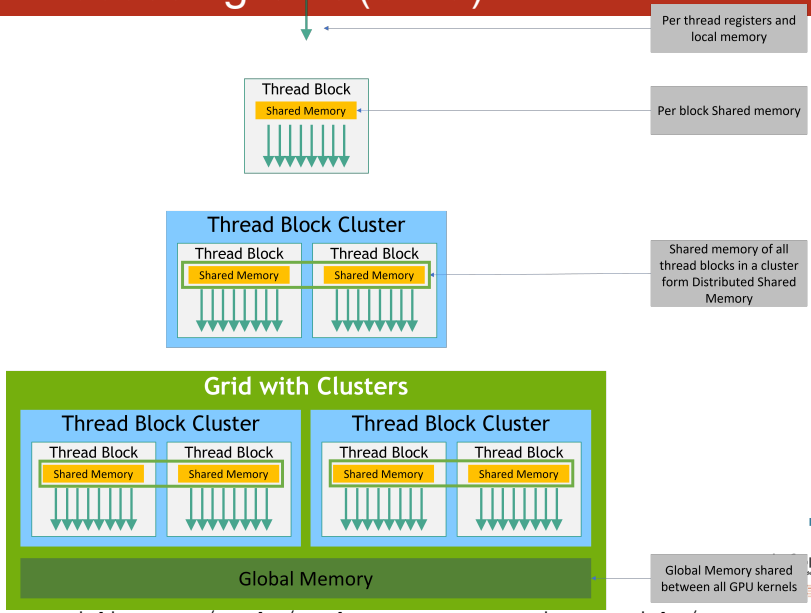
Graphics Processing Unit (GPU)

- CPUs executam uma sequência de instruções o mais rápido possível
- GPUs executam um grande número de instruções concorrentes



https://docs.nvidia.com/cuda/cuda-c-programming-guide/

Graphics Processing Unit (GPU)



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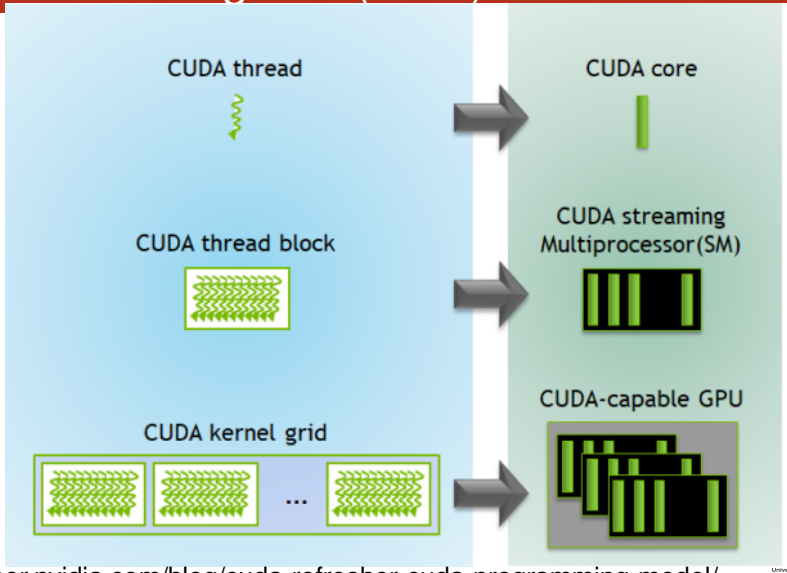
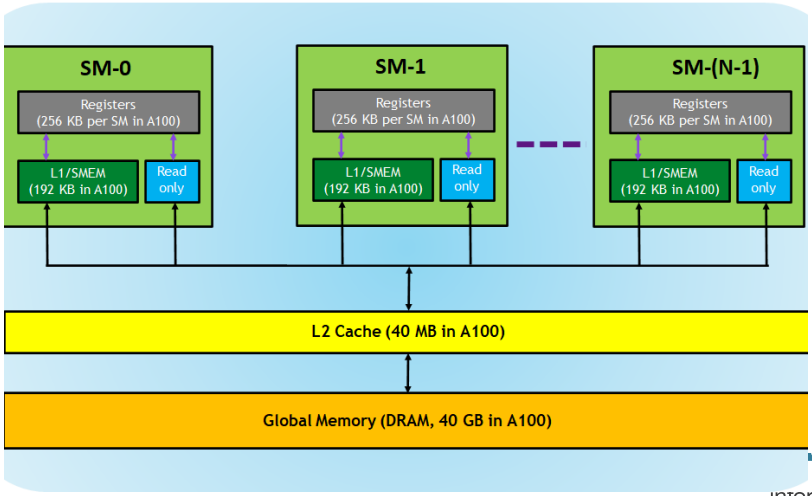
Graphics Processing Unit (GPU)



https://developer.nvidia.com/blog/cuda-refresher-cuda-programming-model/

Graphics Processing Unit (GPU)



https://developer.nvidia.com/blog/cuda-refresher-cuda-programming-model/

Multiple instruction, single data (MISD)

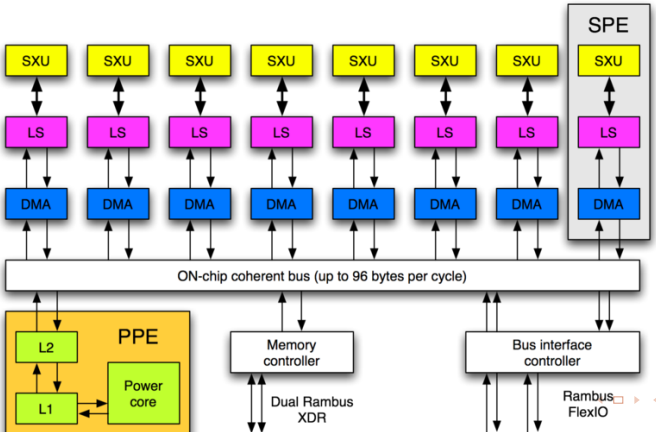
- Múltiplas instruções operam sobre um dado de cada vez.
- Nunca desenvolvida
- Algumas vezes associado a *systolic arrays*

Multiple instruction, multiple data (MIMD)

- Múltiplas instruções operam sobre múltiplos dados simultaneamento.
- Memória compartilhada
  - Multiprocessador simétrico (SMP)
  - Sistemas com acesso não-uniforme a memória (NUMA)
  - Processadores multicore

IBM Cell processor

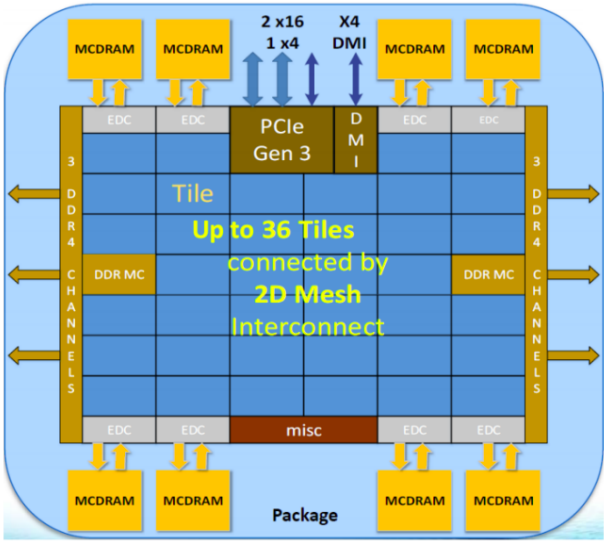
- Processador multi-core baseado no PowerPC
- 1x IBM PowerPC processing element (PPE)
- 8x synergistic processing elements (SPE)
- A movimentação de dados entre caches dependia do programador



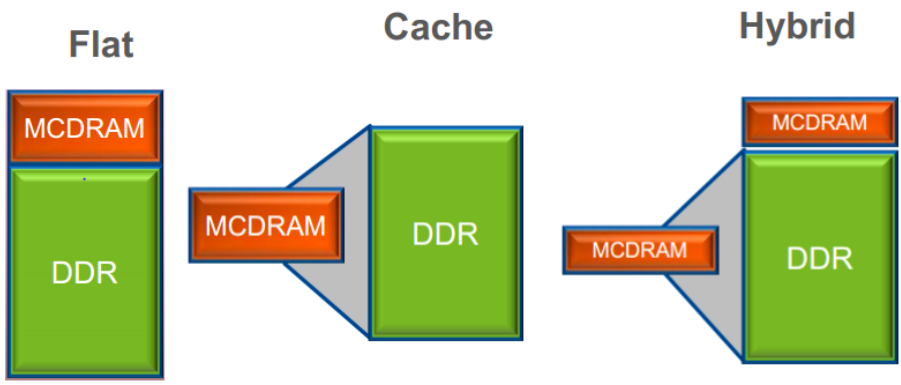
US Condor Cluster (PS3)

Intel Knights Landing

- Processador manycore x86
- 68 núcleos, totalizando 272 núcleos e 1088 threads, 1.4 GHz
- 96 GB DDR4 RAM + 16 GB HBM MCDRAM
- Sistema Linux próprio com comandos



Intel Knights Landing



MCDRAM is NUMA node 1

DDR is NUMA node 0

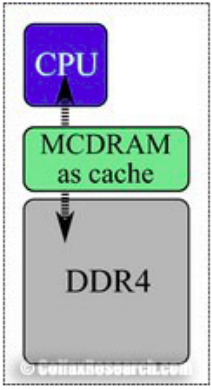
MCDRAM acts as memory-side cache for DDR

DDR is NUMA node 0

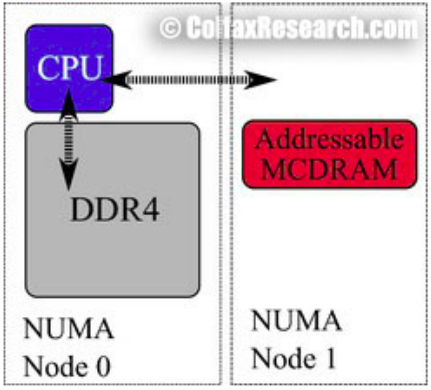
Part of MCDRAM is cache, part is NUMA node 1

DDR is NUMA node 0

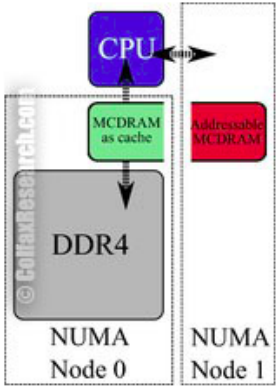
Intel Knights Landing



Cache mode

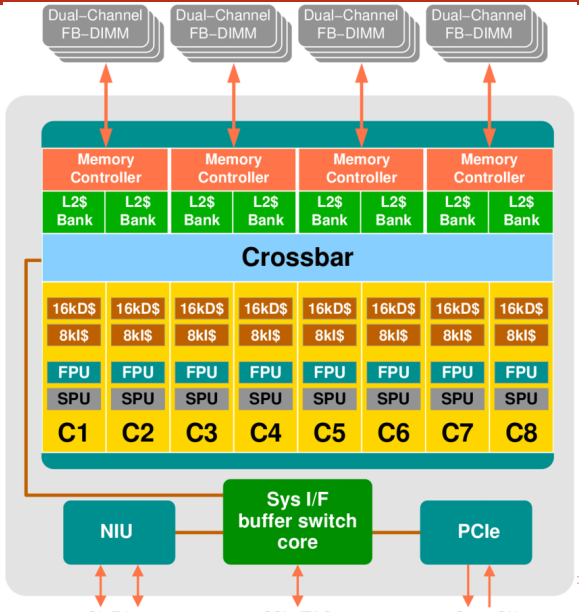


Flat mode

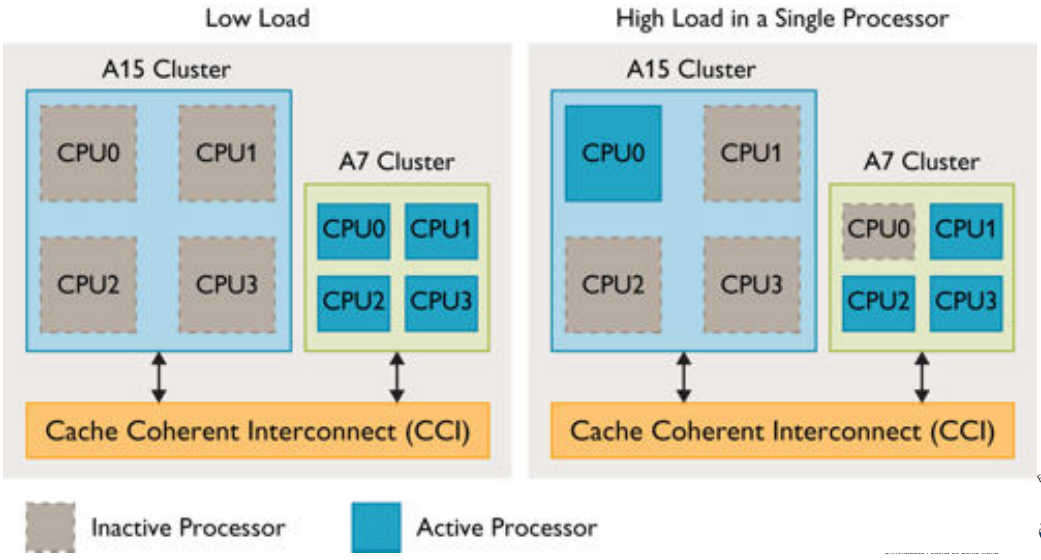


Hybrid mode

Sun UltraSPARC T2



ARM big.LITTLE



https://joao-ufsm.github.io/par2023a/