CS 6023 - GPU Programming

Overview and Logistics

30/07/2018

CS 6023 | GPU Programming | Elective course by CSE dept in Aug-Nov. 2018

Prerequisite:

CS2710 (Programming and Data Structures Lab)

[Soft] CS2600 (Computer Organization and Architecture)

Timetable slots: G | 3 slots per week: Mon 1200-1250 | Wed 1650-1740 | ~~Thu 1000-1050~~ | Fri 0900-0950 | Venue: CS 36

Textbook: None | Reading material will be shared through the course

Introduction - About me

Pratyush Kumar

Contact info

Room: BSB 373 | Phone: 4388 | Email: pratyush@cse.iitm.ac.in

Brief bio

B.Tech., IIT Bombay | Ph.D., ETH Zurich

Ex-IBM Research | Consulting with startups on Deep Learning

Areas of research

SysDL (Systems aspects in Deep Learning)

Formal System Design and Analysis

Cyber-Physical Systems

Acknowledgements

Course content has been motivated by material from different sources:

- CS6023, CSE, IITM taught by Dr. Rupesh Nasre in Aug 2017
- “Graphics and Computing GPUs” appendix B in Patterson, Hennessy
- 15-418/618, CMU taught by Dr. Todd Mowry and Brian Railing in 2017
- CIS 565, UPenn taught by Patrick Cozzi in 2017
- “Programming massively parallel processors” by Kirk, Hwu, Nvidia

Who should take the course

You should take the course, if **at least four** of the following topics interest you

1. Evolution of GPUs
2. Architecture of GPU (vis-a-vis CPU)
3. Programming GPUs with CUDA C
4. Parallel computational thinking
5. Optimizing performance on GPUs
6. Accelerating real-world problems on GPUs
7. Relate Deep Learning evolution to GPUs

Evaluation

- Focus on **broad set of skills** *(Content, critical thinking, creativity, collaboration, communication)*
- Contributions to final score
  - Assignments: **30** (= 10 + 10 + 10) (*Functional correctness, performance)*
  - Midsem: **30** *(Analytical questions on parallel prog. / GPU arch.)*
  - Paper/topic presentation: **10** (*Read, understand, and present recent papers)*
  - Capstone project: **30** (*Propose, execute, and demo a real-world GPU app)*

- Attendance will be taken in class
- No compromise on **academic integrity** (strict action against plagiarism, etc.)

Philosophy of teaching

- Aim is to create an enabling environment for you to learn effectively
- The course is an elective => You will exercise several choices through the course
- This is a programming course => Lot of the learning happens by doing
- This is my first time at teaching a full course => Would need feedback along the way

Philosophy of teaching

The mind is not a vessel that needs filling, but wood that needs igniting. — Plutarch

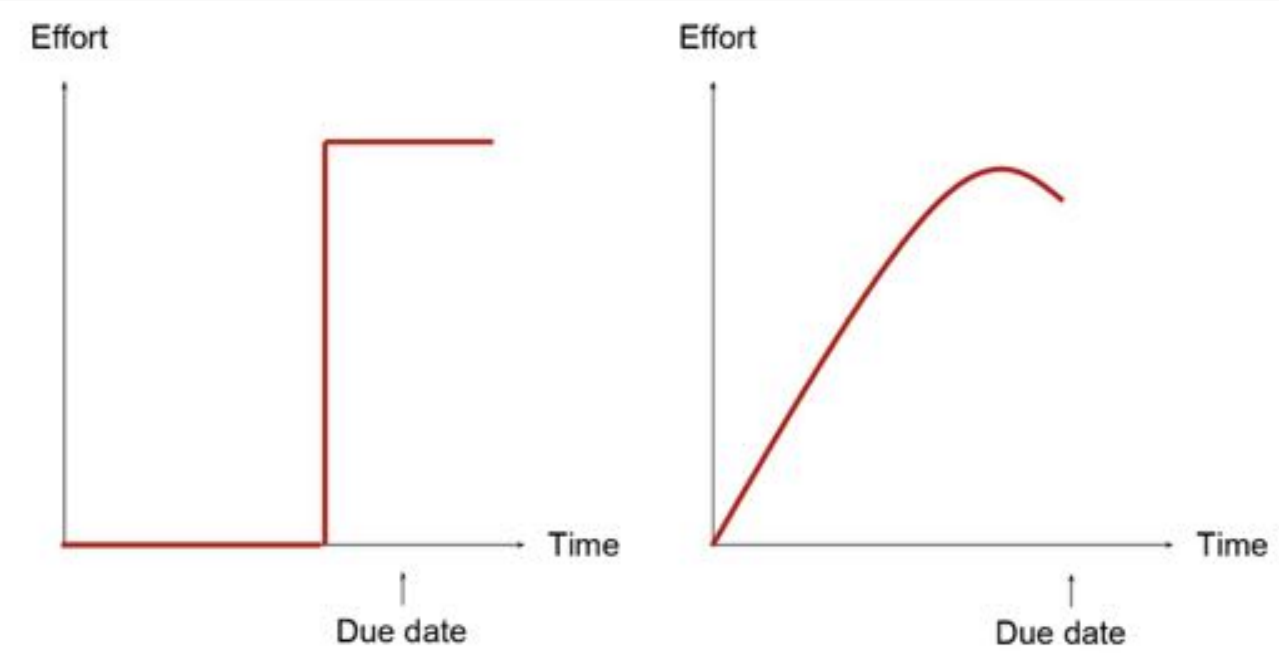
Education is what remains after one has forgotten what one has learned in school. — Einstein

Education is the manifestation of the perfection already in man. — Swami Vivekananda

Compute resource

- You are allowed, in fact encouraged, to practice on own GPU resources
  - Laptops
  - Institute machines and servers to which you have access
  - AWS credits (short demo by TAs later)
- For the practice, submission, and evaluation of assignments we will use a GPU cluster specifically setup in the CSE lab (a detailed demo by TAs later)
- Also, we can support project work on the GPU cluster if you do not have access to compute elsewhere
- Thanks to NVidia for sponsoring graphics cards

Expected intensity timeline



Not only because this is a better approach, but because we are constrained by compute resources and cannot handle peaks

In fact, we will design explicit mechanisms to incentivize this

Teaching Assistants

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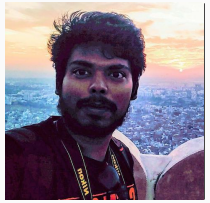

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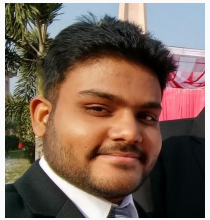
Contact hours
Thu 1000-1050
CS 36
Will be announced in advance



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Student introductions

- Introduce yourself, your stream / dept.
- Why would you like to learn GPU Prog.? Do you have a specific objective?
- How familiar are you with C Programming?
- Do you have access to GPU for practice?

The lens of the course

- Architecture of GPU
- Parallel programming principles
- CUDA programming

Each lecture will have one major theme

Brief history of GPUs

History of GPUs

GPU = **G**raphics **P**rocessing **U**nit

Simple hardware units to drive graphics

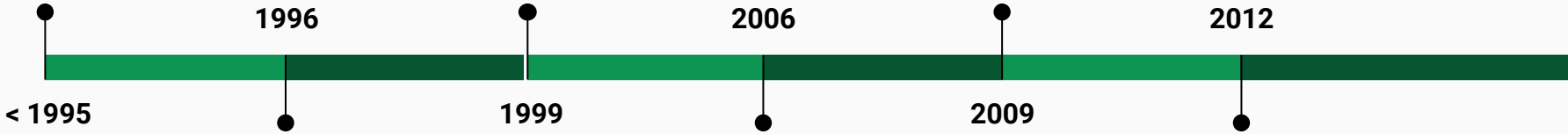
Small hardware units from low-res to monochrome to 2D by IBM, Intel, ...

NVidia launched GeForce 256

GPU as “integrated transform, lighting, triangle setup / clipping, and rendering engines”

OpenCL launched

Open-source framework to simultaneously program GPU + CPU



First 3d card
3DFx’s Voodoo graphics card as the first add-in card for gaming. DirectX

NVidia launches CUDA
Formalized earlier General Purpose (GPGPU) scientific computing. ATI

Deep Learning Era begins
AlexNet wins in the ImageNet competition

The “graphics” age

Source: http://www.nvidia.com/content/GTC-2010/pdfs/2275_GTC2010.pdf

What GPUs do - 3D rendering

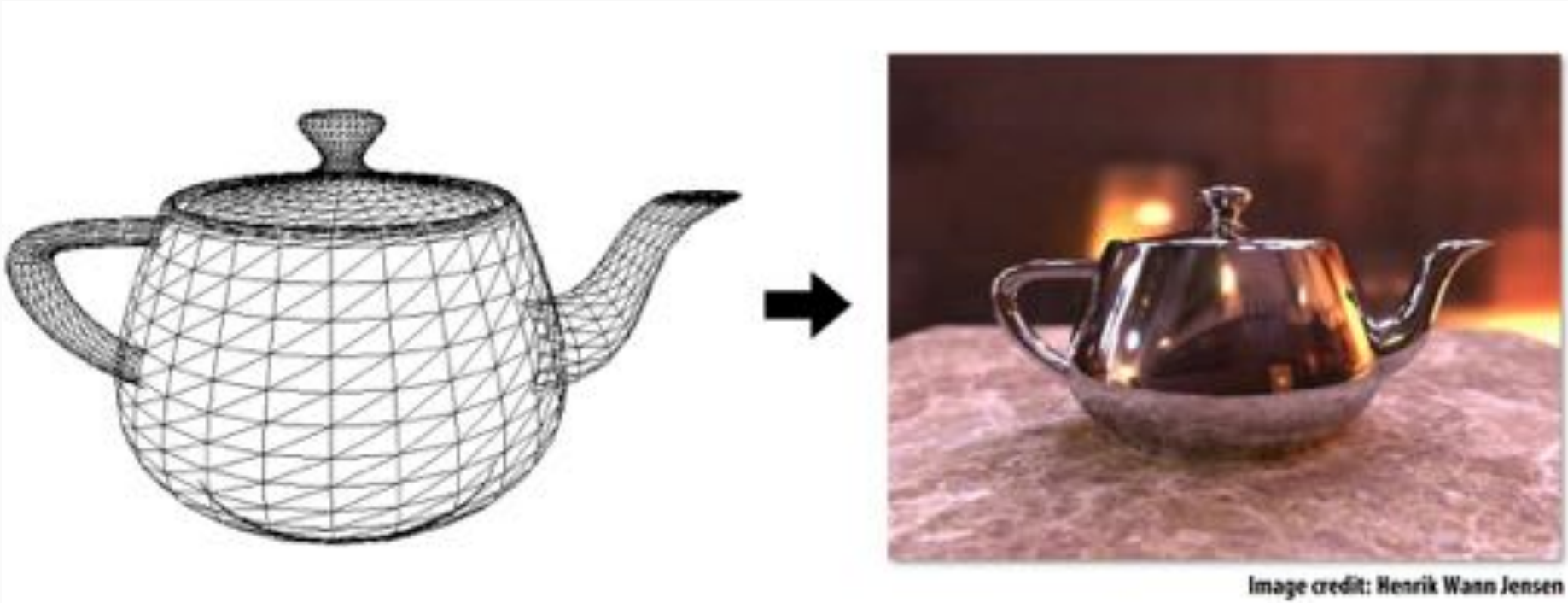
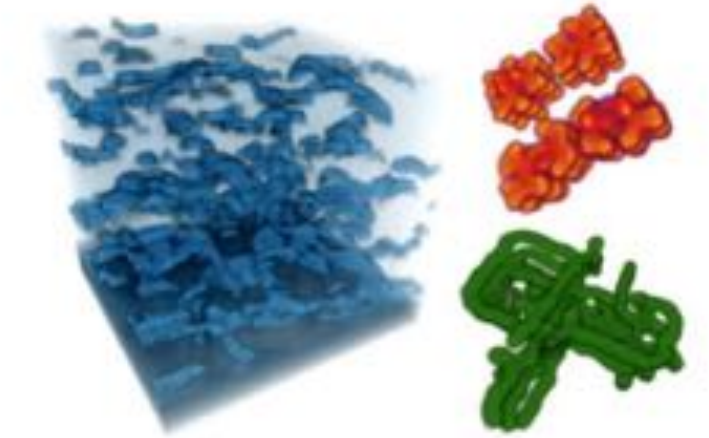
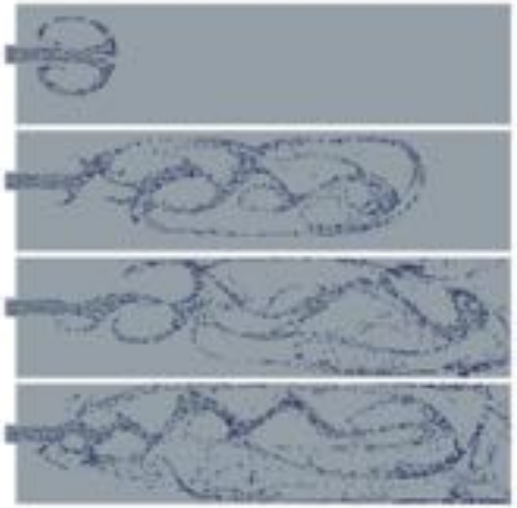


Image credit: Henrik Wann Jensen

GPGPU



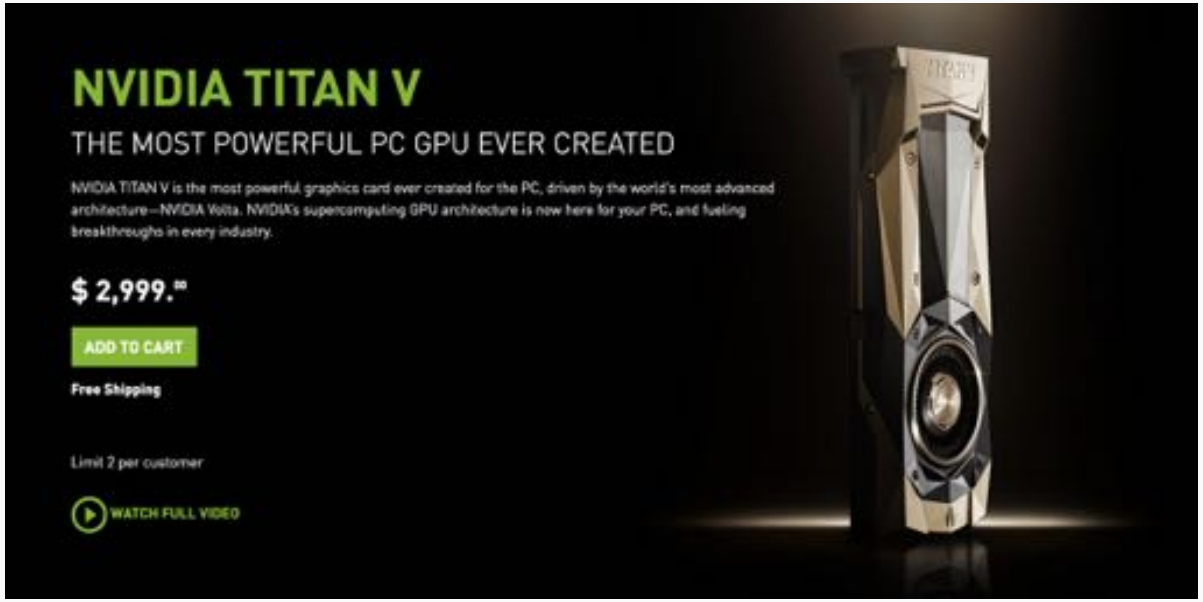
Coupled Map Lattice Simulation [Harris 02]



Sparse Matrix Solvers [Bolz 03]

Ray Tracing on Programmable Graphics Hardware [Purcell 02]

Today - Titan V



110 TeraFLOPs for DL (FLOP = floating point operations per time unit)

Fastest supercomputer in 2004: IBM BlueGene had 70.72 teraflops

Today - Drive Pegasus

320 TOPS (not TFLOPS) in your car!

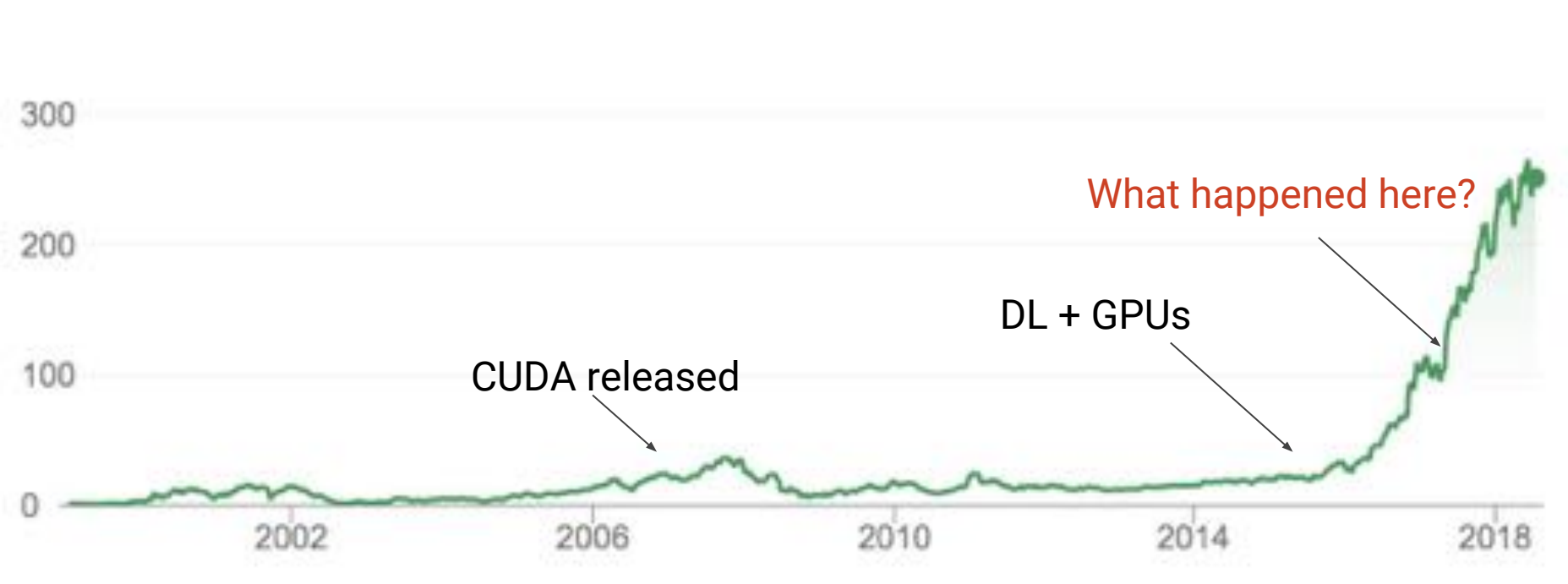
Not a single chip, but an SoC with multiple GPUs

2x Volta iGPU

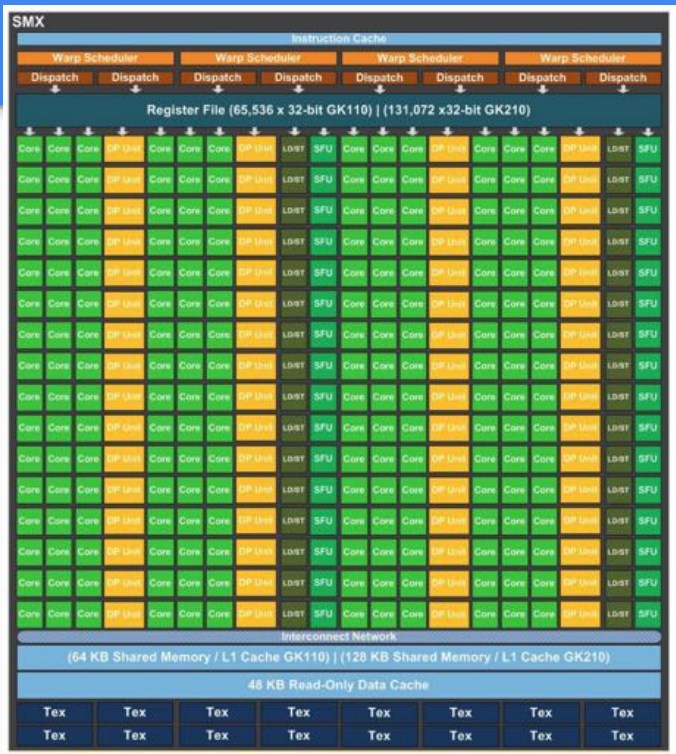
2x post-Volta dGPUs

500 W power consumption!

NVidia share price

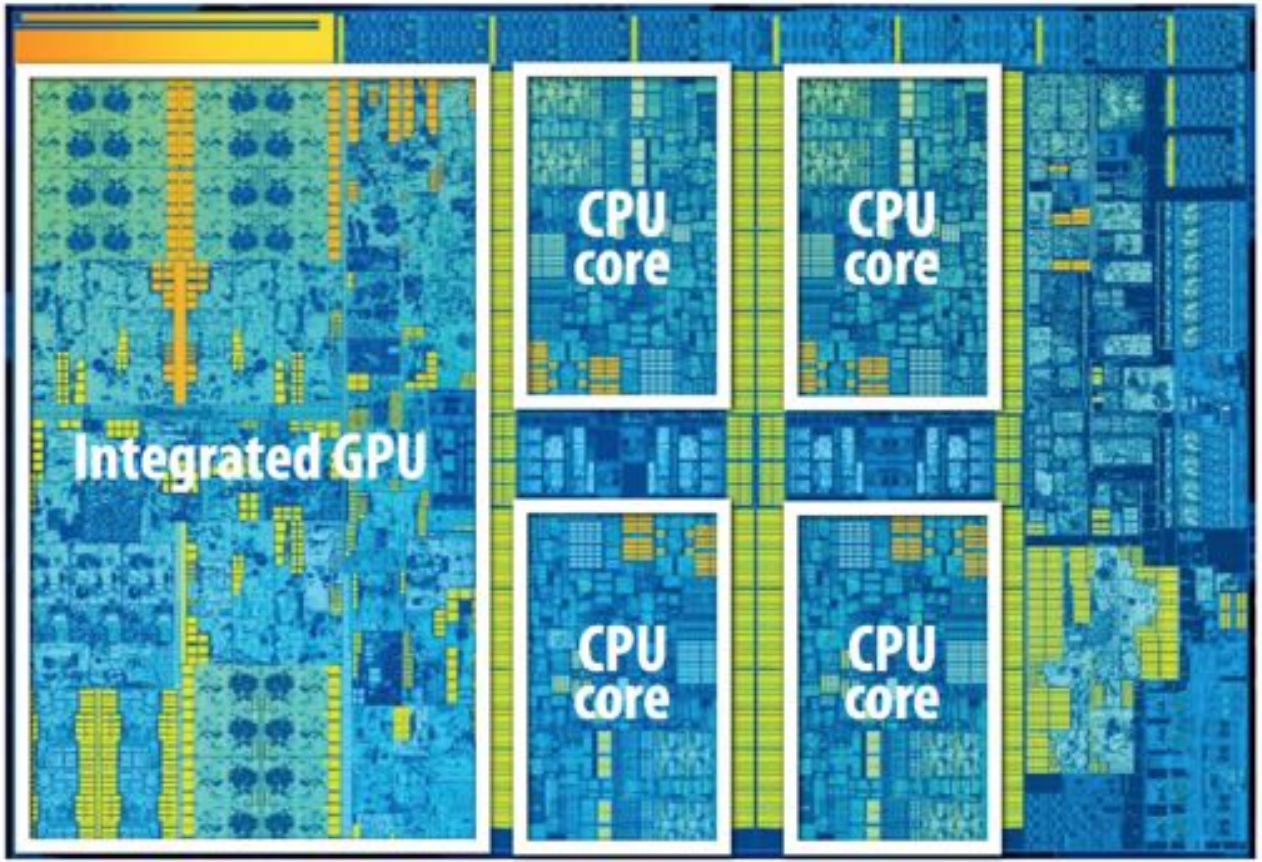


Kepler Architecture



Massively parallel
2880 cores

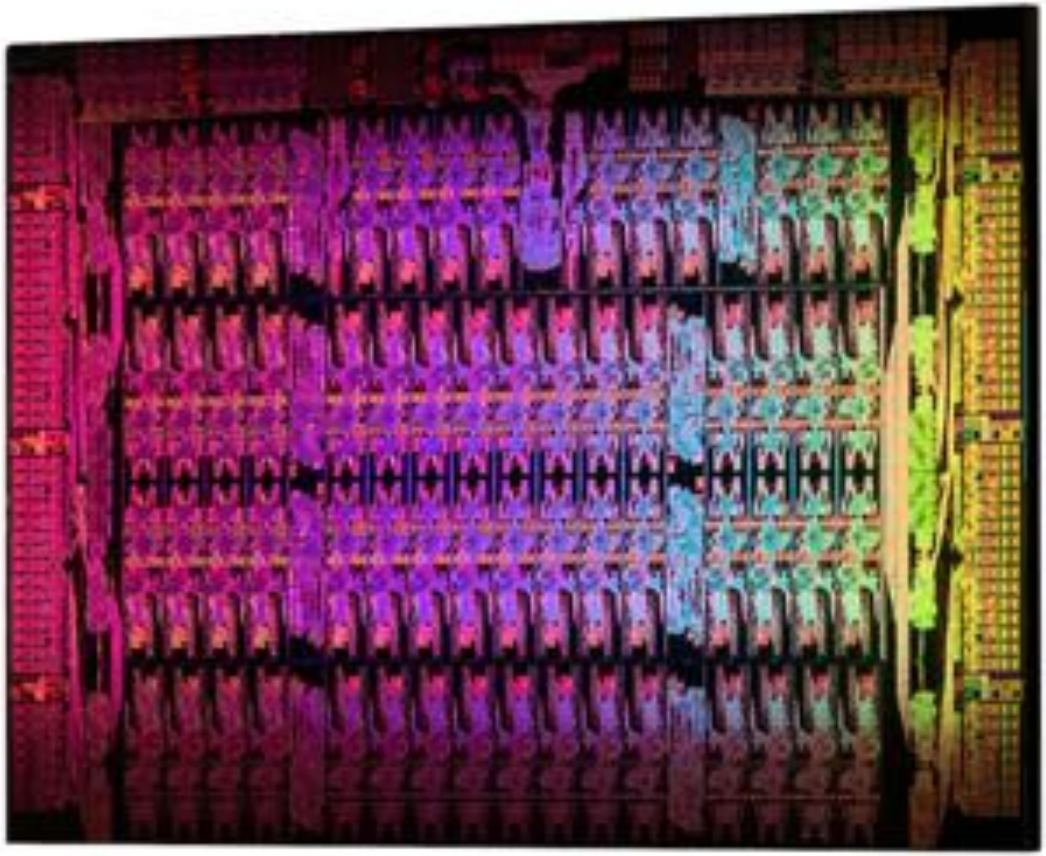
Standard CPU



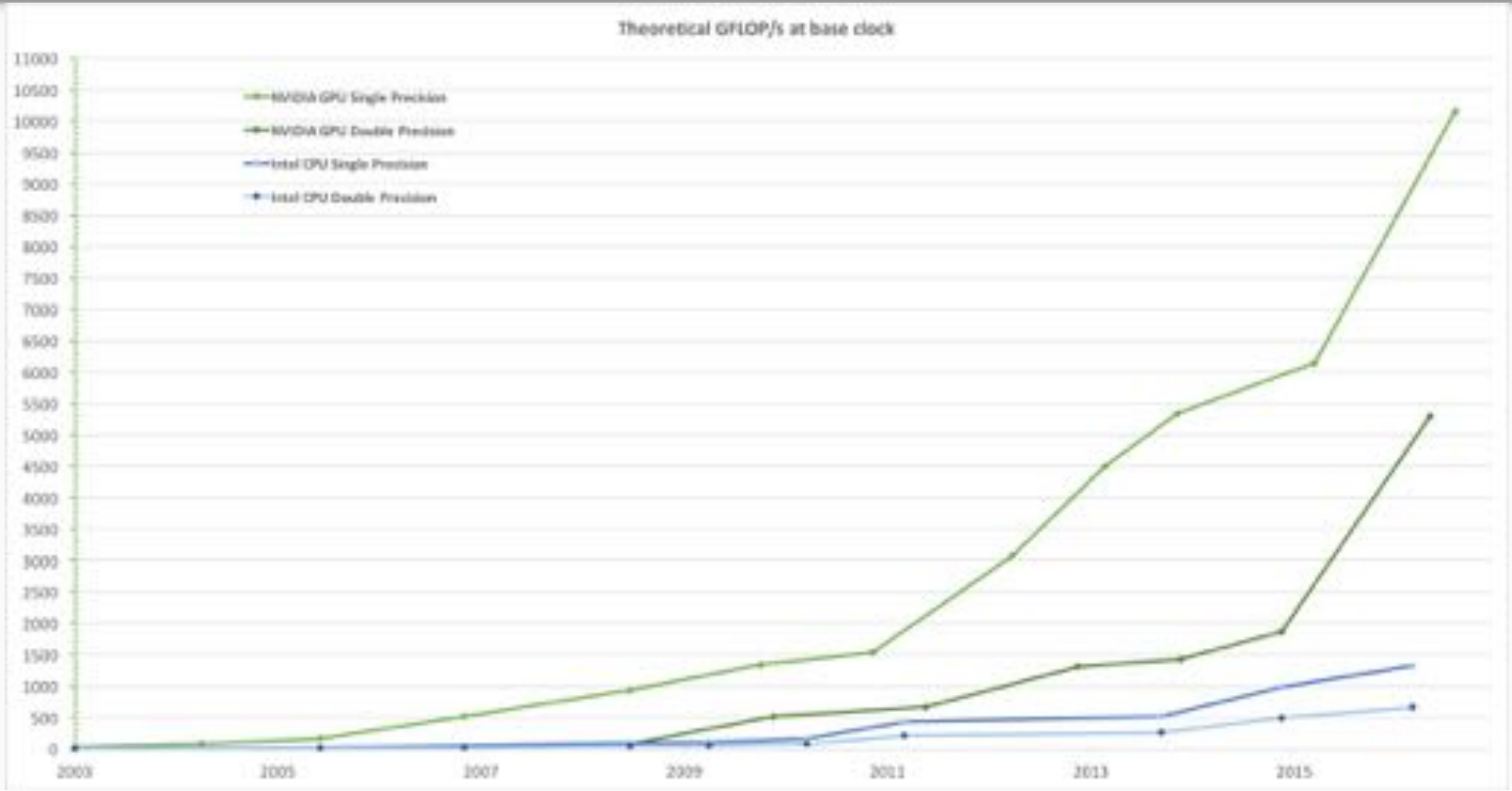
Intel Skylake

CPU accelerator

61 cores

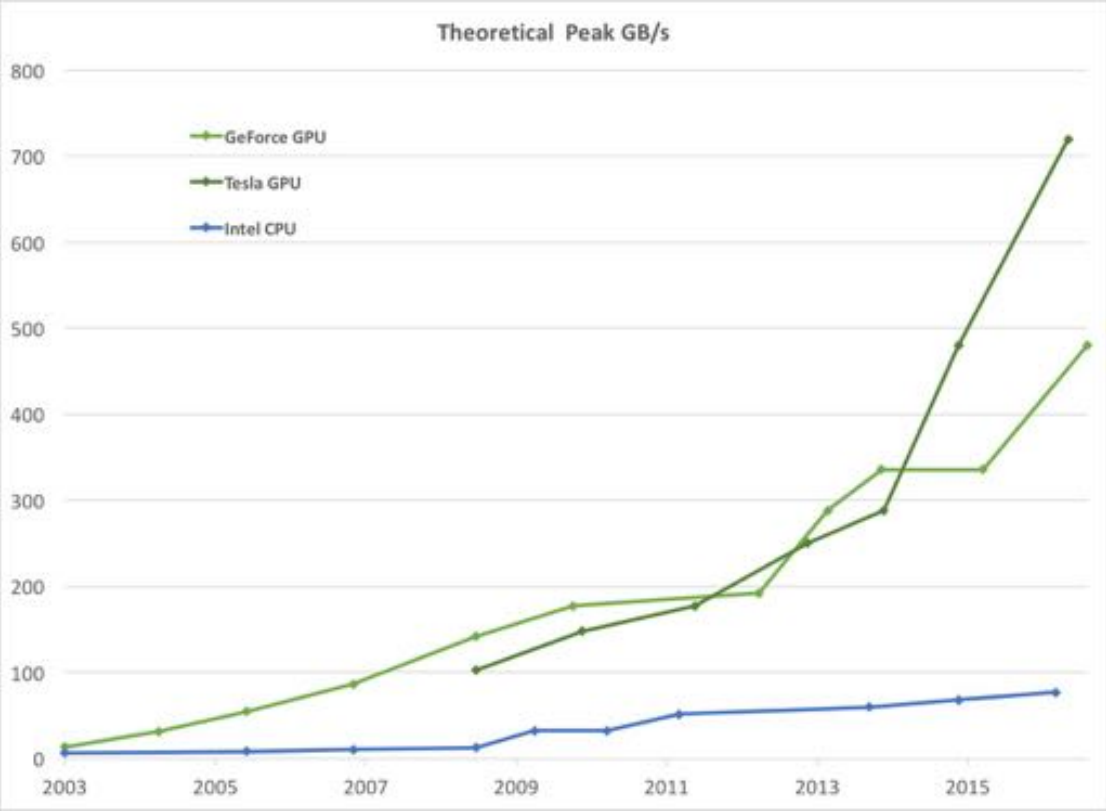


Vis-a-vis CPU - compute



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

Vis-a-vis CPU - memory



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

Compare - GPU and CPU

Hardware	Flops (DP)	Power (W)	Price (k$)
2 Ivybridge EX (2 x 15 cores, 2.8 GHz)	0.672 TFlops	310	8.4-13.7
K40 GPU	1.43 TFlops	235	3-4
GTX Titan Black	1.7 TFlops	250	1

Performance per second
per watt
per dollar

Next time

- Why the big difference between CPU and GPU performance?
- Understand/recap basics of CPU architecture