

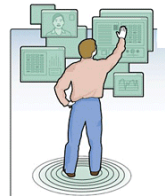


# Embedded Systems



- Computing systems are everywhere
- Most of us know **general-purpose computers**
  - Laptop
  - PC
  - Server
  - Mainframe
  - Supercomputer
- But there is another type of computing system; And it is far more **common**

# An Era of Embedded Computing Systems



Computing system type	Mainframe	Mini computer	Personal computer	Embedded computer
Era	1950s on	1970s on	1980s on	2000s on
Form factor	Multi-cabinet	Multi-board	Single board	Single chip
Owner type	Corporates	Departments	Persons	Things
Users/system	1000s ~ 100s	100s ~ 10s	10s ~ 1s	1s ~ 1/10s
Cost	\$1 Ms +	\$100 Ks +	\$10Ks – \$1Ks +	\$100s – \$1s +
Total units	10Ks +	100Ks +	Billions +	Trillions +

## Definition

- A short name for **embedded computing system**
  - Different from general-purpose computing system, such as desktop computers, it is usually embedded in a larger physical system
  - Carry **one or a fixed set** of specific tasks by design or usage
- 
- Nearly any computing system other than laptop, desktop, server, mainframe, and supercomputer
  - About 50 per household and per automobile
  - Billions of units produced yearly, versus millions of desktops

Computers are in here...



and here...



and even here...



- Consumer electronics
  - Digital camera and camcorder
  - Cell phone
  - CD player
  - Wireless router
  - TV
  - Blu-ray player
  - Microwave oven
  - USB key
  - Remote control
  - Digital watch and clock
- ...



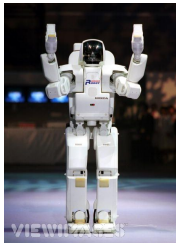
- Also in your desktops and laptops

- Graphics card
- Sound card
- Network card
- Hard disk
- DVD drive
- Keyboard, mouse
- Touch pad
- LCD monitor
- Even inside laptop battery

...



- In robots
  - Vision system
  - Arm and leg control
  - ...
- In medical instruments
  - Blood pressure monitor
  - Diabetes monitor
  - ...
- In telecommunications
  - Internet switch and router
  - Mobile phone base station
  - ...

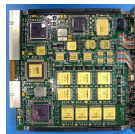
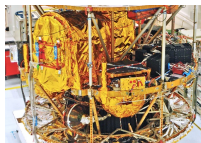


- In aircraft
  - Auto pilot system
  - Communication system
  - ...
- In watercraft
  - Navigation system
  - Radar system
  - ...
- In automobile
  - Engine control system
  - Anti-lock braking system (ABS)
  - Navigation system
  - Collision protection system
  - ...





- In space shuttle
  - Positioning system
  - Communication system
  - Navigation systems
  - ...
- In satellite
  - Communication system
  - Power control system
  - ...
- In Mars rover
  - Automatic driving system
  - Automatic lab system
  - ...





## Limited functions

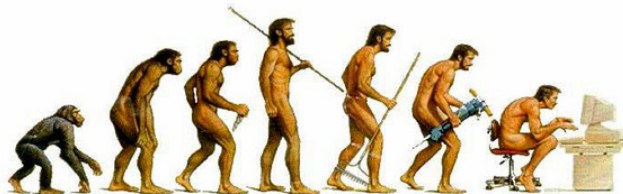
- Doing a specific set of tasks repeatedly
- High-end embedded systems are often multi-function systems
- Cell phone, slate ...

## Tightly constrained

- Low cost, energy efficient, small, fast, etc.
- Usually must meet the performance requirement (such as speed)

## Reactive and even real-time

- Continually reacts to changes in the system's environment
- Some systems must compute certain results in real-time without delay
- ABS, auto-pilot system ...



- **Information** is the center of the Information Age
- Information is any knowledge, and one possible method to represent information is by **data** which are quantities with or without natural physical meanings.
- Embedded system is used to collect, convert, store, protect, process, transmit, retrieve, and share information
- Human spend more time to design and let embedded system to do tedious and dangerous jobs

## Develop ES applications

- Microsoft, Google, telecom companies, banks ...

## Develop ES

- IBM, Apple, Samsung, NEC, Philips, Oracle, Dell, HP, Sony, Nokia, Cisco, Huawei, Lenovo ...

## Develop IC for ES

- Intel, AMD, TI, ST, Qualcomm, Broadcom, Xilinx ...

## Develop design automation tools for ES

- Cadence, Synopsys, Mentor Graphics ...

Many companies work in multiple areas instead of one

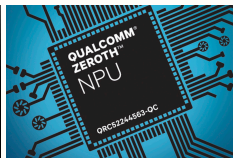
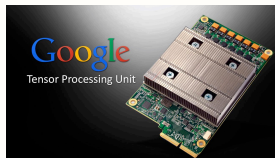


Convolution layer is one of the most expensive layers

- Computation pattern
- Emerging challenges

More and more end-point devices with limited memory

- Cameras
- Smartphone
- Autonomous driving

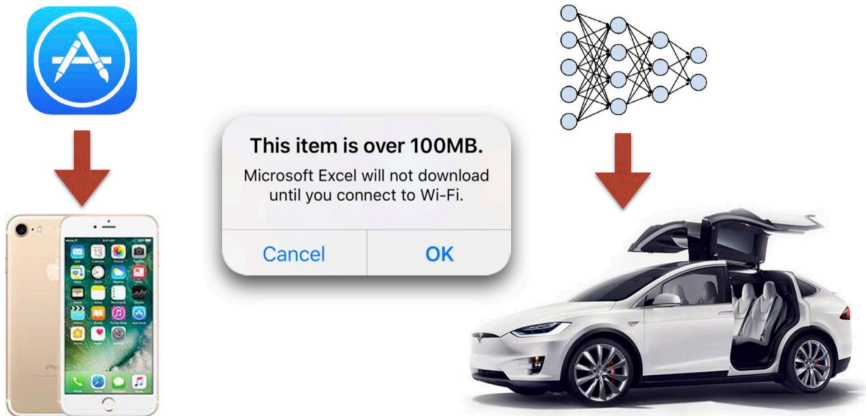


XILINX



An Intel  
Company

Hard to distribute large models through over-the-air update





AlphaGo: 1920 CPUs and 280 GPUs,  
**\$3000 electric bill** per game



on mobile: **drains battery**  
on data-center: **increases TCO**





## Application Category

Both	Datacenter	Edge
Intel, Nvidia, IBM, Xilinx, HiSilicon, Google, Baidu, Alibaba Group, Cambricon, DeePhi, Bitmain, Wave Computing	AMD, Microsoft, Apple, Tencent Cloud, Aliyun, Baidu Cloud, HUAWEI Cloud, Fujitsu, Nokia, Facebook, HPE, Thinkforce, Cerebras, Graphcore, Groq, SambaNova Systems, Adapteva, PEZY	Qualcomm, Samsung, STMicroelectronics, NXP, MediaTek, Rockchip, Amazon_AWS, ARM, Synopsys, Imagination, CEVA, Cadence, VeriSilicon, Videantis, Horizon Robotics, Chipintelli, Unisound, AISpeech, Rokid, KnuEdge, Tenstorrent, ThinCI, Koniku, Knowm, Mythic, Kalray, BrainChip, Almotive, DeepScale, Leepmind, Krtkl, NovuMind, REM, TERADEEP, DEEP VISION, KAIST DNP, Kneron, Esperanto Technologies, Gyrfalcon Technology, GreenWaves Technology, Lightelligence, Lightmatter, ThinkSilicon, Innogrit, Kortiq, Hailo, Tachyum

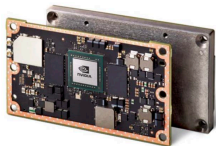
Source: <https://basicmi.github.io/Deep-Learning-Processor-List/>



# Flexibility vs. Efficiency



CPU  
(Raspberry Pi3)



GPU  
(Jetson TX2)

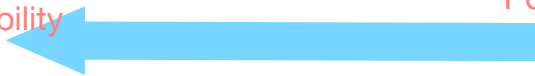


FPGA  
(UltraZed)



ASIC  
(Movidius)

Flexibility



Power/Performance  
Efficiency

