

CENG 4480

Embedded System Development & Applications



Lecture 01: Introduction

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Important Notes



- Be **PUNCTUAL** to class
- Keep **QUIET** during class, unless
 - you are raising questions to teachers or tutors
 - during in-class activities



Zero Tolerance

- Plagiarism, cheating, misconduct in test/exam will be reported to the Faculty Disciplinary Committee for handling.

Penalty

- **Zero** marks for the concerned assignments/test/exam/whole course, reviewable demerits, non-reviewable demerits, suspension of study, dismissal from University.

University Guidelines to Academic Honesty

- <http://www.cuhk.edu.hk/policy/academichonesty/>



- Let's join hands to create a positive, respectful, and engaged academic environment inside and outside classroom.
- Full version of Student/Faculty Expectations on Teaching and Learning
- <http://www.erg.cuhk.edu.hk/upload/StaffStudentExpectations.pdf>



Grading System



- Class Attendance (5 marks)
- Homeworks (20 marks)
- 8 Labs (25 marks)
- Midterm Exam (15 marks)
- Final Exam (35 marks)

A student must gain at least **50 marks** in order to pass the course.



- Individual lab (academic honesty!)
- About Absence in mid-term
- Class attendance: **uReply** or **in-class quiz**
Ex: http://www.cse.cuhk.edu.hk/~byu/doc/quiz_example.pdf
- Lecture review
- Bonus question
- Please read your marks from Blackboard (<https://blackboard.cuhk.edu.hk>)

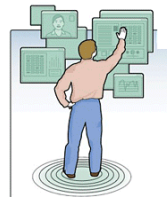


Embedded Systems



- 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

...



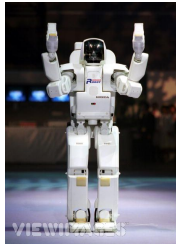


- Also in your desktops and laptops
 - Graphics card
 - Sound card
 - Network card
 - Hard disk
 - DVD drive
 - Keyboard, mouse
 - Touch pad
 - LCD monitor
 - Even inside laptop battery
 - ...





- 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
 - ...

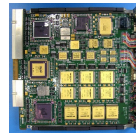
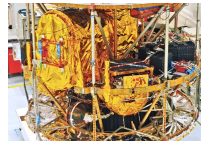


- In aircraft
 - Auto pilot system
 - Communication system
 - ...
- In watercraft
 - Navigation system
 - Radar system
 - ...
- In automobile
 - Engine control system
 - Anti-lock braking system (ABS)
 - Navigation system
 - Collision protection system
 - ...





- 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

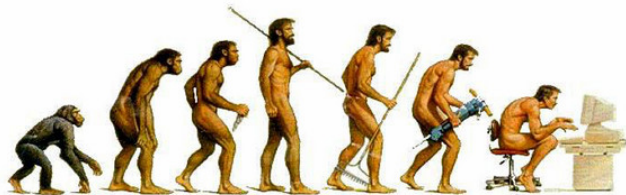
- Doing a specific set of tasks repeatedly
- High-end embedded systems are often multi-function systems
- Cell phone, slate ...

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 ...

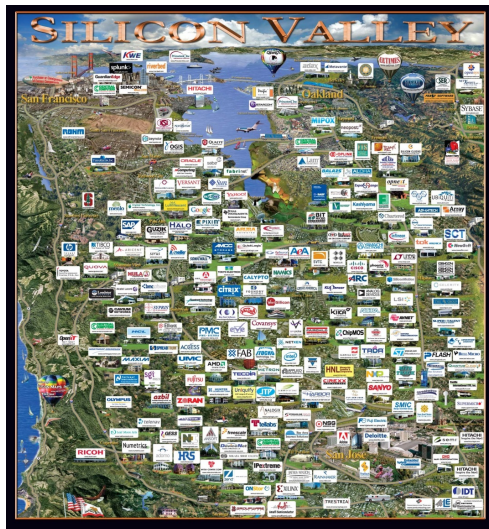
Develop **IC** for ES

- 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



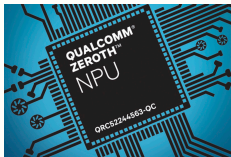
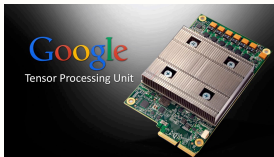


Convolution layer is one of the most expensive layers

- Computation pattern
- Emerging challenges

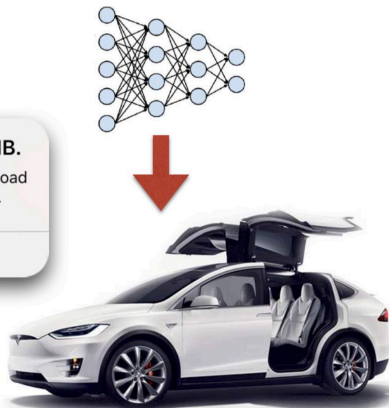
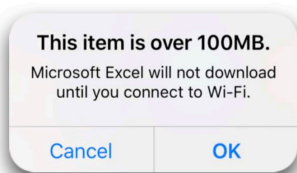
More and more end-point devices with limited memory

- Cameras
- Smartphone
- Autonomous driving



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

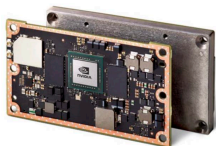
| Both | Datacenter | Edge |
|---|---|--|
| Intel, Nvidia, IBM, Xilinx, HiSilicon, Google, Baidu, Alibaba Group, Cambricon, DeePhi, Bitmain, Wave Computing | AMD, Microsoft, Apple, Tencent Cloud, Aliyun, Baidu Cloud, HUAWEI Cloud, Fujitsu, Nokia, Facebook, HPE, Thinkforce, Cerebras, Graphcore, Groq, 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, ThinCl, 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)

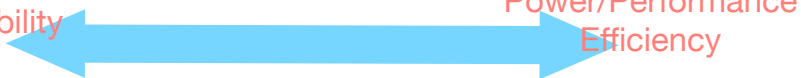


FPGA
(UltraZed)



ASIC
(Movidius)

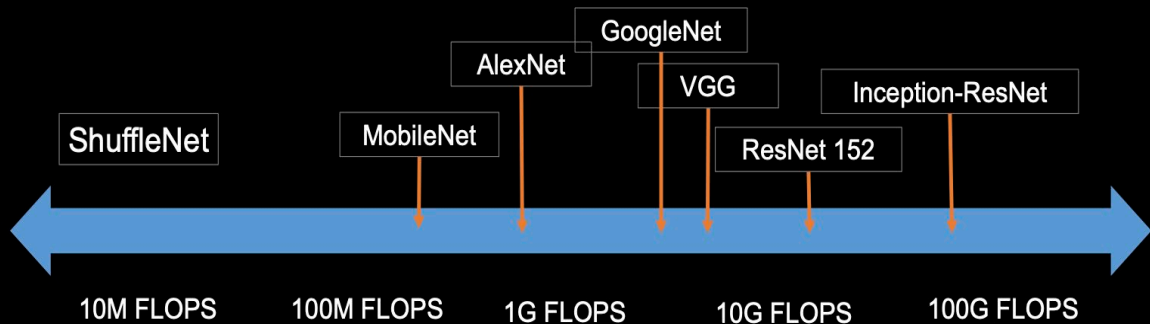
Flexibility



Power/Performance
Efficiency



Computing Spectrum





Course Overview



How to build up a Robot?



A1 Sensors

- Use of different sensors and their characteristics

A2 Op Amps and Analog Interfacing

- How to connect sensors to systems



Sensor demo (<http://www.youtube.com/watch?v=9NEiBDBXFEQ>)



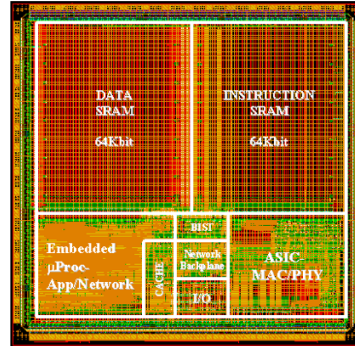
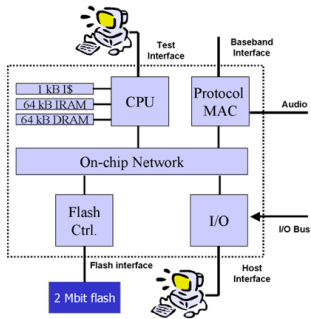
A3 Analog-to-digital conversions ADDA

- Internal operations of different ADDA devices

A4 PID controller

- feedback control of motors





How to design an embedded system?

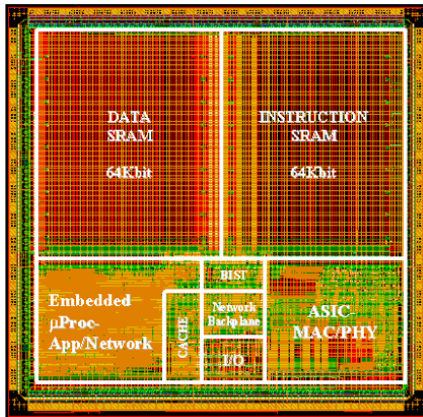


B1 HW/SW Co-design

B2 Memory

B3 Clock

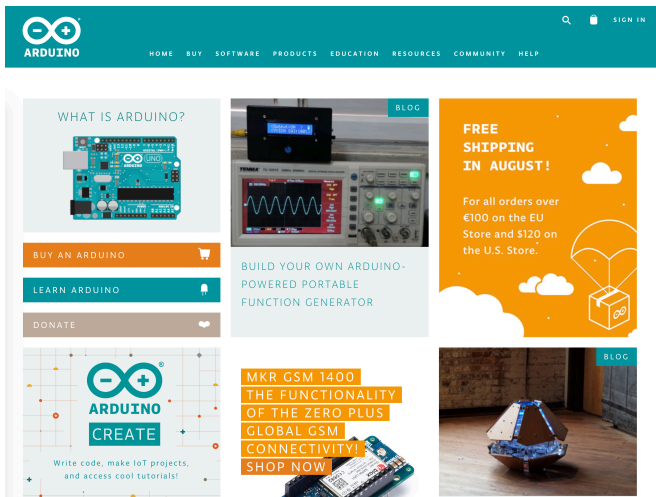
B4 Design Style (Optional)





- Demo 1: Self-Balancing Robot
<https://youtu.be/dQWATsLa30g>
- Demo 2: Robot Car w. Color Sensor
<https://youtu.be/PKCPdWjZCqY>
- Demo 3: Robot Hand
<https://youtu.be/ai94rHHuaXc>
- Demo 4: Robot
<https://youtu.be/1D0e7SS85Xc>

- <https://www.arduino.cc/>
- <https://youtu.be/nL34zDTPkcs>



The screenshot shows the Arduino website homepage with a teal header. The header contains the Arduino logo, a search icon, a shopping cart icon, and a 'SIGN IN' link. Below the header is a navigation menu with links for HOME, BUY, SOFTWARE, PRODUCTS, EDUCATION, RESOURCES, COMMUNITY, and HELP. The main content area features several promotional tiles:

- WHAT IS ARDUINO?**: A tile with an image of an Arduino Uno board and three buttons: 'BUY AN ARDUINO' (with a shopping cart icon), 'LEARN ARDUINO' (with a bell icon), and 'DONATE' (with a heart icon).
- BLOG**: A tile with an image of a function generator and an oscilloscope, with the text 'BUILD YOUR OWN ARDUINO-POWERED PORTABLE FUNCTION GENERATOR'.
- FREE SHIPPING IN AUGUST!**: A large orange tile with the text 'For all orders over €100 on the EU Store and \$120 on the U.S. Store.' and an illustration of a box with an Arduino logo being lifted by a parachute.
- ARDUINO CREATE**: A tile with the text 'Write code, make IoT projects, and access cool tutorials!' and a grid background.
- MKR GSM 1400**: A tile with the text 'THE FUNCTIONALITY OF THE ZERO PLUS GLOBAL GSM CONNECTIVITY! SHOP NOW' and an image of the MKR GSM 1400 board.
- BLOG**: A tile with an image of a small robot on wheels.