REAL-TIME

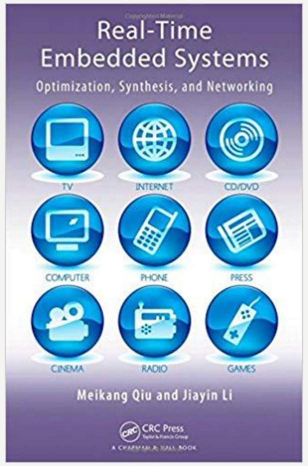
EMBEDDED SYSTEMS

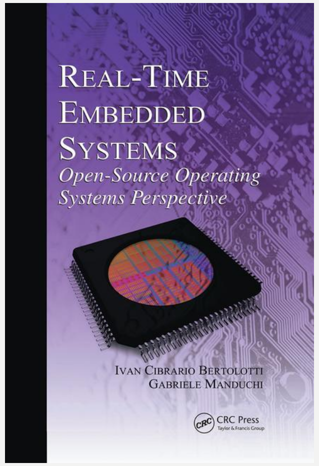
ABOUT THIS COURSE

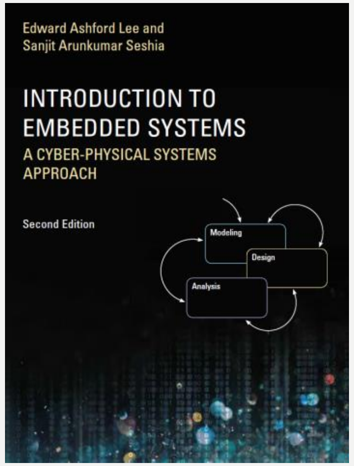
- **Course Meeting Times:**
  - Weekly : Tuesday + Wednesday: 1-2-2-2-2-2(1rst half of the sem)
- **Prerequisites**:
  - CA, OS, DSD…

  TAs:
  - Mariam
  - Ghada

- **Readings :**







- **Course Material**: Lecture notes + references + etc.

COURSE'S OUTLINE

- The Real-time paradigm and embedded concept
- Hardware and Software aspects
- RTOS : FreeRTOS
- Embedded buses: I2C, UART, …
- RTES challenges: Security, dependability and autonomy.
- RTES standards in the Automotive industry (ECUs, CAN -intro: AUTOSAR)

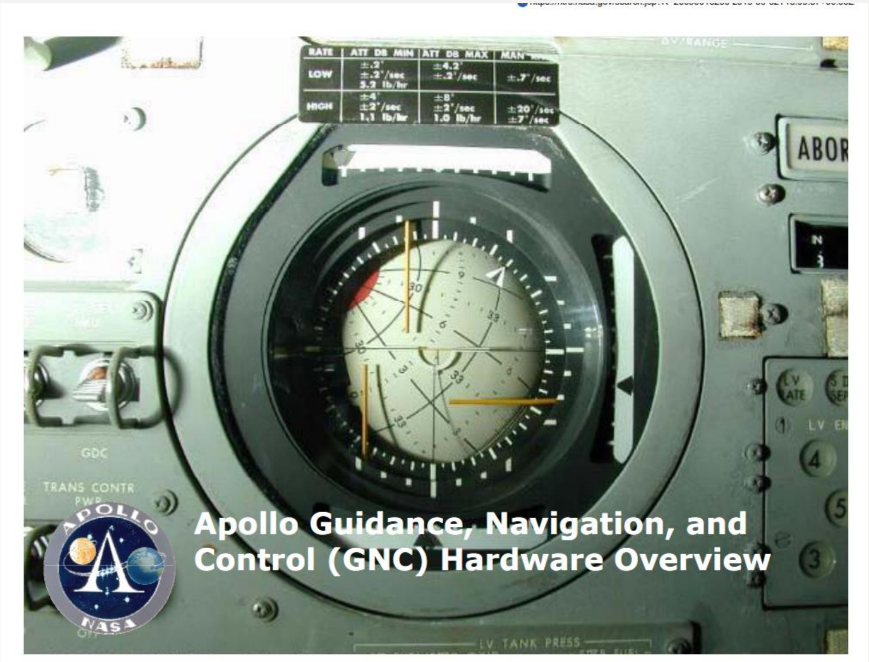
TUTORIALS

- Nios II on FPGA
- Arduino standalone
- freeRTOS on Visual Studio/on Arduino
- Communication (Buses)
- Exercises and Case studies

- *At home:Vector CANoe (optional)*

COMPUTER?

NUMBER OF COMPUTERS IN…



https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20090016290.pdf

- **Apollo command module (CM) and Apollo Lunar Module (LM)? :**

Only one! ***Apollo Guidance Computer*** (**AGC**) : 16-bit! ~2Mhz

NUMBER OF COMPUTERS IN…

- Average cars: ~80
- Luxury cars? >=150 ECUs

NVIDIA Tegra 3 CPU board from S/X MCU1

Name	Area	Notes	Sets	CPUs	Sub-total
ABS (Anti-lock Braking)	?		1	1	1
AC Motor Inverter/Charger	Rear		1	2	2
Active Cruise Control	?	Cars built after 14-Sep-2014	1	1	1
Air Suspension	?	Continental	1	1	1
AM/FM/HD radio	Dash	Panasonic	1	1	1
Audio System	Dash	PIC18f2550	1	1	1
Autopilot 1 Camera CPU*	Windshield	Mobileye EyeQ3	1	1	1
Autopilot 1 Processor*	Windshield	Freescale SPC5603	1	1	1
Autopilot 2.0 Processors*	Dash	Nvidia PX2 & one Freescale CPU	1	2	2
Battery Sub-Module	Battery	16 in 85/90 kWh, 14 in 60/70 kWh models	16	1	16
Bluetooth	Dash		1	1	1
Charger Module	Rear Seat	1-Standard, 2-optional	2	1	2
Connectivity – 3G/LTE	Dash	Sierra Wireless AR8550 (3G), later AR755X (LTE)	1	1	1

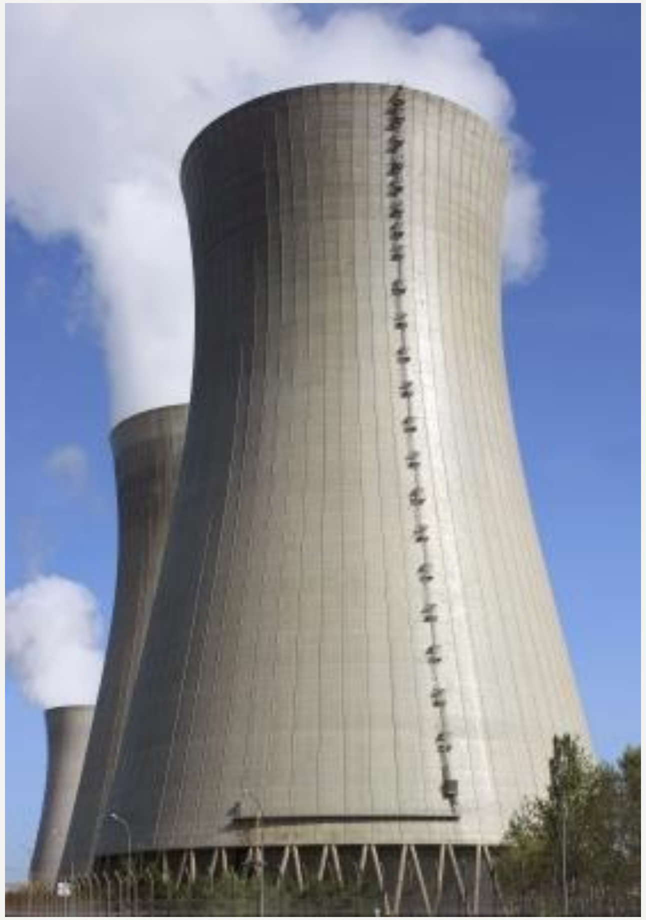
NUMBER OF COMPUTERS IN…

- Smart homes?…………..

RESEARCH CLUSTER

Looking for motivated junior apprentices!

WHAT ARE REAL-TIME SYSTEMS?



WHAT ARE REAL-TIME SYSTEMS?

"A real-time system is any information processing system which has to respond to externally generated input stimuli within a finite and specified period"

WHAT ARE REAL-TIME SYSTEMS?

- Soft RT systems
- Firm RT systems
- Hard RT systems…and also Weakly Hard

WHAT ARE REAL-TIME SYSTEMS?

Soft RT systems:

- Deadline overruns are not desired, but tolerable.
- No catastrophic consequences of missing deadlines.
- There is some cost associated to overrunning.
- Often connected to Quality-of-Service(QoS)

WHAT ARE REAL-TIME SYSTEMS?

Soft RT systems examples:

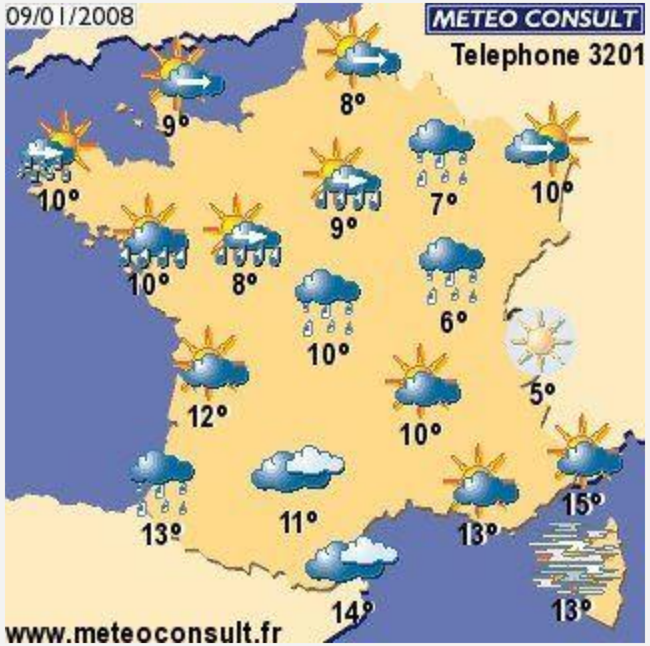
WHAT ARE REAL-TIME SYSTEMS?

Firm RT systems

- The computation is obsolete if the job is not finished on time.
- Cost may be interpreted as loss of energy/time/money.

WHAT ARE REAL-TIME SYSTEMS?

Firm RT systems examples:



WHAT ARE REAL-TIME SYSTEMS?

- Hard real-time systems…
  - They are safety critical.
  - A deadline overrun leads to a catastrophe (loss of lives and/or huge damage)

- …and also **Weakly** hard real-time
  - Systems where a fixed number of deadlines have to be at least met.
  - Probabilistic guarantees are sufficient for these systems.

WHAT ARE REAL-TIME SYSTEMS?

- Hard real-time systems:

WHAT ARE REAL-TIME SYSTEMS?

- Weakly Hard real-time systems:

WHAT ARE EMBEDDED SYSTEMS?

WHAT ARE EMBEDDED SYSTEMS?

"An embedded system is a computer system that is part of a larger system.

It interacts with its environment, often with real-time computing constraints"

EMBEDDED SYSTEMS: FACTS AND FIGURES IN 2008!

- Over 4 billion embedded processors were sold last year [2007] and the global market is worth €60 billion with annual growth rates of 14%.

- Forecasts predict more than 16 billion embedded devices by 2010 and over 40 billion by 2020.

- Within the next five years [2013], the share of embedded systems are expected to increase substantially in markets such as automotive (36%), industrial automation (22%), telecommunications (37%), consumer electronics (41%) and health/medical equipment (33%).

[1] Embedded Systems http://www.artemis-ju.eu/embedded_systems, 2008

REAL-TIME EMBEDDED SYSTEMS: CONSTRAINTS

- Time-related: Must fulfill execution on 'strict' timing: latency, throughput
- Resources: power, size, weight, heat, etc.
- No or minimal user interface

REAL-TIME EMBEDDED SYSTEMS: DESIGN ISSUES

1. The selection of hardware and software, and evaluation of the tradeoff needed for a cost-effective solution
2. Dealing with distributed computing systems and the issues of parallelism and synchronization.
3. Correct representation of temporal behavior.
4. Understanding the nuances of the programming language(s) and the real-time implications resulting from their translation into machine code.

REAL-TIME EMBEDDED SYSTEMS: DESIGN ISSUES

5. Maximizing of system fault tolerance and reliability through careful design.

6. The design and administration of tests, and the selection of test and development equipment.

7. Taking advantage of open systems technology and interoperability.

8. Measuring and predicting response time and reducing it.

9. Performing a schedulability analysis, that is, determining and guaranteeing deadline satisfaction, *a priori*, is largely “just” scheduling theory.

REAL-TIME EMBEDDED SYSTEMS: DESIGN AND MODELING

Step 0:High level requirements	• Informal requirements • Text & algorithms
Step 1: Modeling	• Functional requirements (FR) • Non FR
Step 2: development	• Development process

EMBEDDED SOFTWARE OR HARDWARE?