In4073
Embedded Real-Time Systems

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Embedded Software group
Embedded System

ES = computer system embedded within other system defining its functionality

user interface

printer

printing system
Example Systems

- Phone, cam, audio, VCR, TV, PDA, games ..
- Heater, refrigerator, microwave, aircon, ..
- Printer, copier, fax, modem, comm hub, ..
- Car engine, brakes, CC, car navig, ..
- Missiles, planes, subs, ships, trains, ..
- Power plants, chemical plants, ..
- Wafer scanners, medical devices, ..
Embedded Systems Boom

- Provides functionality of almost everything
- 100 times PC market size
- 25% annual growth rate (E Linux > 60%)
- Accounts for 25-40% costs in automotive
- In society’s critical path
- Must be dependable, but affordable
ES Technology Today

- $\mu$proc + peripheral I/O (boards, racks)
- $\mu$controller (all on single chip)
- DSP (idem, optimized for signal proc)
- FPGA (idem, no ISA)
- ASIC (idem, not programmable)

- Shift from HW to SW (> 10 MLOC in ConsElec)
- in4073: Focus on Embedded Software
Embedded Software Crisis

- TV, mobile phone, car: > 10 MLOC
- Code complexity is growing exponentially
- Number of bugs is growing exponentially
- Despite good SW eng’g 1 – 10 bugs / KLOC
- Therac-25, Ariane 5, USS Yorktown, Mars Climate Orbiter, Mars Polar Lander, Patriot
- your car ..?
- 100 G$ / yr on bug costs
- Embedded SW is difficult!
What’s so Special About ES?

- Tight interaction with embedding system
- Real-time response
- Adequately react to unpredictable events
- Cope with failures of embedding system

- Physics (electronics, optics, mechanics, ..)
- Concurrency
- Performance
- Power
- Dependability
Outline

1. Embedded Systems
2. Course Goal
3. Lab Project
Course Goal

• Introduction to multidisciplinary design
• Work with embedded SW
• For CS to get comfortable with embedded HW, Physics, Signals, Control, ...
• For EE, CE, .. to get comfortable with Emb SW
• For ES bit of both, “mandatory” course
• Focus: SW instead of HW
• HW: programmable (COTS)
• Allows you to do ES as personal hobby
Course Format

- **Lab** + supporting lectures
- Case: embedded control unit for a QR UAV
  - Physics, electronics, control (SW), communication (SW), simulation (SW)
- Technology: PC (C), uctrl (Emb. C)
- Lab teams (3 students, mixed-ES-CE-XX)
- Project deliverables: Demonstrator + Tech-rep.
- Grading: deliverables + ranking + individual
- Grading: $0.75 \times D + 0.25 \times T$ iff $D \geq 50, T \geq 50$
Course Support

- Lecture material: course site + WWW
- Lab assignment: course site
- Assignment: your problem ... so be pro-active, dig up knowledge yourself, and ASK!
- Course site: Resource page
- Lab facilities: Tellegenhal, practicumzaal 3
  - Two 4-hr slots (Thu|Fri aftern.) for 8 weeks
  - Lab Leader: Ioannis Protonotarios
  - 2 TAs: Henko Aantjes, Sujay Narayana
Project: Drone Controller

- Electrical model quad-rotor AV ("QR")
- QR: no stabilization, just rotors + sensors
- Lab goal: roll, pitch, yaw stabilization
- Long-term goal: autonomous UAV

- Experimental sequence:
  - Control from PC
  - Yaw stabilization
  - Roll, pitch stabilization
Hardware of Choice

- PC: user I/O (JS, Data Visualization)

- Embedded system alternatives:
  - PC I/O card: expensive, inflexible
  - μcontroller: cheap, flexible, but slow
  - FPGA card: cheap, reconfigurable
  - ASIC: dirt cheap, but inflexible
System Setup

user I/O (pilot)

PC

joystick

flight control (ES)

drone

PC link

(source: assignment.pdf)
Quadrupel drone

- Frame: Turnigy Talon V2.0 (550mm)
- Motors: Sunnysky X2212-13 980kV
- ESC: Flycolor 20A BCHeli 204S Opto
Flight Control Board

- Sensor module: GY-86
  - 3-axis gyro + accel.
  - barometer

- RF SoC: nRF81522
  - BLE
  - ARM Cortex M0 (14 MIPS, 256 KB Flash, 16 KB RAM)
  - 1 Mb Flash
LIFT OFF!
Lab Assignment

- assignment.pdf on in4073 web site
- Teams will be assigned tomorrow
- Read assignment carefully
- Team KO meeting ASAP!
- Start system design ASAP!
- Final demo during lab session 8
- Submit report at Tue Nov 1st 09:00 CET
- 10 pp. pdf file to CPM
- Late submissions are NOT graded
- Reports > 10 pp. are NOT graded
Lab Resources

- 12 Quadrupels (shared by all teams)
- Per team:
  - PCs
  - 1 FCB (€50 deposit)
  - Basic software tools
- In4073 Resource Web Page
Course Requirements

- 2\textsuperscript{nd}-year MSC students only
- Decent C-programming experience
  - Hundreds lines of code
  - Debugging skills
- Commitment
  - Lots of time: load \( \sim 4 \times \text{lab} + \text{lectures!} \)
  - Compulsory labs: no show = no grade
  - Approx. 10-15\% drops out

- Online registration (FCFS)
Lab Kick-Off

- Read Assignment ASAP
- Study in4073 Resource Web Page ASAP
- Read lab notes by TAs
- Start software architecture design
- Study/program RS232 communication
- Study/program PC – joystick SW
- Lab registration issues: Koen Langendoen (k.g.langendoen@tudelft.nl)