CS4140
Embedded Systems Laboratory
(2021/2022 edition, Apr-Jun)

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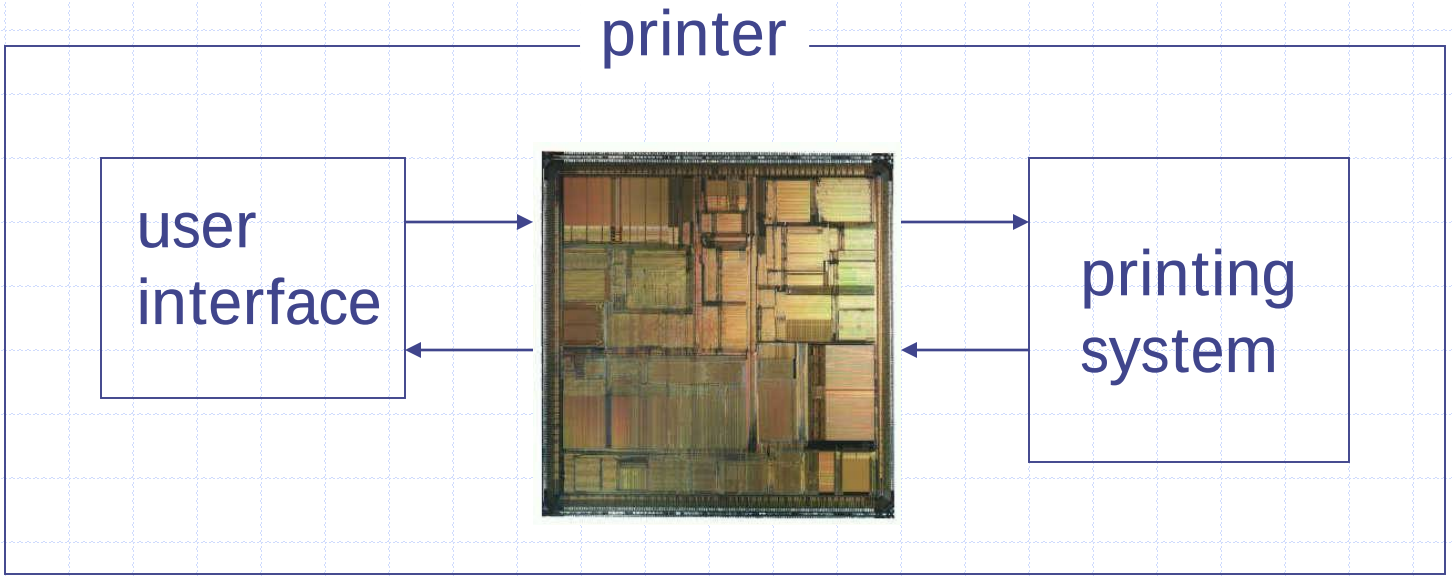
Embedded System

ES = computer system
embedded within other system
defining its functionality



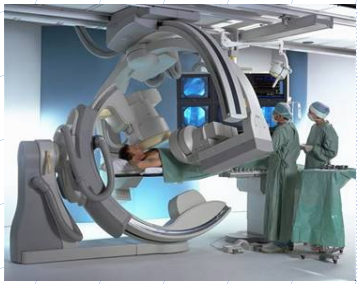
Example Systems

- Phone, cam, audio, VCR, TV, PDA, games ..
- Heater, refrigerator, μwave, airco, ..
- 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

- µproc + peripheral I/O (boards, racks)
- µcontroller (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)
- cs4140: 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, common-core 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 (4 students, ES)
- Project deliverables: Demonstrator + Tech-rep.
- Grading: deliverables + ranking + individual
- Grading: 0.75 D + 0.25 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: Lecture Room L+M (building 36)
  - 4-hr slot (Wed|Thu|Fri) for 8 weeks
  - Lab master: Vito Kortbeek
  - TAs: Talia, Eric, Sourav, Jasper, Jasper-jan

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

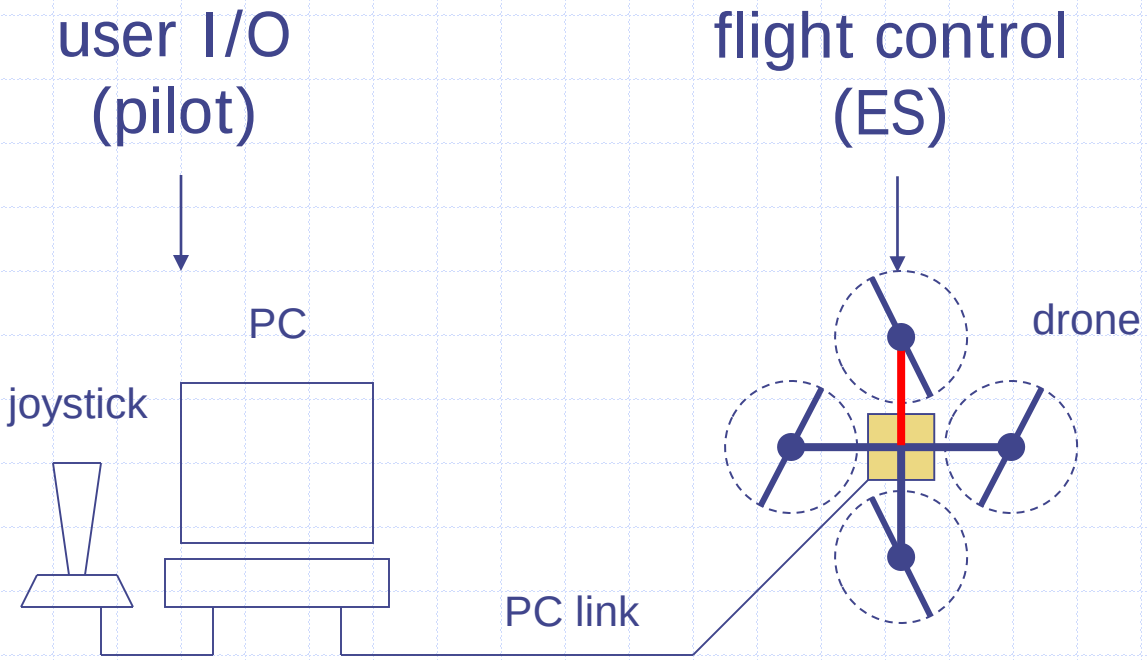
- Experimental sequence:
  - Control from PC
  - Yaw stabilization
  - Roll, pitch stabilization

Hardware of Choice

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

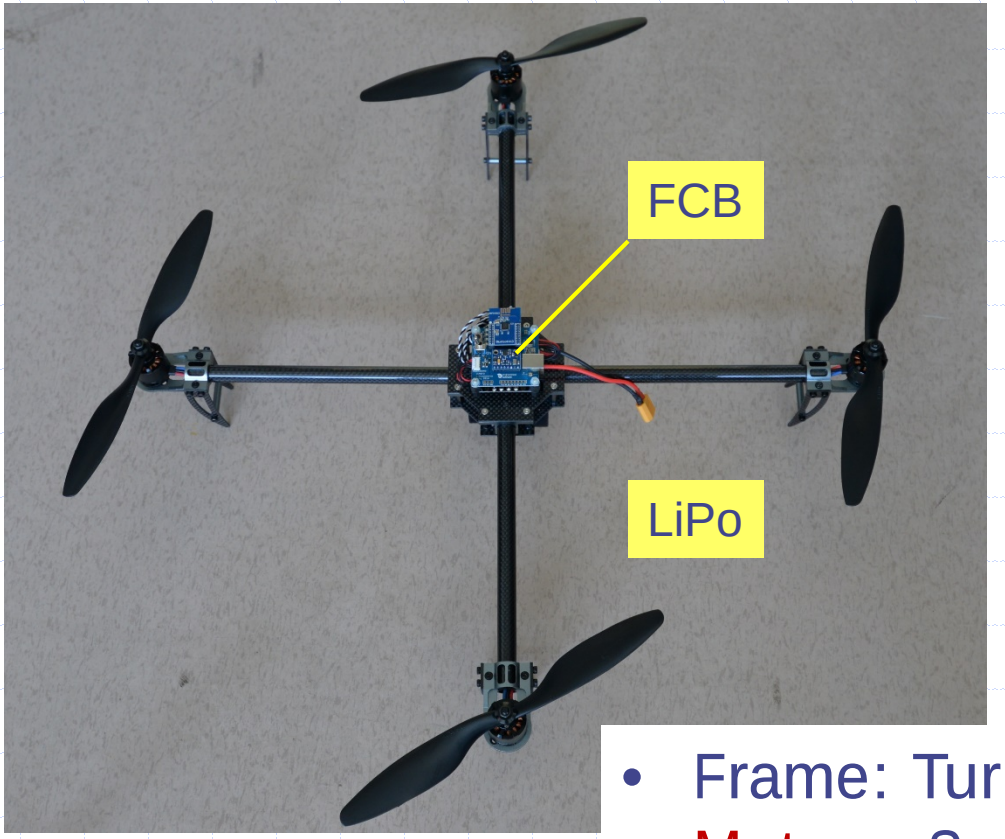
- Embedded system alternatives:
  - PC I/O card: expensive, inflexible
  - μcontroller: cheap, flexible, but slow(ish)
  - FPGA card: cheap, reconfigurable
  - ASIC: dirt cheap, but inflexible

System Setup



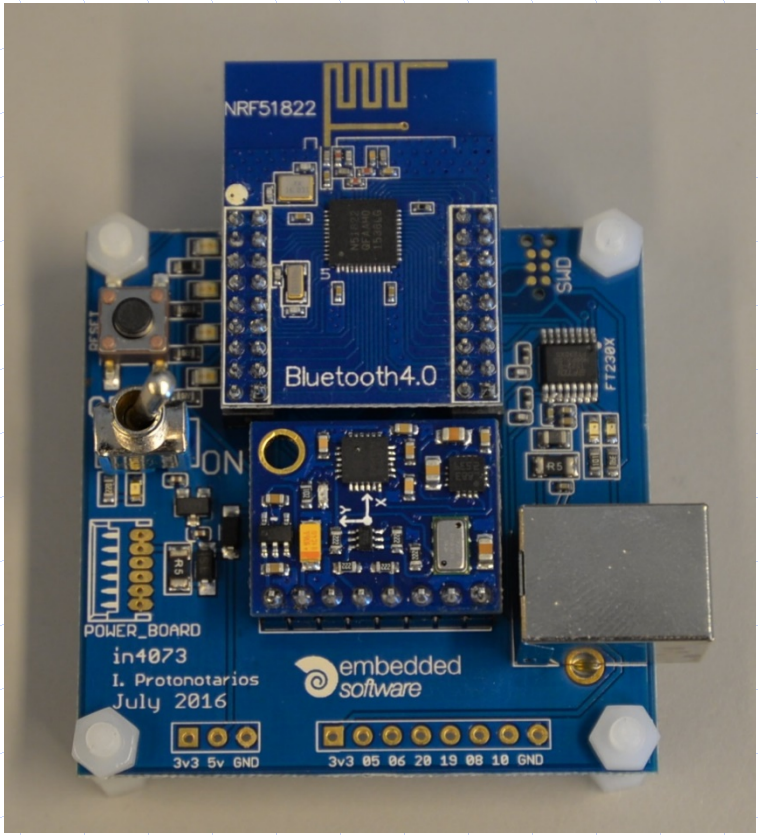
(source: assignment.pdf)

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: nRF51822
  - BLE
  - ARM Cortex M0 (14 MIPS, 256 KB Flash, 16 KB RAM)
  - 1 Mb Flash

LIFT OFF!

Lab Assignment

- **`assignment.pdf`** on course 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 by Mon June 20th 2022
- 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 (= your laptop!)
  - 1 FCB (€50 deposit)
  - Basic software tools
- CS4140 Resource Web Page

Course Requirements

- ES students (+ 2nd-year MSc students)
- Decent C-programming experience
  - Hundreds lines of code
  - Debugging skills

  } Acceptance Test CSE2425
- Commitment
  - Lots of time: load ~ 4 x lab + lectures!
  - Compulsory labs: no show = no grade
  - Approx. 10-15% drops out

- Online registration (FCFS)

Lab Kick-Off

- Ingrain safety instructions
- Read Assignment ASAP
- Study CS4140 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: Vito Kortbeek (v.kortbeek-1@tudelft.nl)

Registration form