Embedded Systems

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Course structure

- Introduction to Embedded Systems
- Modeling of systems - continuous, discrete, hybrid
- Sensors & Actuators
- Embedded processors, memory architecture
- RTOS, scheduling, multi tasking
- Input, output
- Temporal logic, verification
- Advanced topics

Evaluation policy

- Mid-sem - 30%
- Project - 30%
- End-sem - 40%

Project

- Group wise project
- A group can have at most 3 students

Books

- **Introduction to Embedded Systems** by Edward Ashford Lee, Sanjit A. Seshia
- **Embedded Systems and Software Validation** by Abhik Roychoudhury
- **Hard Real-Time Computing Systems** by Giorgio C. Buttazzo
- **Real-Time Embedded Systems** by Meikang Qiu, Jiayin Li

Introduction

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- A **cyber-physical system** (CPS) is a mechanism controlled or monitored by computer-based algorithms, tightly integrated with the internet and its users
- The **internet of things** (IoT) is the inter-networking of physical devices, vehicles, buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data

Applications: Automotive

- Safer drive
- Fuel optimization
- Smart transportation
- Self-drive car
- Reduced emission
- Traffic management

Image source: Internet

Applications: Smart Building

- Efficient control of
  - Heating
  - Ventilation
  - Air conditioning
  - Security
  - Lighting

Image source: Internet

Applications: Manufacturing

- Human labor
- Repetitive job
- Asset management
- Maintenance

Image source: Internet

Applications: Smart Grid

- Integration of renewable source
- Efficient usage
- Black-out
- Protection

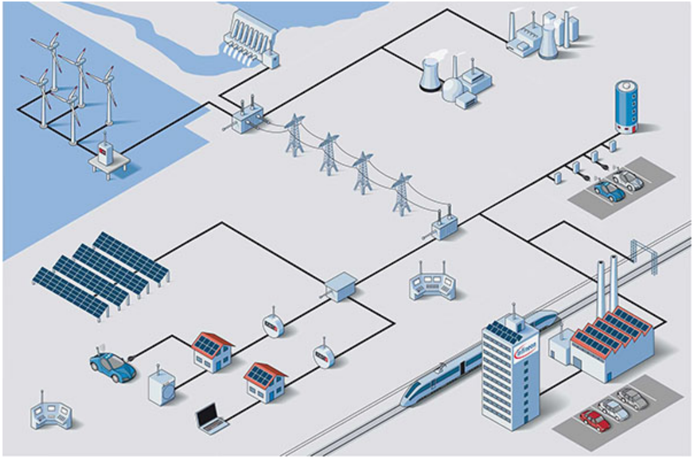

Image source: Internet

Applications: Bio-Medical

- CT-scan, MRI
- Ventilation support
- Remote supervision
- Assistive technology
- Reliable

Image source: Internet

Applications: Avionics

- Highly complex task
- Several sensors
- Complex control
- Reliable
- Safety
- Fault tolerance

Image source: Internet

Applications: Robotics

- Repetitive task
- Human labor
- Product is bad for human
- Human is bad for product
- Quality control

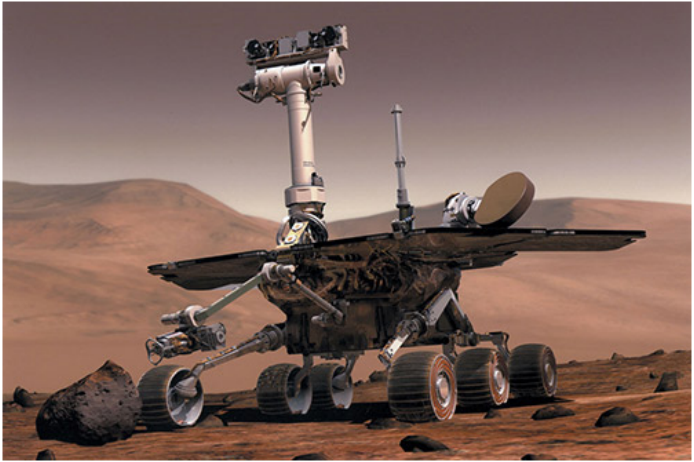

Image source: Internet

Applications: Nuclear control

- Safety
- Reliability
- Monitoring parameters

Image source: Internet

General view of the problem

Image source: CPS Slides, Lee

General view of the problem

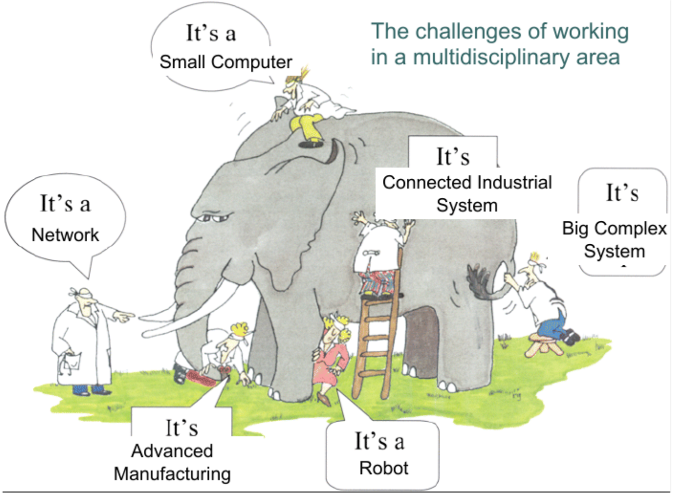

Image source: CPS Slides, Lee

Two examples

- Pacemaker

- Quadrotor

Image source: Internet

Things to consider

- System dynamics
- Operation modes
- Hybrid system
- Sensors
- Actuators
- Processor
- Memory architecture
- Interfacing
- Real time scheduling
- Verification
- Security & privacy
- Delay
- Area
- Power
- Reliability
- Fault tolerance
- Testability
- Cost

Embedded systems

- Applications
  - Power
  - Communication
  - Healthcare
  - Manufacturing
  - Robotics
  - Transportation
  - Military
  - Industrial control
- Design methodology
  - Specification, Modeling, Analysis
    - Heterogeneous/Hybrid model
    - Interoperability
    - Networking
  - Scalability
    - Composibility
    - Synthesis
  - Validation, Verifiability
    - Certification
    - Simulation
- Security
  - Privacy
  - Intrusion detection
  - Malicious attack
- Feedback systems
  - Real time
  - Economics
  - Adaptive/predictive
  - Distributed/networked

Modeling, Design & Analysis

- **Modeling** is the process of gaining deeper understanding of a system through imitation. Models express **what** a system does or should do.
  - All models are wrong; some models are useful. — George E. P. Box

- **Design** is the structured creation of artifacts. It specifies **how** a system does what it does.

- **Analysis** is the process of gaining a deeper understanding of a system through dissection. It specifies **why** a system does what it does (or fails to do what a model says it should do).

Modeling

- Models are abstraction of the physical systems
- Modeling of dynamic behavior of the system
  - Continuous dynamics
  - Discrete dynamics
- Composition of state machines
- Concurrent modules

Design

- Require knowledge of sensors and their role
- Require knowledge of actuators and their role
- Processor architecture
- Memory architecture
- Input, output
- Multitasking, scheduling
- Specialized operation

Design (contd.)

- It is complex process
- Need to create abstraction layers
  - Hardware & software
  - Computation
- Physical processes are heterogenous in nature
  - Programmer must have knowledge of real valued function
  - Automative application must have knowledge about pipelines, cache
  - Multithreaded program must know atomic operation

Analysis

- A system must meet desired specification
- Specification should be precise
- Need techniques for comparing specification

System development

- Functionality decomposition and modeling
- Architecture Selection: Choice of processors, standard hardware
- Mapping of functionality to HW and SW
- Development of Custom HW and software
- Communication protocol between components
- Prototyping, verification and validation

Project ideas

- https://www.hackster.io/intel/products/intel-galileo-gen-2
- http://www.instructables.com/id/Intel-Galileo-Projects/
- https://github.com/MPC-Berkeley/barc
- V-REP - www.coppeliarobotics.com/
- Gazebo - http://gazebosim.org/