

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 2-3 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: Manufacturing

- Human labor
- Repetitive job
- Asset management
- Maintenance



Image source: Internet

Applications: Smart Grid

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

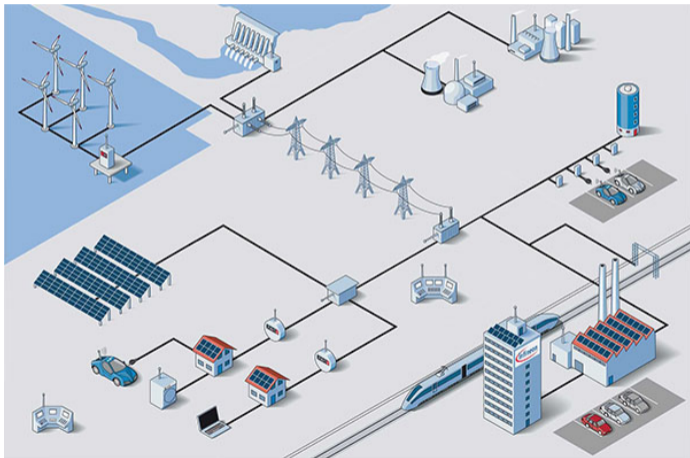


Image source: Internet

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

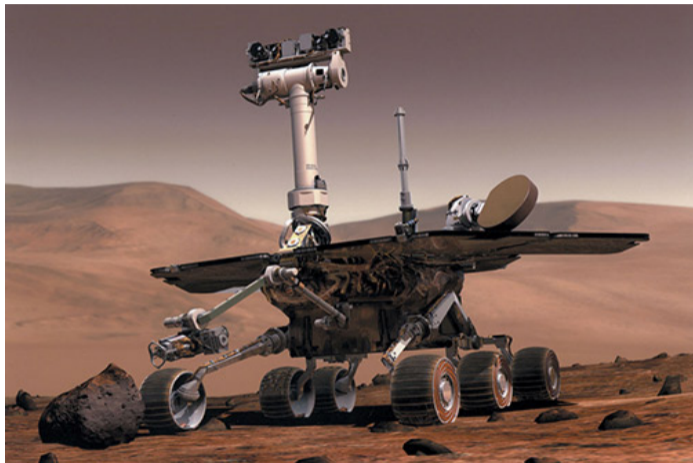


Image source: Internet

Applications: Nuclear control

- Safety
- Reliability
- Monitoring parameters



Image source: Internet

General view of the problem

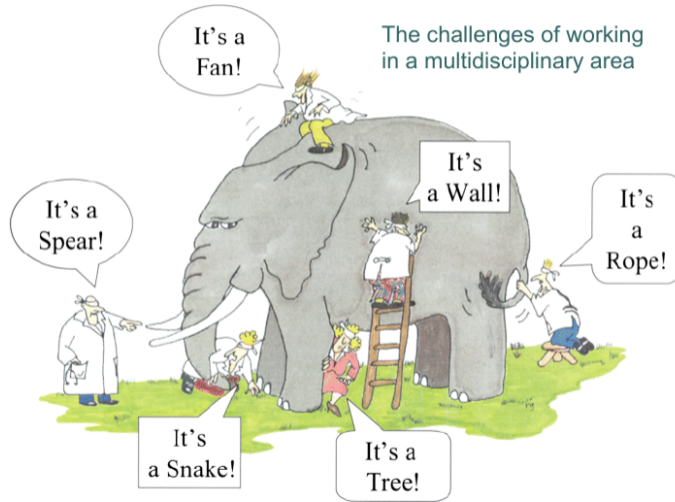


Image source: CPS Slides, Lee

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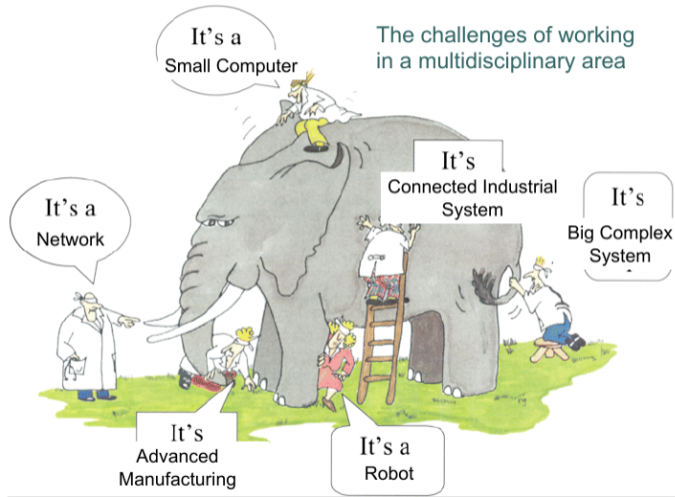


Image source: CPS Slides, Lee

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://gazebo.org/>