Toward HW/SW Integration: Networked Embedded System Design

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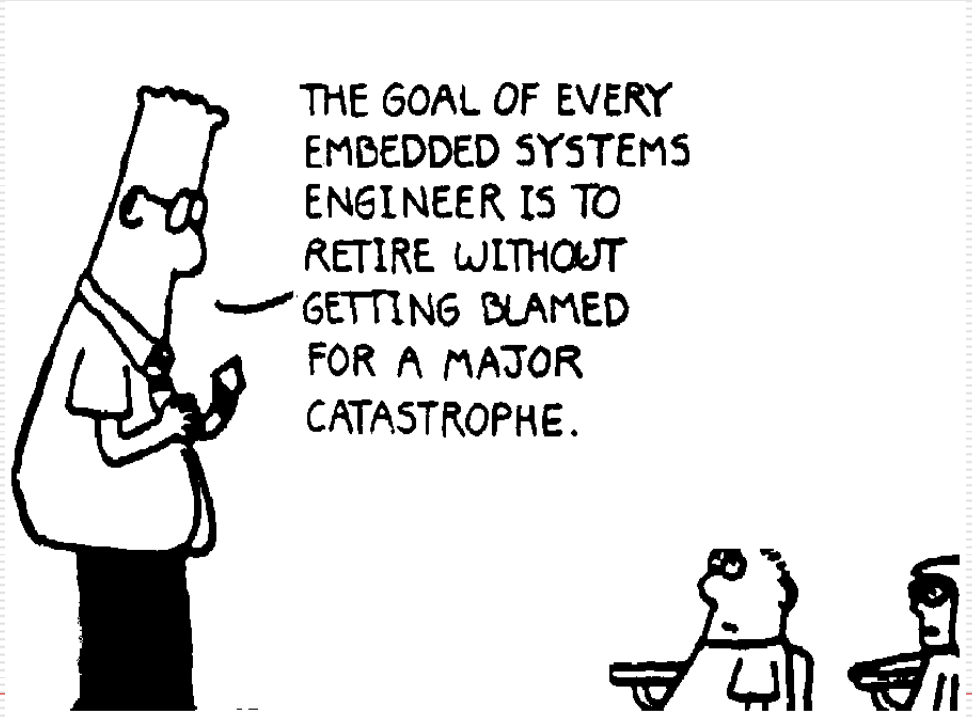
Background –Embedded Courses in Universities

- High-level design methodology
  - UML, Component-based design, etc.
- Software Design:
  - Dr. Muppala's at The Hong Kong University of Science and Technology
  - Dr. Evan's embedded software systems at UT, Austin
- Hardware Oriented:
  - SoC Architecture design, VLSI design, and FPGA-based system design.

What are missed in CS Curriculum for embedded systems engineers?

- Embedded SYSTEMS not embedded software.
- Hardware and Software have to collaborate.
- Reliability



Embedded System Design Program

Embedded System Program

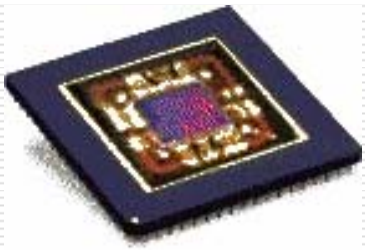
SoC/Embedded Systems Faculty

Networked Embedded Real-Time System Design

Lab Facility

Software-Oriented Design Courses

Hardware-Oriented Design Course

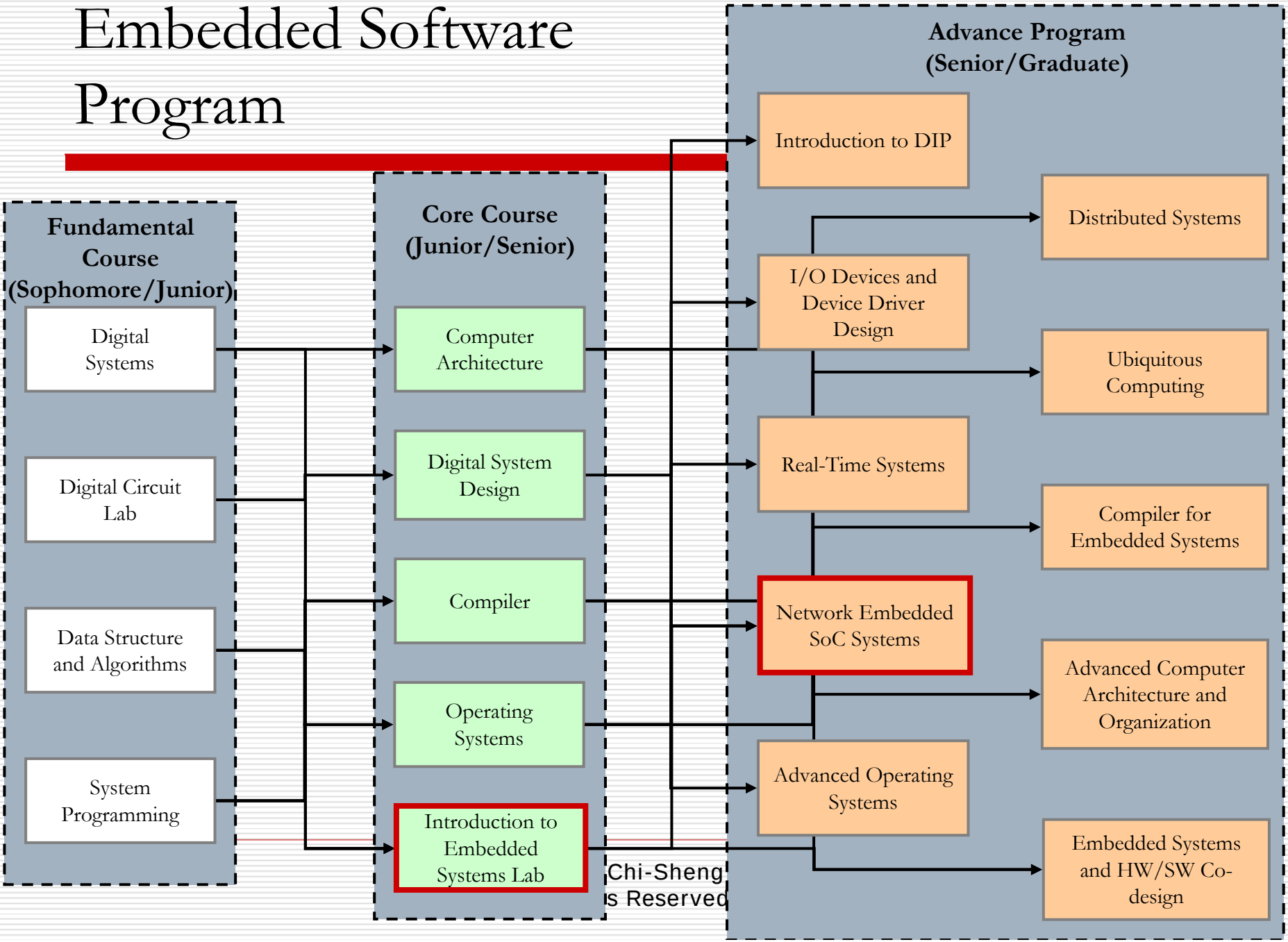


Government Force for Embedded Software Education

嵌入式軟體聯盟 Embedded Software Consortium

- In 2004, the professors from four universities submitted a curriculum enhancement proposal. It aimed at
  - bridging the gap between HW and SW designs for Computer Science seniors and first-year graduates.
  - skills for network programming for embedded systems and low-power programming.
- Embedded Software Consortium
  - Founded in March 2004.
  - Funded by Ministry of Education, Taiwan.
  - Objectives:
    - To enrich the embedded curriculum for universities and colleges,
    - To engage academia and industry in dialogue, and
    - To support the embedded software researches.

Embedded Software Program



Network Embedded SoC Systems

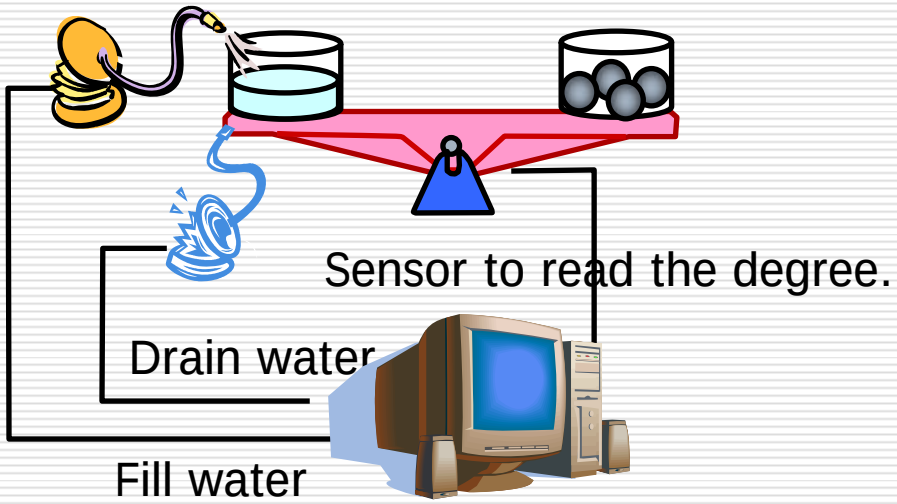
- Course Description:

  The purpose of this course is to get the students familiar with the knowledge and hands-on programming skills for networked embedded systems.

- Students: Senior/Graduate students
- Class Schedule:
  - Lecture: 2 hours/week for 18 weeks.
  - Lab: 2 hours/week for 16 weeks.

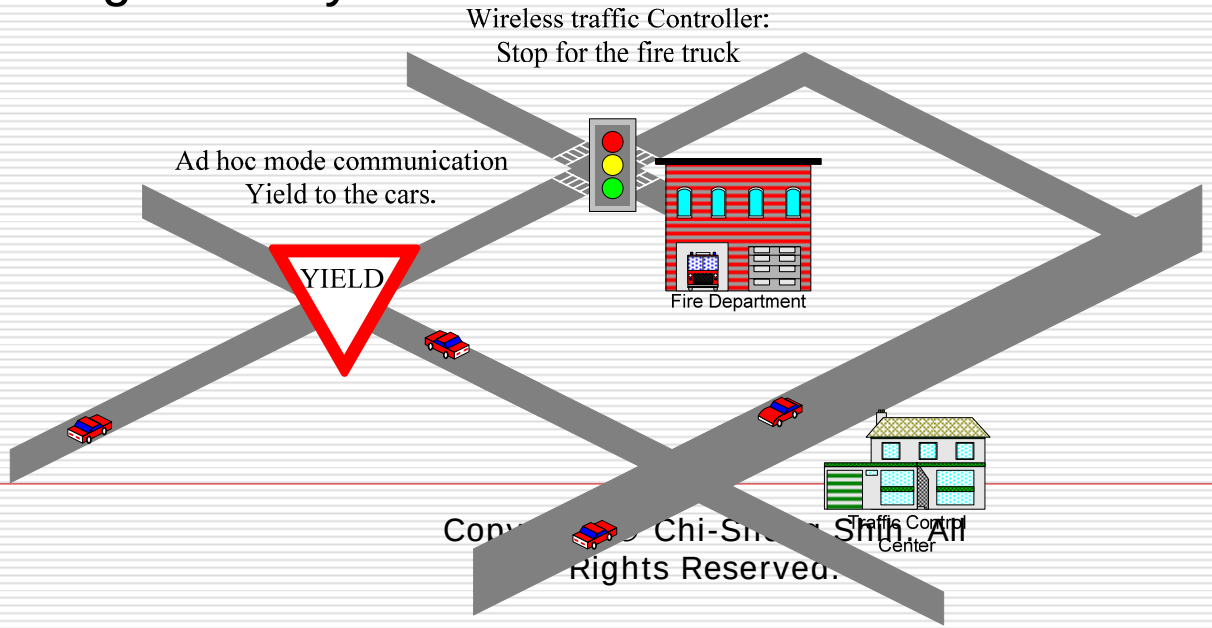
Outline for Lectures

- Introduction for Embedded Systems
- Real-Time Systems
- Embedded Programming
  - Real-Time Sensing and Control
  - Clock Jitter and Drift
  - Real-Time Scheduling
  - Rate Monotonic Scheduling
  - Priority Inversion
  - Priority Inheritance/Ceiling Protocol
- Power Management and Low Power Design of a Networked SoC System
- Networks for Embedded Systems
- Mobile Ad-Hoc Networks



Lab Modules

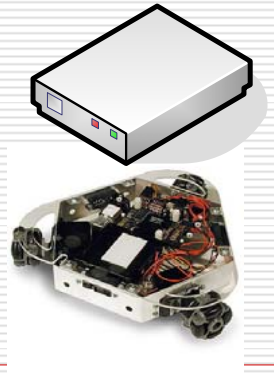
- Labs are conducted in a group of 2 to 3 students or individually.
- Every week, the students need to complete the pre-designed lab.
- At the end of the semester, the students complete a complete networked embedded systems, Intelligent Navigation Systems



The Environment

- Hardware：PPRK, PCM7230, wireless card, and PC
- Target Operating Systems on pcm7230:
  - Embedded Linux
  - Windows CE.

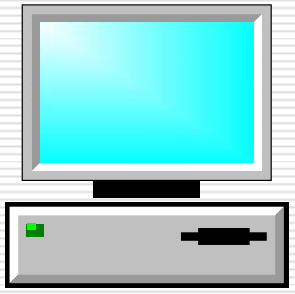
pcm7230 carried by PPRK



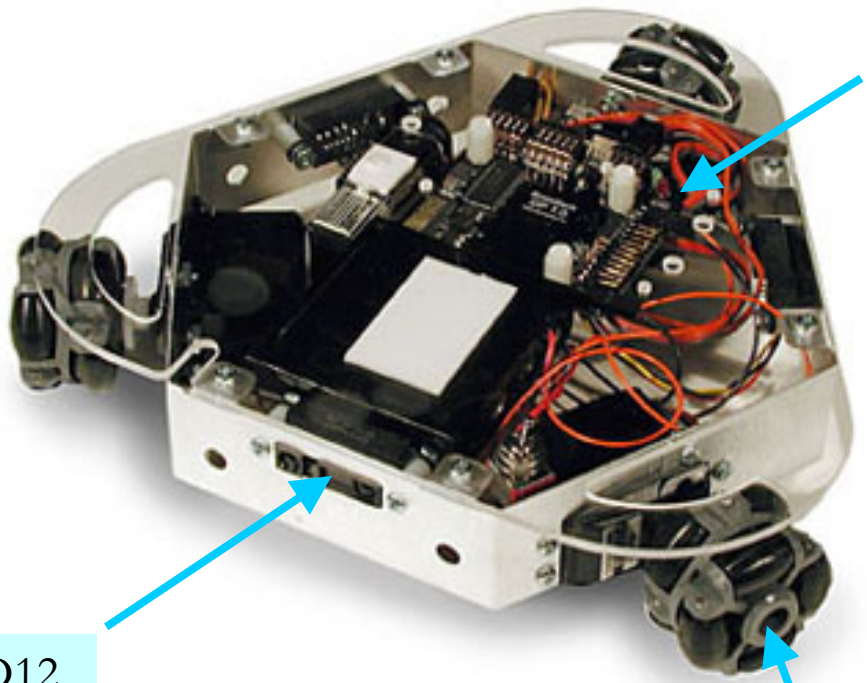
PPRK

Communicate through wireless

host computer



PPRK (Palm Pilot Robotic Kit)



The BrainStem controller
40 MHz RISC processor
RS-232 serial port

IR Sensor: Sharp GP2D12
Distance range between
10cm (~4") to 80cm
(~30").

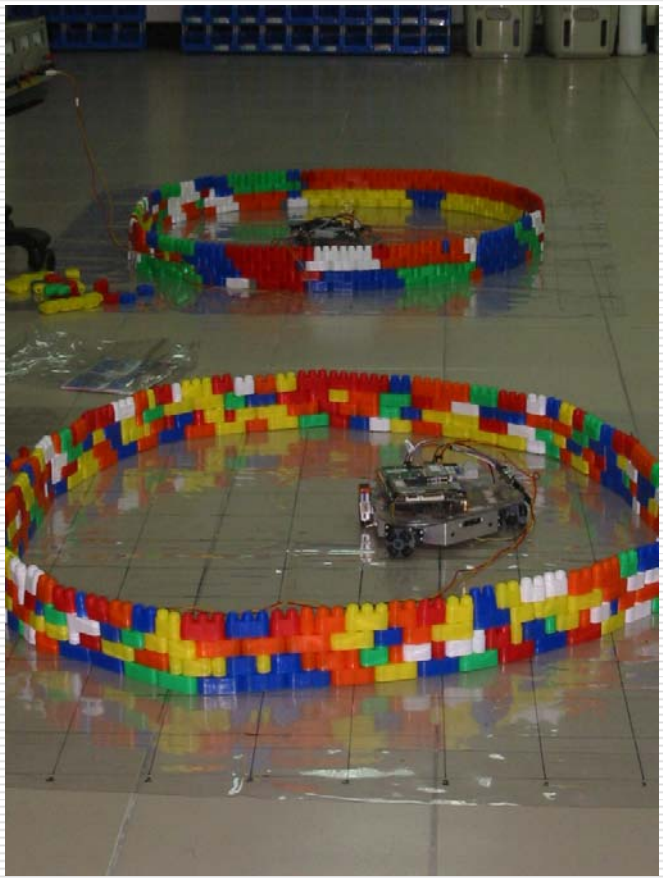
Servo motor and Wheel

The target board pcm7230

- Embedded with PCM-7230S-230CE SBC
- Intel® Xscale® PXA255 400 MHz CPU
- 10.4” SVGA LCD display with touchscreen
- Integrated 4-cell pack and charger system
- 8 DI & 8 DO function bundled with selection utility
- 4-COM AMI-120 module is bundle for function expansion

Monitoring and Control

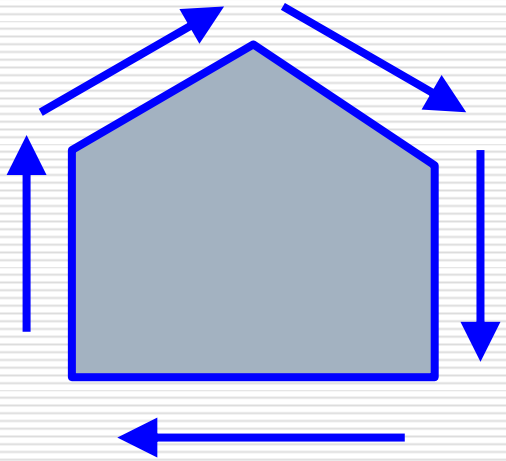
- In the lab, the PPRK will be put in the provided LEGO castle, and the students will be asked to write a program to estimate the shape of the castle.



- The objectives of this lab is to develop a program using the infrared sensors on PPRK (GP2D12) to collect the environmental information.

Real-Time Control

- In the lab, the students should develop a program to control the PPRK to move along the given direction and distance.



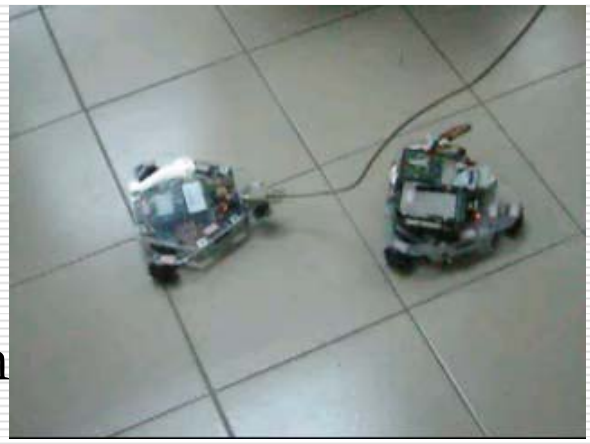
Chase with Single Thread

- The goal of this lab is to develop a program that controls the PPRK to chase a moving object.

- In the lab, TA will put a ball in front of PPRK, and the PPRK shall chase the ball for a certain amount of time.

Chase with Multiple Threads

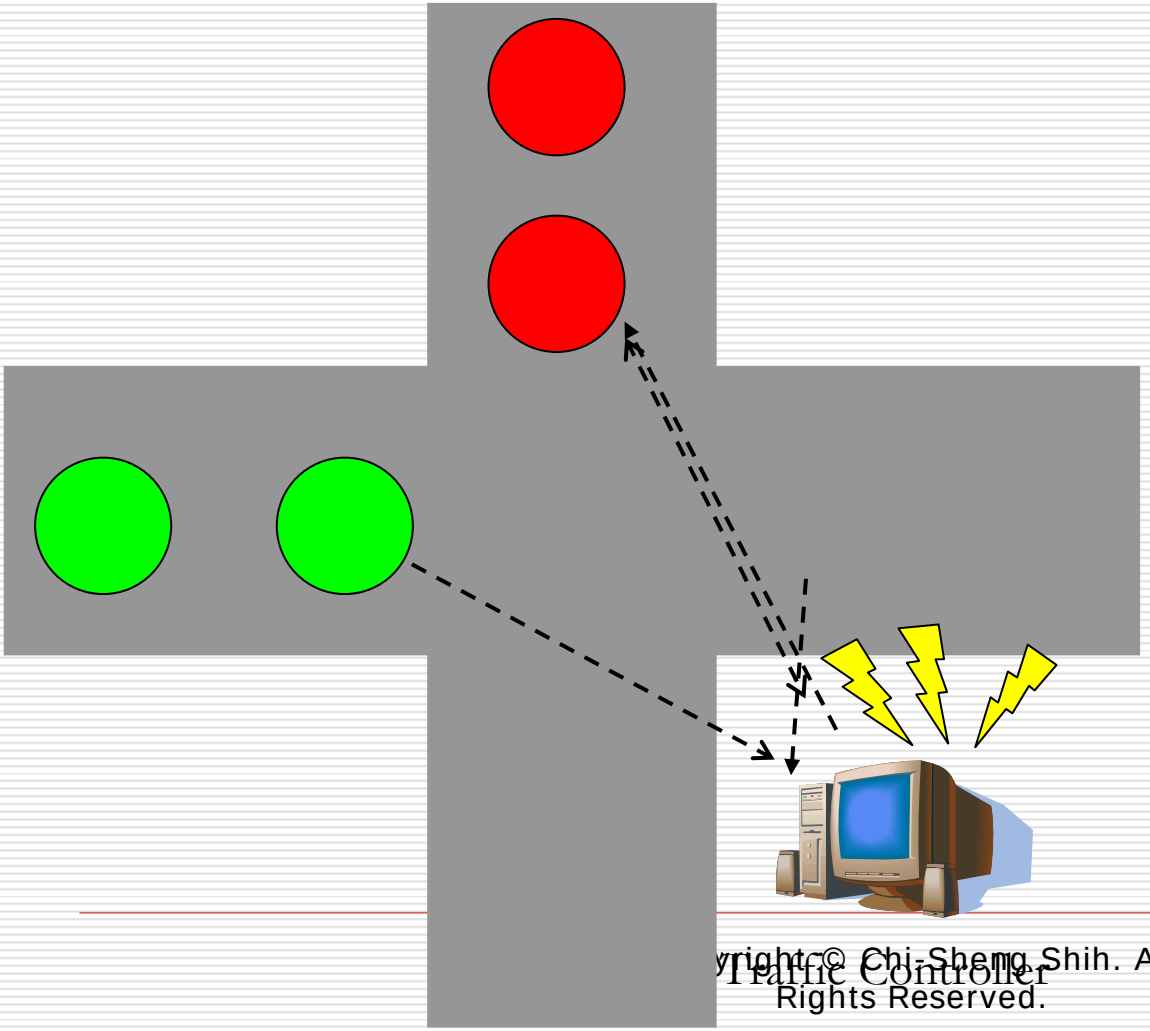
- The goal of this lab is to develop a multithread program to control PPRK so that it can follow another PPRK controlled by TA.
- In this lab, PPRK should
  - follow the target and
  - avoid collision.
- The students will learn and hands-on
  - Multithread programming
  - Mutex
  - Resource Synchronization



Traffic Controller

- The goal of this lab is to build an intelligent traffic coordination system.
- The students will design an intelligent vehicle that
  - communicates with traffic controller to receive the traffic control command, and
  - cross the intersection without any accident.

Scenario in Infrastructure Mode



1 Cars start running.

2. Detect an Intersection. Stop.

3. Negotiates with the AP

4. Green car goes.

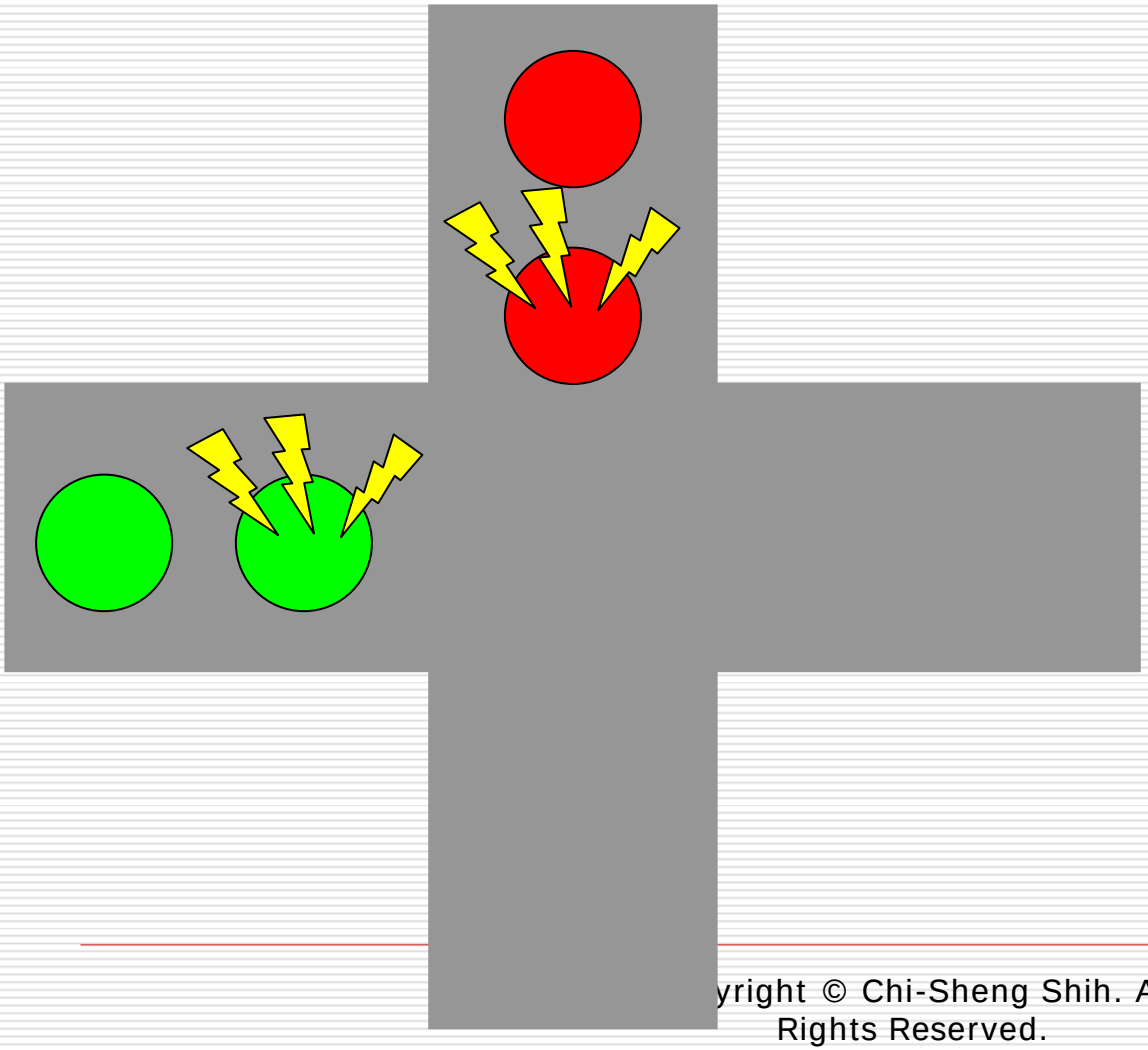
5. Green car done.

6. Red goes!

Traffic Controller using Ad Hoc Network

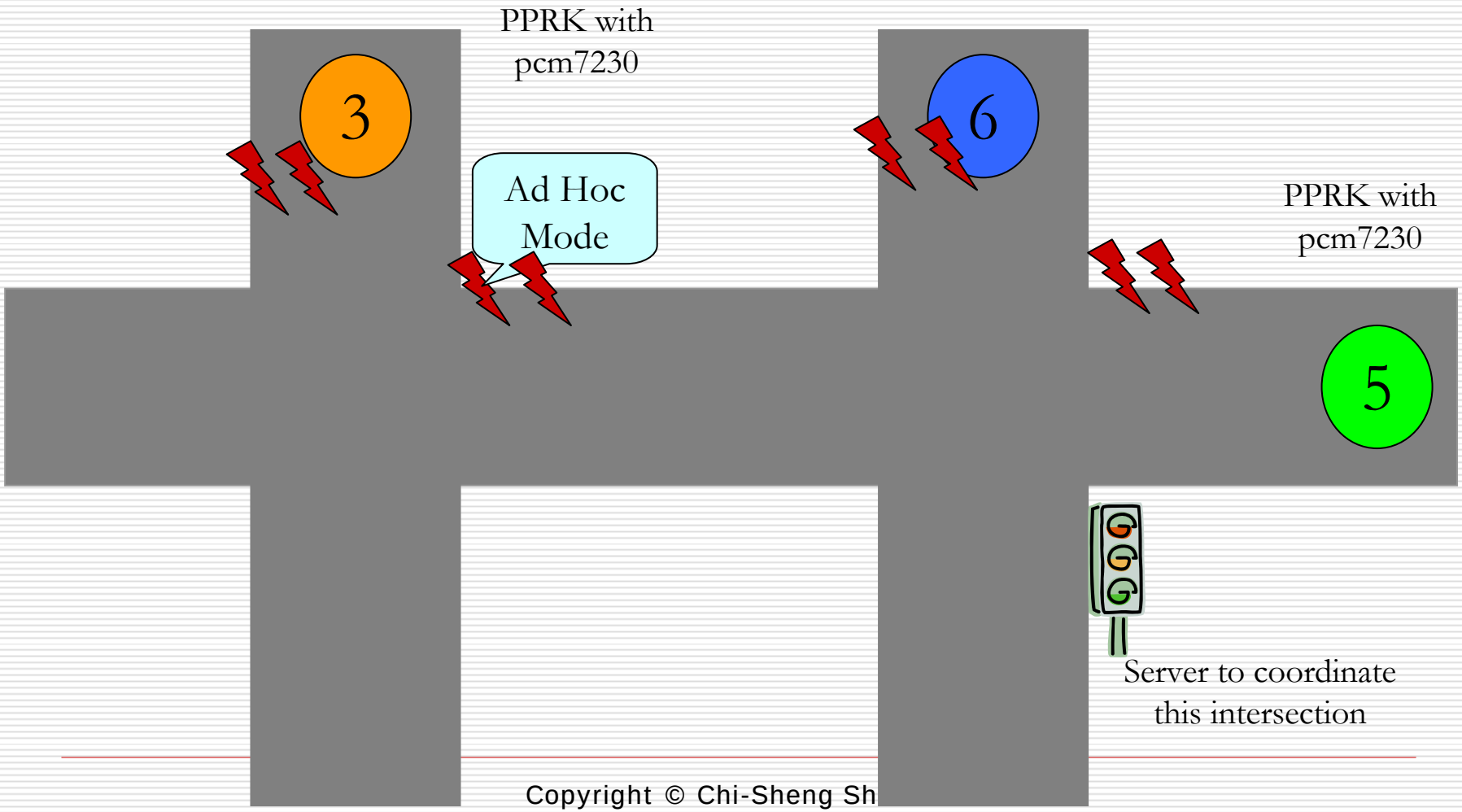
- To build an intelligent traffic coordination system, the PPRKs have to negotiate with each other for the right of way so that there is no car accident on the way.
- This lab works in non-infrastructure mode.

Scenario in Non-Infrastructure Mode



1. GO!
2. Detect an Intersection, Stop!
3. Negotiate with each other
4. Green GO!
5. Green Done.
6. Red Go!

Traffic Control with infrastructure and non-infrastructure mode



Reflections from lecturers and students

- Well-designed lectures and labs provide the students in-depth lessons for embedded real-time systems design.
- The semester-long step-by-step labs and final project provide the students the skills to design the system and the opportunity to write their own code at the end of the semester.
- Well-trained TAs are the key for the success of this course.

Acknowledgement

- This curriculum development was supported in part by
  - Ministry of Education, Taiwan and
  - Microsoft Research Asia