

Bringing Soccer to the Field of Real-Time Embedded Systems Education

By

Akash Kumar



Motivation

- Embedded systems penetrating our daily lives
- Need to teach and train engineers well-versed with embedded systems
- Embedded systems – multi-disciplinary and diverse
 - Hard to teach
- Needs hands-on project to give future engineers a good flavor of skills required for designing real-time embedded systems



Contributions

- Describe a real-time embedded systems project that
 - Has a balance of breadth and depth
 - Provides hands-on experience to students
 - Motivates students with fun and competitive element
 - Exposes students to share ideas and work in teams

Related Work

- Most existing projects use single-processor systems
- Very few use FPGA boards
 - FPGA boards allow students to use custom hardware
 - Encounter low-level issues that may not be apparent in other architectures
- Distinguishing features of this project
 - Multiple FPGA boards are used
 - Each FPGA board runs a multi-processor system
 - Students can expand the hardware system as necessary

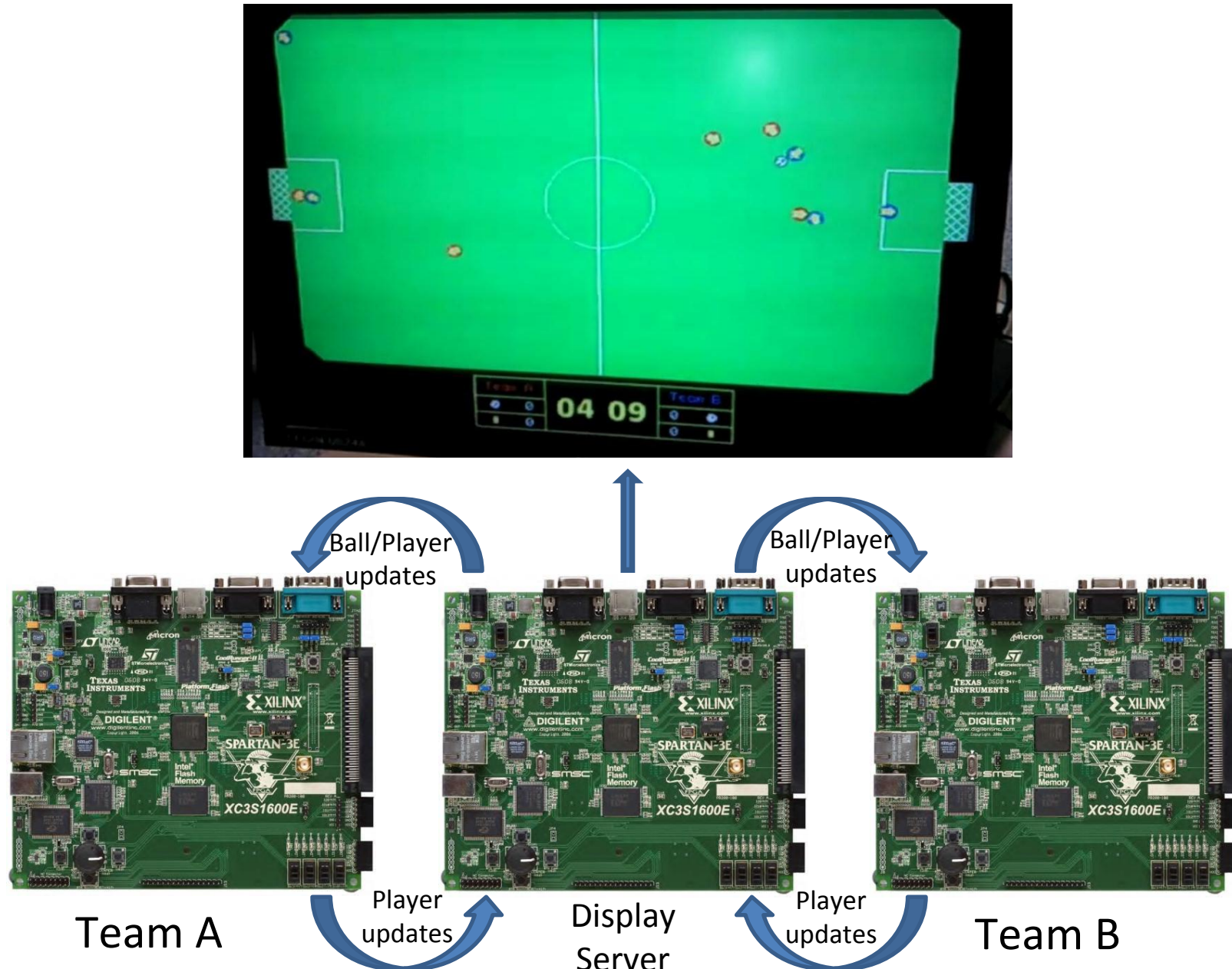
Real-Time Embedded Course

- Stresses on importance of making embedded systems real-time
- Concepts covered
 - Scheduling, accessing shared resources, PIP, PCP
 - Concurrent programming, deadlock, synchronization mechanisms
- 4 modular credit course = 130 hours in a sem
- About 80 students annually, 4th year elective
- 50% grade project, 50% written exam

Project

- Motivated from Soccer 2010 world-cup
- Develop a system for 5-a-side soccer
 - A client strategy controller
 - A server to referee and display game in real-time
- At the end of semester, all teams compete against each other
- Each part is carried out on an FPGA board with multi-processor system
- A number of real-time constraints need to be met in the entire system

Soccer Project Setup



Client Tasks

- Develop strategy
- Send initial player co-ordinates
- Send player movement updates
- Receive ball/player positions

Server Tasks

- Display game at 25 Hz
- Referee the game
- Simulate game physics
- Receive initial player co-ordinates
- Receive player movement/kick updates
- Send ball/player positions

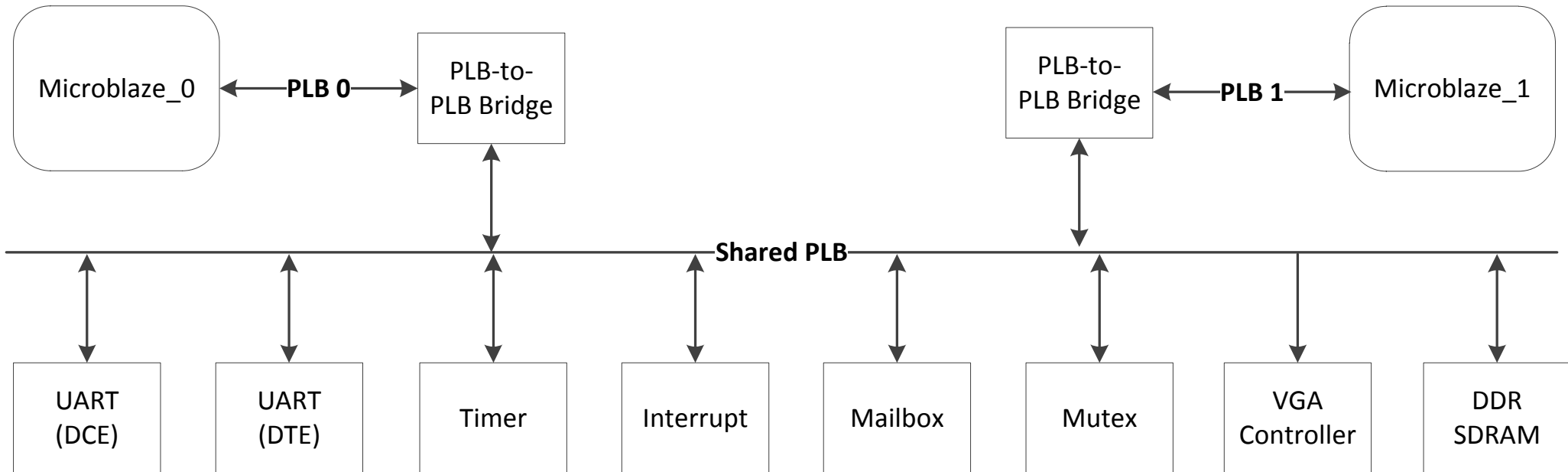
Protocol and Physics

- Well-defined protocol needed to ensure multiple teams can talk to each other
 - Packet format defined with precise bit order
- Physics of the game defined
 - What happens in communication
 - Real-life behaviour emulated e.g. friction slowing ball
 - Collision properties i.e. conservation of momentum and energy

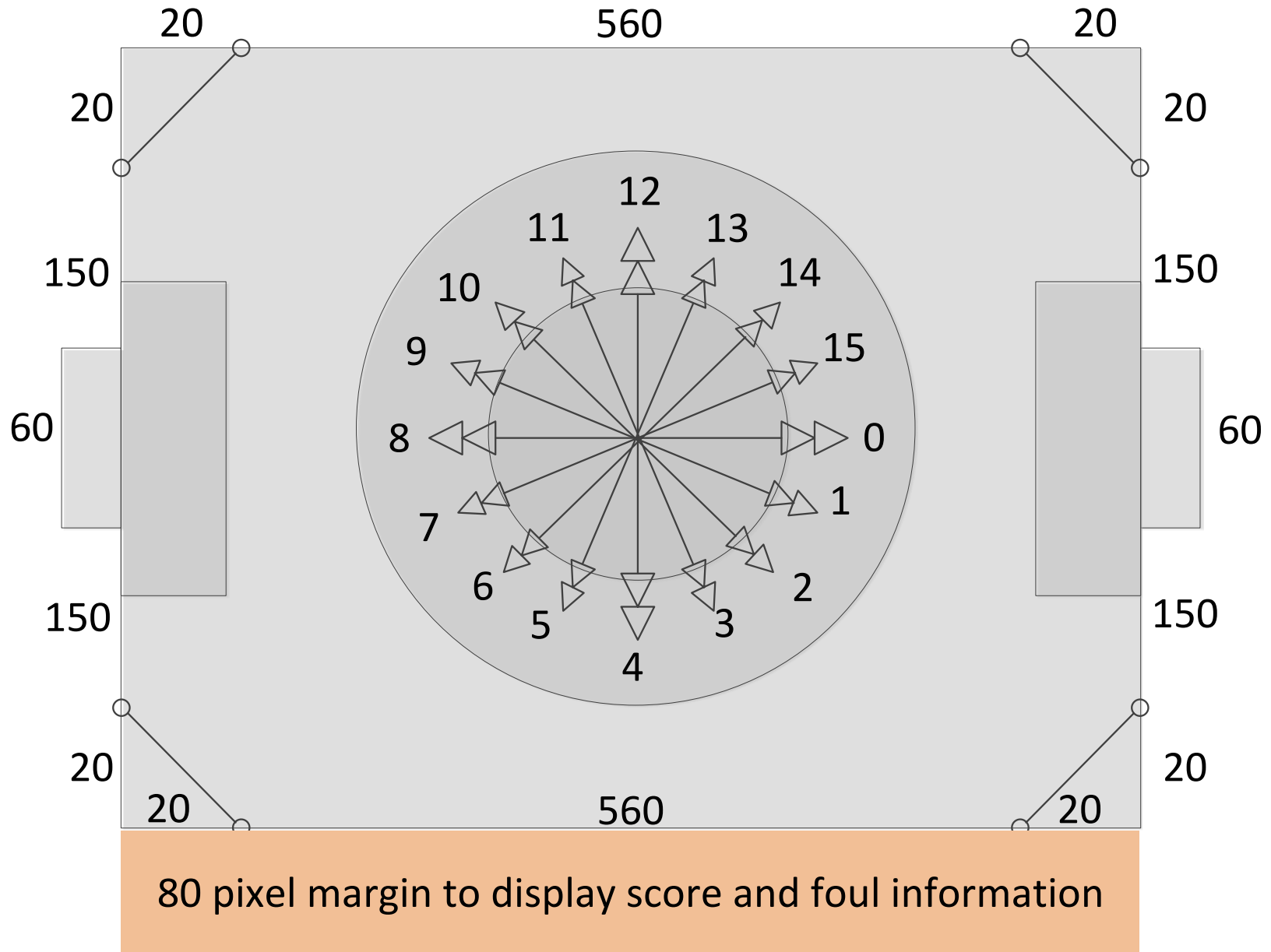
Lab Exercises

1. Familiarization of FPGA and EDK design
2. Threads – different scheduling algorithms
3. Software and hardware mutexes
4. Message queues and mailboxes
5. Binary and counting semaphores
6. Priority inheritance and ceiling protocol

Hardware System Block Diagram



Soccer Field Setup



Demonstration



Quantitative Evaluation

Year	2009	2010
Number of students	76	83
Number of respondents	29	39
Percentage of respondents	38%	47%
Nominations for best teacher	3	7
Percentage of nominations	10%	18%
Overall numerical score (out of 5)	4.037	4.242

Qualitative Feedback

- *This module provides maximum practical exposure of the concepts learnt. Able to understand the module. The project in this module was time consuming, but gave an in-depth knowledge.*
- *This module is perfect. It teaches us a lot of stuff about real-time systems and the project is very fun to work on.*
- *This is a very interesting module because of the project.*

Conclusions

- A soccer project proposed to teach students about real-time embedded systems
- The real-time constraints in the system force students to appreciate and solve them
- Multi-processor multi-board project brings new challenges to be solved
- Fun and competitive element to keep students motivated

Questions and Answers



Email: **akash@nus.edu.sg**