An Advanced Course Design for Mobile Embedded Software through Android Programming

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ICS, UC Irvine, USA
EECS, Kookmin University, Korea

Contents

- Introduction
- Background and motivation
  - Recent trend of embedded systems and apps
  - Main objectives of mobile embedded SW programming
  - Point of views
- MESA design
  - Course design
  - Weekly items
  - Project
  - Evaluation
- Feedback and discussion
- Concluding remarks
Mobile Embedded System Lab@Kookmin Univ.

Embedded System & CPS
- Embedded HW & SW
- Automobile, Smartphone and Robot

Embedded Systems
- Application
- Platform/Middleware
- RTOS
- HW (SoC, MCU, MP)

Automobile

smartphone

Robot

Smartphone programming
Mobile Embedded System
2010~Now

Automobile Embedded Systems
16/32/Multicore MCU, OSEK/AUTOSAR
2007~Now

Embedded SW for Automobile
MCU & OSEK
2011~Now

Advanced Android Programming
2011

OPRoS (Robot SW Platform)
T.B.D.

Korean Research Center

Mobile & Smart@KMU
Background and Motivation

- Recent trends
- What to obtain
- Point of views
  - Student
  - University
  - Instructor

Recent trends

- **Embedded system aspect**
  - SW platforms and applications have become more and more important.
  - The platform similarity for smartphone, PC, TV, car, robot, etc. has increased rapidly.

<table>
<thead>
<tr>
<th>Single-core</th>
<th>Multi-core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolithic kernel</td>
<td>Microkernel</td>
</tr>
<tr>
<td>Native coding / poor portability</td>
<td>Platform architecture of SW</td>
</tr>
<tr>
<td>Closed platform</td>
<td>Open platform</td>
</tr>
<tr>
<td>Hard-to-develop</td>
<td>Easy-to-develop (application)</td>
</tr>
</tbody>
</table>
Recent trends

- **Industry aspect**
  - No layers between companies
  - Value chains made by major companies

<table>
<thead>
<tr>
<th>Content/Service</th>
<th>Google</th>
<th>Amazon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application SW /Platform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPU /Semiconductor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **App market aspect**
  - App market has changed into a ‘mass market’.
  - Due to cross platform issues and others, server/web side development has become more and more important
  - Developers should be accustomed to multi-language issues.

- Early stage – direct connection
  - Using APIs in Android platform
  - (Bluetooth, SMS, etc.)

- Nowadays – Server based model
  - Similar to general web-based model
  - 3G / Wi-Fi connection
  - Server based model

- Up to date technology – Hybrid model
  - Smartphone + web
  - Wi-Fi direct for P2P connection
  - NFC pairing for Bluetooth
What to obtain

- Mobile embedded SW programming to students
  - What to obtain
  - 1st step: study
  - 2nd step: research, profit and contest

<table>
<thead>
<tr>
<th>Mobile Embedded SW Course</th>
<th>Study</th>
<th>Research</th>
<th>Profit</th>
<th>Contest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st step</td>
<td>2nd step</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Point of views

- Student
  - Currently
    - Increasing demand for the mobile embedded SW related courses
    - Already, many experts
      => Introductory course is meaningless
      => Advanced course design
      => Should provide professional examples

- University
  - Limited resource
    - Budget
    - Course
    - Instructors
    - Assistants
  - Conservativeness: 4 years curriculum
    => Advanced course design for 1 quarter giving fundamental insights
**Instructor**

- Interest of the students for embedded system
- ES and CPS point of view
  - Application perspective of embedded system
  - Cross-layer perspective of embedded system
- **Fundamental knowledge**

<table>
<thead>
<tr>
<th>Content/Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application SW/Platform</td>
</tr>
<tr>
<td>Device</td>
</tr>
<tr>
<td>OS</td>
</tr>
<tr>
<td>CPU/Semiconductor</td>
</tr>
</tbody>
</table>

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**Course Design**

- Course design
- Weekly items
Course design

What to consider

- Limited resources: Budget, Instructor, Lecture/lab hours
- Increasing demand: Design of new courses, Basic/Intermediate/Advanced courses, Various aspects of smartphone
- Keeping up with Industry trend: Embedded system, Various smartphone platforms, Cross platform, Cloud, N-screen, Mechanical platforms

CS 190: Mobile Embedded Software with Android
- One Quarter, Advanced course, Project course

Pedagogical issues

- Design one quarter (10 week) course
- Enhance the knowledge of related courses and to develop highly advanced applications.
- Review key mobile embedded system platforms and technologies
- Provide many sample applications and open source codes
- Lead the students to develop advanced applications.
Objective of the course design

- Stimulating students’ interest for the embedded system
- Introducing recent trend of embedded system and smartphone app
- Supporting various application examples which can be used directly for the students’ application design
- Analyzing popular open source projects for Android
- Connecting to other courses
- Introducing new keywords in embedded systems, cyber-physical systems and app related issues
- Summarizing recent trends in related industries such as smart cars, smart robots and others.

Technical report

(http://www.cecs.uci.edu/technical_report/TR%202012-10.pdf)
Introduction to Embedded system, Smartphone app, and smartphone
Basic Android UI Programming
Theories and trend
- Multimedia
- Network
- LBS/AR
NDK/debugging
Advanced Topics
- Embedded System
- Smartphone app
**Weekly items**

**Week 1**

- **Overview**
  - Introduction
  - Popular Apps
  - AndSync

**Introduction to the course**

<table>
<thead>
<tr>
<th>Monday</th>
<th>Introduction – Instructors and courses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Examples – Project examples</td>
</tr>
</tbody>
</table>

**Wednesday**

- Apps - Popular Apps
- Research using Apps – Embedded system, Platform, Multimedia, Network Sensor, AR, LBS, OPRoS, ROS, etc.

**Friday**

- H.O.T.: AndSync app
- Tool installation
- AndSync app

**Lab hours**

**Homework**

---

**Week 1**

- **AndSync**

**Created threads**

- Num. 1
- Num. 5

**Main thread**

- TextView
- Button

**Using intent**

**AndroidSynchronization Activity**

**AndroidSynchronization Activity**

**Handler**

**AndSync Activity**

**OnClickListener**

- AndroidonClick
### Week 2

#### Overview
- **Monday**: Introduction – recent trend of embedded systems and smartphone
- **Wednesday**: Android programming overview
- **Friday**: H.O.T.: BMP Compare

#### Lab hours
- Homework: Homework of Week 1
- Homework: BMPCompare

### Platform convergence

- **Multimedia Platform**
- **Control Platform**
- **Cloud**
- **Android Platform**
- **ROS.org**
- **Google**
周 2

智能手机作为嵌入式系统

- Power AMP
- Transaction
- Baseband Processor
- AMSS
- REX
- REX Wrapper
- L4 Microkernel
- 6290 (ARM 9)
- Application SW
- AMSS
- REX
- REX Wrapper
- L4 Microkernel
- 6290 (ARM 9)
- Application SW

周 2

BMPCompare

- Tap for BMP handling
  - BMPJava
  - BMPAndroidAPI
  - BMPJNI

- EditText for inputting to turn angle

- ImageView for showing image

- Reset original image on ImageView
- Make image grayscale
- Rotate image clockwise
- Rotate image counterclockwise
Week 3

Overview

Monday
- Activity, View
  - structures of activity, kinds of view and view group

Wednesday
- Views and UI
  - Event Handler, MapView, AdapterView, CustomView, SurfaceView, menu, etc.

Friday
- Layout change, Address book, Block game, Animation example

Lab hours
- Homework of Week 2

Homework
- Layout change, Address book, Block game, Animation example

Weekly items

Week 3

Layout change / AdapterView example
### Week 3
- **Animation using SurfaceView**

- Background Image (BMP file)
- Twinkle star according to time
- 4 star Image (PNG file)
- First direction is decided randomly
- Disappear

### Week 4
- **Overview**

<table>
<thead>
<tr>
<th>Day</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>Intent, Service</td>
</tr>
<tr>
<td></td>
<td>– Intent, broadcast receiver</td>
</tr>
<tr>
<td></td>
<td>– Local Service, Remote Service</td>
</tr>
<tr>
<td>Wednesday</td>
<td>Data management</td>
</tr>
<tr>
<td></td>
<td>– bundle, parcelable</td>
</tr>
<tr>
<td></td>
<td>– preference, SQLite, File I/O</td>
</tr>
<tr>
<td></td>
<td>- Content provider</td>
</tr>
<tr>
<td>Friday</td>
<td>Drawing App, Address book, Service example</td>
</tr>
<tr>
<td>Lab hours</td>
<td>Homework of Week 3</td>
</tr>
<tr>
<td>Homework</td>
<td>Drawing App, Address book, MapView</td>
</tr>
</tbody>
</table>

Mobile&Smart@KMU
Week 4

- Address book
  - Study AlertDialog and OnItemClickListener
  - Make modification function
    - SQLite
    - ListView
  - Make delete function
    - SQLite
    - ListView

Week 4

- Drawing app
  - Draw Test
Week 5

Overview

- Audio and Video signal processing
- Other issues in multimedia

Android multimedia
- Media player
- VideoView
- Camera
- Etc.

Ringdroid, Cocos2D, FFmpeg, AndAR

Homework of Week 4

Address book, Audio cutting, Cocos2D example, AndAR

- Address book app using camera APIs

Taking a Picture
Select a picture in gallery
**Weekly items**

### Week 5
- Audio cutting example
- Video cutting example
- AndAR

![Audio cutting example](image1)

![Video cutting example](image2)

![AndAR](image3)

Select a time of cutting
Start cutting mp3 file
Play the original mp3 file
Play the cut mp3 file
Create folder. And copy ‘test.mp3’

### Week 6
- **Overview**

<table>
<thead>
<tr>
<th>Monday</th>
<th>Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Network / Wireless communication</td>
</tr>
<tr>
<td></td>
<td>- Bluetooth / WLAN</td>
</tr>
<tr>
<td></td>
<td>- Other issues in network</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wednesday</th>
<th>Android network</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3G / WLAN / Bluetooth / etc.</td>
</tr>
</tbody>
</table>

| Friday | BlueChat, Wi-Fi based Chatting, Bluetooth based data exchange |

<table>
<thead>
<tr>
<th>Lab hours</th>
<th>Homework of Week 5</th>
</tr>
</thead>
</table>

| Homework | Wi-Fi based chatting, Data exchange using Bluetooth in Address book |
**Weekly items**

- **Week 6**
  - Wi-Fi based chatting
  - CandleSync

**Weekly items**

- **Week 6**
  - Address book exchange with Bluetooth
周 7

概述

- LBS
- AR
- 其他传感器问题

周 6

- Android Camera
- Android LBS
- Android sensors
- Etc.

Friday

- LBS app, Gyroscope app, Sensor based app
- Homework: LBS app, Gyroscope app, Sensor based app

如何使用 Android 传感器 API

SensorManager

- Sensor
  - Illumination
  - Proximity Sensor
  - Orientation Sensor
  - Accelerometer Sensor
  - Gyroscope
  - Etc.

SensorListener

- Context.getSystemService()
- SensorService
  - Sensor_Service
  - Location_Service
  - Etc.
**Weekly items**

**Week 7**
- An LBS app and a sensor app

**Week 8**
- **Overview**

<table>
<thead>
<tr>
<th>Day</th>
<th>Monday</th>
<th>Wednesday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JNI/NDK</td>
<td>Debugging and performance analysis</td>
<td>Spiral image app, FMOD, etc.</td>
</tr>
<tr>
<td></td>
<td>JNI and NDK</td>
<td>NDK and debugging related examples</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- JNI</td>
<td>- DDMS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- NDK</td>
<td>- Traceview</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- NDK development</td>
<td>- Profiling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Debugging</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Homework of Week 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab hours</td>
<td>Homework of Week 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homework</td>
<td>Spiral image</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Week 8

- Android app development using NDK

- Android profiling using TraceView

- Making a spiral image
**Weekly items**

### Week 9

#### Overview

<table>
<thead>
<tr>
<th>Monday</th>
<th>Power dissipation and energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wednesday</td>
<td>Performance analysis and tools: a trend</td>
</tr>
<tr>
<td>Friday</td>
<td>Cloud computing</td>
</tr>
<tr>
<td>Lab hours</td>
<td>Homework of Week 8</td>
</tr>
<tr>
<td>Homework</td>
<td>No homework</td>
</tr>
</tbody>
</table>

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**A performance analysis tool for Android**

Week 9

A power consumption example

Power value of devices

![Power consumption chart]

1. Kim, H. Smart phone, where does the power go? 2011 EU - Korea Conference on Science and Technology (EKC 2011), 2011.

Week 9

A cloud computing example

SaaS (Software as a Service)
- Provide software using cloud
- Word, or spreadsheet through web browser
- E-mail services, Google Docs, Google Apps

IaaS (Infrastructure as a Service)
- Provide infrastructure(server storage, network)
- Provide server and physical resource of server by IaaS provider
- Power supply, cooling, management of fire-fighting equipment except server by IaaS business
- AWS(Amazon Web Service)

PaaS (Platform as a Service)
- Provide platform as a service
- Provide tools for online application development and operation
- Provide new SaaS through PaaS
- Google App Engine, MS Windows Azure

Cloud should be accessed in various environment
- We need
  - Abstract server interface on user’s position
  - Server virtualization technology is needed
### Weekly Items

**Week 10**

- **Overview**

<table>
<thead>
<tr>
<th>Day</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>N-screen</td>
</tr>
<tr>
<td>Wednesday</td>
<td>Mechanical platform (AUTOSAR, ROS, OPRoS, etc.)</td>
</tr>
<tr>
<td>Friday</td>
<td>Cross platform / Hybrid app</td>
</tr>
<tr>
<td>Lab hours</td>
<td>Project related issues</td>
</tr>
<tr>
<td>Homework</td>
<td>No homework</td>
</tr>
</tbody>
</table>

### N-screen

- Contents
- Cloud
- N-SCREEN
- PC
- Smartphone
- TV
- Automobile
Week 10
- Robot application development using OPRoS

Cross platform
- Visual tool - Verivo
**Weekly items**

- **Week 10**
  - HTML 5 related issues
  - B2G and WAC/Tizen

**Project**

- **Project schedule**
  - 20 phones from SK Planet
  - 2 robots from KITECH

<table>
<thead>
<tr>
<th>What to do</th>
<th>Due date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td>Week 1-3</td>
</tr>
<tr>
<td>Project plan</td>
<td>Week 3-5</td>
</tr>
<tr>
<td>Development &amp; discussion</td>
<td>Week 3-10</td>
</tr>
<tr>
<td>Final report and presentation</td>
<td>Week 10-11</td>
</tr>
<tr>
<td>Showcase</td>
<td>Week 11</td>
</tr>
</tbody>
</table>
Tentative projects
- Remote control of robots using smartphone
- Cell-bot / Cloud robotics
- Black box application in automobile
- Character recognition using smartphone
- AR(Augmented Reality) application using NYAR or AndAR tool kit
- LBS application in UCI
- LBS application in UCI using AR
- Mobile album – connect UCI
- Send my firework!
- App analyzer
- Control My PC

<table>
<thead>
<tr>
<th>Project</th>
<th>Remote control of robots using smartphone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples</td>
<td><img src="image1.png" alt="Example Image 1" /> <img src="image2.png" alt="Example Image 2" /> <img src="image3.png" alt="Example Image 3" /></td>
</tr>
</tbody>
</table>
| Description | Control the robot using smartphone  
Bluetooth / Wi-Fi / WCDMA connection  
N-screen between robots and smartphones  
E-learning using robot for children  
OPRoS / ROS platform |
| Sample Applications | iRobiQ, KMU/Yujin robot  
Hexapod Robot, University of the West of England  
Walky, Keio Univ. |
## Tentative projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Augmented Reality using AR toolkits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples</td>
<td><img src="image1.png" alt="image" /> <img src="image2.png" alt="image" /></td>
</tr>
<tr>
<td>Description</td>
<td>AR applications using AR toolkits NyAR, AndAR toolkits On/off-line applications using AR engine and OpenGL</td>
</tr>
<tr>
<td>Sample Applications</td>
<td>NyAR AndAR Popcode</td>
</tr>
</tbody>
</table>

## Project results

<table>
<thead>
<tr>
<th>Team name</th>
<th>Theme</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Let’s</td>
<td>Location-based social networking service</td>
<td>LBS, SNS</td>
</tr>
<tr>
<td>WiFi Flash drive</td>
<td>File sharing service between smartphone, PC and servers</td>
<td>Network, File sharing</td>
</tr>
<tr>
<td>RoboControl</td>
<td>Interaction app with OPRoS based robot</td>
<td>Remote control, Robot Gesture Recognition</td>
</tr>
<tr>
<td>Scheduleshare</td>
<td>Schedule sharing between users with 'BUMP' APIs</td>
<td>Schedule sharing</td>
</tr>
<tr>
<td>Gyan</td>
<td>Quiz taking app with SNS characteristics</td>
<td>SNS, Game, Quiz</td>
</tr>
<tr>
<td>GBC (Ginger Bread Car)</td>
<td>app interaction with Android car using OpenCV</td>
<td>Robot, Pattern recognition</td>
</tr>
<tr>
<td>ShuttleScheduler</td>
<td>UCI bus system app providing bus/walking navigation at UCI</td>
<td>LBS, Navigation</td>
</tr>
<tr>
<td>BooksInteractive</td>
<td>AR app for child books using Qualcomm Vuforia</td>
<td>AR, Learning</td>
</tr>
<tr>
<td>Dungeon Master</td>
<td>SNS based game which simulates combat between players and monsters</td>
<td>Game, SNS</td>
</tr>
<tr>
<td>PhotoGam</td>
<td>SNS based photo editing app</td>
<td>SNS, Photo</td>
</tr>
<tr>
<td>KOBOT</td>
<td>Remote control of an OPRoS based robot</td>
<td>Remote control, Robot</td>
</tr>
<tr>
<td>IFM (Intelligent Food Monitor)</td>
<td>A reminder app that tracks and monitors your groceries and diet</td>
<td>u-health, - Barcode Scanner</td>
</tr>
</tbody>
</table>
**Project**

- **BooksInteractive**
  - Augmented reality based interactive book

- **GBC**
  - Android phone based autonomous car
Project

- ShuttleScheduler
  - Anteater Express shuttle system

- ScheduleShare
  - Schedule trading by ‘bumping’
Project

- **KOBOT**
  - OPRoS based robot
  - Interaction with smartphone

- **Gyaan**
  - SNS based quiz app
Project

- **Wi-Fi Flash Drive**
  - File transfer app for Android phone

**AMASE@UCI**
- Sponsored by
  - SK Planet, KITECH, Google, Samsung, D&CI
Evaluation

- **Total score**

<table>
<thead>
<tr>
<th>Score</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>40</td>
</tr>
<tr>
<td>Project</td>
<td>60</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

- **Project rubrics**

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creativity</td>
<td>20</td>
</tr>
<tr>
<td>Market</td>
<td>30</td>
</tr>
<tr>
<td>Technology</td>
<td>30</td>
</tr>
<tr>
<td>Usability</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Feedback & Discussion
Feedback & Discussion

☐ Students’ feedback
  • Received excellent feedback from the students
    • students’ final reports
    • lecture management system

☐ Main concern of the students
  • Burden to the homework
    • 2-3 times more than other courses.
    • Main reason
      ✓ Lots of examples
      ✓ No official lab hours

Feedback & Discussion

☐ Towards future lectures

Week 1
Lecture Day 1
Lecture Day 2
Exercise Day 3

Week 2
Lecture (Day 1)
Lecture (Day 1½)
Lecture (Day 2)
Exercise (Day 3)

Week 3
Lecture Day 1
Lecture Day 2
Exercise Day 3

Week 4
Lecture (Day 1)
Lecture (Day 1½)
Lecture (Day 2)
Exercise (Day 3)

Week 5
Lecture Day 1
Lecture Day 2
Exercise Day 3

Week 6
Lecture (Day 1)
Lecture (Day 1½)
Lecture (Day 2)
Exercise (Day 3)

Week 7
Lecture Day 1
Lecture Day 2
Exercise Day 3

Week 8
Lecture (Day 1)
Lecture (Day 1½)
Lecture (Day 2)
Exercise (Day 3)

Week 9
Lecture Day 1
Lecture Day 2
Exercise Day 3

Week 10
Lecture (Day 1)
Lecture (Day 1½)
Lecture (Day 2)
Exercise (Day 3)

Lecture hours
unofficial lab hours

MESA lecture
Future course design
Feedback & Discussion

Towards future lectures

- Additional items
  - More explanation for the Linux and Android platform itself
  - New open platforms and API sets such as Vuforia, Samsung Galaxy Note APIs, SNS APIs, etc.
  - More examples for the cross-platform issues (HTML5, PhoneGap, B2G, etc.)
  - More examples for advanced apps
  - Examples for mechanical platforms (ROS, OPRoS, etc.)

Concluding Remarks
Concluding remarks

- **Notes from the recent trend**
  - Increasing importance of SW platform and application
  - Platform similarity between industries
  - App market as a ‘mass market’

- **Tradeoff between students and university**
  - Advanced course within 1 quarter

- **Advanced course design**
  - Increase interest of the students for embedded systems using Android
  - Hope to be a good examples for the course design in mobile embedded system
  - Hope to be a good pedagogical path to reinforce and stimulate interest in an Embedded Systems curriculum.

Thank you!

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