CG4002

Computer Engineering Capstone Project

Lecture 1

Overview

Peh Li Shiuan, Professor, Computer Science &
Electrical and Computer Engineering (Courtesy)
peh@nus.edu.sg

NUS National University of Singapore
School of Computing

1

NUS National University of Singapore
School of Computing

Outline

- **Course overview**
  - Teaching staff
  - Teaching mode
  - Resources
- **Project overview**
- **Course assessment**

2

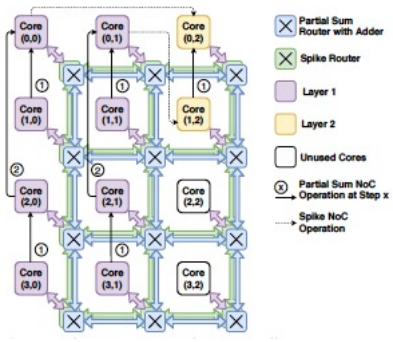
Teaching Staff – The "Human Resource"

- **Sangit Sasidhar**
  - From ECE
  - Co-lecturer
  - Oversees the hardware aspects
- **Wang Ye**
  - From SoC
  - Co-lecturer
  - Oversees the software aspects
- **Peh Li Shiuan**
  - From SoC and ECE
  - Co-lecturer & Module Coordinator
  - Oversees the communications aspects

3

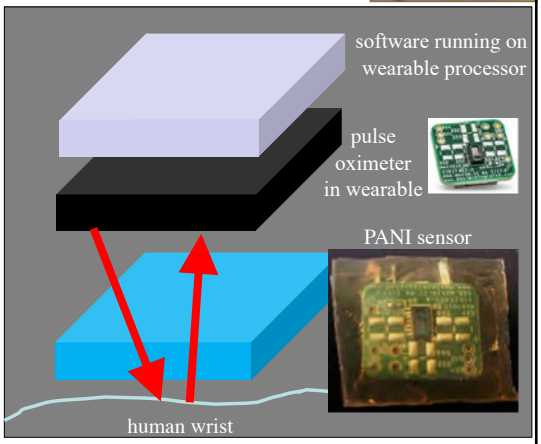
Peh's research into wearables

Shenjing: AI accelerator chip for wearables
- MNIST: 96% accuracy at 1.45mW
- SNN chip that can be configured so deep learning models can be mapped by software



[Wang, Zhou, Wong and Peh, DATE 2020]

pHWatch: Sensing your sweat with a smartwatch's heart rate sensor



[Balaji, Chen, Wang, Peh and Shao, Mobisys 2019]

4

Teaching Staff – The "Human Resource"

- **TAs – A go-to TA for each group + hw/comms/sw**
  - Thursday morning lab:
    - ✓**Modak, Jiajun and Brandon**
  - Thursday afternoon lab:
    - ✓**DMD, Santos, Thilini**
- **Reach us through CG4002 Forum on LumiNUS so we can "crowd-source" and "crowd-solve" problems**

5

Hybrid CG4002 Teaching Mode

- **This is a project module**
  - 6 topic lectures will be online, live:
    - ✓**Peh: Comms Internal, Comms External [Today]**
    - ✓**Sangit: Hardware Sensors, Hardware FPGA [Next Thurs]**
    - ✓**Wang Ye: Software AI, Software Dashboard [Next Thurs]**
  - Labs will be face2face: See you at Week 3's lab
    - ✓**SR1, TraceTogether, uNivUS, ARTs, safe distancing, masks on at all times**
  - Tests will be hybrid, during lab hours:
    - ✓**Weeks 6 and 7: 1-on-1 online with Sangit, Wang Ye or Peh**
    - ✓**Group tests face2face (backup: online tests)**

6

Week 2: Online lectures during labs

- **Topics mini lectures on hardware and software by Sangit and Wang Ye**

7

Course Resource

- **Mainly on LumiNUS portal**
- **Lesson Plan**
  - Will be updated to reflect any changes in schedule
  - Lab activities and deliverables will be indicated
- **Forum**
  - Use for enquiries instead of emails! TAs and Lecturers will be monitoring it
- **Project Grouping**
  - Will be randomly assigned before week 3's lab

8

PROJECT OVERVIEW

9

Course Synopsis

This module exposes students to the development of a **large system from conceptualization to its final implementation.**

It is structured to contain substantial design and development of hardware and software components

- **A culmination of theories and practices learned in several modules:**
  - EPP1 and EPP2
  - Intro Programming, Data Structures, Software Engineering
    - ✓**Software Track**
  - Programming Devices & Interfaces, Real-time Systems
    - ✓**Hardware Track**

10

Course Objectives

- **Able to apply hardware and software engineering design principles in specifying, architecting and implementing a complex embedded system**
- **Able to understand team dynamics and successfully manage a reasonably large project**

11

Motivation - CDIO

- **The CEG degree embodies the CDIO framework**
  - Conceive
  - Design
  - Implement
  - Operate
- **This project aims to be:**
  - Challenging
  - Open ended
  - Solve a meaningful and real problem

12

Motivation – Real World

- **This project echoes many real world settings:**
  - You have meaningful design decisions to make
  - You need to learn stuff on your own
  - You need to manage the complexity
  - You are cooperating with others to achieve best results
  - You are competing with other teams to "sell" your product
- **A well done project of this complexity will look very good on your portfolio**

13

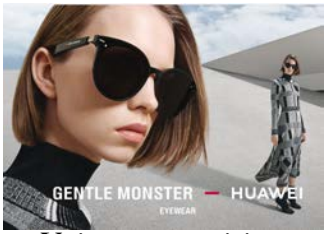
Wearables

Fitness tracking on Fitbit

Here Maps on Samsung gear s2

Location-based games on smartwatch

Health care apps on smart watches

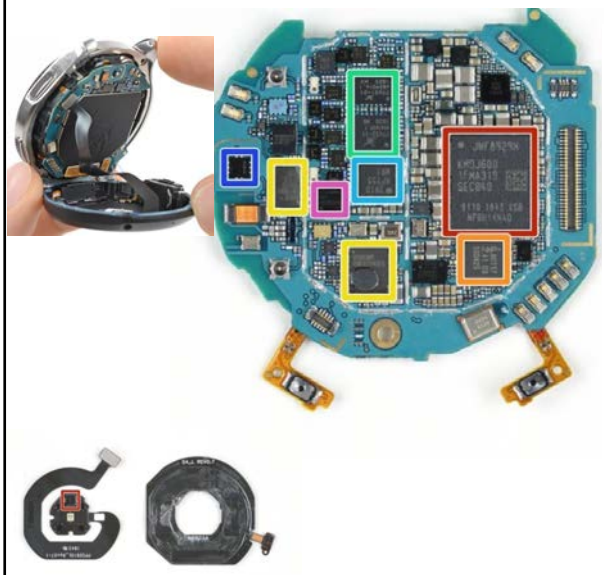


Voice recognition on Huawei glasses

AR on Google glass

14

How does a wearable work (at 10000 feet)



- Samsung Exynos 9110 SoC (dual-core, 1.15 GHz)
- NXP 80T17 NFC controller
- Broadcom BCM430131 WiFi/BT chip and BCM47758-GPS/GLONASS chip
- Skyworks 77651-21 and 77652-11 multimode/multiband power amplifier modules for 3G/LTE
- S910 NFY55 WR1
- STMicroelectronics barometric pressure sensor
- ST Micro ST33G1M2 32-bit ARM® SecurCore® SC300 (secure element)

[https://www.ifixit.com/Teardown/Samsung+Galaxy+Watch+Teardown/117519]

16

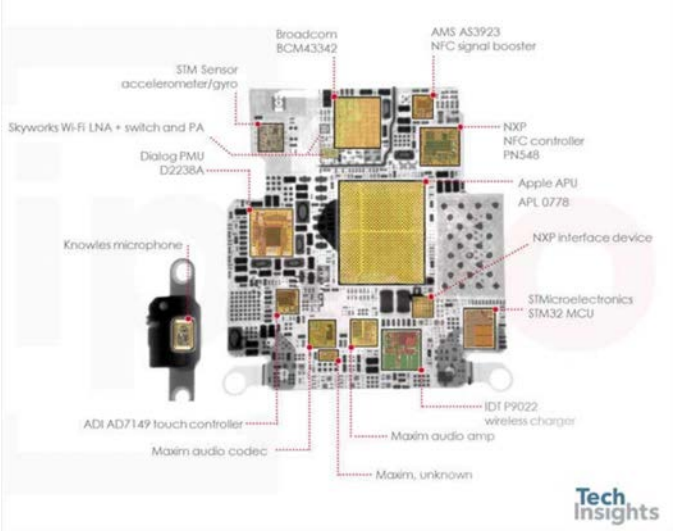
How does a wearable work (at 10,000 feet)?

- **Hardware:**
  - HW1 Sensors: Sensors (accelerometer, step counter, heart rate sensor) processed by sensor coprocessor
  - HW2 Accelerators: Software running on main processor + Hw accelerators
- **Communications:**
  - Comms1 Internal: Internal communications between sensor and main processors
  - Comms2 External: Wireless communications with your phone
- **Software:**
  - Sw1 AI: Algorithms for distinguishing between idle and steps, learning your sleep pattern, etc.
  - Sw2 Dashboard: Analytics app dashboard on your phone

17

How does a wearable work (at 10,000 feet)?

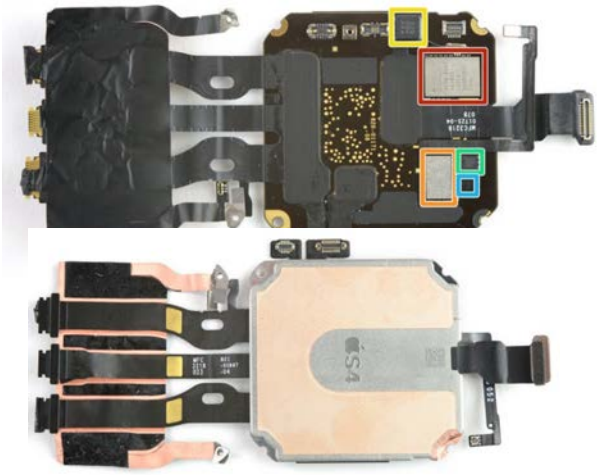
Teardown of Apple Watch



https://www.techinsights.com/about-techinsights/overview/blog/apple-watch-teardown/

How does a wearable work (at 10,000 feet)?

Teardown of Apple Watch Series 4



https://www.ifixit.com/Teardown/Apple+Watch+Series+4+Teardown/113044]

Platform overview of this fitness tracker

Sw: Dashboard for visualizing and analyzing sensed data

Phone

Hw: sensors

Hw: programmable accelerator

Comms: External

Comms: Internal

Sensor Co-Processor ⟷ Main Processor

Sw: Machine learning for activity detection

20

CG4002 Project: Human activity tracking

Problem Statement:

A wearable device that automatically detects human activities

dance moves

21

Fun Problem Statement:
Dance Dance:
A wearable system that can automatically coach a dance group

1. Dance moves and positions?

Positions: 1 2 3
Dance move A

22

Fun Problem Statement:
Dance Dance:
A wearable system that can automatically coach a dance group

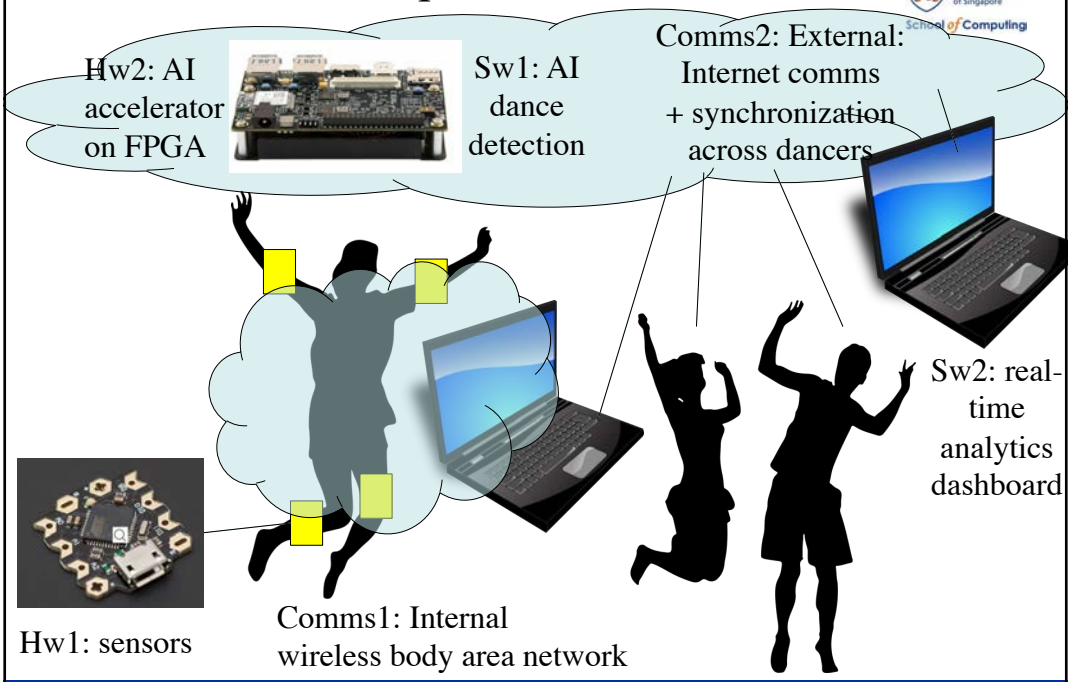
1. Dance moves and positions?

Positions: 2 3 1
Dance move B

2. Synchronized?

23

Virtual CG4002 in 6 parts:



24

Virtual CG4002:

25

CG4002 and the real world….

- Hw1 Sensors: IoTs, phones/wearables for activity sensing, sensors
- Hw2 FPGA accelerator: AI accelerators, NPUs, TPUs, FPGA for AI

- Comms1 Internal body-area-network: Bluetooth low energy, multithreading
- Comms2 External: Clock synchronization, distributed systems, secure socket communications with servers

- Software1 AI: Machine learning, activity classification
- Software2 Dashboard: Analytics, real-time streaming database, dashboard visualization design

26

Flashback: How does a wearable work (at 10,000 feet)?

- **Hardware:**
  - HW1 Sensors: Sensors (accelerometer, step counter, heart rate sensor) processed by sensor coprocessor
  - HW2 Accelerators: Software running on main processor + Hw accelerators
- **Communications:**
  - Comms1 Internal: Internal communications between sensor and main processors
  - Comms2 External: Wireless communications with your phone
- **Software:**
  - Sw1 AI: Algorithms for distinguishing between idle and steps, learning your sleep pattern, etc.
  - Sw2 Dashboard: Analytics app dashboard on your phone

27

CG4002 wearable project:

- **Hardware:**
  - HW1 Sensors: Sensors processed by Arduino Beetle -> Start of moves, positions
  - HW2 Accelerators: Software running on Ultra96 main processor + Ultra96 FPGA accelerator for AI
- **Communications:**
  - Comms1 Internal: Internal BLE communications between Arduino Beetle and laptop
  - Comms2 External: IP communications between laptop and Ultra96, and Ultra96 to servers, and clock synchronization between laptops and Ultra96
- **Software:**
  - Sw1 AI: Algorithms for detecting dance moves
  - Sw2 Dashboard: Analytics app dashboard on your server to coach dancers

28

Dance move videos on LumiNUS ☺

mermaid (hands straight in front waving up and down)
jamesbond (fingers in 7, point up left and right)
dab (1 hand elbow bent, the other hand straight)
window360 (hands wiping imaginary windows, turning 360 degrees)
cowboy (hands spinning imaginary rope, turning 360 on the spot)
scarecrow (arms in right angle up like letter H, invert down)
pushback (hands pushing out with open palms, then back into fist)
snake (hands and body in a T shape, forming waves)

29

Design your own move!

- **Final move**
- **Neutral move?**

30

Requirements

- Wearable
- Automatic detection
- Works for anyone
- Secure communication of detected moves to server
- Low power
- Low cost ($300 budget per team)
- *Virtual CG4002: Dancers may be in different physical locations, video conferencing*

31

Evaluation metrics

- **Performance:**
  - Move accuracy
  - Position accuracy
  - Synchronization delay accuracy
  - Speed
- **Design:**
  - Aesthetics: Wearable
  - User interface: Dashboard
  - User experience: Reliability

32

CG4002 Assessments

- **This is a 100% CA module**
  - There is no midterm test nor final exam
  - There are multiple check points along the way
  - Consistency is critical for a good grade
- **This is a group project**
  - Individual assessments
  - Group tests
  - Peer review

33

Week 3: First lab session (face2face)

- **You will meet your group mates in person**
- **You will meet the teaching team in person**
- **Components will be given out**
- **Start brainstorming design**
- **Which individual component**
- **How to interface the various software/hardware components**
- **Define interfaces clearly**

34

Week 4: Design Report (15%: 10% indiv, 5% group)

- **Section 1: System Functionalities**
  - How will a user use your system?
- **Section 2: System Architecture**
  - High level architecture, components, form factor
- **Section 3: Hardware Details**
  - Part numbers, pins, schematic, power consumption
  - Neural network design, FPGA simulation and evaluation
- **Section 4: Comms Details**
  - Processes, BLE protocol, packets, handshaking
  - Sockets, secure, clock synchronization protocol
- **Section 5: Software Details**
  - Segmentation, features, machine learning algorithms, training/testing
  - Dashboard design features, real-time streaming, user survey evaluation
- **Section 6: Project Management Plan**
  - Timeline, milestones, communication tools

35

Week 5: Feedback on design report

- **Feedback on design report by lecturers and TAs**

36

Week 6: Progress checkpoint (5% indiv)

- **1-on-1 walkthrough progress on implementation (video conference)**
- **See progress towards individual subcomponent test**

37

Week 7: Individual subcomponent tests (20% indiv)

- **1-on-1 walk through via video conference with lecturers**
- **5 mins max video recording**

38

Week 7: Individual subcomponent test (20% indiv)

- **HW1: Sensors**
  - Sensors integrated into wearable
  - Working wearable
  - Sensor data preprocessed
  - Start of move detection

- **HW2: FPGA**
  - 1 specific neural network inference model implemented onto FPGA
  - Run model with test data provided
  - Evaluate hardware utilization, timing, power

39

Week 7: Individual subcomponent test (20% indiv)

- **Comms1: Internal**
  - Walkthrough protocol for BLE communications
    - ✓**Handshaking**
    - ✓**Packet format**
  - Dummy sensor data
  - Demonstrate concurrent BLE connections from 3 Beetles to laptop lasting at least a minute

- **Comms2: External**
  - Walkthrough and demo secure socket comms between laptop, virtualized Ultra96 and evaluatio

  - Walkthrough protocol for estimating dancer synchronization delay

40

Week 7: Individual subcomponent test (20% indiv)

- **Sw1: Machine Learning**
  - Find an online dataset that is as close as possible to your application and design
  - Walkthrough your code of at least 2 ML models compatible with FPGA's neural network
  - Show evaluations of your ML models on the dataset
  - Explain how they classify dance moves and relative locations

- **Sw2: Dashboard**
  - Walkthrough dashboard design from UX to implementation
  - Show dashboard with real-time streaming in of dummy sensor data (localhost)
  - Show how dashboard can enable analytics of wearable system (vs. ground truth) and dancer
  - Design user survey

41

Week 8: System test details

- **Demo by teaching team**
- **Clarification of test setup**
- **Default: face2face tests**

42

Week 9: First system checkpoint (10% group) [1 dancer, first 3 moves, NO positions]

- **Test script runs on class server**
  - Test script will be provided so you can test beforehand on your own
- **Test script randomly selects a move, and displays it**
- **Dancer wearing your wearable system, perform the displayed move**
- **Wearable system detects move and sends to server**
- **Once test script receives a move, it logs it, and generates the next move…**
- **Dashboard can be used to prompt and coach dancer**

43

Week 11: 2nd evaluation test (15% group) [3 dancers, first 3 moves, positions]

- **Test script runs on class server**
  - Test script will be provided so you can test beforehand on your own
- **Test script randomly selects a move, and displays it**
- **Dancers, wearing your wearable system, move to specified relative locations and perform the displayed move**
- **Wearable system detects location, move and sends to server**
- **Once test script receives a move, it logs it, and generates the next move…**
- **Dashboard can coach or prompt dancers**

44

Week 11: Peer review (factored into grading)

- **Teammates**
- **Online survey done by each of you on you and your team mates' contribution**

45

Week 13: Final evaluation (25% group) [3 dancers, 8 moves, positions]

- **Dancers randomly chosen from your group**
- **Same server script will be given to you, running on class server**

- **Dashboard *cannot* coach student dancers**
- **System will also be tested with unseen dancers from teaching team**
  - Dashboard can coach these unseen dancers

46

Week 13: Final Design Report (10%: 5% indiv, 5% group)

- **Update design report with final design and societal impact**
- **Document final system (photos!) – Form factor**
- **Code submission**

47

NUS National University of Singapore
School of Computing

Let's dance!
Q&A