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Virtual CG4002 Embedded System Design Project
AY 2021/2022 Semester 1
Project Specification (Overview)

Welcome to CG4002, the capstone project (aka weekend burning, lab camping, crazy final project) for the CEG programme. This project module is meant to challenge your creativity, knowledge and skills to the extreme, i.e. it is going to be very demanding! Be prepared for head-scratching confusions, wall-banging frustrations, but also jumping-up-and-down eureka moments ahead. You have been warned. ☺

For a start, we will give an overview of the project specification. Instead of dumping a whole lot of information on you, this document gives you only an overall picture with limited detail. We will dish out information at the right moment in the upcoming weeks.

There are two sections in this document:

1. Specification overview
2. Timeline of evaluations and milestones

Section 1: Specification Overview

Wearables provide a way for detecting human activity automatically, and have been used in wide-ranging scenarios. Fitness tracking is likely the most prevalent use of activity detection. Using wearables such as smartwatches or fitness trackers, users can monitor their step count, as well as more advanced sports training such as stride and pace for running, strike force for tennis, stance for basketball etc. Activity detection has also been used in medical scenarios, such as detecting falls or anomalous movements that indicate medical conditions. In our daily life, activity detection has been applied to infer our minute-by-minute activities at home, during commute, at work or school, while shopping, exercising, etc.

In this project, the goal is simple – design a wearable system that can detect, and coach dancers as they dance!

Problem Statement:
A wearable system that detects and coaches dance moves of a dance group

Main requirements:

- A wearable device and system to be designed to coach the dancers as they perfect and synchronize the dance moves.
- <u>Three</u> dancers will move into the specified relative positions, then perform each specific <u>dance move</u> shown on the server screen.
- Server will display a randomly selected routine of 8 different dance moves with relative positions of dancers on the screen. For instance, the screen will show:

DanceMove1

Locations: 1 2 3

Initial position with all 3 dancers facing the screen, all dancing DanceMove1.

DanceMove2

Locations: 2 1 3

Facing the screen, Dancer 1 will move to the right, Dancer 2 will move to the left, and Dancer 3 remains in the same position, then all 3 dancers will perform DanceMove2.

- For each dance move, the wearable system will respond to the evaluation server with the predicted dance move, dancers' relative locations, and how synchronized the dancers are (time in ms from when the earliest dancer starts the dance move to when the latest dancer starts dancing the move). Evaluation server script will be provided.

- Wearable automatically detects these dance moves (Check out videos of dance moves on LumiNUS), the dancers' positions, and how synchronized they are with each other.

- The wearable system should work when worn by anyone and used anywhere (i.e. no infrastructure sensors), *even when the three dancers are dancing in separate physical locations (virtual CG4002).*

- The system should be realized with the hardware platforms provided: Arduino Beetles and Ultra96 FPGA board. Each group's Ultra96 FPGA board will be housed in Makers@SoC lab and accessible remotely via an IP address that will be provided, enabling virtual CG4002.

- The system should communicate the system's outputs to the class evaluation server in a secure manner. (The wireless interface with the server will be published)

- One wearable should have a sensor that measures the muscle fatigue of a dancer so as to track the fitness level of the dancers.

- The system must include a coaching dashboard that accepts in real-time information from the wearable system so as to provide analytics feedback to dancers. This dashboard can run on your own server or in the cloud, but needs to support secure access.

- The wearable should track timing information as feedback to the dancers on how synchronized they are in performing the dance moves, and send the timing difference between dancers starting a new move to the server for validation, and to the dashboard for feedback to dancers.

- You should design a final move that will trigger your system to send a "logout" message to the server indicating the end of the dance routine.

- Each team has a budget of $300 for purchasing additional components.

- The system will be evaluated based on performance, power and design. Performance refers to detection accuracy – whether dance moves and relative locations and synchrony are detected correctly, and detection speed – how fast each move is detected, measured from when the server displays the specific move to when the message with the detected move is received at the server. Power refers to the power consumption of overall wearable system. Design refers to functionality, reliability, aesthetics, comfort, weight, etc.

- Hardware platform:
  - An Ultra96-V2 Processor+FPGA board as the main processor
  - Arduino Beetles sensor boards
  - A set of standard sensors

Total (and scary) Design Freedom:

Most aspects of the project are open:

- Hardware Sensor: What kind of sensors will you use to detect each move and differentiate amongst the moves? How will you detect the start of a dance move? Can you detect the positions of the dancers?

- Hardware FPGA: How can the FPGA board be used to improve power and performance? Can the software AI be accelerated with the FPGA? What are the constraints on the AI models that are supported? How can you optimize entire system power-performance?

- Communications Internal: How will you wirelessly receive the sensed data from the three dancers to your laptop?

- Communications External: How can you communicate between your laptop to your Ultra96 board via IP? How will the Ultra96 board communicate predicted results to the dashboard server and our evaluation server in a secure and reliable manner? How can you determine how much time lag there is between the dancers dancing so you can provide feedback on how synchronized the dancers are?

- Software AI: How will you learn and classify the different moves, and handle different individuals, including new dancers? How will your software be run on the Ultra96 FPGA board – which parts on the processor, which on the FPGA?

- Software Dashboard: How will the dashboard store, analyze and display the data from the dancers in real-time, and what analytics can you provide to coach the dancers? How can the dashboard handle many simultaneous users? How will you assess user feedback of the dashboard?

Section 2: Timeline of evaluations and milestones

The project has the following milestones:

1	**Overall System Design** Design the high-level system architecture. Figure out the interfaces between subsystems. A good design allows each subsystem to be developed and optimized independently.
2	**Individual Subsystems** Develop the subsystems concurrently. By adhering to the designed interfaces, the subsystems should be able to work together in the next phase.
3	**Integrated System** The subsystems are integrated and works as a whole. Fixing integration bugs is the main focus in this phase.
4	**Baseline System for 1 Individual** The integrated system is working well and meets the baseline requirements as given below, for a known dancer: 1. Detects first 3 dance moves and relative positioning of a dancer 2. Communicates the moves to the server securely
5	**Baseline System for 3 Individuals** The integrated system is working well for 3 known dancers, and meets the baseline requirements as given below: 1. Detects first 3 dance moves and relative positioning of 3 dancers 2. Communicates the moves to the server securely
6	**Final System** The integrated system works well for the full project specs: When given a sequence of specific relative locations and dance moves, the dancers perform each move in turn and the system detects and communicates the moves and locations to the server. This should work for unseen dancers.

The evaluation timeline follows closely the milestones given above. The criteria of each evaluation will be clarified at the appropriate time. Note that the schedule and evaluation criteria may be adjusted depending on the cohort's progress as a whole.

Week	**Evaluation**
4	**Initial design report: (15%)** - Overall system design - High level subsystem design

	- Independent research describing prior art and explaining proposed design - Submission through LumiNUS
5	**Feedback on design report**
6	**Individual progress checkpoint : (5%)** -Ensure individual is on track for subsystem test
7	**Individual component test: (20%)** - Subsystems will be evaluated independently and individually - Criteria will be given
9	**Single dancer system progress checkpoint (10%):** -One dancer integrated system working -Ensure team is on track in integration
11	**3 dancers system demo (15%)** - 3 dancers, 3 dance moves evaluation
11	**Peer review: (Potential grade adjustment)**
13	**Final demo (25%)** - Based on final system requirements as stated in the milestones
13	**Final design report (10%)** - Detailed description of final design and components - Detailed explanation of final design choices - Submission through LumiNUS