CS352 SOFTWARE ENGINEERING 2

COURSE PROJECT INSTRUCTIONS SPRING 2021

Instructions to students:

This is a group project; each group consists of 5 or 8 students. You are to choose your own team members. A Student, who is not assigned to any team, will be assigned to a team randomly by the TA.

It is expected that students will participate equally in the work of the group. Group meetings minutes specifying the attendees should be included, and the contribution of each student must be documented in each report.

Deliverable(s): A report that should document and present the analysis and design practices and artefacts of a chosen real-time system. The report may also conclude by a section that highlights the problems encountered and lessons learned during the real-time software analysis and design process.

Submission: Submission of the reports required will be a softcopy uploaded (as per the instructions provided by the TAs) on the deadline specified, in addition to a hardcopy during the on-campus discussions.

Assessment: Assessment evaluates individual performance through oral discussions, teamwork performance, and project technical achievements.

Suggested Approach to carry out the project:

To complete the required work, follow the guiding steps below:

- Research the assigned idea *(e.g., by reading articles on existing/planned systems that are relevant to your idea)*.
- Decide - in an abstract & simple approach - how your proposed system should work, how many real-time robotic systems are involved, what are the functions/tasks assigned to each of them.
- Decide what types of motors, cameras, or any sensors in general are required.
- Draw a block diagram of the proposed system, consider any architectural concepts/patterns.
- Draw Activity Diagram(s) for the main functions of the proposed system.
- Draw a use case diagram *(using the COMET UML profile and constraints)*.
- Draw an initial class diagram *(consider object/class structuring)*.
- Draw interaction diagrams, for the functions presented in the use-case diagram, using the classes determined in the initial class diagram.
- Draw state-machine diagrams *(for any state dependent objects)*.
- Update & finalize the class diagram using the details/insights from both the interaction & the state-machine diagrams *(and consider any design patterns)*.

Detailed Deliverables:

A technical report that is expected to include the following sections:

- Problem definition: You need to provide 1 to 1.5 pages describing the requirements and timing constraints of your assigned software system.
- Then you need to apply the design process activities. By combining the studied design methodology: the COMET and RT-UML methods, you may include the following Sections:

    a. Requirements modelling – This includes:
        - A block diagram of the required system.
        - Activity Diagram(s) for the main functions of the proposed system.
        - An extended use case diagram (using the COMET UML profile and constraints).
        - Stimuli/response identification: this involves identifying the stimuli that the system must process and the associated response(s) for each stimulus.

    b. Static Analysis modelling – This includes:
        - Detailed class diagram.

    c. Dynamic Analysis modelling – This include:
        - State machine diagrams.
        - Interaction diagrams (Collaboration and/or Sequence) by using the COMET UML profile. You need to ensure the consistency between the state machine diagram and the set of interaction diagrams.

COURSE PROJECT DESCRIPTIONS [17 IDEAS]

- The descriptions are indicative and not final, thus you need to do your own refinements to these requirements, by adding your assumptions and constraints.
- Some of the ideas are well defined and detailed while others are NOT. For those ideas that are not fully detailed, you need to elaborate more and explain in detail how things are working.
- Finally, feel free to discuss your refinements with your TAs during the labs.

Projects' Descriptions:

Contents

1] An Autonomous Farming/Agriculture Robot for Monitoring Plant Health, Soil Monitoring, and Watering Crops.

Design an Agricultural Autonomous Robot which will sense the conditions *(of a specific field or plants/crops)* in real time. The robot may do the following:

- The robot includes a vision-based row guidance method to guide *(in real-time)* the robot platform driven along crops planted in row.
- The autonomous robot may sense the conditions of a specific field (such as: temperature, humidity, soil-moisture, etc.) and then decide which plantation is best suited for that particular field.
- The autonomous robot may also have a Plough to plough the fields, and then a Seed Dispensing Mechanism, a Watering Mechanism.
- The Watering Mechanism will water the plants according to their needs (e.g., by observing soil moisture and humidity).
- The robot may sense the health of the plants *(e.g., by using special purpose cameras & Image processing)*. The robot can take photos inside the field and analyze the growth according to the height, leaves' colors, etc.

2] An Autonomous Crop-Harvesting Robot.

Decide on a specific crop (fruit/vegetable) that you'd like to harvest, then develop an advanced autonomous harvesting robot that:

- A component for safely navigating the field/orchard.
- A computer vision component that differentiates ripe from non-ripe ones before plucking/picking (e.g., a camera that scans the vegetable/fruit and gives a thumbs up or down for harvesting).
- A machine-learning algorithm teaches the robot to avoid unripe/diseased vegetables/fruit.
- A component that guides the pick without crushing the plant (e.g., a mechanism to grab the leaf, and then pick the specified fruit/vegetable).

3] An Autonomous Weeding Robot (Weed-Management Robots).

Design a robotic weed killer that:

- Includes a navigation component to stay on course *(and avoid damaging crops)*.
- Includes an advanced AI component to help distinguish between weeds and crops *(so the former are stripped and the latter are left to grow)*.
- Includes component(s) for pulling unwanted weeds *(e.g., blades)*, and thus consequently decreases the need for herbicides.
- As it runs, the robot may also gather data that help farmers with soil analysis and environmental monitoring.

4] Autonomous Robotic Greenhouses (Robot Farming).

For certain crops *(such as basil, cilantro, etc.)* Robotic Greenhouses (Robot Farming) offers striking improvements; for example, dramatic decrease in the amount of water used (about 90% to 95% less) for an equivalent crop yield, controlled indoor environments that eliminate the need for pesticides, etc.

- A Robotic Greenhouse is an autonomous farm.
- Two cloud-connected robots oversee the growth of some crops (leafy greens and herbs).
- All crops are grown inside heavy hydroponic pods (systems that let people grow vegetables and plants indoors).
- Using computer vision and sensors as its “eyes,” one robot does the heavy lifting, transporting the pods across the facility; the second Robot analyzes and picks the individual plants.

- A proprietary operating system and complex array of sensors collect data and maintain an ultra-precise balance of water, temperature, nutrients and humidity.

5] An Autonomous Robotic Fruit/Vegetable Grading & Sorting System.

Before a particular vegetable or piece of fruit reaches its final point of sale, it's been through various sets of hands to guarantee its quality and to sort it into the right quality class. The vegetable is scrutinized manually on deviations in color and shape, and blemishes or damages *(all because the standards and norms as set by supermarkets and other retailers are unrelenting and high)*. Inspection of the fresh produce to evaluate & guarantee its quality is vital, and is still a job mainly done by hand, but the current manual inspections are prone to error and demand a capacity in personnel that is becoming increasingly hard to meet. Recently, grading & sorting robots *(that usually combines computer vision technology with AI)* have been introduced to evaluate the quality of up to 100% of passing fruit and vegetables *(e.g., for orange, apple, peach, pear, tomato, eggplant, leek, asparagus, and other fruits and vegetables)*. This system also allows data accumulation on fruit/vegetable grading for traceability and farming guidance to producer.

- Grading & sorting robot systems, which automatically provides fruits from containers and inspects all sides of the fruits have been introduced.
- The robot system may consist of up to three robots: Fruit/Vegetable providing robots, grading robots, and sorting robots.
- Providing Robot(s) may have Cartesian Coordinate Manipulators, and Suction Pads as end-effectors for transporting fruits.
- Smart Grading Robot(s) may have color TV cameras, and lighting devices as a machine vision system, and thus are able to deliver a thorough quality analysis, and an objective grading operation without human subjective judgment.
- Sorting Robot(s) optimally sort the produce according to its quality.

6] Aerial-Imagery (Crop-Health Surveillance) Drones

Aerial imagery can save farmers a lot of time by giving them a bird's eye view of crops; that way, they can quickly get a sense of vegetation's health, insect issues, irrigation layouts and weed growth. It even allows them to precisely determine how much pesticide the crops require.

- Between flights, the drone typically lives inside a weatherproofed box, where it self-charges and processes all the data it collects.
- When the drone takes flight to examine fields, the box top opens and the fully autonomous drone lifts off, using AI to plot and conduct the run.
- Drone missions can be scheduled or launched on demand.
- The drone inspects crop health and gathers crop stress data that farmers can use throughout a crop's life cycle. A stress in crop production is an external factor that decreases crop yields (e.g., diseases, insects, salinity, etc.).

7] Seed-Planting & Crop-Spraying Drones

As a part of the agricultural industry, drones are being employed for various operations in aerial surveillance, mapping, land inspection, monitoring, spraying fertilizers, checking for diseased or rotting crops, and much more.

- Seed-Planting Drones take to the skies loaded with seedpods containing a germinated seed and nutrients.
- Once in position, the seed-planting drones use pressurized air to fire the seeds into the ground *(the seedpods penetrate the earth and start to grow once activated by water)*.
- One of the most critical uses of drones in agriculture is its flexibility to move around in swift motions and maneuver to the destined locations. This ability of drones helps spray fertilizers and insecticides to nurture crops and provide them with the needed nutrients.

- Drones that spread seed and fertilizer have specific payload capacities *(for instance, 4-pounds payload or an 11-pound payload)*. They also have flight ranges and time limits *(e.g., a two-mile flight range, and a 20-minute limit)*.

8] A Human Detection Robot.

Human detection robots were designed depending on the application. The main applications are:

- At the time of natural calamities to save the lives of human.
- To detect humans in the war field.
- For security purpose in the jewelry shops, museums, etc.
- E.g., During the natural calamities like earthquakes, it is difficult to rescue the human beings under the buildings. Though detection can be done by rescue teams, it is time consuming.

While the robot is moving, if any human is detected by its PIR sensor, the robot stops moving and a buzzer is switched on.

- The PIR (Passive Infra-Red) sensor plays a main role in the design.
- These sensors work on the principle that every human being emits infra-red radiations of very low wavelength. Thus, this sensor senses these radiations.
- A PIR sensor can sense a human within the range of 20 feet.

9] Autonomous Robotic Waste Sorting (Real-Time Waste Identification).

Robotic Waste Sorting identifies recyclables in real-time and is cost-effective. It makes multiple sorting decisions autonomously; for example, separating thermoform trays, aluminum, 3D fiber and residue from a waste stream. The sorting process is 100% autonomous and the need for human contact with waste is eliminated *(reduces any health risks that come along with human labor)*. The Robotic Waste Sorting exceeds human performance in every metric: speed, accuracy, consistency, safety, & cost. Especially with COVID-19 of high importance, it removes gloves and masks from the waste stream.

- The robot can identify almost any material on a conveyor belt in real-time.
- The robot sorts Plastics (PET, HDPE, PVC, PP, PS, etc.), Cardboard, Paper, Aseptic cartons (Tetra), Aluminum/steel cans, and Residue.
- The robot may employ (1) a vision system to see and identify objects (similar to the way a person does), (2) sensors to identify materials, or (3) it may use both technologies.

10] Receptionist Robot

The main functionality of the receptionist robot is assisting customers through responding to phone calls, sending emails or face to face communication.

- It should be able to welcome every visitor as soon as eye contact is made and ask how to help.
- It should be able to type and send emails.
- It should be able to answer and make phone calls.
- The robot should be able to handle more than one task at the same time. This should be synchronized based on the priority of each task. For example, the robot might receive a call while handling customer. In other words, if the robot received a call while serving a customer; it should excuse the customer to see the call. If the call is more important, then robot should answer and then get back to the customer after the call.
- The robot should have a main controller (robot brain) which sends signals to the actuators.

11] An Elevator Control System

There are some classical case-studies' requirements for this system.

- The students are free to implement any elevator control system located in a 3-4 story building.
- Some requirements are to use request buttons at each floor, sensors to locate the current position of the elevator car, door position sensors, etc.
- The requests from individual floors can be served in any chosen strategy, if it is a fair one (e.g. eventually, within predefined time limits, the request will be fulfilled).

12] A Heat Guided Air-to-Air Missile Controller

The missile contains a burner, a proximity trigger, a warhead, two set of wings, yaw *(i.e., left, right)*, pitch *(i.e., up, down)*, a launch sensor and an infra-red camera.

- An algorithm is available that transfers the infra-red image of the camera to yaw and pitch angles of the target.
- Half a second after the missile is launched, the burner is activated, from then on, the burner remains active until the missile explodes or an error is detected.
- The system uses its wings to aim the missile to the target. Each set of wings has five modes: Centered, Small deviation (one to each of the two directions), and Strong deviation to each direction.
- The missile is armed 3 seconds after it is launched. The burner malfunction, or the camera losing the target, causes the arming to be cancelled and the burner to stop.
- If the missile is armed and the proximity detected is activated, the warhead explodes.

13] Traffic Light Control System

This system is typical of many traffic intersection control systems used in any intersection involving pedestrian crossing. The system can be used with simple intersections involving one-way street interrupted by crosswalk. It can also be used with typical more complex intersections involving two two-way streets with left turn lanes. The following paragraphs lists the specific functional requirements for this system.

- The system shall control all the pedestrian and traffic lights at a given intersection. The intersection could be as simple as a one-way street interrupted by a crosswalk. The intersection could be as complex as two two-way streets with left-turn lanes.
- A given traffic light will normally be green for G seconds. Yellow lights will last Y seconds. A red light will remain red for R seconds before the traffic can change direction. For example, R seconds after the north-South Street turns red the east-west light will turn green.
- Traffic sensors may be present to detect car arrivals and departures. To better service heavy traffic, if M cars arrive while the light is red, the subsequent green light will persist P seconds or until all M cars have departed, whichever comes first.
- Pedestrian crossing request buttons may be present. After a button is pressed the pedestrian should wait no longer than C seconds for permission to cross. Only crossing request received while the light is red need be serviced.
- Any conflicts between pedestrian requests and traffic volume should be decided in favor of the pedestrian.
- At some time during the day, the intersection will automatically suspend normal service and its lights will flash red or yellow.
- The above variables G, Y, R, and C are specified and along with other specific intersection and lane information during the initialization process of the control system.

14] A Smart Wheelchair

Such a real-time system should conation the following systems:

- Speed and breaking monitor system: This is the part of the wheelchair responsible for start moving and stopping the chair. The chair should be moving on a pre-defined constant speed. If the chair speed exceeded the constant speed, this means that the chair is moving downhill, and the braking system should manage such a situation. It also should handle the situation of moving uphill.

- Navigation and location monitor system: A smart wheelchair should be able move in a fully autonomous mode. The navigation subsystem with the assist of the obstacle avoidance subsystem is responsible for directing the chair in the right direction.
- Power and energy consumption system: This subsystem will be responsible for charging the chair battery and notifying user of low battery level or full battery.
- Obstacle avoidance subsystem: This is the part responsible for scanning the environment through cameras, measure the distance to the obstacle and communicate with the Navigation system. The navigation system should make the navigation decision based on the information received from this subsystem.

15] Train Protection & Warning (TPWS) System

The Train Protection & Warning System (TPWS) is a train protection system that automatically activates the emergency brake on a train that has passed a signal at danger without authority or is over speeding. A standard installation consists of an on-track transmitter adjacent to a signal, activated when the signal is at danger. A train that passes the signal will have its emergency brake activated. If the train is travelling at speed, this may be too late to stop it before the point of collision, therefore a second transmitter may be placed on the approach to the signal that applies the brakes on trains going too quickly to stop at the signal, positioned to stop trains approaching a specific speed limit. The operation of the TPWS can be described as follow:

- The system acquires information on the speed limit of a segment from a trackside transmitter, which continually broadcasts the segment identifier and its speed limit. The same transmitter also broadcasts information on the status of the signal controlling that track segment. The time required to broadcast track segment and signal information is 50 ms.
- The train can receive information from the trackside transmitter when it is within 10 m of a transmitter.
- The maximum train speed is 180 kmh.
- Sensors on the train provide information about the current train speed *(updated every 250 ms)* and the train brake status *(updated every 100 ms)*.
- If the train speed exceeds the current segment speed limit by more than 5 kph, a warning is sounded in the driver's cabin. If the train speed exceeds the current segment speed limit by more than 10 kph, the train's brakes are automatically applied until the speed falls to the segment speed limit. Train brakes should be applied within 100 ms of the time when the excessive train speed has been detected.
- If the train enters a track signaled that is signaled with a red light, the train protection system applies the train brakes and reduces the speed to zero. Train brakes should be applied within 100 ms of the time when the red-light signal is received.
- The system continually updates a status display in the driver's cabin.

16] An Automated Insulin Pump

This specification is a specification of the basic requirements for the control software for the insulin pump.

- The dose of insulin to be delivered shall be computed by measuring the current level of blood sugar, comparing this to a previous measured level and computing the required dose.
- The system shall measure the level of blood sugar and deliver insulin if required every 10 minutes.
- The amount of insulin to be delivered shall be computed according to the current sugar reading as measured by the sensor:
  - If the reading is below the safe minimum, no insulin shall be delivered.
  - If the reading is within the safe zone, then insulin is only delivered if the level of sugar is rising and the rate of increase of sugar level is increasing.

  - If the reading is above the recommended level, insulin is delivered unless the level of blood sugar is falling and the rate of decrease of the blood sugar level is increasing.
  - The amount of insulin delivered may be different from the computed dose as various safety constraints are included in the system. There is a limit on the maximum dose to be delivered in a single injection and a limit on the total cumulative dose in a single day.
- The controller shall run a self-test program every 30 seconds.
- When switched on, the system is initialized.
- The system shall maintain three displays:
  - Display 1- a text display that shows system messages. It has an associated hardware buffer that can hold several messages. When there is more than 1 message in this buffer, each message is displayed for 5 seconds until all messages have been displayed. The display sequence then restarts with the first message. Hence, several messages may be specified for display on display1.
  - Display 2- shows the last dose of insulin that was computed.
  - Clock - displays the current clock time.
- The user may replace the insulin reservoir with a new reservoir at any time. The design of the reservoir compartment is such that only full reservoirs holding 100 ml of insulin may be inserted. When a new insulin reservoir has been inserted, the system is reset.
- At the beginning of each 24-hour period (indicated by clock = 00:00:00), the cumulative dose of insulin delivered is reset to 0.

17] A Burglar Alarm System

A Burglar alarm system is a system designed to detect intrusion – unauthorized entry – into a building or area. Security alarms are used in residential, commercial, industrial, and military properties for protection against burglary (theft) or property damage, as well as personal protection against intruders. The Burglar alarm system uses several different types of sensors. These include movement detectors in individual rooms, door sensors that detect corridor doors opening, and window sensors on ground floor windows that can detect when a window has been opened.

- When a sensor detects the presence of an intruder, the system automatically calls the local police and, using a voice synthesizer reports the location of the alarm. It switches on lights in the rooms around the active sensor and sets off an audible alarm. Each movement detector should be polled twice per second.
- The sensor is normally powered by mains power but is equipped with a battery backup. Power loss is detected using a separate power circuit monitor that monitors the main voltage. If a voltage drop is detected, the system assumes that intruders have interrupted the power supply, so an alarm is raised. The alarm system includes a display, which reports these anomalies upon occurrence.
- When a single or more sensors are positive, which means that an intruder is detected, the system initiates alarm within half a second of an alarm being raised by a senor, and turns on lights around the site of positive sensor within half a second of an alarm being raised by a sensor. In addition, when two or more sensors are positive, the system calls police with location suspected break-in within 2 seconds of an alarm being raised by a sensor. If alarms are on, each door and window alarm should be polled twice per second.
- If the voltage of the alarm system drops of between 10% and 20%, a battery backup must be switched on within a deadline of 50ms, and the system runs a power supply test. If the voltage drops more than 20%, in addition to the previous actions, the system must initiate alarm and call police. In case of a power supply failure or sensor failure, the system calls service technician. Whenever the console panic button is positive, the system must initiate alarm, turn on lights around console and call police.
- If clear alarms command is activated, all active alarms must be switched off, and all lights that have been switched on should be switched off.