ME EN 495R – Design of Mechatronic Systems

Final Project

Project Description

Working in a team of four students, you will design, construct, and program a robot to compete in a final competition to be held on Thursday, December 10th, 2015, in class.

The objective of the game is to get ping pong balls from an automated ball dispenser and shoot them into goals located in the corners of a square arena. Each of the three goals will be "active" during a different portion of game play. Your robot must only shoot balls into active goals. Each goal will only be active once, after which another goal will be made active in a random order. Points will be awarded for each successful shot into an active goal, and points deducted for shots made in inactive goals. Shots cannot be taken from a "no-shoot zone" around the dispenser. None of the goals will be active while any portion of your vehicle is in the no-shoot zone.

Each round will last 105 seconds, comprised of an initial 10-second period when none of the goals are active, followed by three 30-second periods. One goal will be active during each of the three 30-second periods. During the first 5 seconds of the initial 10-second round, one IR LED will be illuminated as a reference. The reference IR LED is shown in Figure 1. The robot must finish the round in its initial configuration (all extendable parts retracted) and must be outside the square dispensing area (see below). The final 5 seconds of the round can be used for this process.

Each robot will compete in 3 rounds. The score from the worst round will be dropped. The score from the remaining two rounds will be averaged to obtain the final score.

When the beginning of a round is signaled, one of the team members must activate the robot, after which all robot actions must be done autonomously, without any human intervention.

Arena

The arena (see Figure 1) has a 47 in. by 47 in. square base with 24 in. walls. Three of the arena corners contain goals that are 5 in. square and centered 19 in. above the base. Active goals will be signaled using an IR beacon emitting at a specific wavelength, located a height of 6 in. from the ground. A colored LED placed above each goal at the top of the wall will give a visual indication of which goal is active.

One of the corners of the arena will house the ball-dispensing mechanism, which will be indicated by a IR beacon that blinks at a frequency of 100 Hz. The corner will be marked by an 8 in. by 8 in. square on the floor. Balls will be dispensed from the bottom of the dispenser, which will be located at a height of 12 in. The center of the dispensing hole will be positioned 9 in. from the corner of the arena along a line that bisects the corner's 90 degree angle, as shown in Figure 2. One ball will be dispensed straight down each time your robot disrupts a vertical light beam shining from the floor to the bottom of the dispensing mechanism at a distance of 3 in. from the corner of the arena. The beam must be disrupted for each ball that is dispensed. For example, if your robot is designed to hold two balls, it must disrupt the beam, wait for the ball to be dispensed, and then disrupt the beam again for the second ball. The delay between disrupting the beam and receiving a ball will be determined experimentally after the dispensing mechanism has been constructed. Note that the beam must be physically disrupted, i.e., you cannot use a light emitter to simulate disrupting the beam.

Robot Rules

- At the start of the round, the robot must fit fully within an 8 in. cube, with the exception of the device for storing ping pong balls. The ball storage unit can extend outside the 8 in. cube, although it clearly should not be taller than 12 in. so that it will fit under the ball dispenser. Any other parts must lie within the 8 in. cube.
- After the round starts the robot can expand or extend appendages outside the 8 in. cube. The expansion/extension must be controlled, meaning that the energy to expand/extend cannot be provided by gravity, springs, etc. Anything that extends outside the 8 in. cube must be able to be retrieved. In other words, the robot must be able to return to its initial state autonomously.
- At the beginning of the round, the robot will be placed in the arena in a random location and at a random

orientation by the instructor or one of the TAs. The robot will not be placed within 6 in. of any wall, within the dispensing area, or within 12 in. of any of the goals.

- The only power source allowed for your robot is battery power; no wall power, CO_2 cartridges, stored compressed air, nuclear power, combustion, etc.
- Each robot can store up to 6 ping pong balls.
- Each robot must have a "kill" button/switch that disconnects power from all motor circuits.
- All robots must be controlled using PIC microcontrollers.
- No prebuilt robots or significant prebuilt chunks of robots will be allowed.
- The robot must be fully autonomous.

Additional Rules

- The robot cannot score points in an active goal if the robot base or part of the base lies within 12 in. of the active goal's corner. See Figure 1.
- The robot cannot score points if the robot base or part of the base lies within 12 in. of the dispenser corner. No goal will be active if your robot is in the "no-shoot zone".
- The robot cannot score points in an active goal while touching any part of the arena on the floor or walls within the 12 in. radius. See Figure 1.
- At the beginning of the round, the robot cannot store any ping pong balls – the robot storage device must be empty.
- All ping pong balls must be obtained autonomously from the ball dispenser (no manual loading or picking them up off the floor).
- To receive a ball from the dispenser, the beam must be physically disrupted, i.e., you cannot just use a light emitter to simulate disrupting the beam.
- Before the start of the round, the team may not enter any information into the robot about its initial placement, distance from goals, location of the dispensing mechanism, etc. In other words, after the robot has been placed in the arena by one of the TAs or the instructor, the only thing the team can do is push a button to start the robot.
- Damage to another robot or injury to a spectator will result in a disqualification.
- There shall be no broadcasting interference while another robot competes.

Scoring

- Each ball shot into an active goal earns 1 point.
- Any ball shot into an inactive goal results in a deduction of 1 point.
- Any ball shot into an active goal within the 12 in. radius will neither earn nor deduct any points.
- Ending the round with any part of the robot inside the dispensing area will result in a 50% point deduction. For example, if the robot scored 12 goals during the round, the score will be 6 points.
- Ending the round with the robot not returning to its original configuration will result in a 50% point deduction. For example, if the robot scored 12 goals during the round, the score will be 6 points.
- The minimum score possible in a given round is 0 points, i.e., you cannot earn negative points.

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Grading

The project is worth 40% of your grade. Here is the breakdown:

Milestones:	15%	Points awarded on a weekly basis as a function of how well you achieve the milestones.
Competition Rank:	5%	The top 3 teams will receive 5 points, 4th through 6th place will receive 4 points, 7th through 9th place will receive 3 points, others will receive 1 point.
Competition Performance:	5%	Teams will receive percentage points based on their final score according to the equation: points = final score/3, where points is rounded down to the nearest integer with a maximum value of 5.
Engineering:	7.5%	Points awarded based on quality of design and construction, including mechanical subsystems and electrical subsystems. *The use of PCBs will be considered in awarding these points.*
Presentation:	7.5%	Points awarded based on quality, thoroughness, and presentation style. See below for presentation guidelines.

Milestones

Milestones are extremely important in engineering work–they force the team to design, build, and test components and subsystems in a way that will lead to a successful product. The more successful your team is at achieving the milestones, the more successful you will be at the final competition. Working in parallel as a team can be very effective, with some team members working on future milestones while others work on the current milestone. Remember that subsystem integration (combining and testing the subsystems, and refining the whole system) takes as much time as developing the individual subsystems. Try to get ahead of the milestones to give yourself more integration time at the end. **Note: all milestones need to be accomplished by 11:59 pm on the date indicated.**

1. **9/25/15 – (1 point) Team Selection.** Select four-person teams. Each team member must be in the same lab section. Select a team name. Submit a list of team members and your team name to the instructor by email.
2. **10/5/15 – (5 points) Initial Concepts.** Select initial robot concepts related to mobility, loading, and scoring. Submit a single document viaLearning Suite containing: (1) an outline of your navigation, loading, and scoring approach; (2) a description of your initial design concept, including sketches; (3) an initial list of how many actuators and sensors you need (remember to consider navigation, loading, and scoring).
3. **10/16/15 – (10 points) Base Design.** Design the basic structure of your base. Design your mobility system (wheels, treads, or legs) and select parts. For example, if you are using wheels, select all wheels, shafts, and motors. Create a design using the solid modeling package of your choice. Submit a few paragraphs, parts list, and renderings of the assembly (not part drawings) as a single document via Learning Suite.
4. **10/23/15**
    a. **(10 points) Base Construction.** Construct your base, including actuators and wheels or legs or treads. Submit a photo of the base via Learning Suite.
    b. **(7 points) Basic Circuit.** Design the basic microcontroller circuit to use with your base. Create a "pin inventory" to determine which pins will be used for which functions in your robot. Determine how many voltage regulators, and which voltages, will be needed in your robot. Include a power supply or supplies, microcontroller, and motor driver circuits (if applicable). Construct and test a breadboard prototype of the circuit. This can be constructed on a breadboard. Submit a pin inventory, schematic, and photo of the prototype circuit as a single document via Learning Suite.

5. **10/30/15**
   a. **(10 points) Base Mobility.** Demonstrate controlled mobility of your base, including driving in a straight line and making a 90-degree turn. Submit a video of the controlled mobility via Learning Suite. If your robot is not going to have any mobility, talk to your instructor about a different milestone.
   b. **(10 points) Scoring System Design.** Design the basic scoring and ball storage subsystems of your robot. Select parts, including actuators, gears, and sensors. Create a design using the solid modeling package of your choice. Submit a few paragraphs, parts list, and renderings of the assembly (not part drawings) as a single document via Learning Suite.
6. **11/06/15 – (10 points) Scoring System Construction.** Construct and demonstrate your scoring system. Submit a video of the scoring system in action via Learning Suite.
7. **11/13/15 – (10 points) Controlled Navigation.** Demonstrate controlled navigation of your robot. Show that if the robot is placed in an arbitrary location, it can navigate to a location appropriate for your scoring method. Submit a video of the navigation via Learning Suite.
8. **11/20/15 – (10 points) Ball Collection.** Demonstrate the ability of the robot to find the dispenser and collect a ball. Submit a video of the robot in action via Learning Suite.
9. **12/04/15 – (15 points) Functional Robot.** Demonstrate all robot functionality, including navigation, ball collecting, target sensing, shooting, etc. Submit a video via Learning Suite.

Materials

Some of the materials that you will use for your project will be available by check out from on-hand supplies for the course (e.g., motors, motor drivers, batteries, battery elimination circuits). You may also check out materials from the ME checkout room or the EE shop. You are also encouraged to “scrounge” parts from old machines. Out-of-pocket expenditures are limited to $80 per team (approximately $20 per person).

Presentation and Submission of Materials

In place of a final exam, each team will make a presentation to the class on Monday, December 14, 2015. The presentation should take 12 minutes, followed by 3 minutes for questions. Each team member must participate in preparing and delivering the presentation. The dress standard is “professional,” meaning no t-shirts or shorts, but also no ties (unless you really want to). The presentation should focus on results, including:

- Hardware features of the robot (tell us what is cool about your mechanical and electrical hardware)
- Software architecture and features (tell us what is cool about your software) – finite-state diagram suggested
- Important design decisions that you made
- Lessons learned (what would you do differently)

Your presentation should **not**:

- Be a travelogue (“first we did this, and then we did this, and then we tried this…”)
- Be too casual (pretend that I’m your engineering manager, and you want to impress me)
- Be boring – I hate boring

Your presentation should:

- Show the team name
- List the team members
- Highlight photos, CAD models, and videos
- Employ a clean, interesting style for the slides
- End on time (12 minutes)
- Be interesting

The presentation is worth 25% of your project grade (see above). Points will be awarded based on quality, thoroughness, and presentation style. Following the presentation, you will submit (via Learning Suite) to the instructor an electronic folder containing:

- Your presentation slides
- A video of your robot in action
- A video of your team describing your robot

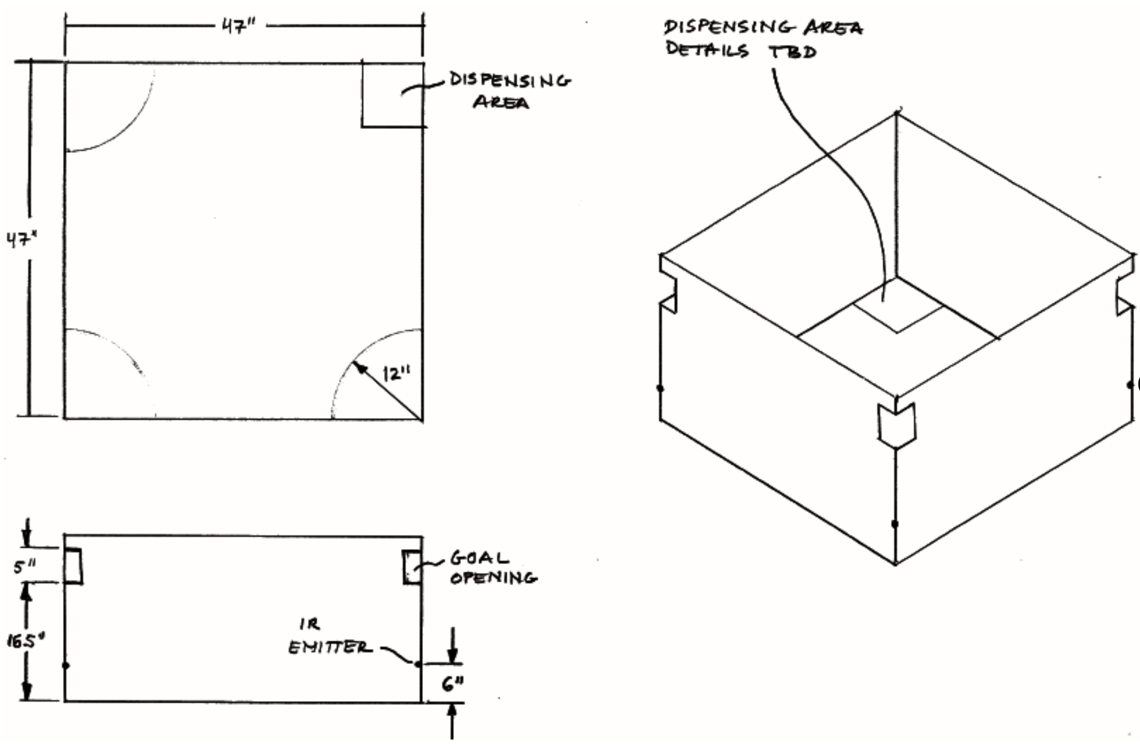

Figure 1. Arena design. Note the 12" quarter circles within which the robot cannot score goals, and the 8" square dispensing area. Details of the dispensing mechanism will be given at a later date. The infrared LED marked with a ① will be illuminated during the first 5 seconds of the initial 10-second round.

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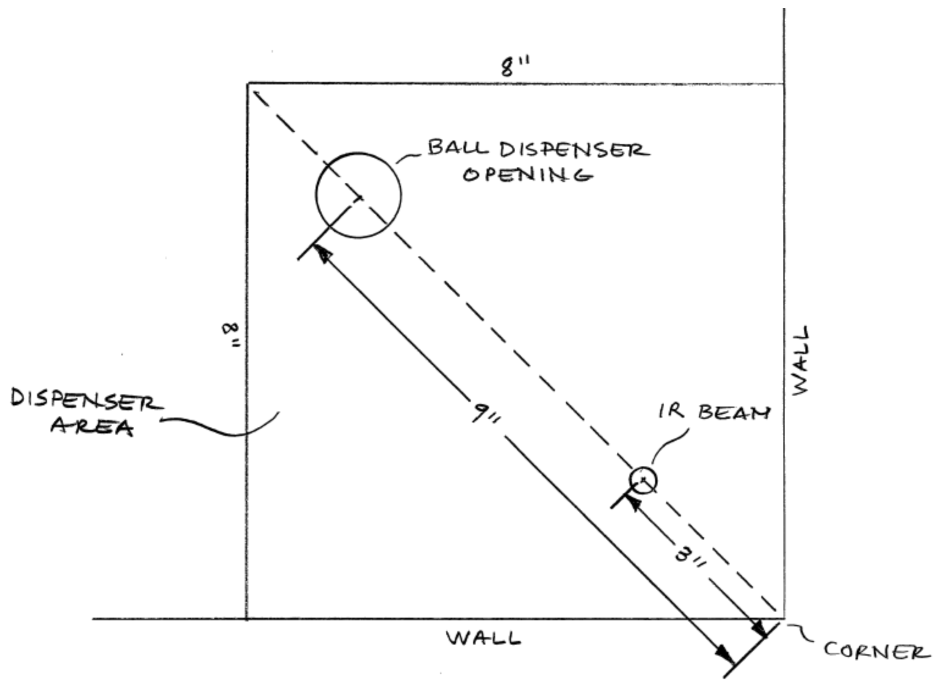

Figure 2. Overhead view of dispensing area. Disrupting the vertical IR light beam causes a ball to be dispensed from the opening shown. Details of the dispensing mechanism will be given at a later date.