UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN ELECTRICAL AND COMPUTER ENGINEERING

ECE-118/218: INTRODUCTION TO MECHATRONICS

SLUG WORLD CUP

Background Briefing:

Months after the exhilarating Qatar World Cup, excitement persists with our unique Slug World Cup. The tournament is reaching its peak with the grand shootout, where robots aim to score against the formidable "Giant Slug" goalie. Higher scores are awarded for challenging long-distance shots, encouraging strategy and skill.

Droid players carry three soccer balls each, carefully planning shots while avoiding the dreaded penalty zone. The Giant Slug dominates this territory, effortlessly blocking shots. Spectators watch intently as robots maneuver, calculating angles and distances for higher points.

As goals are scored and points accumulate, the Slug World Cup shootout becomes an unforgettable event, capturing competition, innovation, and camaraderie. The memory of the World Cup lives on, fueling excitement for the beautiful game in both human and robotic soccer realms.

Purpose:

The purpose of this project is to provide an opportunity to apply all that you have learned in ECE-118 to solve an open-ended problem. Your task is to build an autonomous robot that will navigate the game field, locate and deposit your ping-pong ball ammo into the designated basket, navigate back to the reload area, and scoring as many points as possible in the 2-minute round.

Project Requirements:

A. Team and robot meet three Design Reviews (Brainstorm, Mid-Project Review, Final Check-Off)
B. Team maintains an active lab notebook (or website) detailing their progress and designs
C. Each and every week team satisfies Check-offs and meets with their mentor
D. All loaned parts returned to TAs (IO stack, etc.) after tournament
E. Lab cleaned up before end of finals week
F. Final Report due at end of finals week
G. Participation in Public Tournament (0% of your grade; 100% fun)

Project Overview

Your objective is to construct a small independent robot (droid) that can navigate a standardized field with efficiency and robustness, locate the goal location (and optionally the goalie's pose), and shoot the ping-pong ball into the goal. Points will be awarded for each ball that makes it into the goal, and additional points will be given for more difficult zones on the field. The team with the highest score at the end of the match wins. Over the next five weeks, you will work in teams of three to design, create, test, and refine your robot until you can successfully complete the task. You will have access to practice fields in the lab and plenty of assistance and guidance. Don't panic. Yet.

Field Specifications (see Figures for more details):

- The field of play is a large white 4'x8' surface with 2" black tape markings and a low wall around the field.
- The reload zone is at the end of the field, and teams will be assigned their loading zone.
- There are 3-point zone, 2-point zone, and 1-point zone.
    - Boundaries are marked by black tape and/or track wire (at the standard 24-26 KHz).
- There is a penalty zone that should be avoided.
- No shots will be counted if they are made in the loading zones and penalty zone, even when the robot steps on the boundary lines.
- The goal will have a 2kHz IR Beacon on top of the crossbar, which will always be on.

- The goalie's position will be randomly set to one of the three possible positions (0deg, +-45deg) for 3 seconds. The goalie will have a 1.5kHz IR Mini Beacon on its head, which will also always be on.

Robot Specification

- The robot should fit in 11” cube volume (parts may move after the round begins) and remain intact throughout the match. Robot sizing will be checked with the *Cube of Compliance*.†
- Ensure the robot can detect collisions
- More details in **The Droid** section.

Game Rules

- The Robot will start in the loading zone assigned to the team with 3 initial balls loaded, and the initial position of the robot will be randomly set by a referee (teaching team).
- If the robot does not resolve collision and is stuck for 5 seconds, then the team will receive the dreaded “Red card.”
    - Only if both robots are stuck to each other, the referee will reset the robots to the reload zone. Each team will receive one Yellow Card. The microcontroller will NOT be reset.
- Up to 3 balls can be reloaded in the loading zone. The robot can be reloaded only when there are no balls on the robot.
- Observe the shooting zone sequence: try 1-point zone before each 2-point zone trial, try 2-point zone before each 3-point zone trial. No restrictions on 1-point zone trials.
- If any part of the robot is on the zone boundary, the shooting zone will be considered as the lower point zone (0-point, 1-point, 2-point).
- If any part of your robot is on the penalty zone boundary, the team will receive a Yellow card. Failure to leave the penalty zone in 5 seconds will result in another Yellow card.
- If the team gets two Yellow card, or equivalent to a Red Card, then the team is disqualified.
- Do not intentionally jam your opponent's robot or attempt to interfere with their performance.

Minimum Specification Checkoff Requirements

In order to pass this class, your robot must demonstrate that it can complete the task. Teams are free to embellish, go beyond, and otherwise have fun—however, we

† We have (and will) require you to modify your robot because it does not fit inside the dreaded Cube of Compliance. Remember to take into account things that stick off your robot (e.g.: wires).

suggest you aim for "min spec" first, and then go back (and go nuts).

- The robot should score a minimum of 6 points within the 2 minutes round, including at least one reload. The robot will play solo for this checkoff.
- For this checkoff only, there will be a dead robot (immobile) in the field—your robot must resolve collusions with the dead 'bot.

Tournament

- You play against another team
- Each team will be assigned their loading zone by flipping a coin.
- If you win the match, your robot advances in the tournament, victory will be awarded by points.
- Should a tie occur, we will attempt a rematch[‡].

We may (will) update these rules and/or points should (when) flaws become apparent.

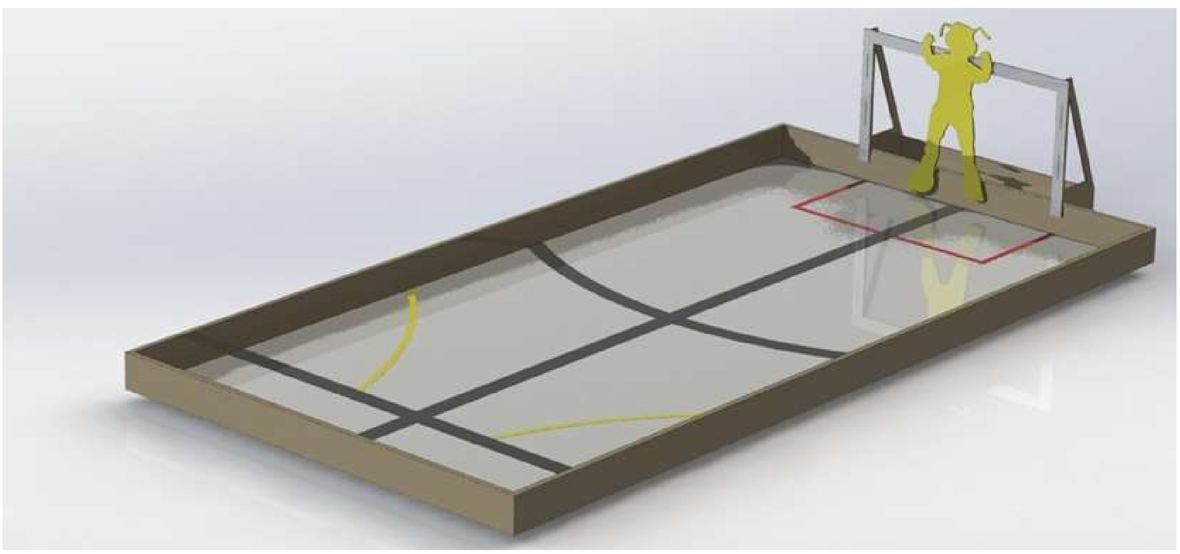

Figure 1: Field of Play for the SLUG WORLD CUP. Black tape boundaries and alignment marks are 2" thick PVC tape. 3pt and penalty areas are marked by track wire (24-26KHz), 2pt/1pt boundary marked by black tape. The goal is centered at the end of the field. The standard 2Khz beacon is placed on the crossbar of the goal. The field has been finalized but the goalie and goal will be updated after the CAD model is finalized.

[‡] If you both continuously tie, we will flip a coin and move on.

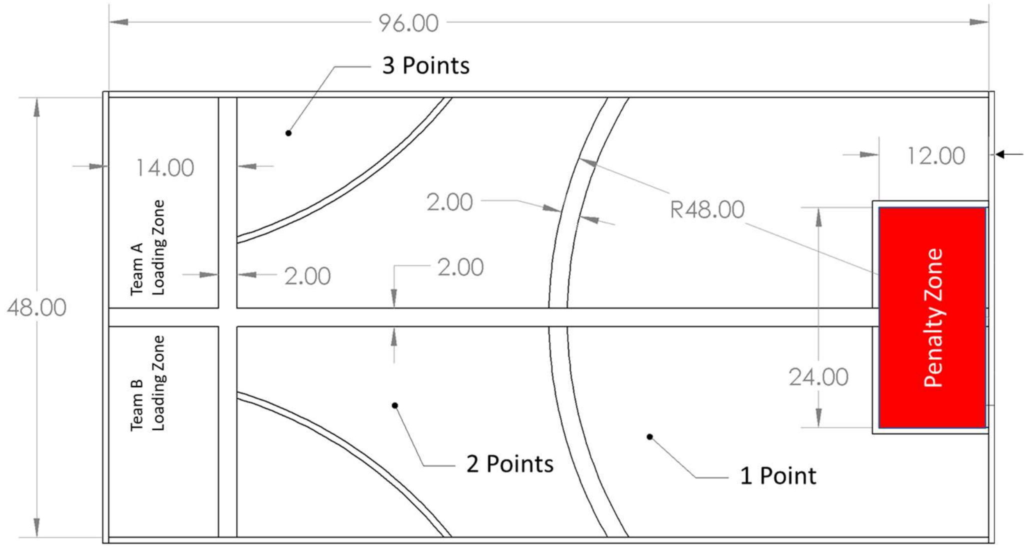

Figure 2: Scale drawing of the field of play including dimensions and point areas (all dimensions in inches).

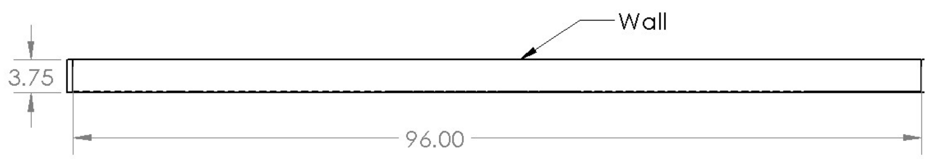

Figure 3: Dimensioned drawing of the side of the field, showing the height of the walls. (all dimensions in inches).

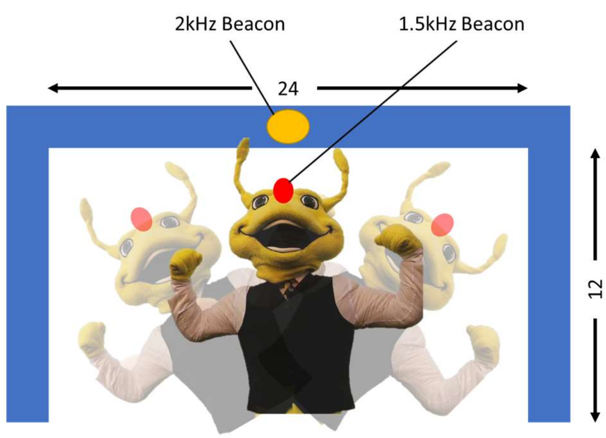

Figure 4: Concept drawing of the goal and the Giant Slug Goalie. The goalie can be randomly in 0, ± 45 deg. **Finalized CAD drawing will be updated soon. Dimensions may be updated as well.**

The Droid

Droids will be programmed in C, using the standard MPLAB-X IDE. Your droid behavior will be constructed using the ES_Framework from Lab 0 (however you may NOT use the Roach projects you wrote).[§] You may reprogram your droid between rounds if you desire, but you may not alter it once the field configuration is established.

Each droid must be equipped with a remote power switch (using the remote switch header on the Uno stack). At the beginning of the round, you will switch on your droid, and may not interfere with it until the round ends (other than reloads when inside the reload zone).

Materials

Each team will be provided with one Uno Stack, one L298N H-Bridge, one Stepper Board (if needed), one DS3658 board (if needed), one battery, and one ULN2003 (if needed). There will be also wire, regulators, and solder freely available in the 118 labs.

BELS has microswitches, RC servos, wheels, and brushed DC motors for every team (note that these are not very good ones, and if you use them they are expected to come back to BELS in usable form). You are free to buy your own motors or any other part you need for your project.

Each team should not exceed a budget of $150 total for other parts on the robot, and must maintain an up-to-date bill of materials (BOM). If we spot a nice $5K gyro on your bot, we will hand you $150 and take it. We don't want the project to be an arms race over who can purchase better stuff. We will have MDF and Foamcore available for purchase at cost. BELS, Ace Hardware, Fastenal, and Home Depot are all decent local sources. HSC and Tap Plastic (Acrylic for $1) are most excellent resources in the Bay Area (get together and caravan). McMaster-Carr will deliver nearly any piece of hardware within a couple days but they tend to be expensive. Amazon Prime is free to students for a six-month trial, and will get things to you in two days.

Available Tools

It should go unsaid that all work needs to be done by the team and not contracted out. *3D printing is disallowed* except for small bracket-type things and holders.[**] You will have the resources in Mechatronics Labs, as well as the drill press, tool chest, and Laser cutter in BE138. Your circuits must be soldered on perfboards, no breadboards. Those of you thinking about PCB houses, you most likely won't get turn-around in time without

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[§] If we see a Roach_HSM file we will delete all of your code. Seriously, write your own state machine.

[**] Again, the point of the class is to teach you how to use the resources you have, not to simply have a machine build the entire chassis for you. Building your own robot is part of the experience.

blowing your $150 budget. Off-the-shelf sensor boards, such as those sold by Sparkfun or Adafruit, are fine (but understand that the software integration for these sensors can take much longer than you anticipate—manage your time carefully).

Safety:

The machines should be safe to the user, the lab, and the spectators. For this project, excessively high velocity ball delivery will be discouraged (so go ahead and forget about that CO2 PVC pipe launcher you were thinking about.) Voltages are limited to the rechargeable batteries in the lab (you may purchase your own if you'd like, but consider 10V an upper limit), and intentional jamming or blocking of the opposing robot or masking of any beacon/trackwire is considered foul play and not allowed. 'Bots deemed unsafe will be disqualified.

NOTE: Young children line the competition field; take this into consideration when designing your launch mechanisms. Each team will be required to take three Ping-Pong ball shots from their own robot on bare flesh at a distance of 3ft from the barrel of their 'bot. <u>All members of the team must do this</u>.[††]

Evaluation:

Performance testing procedures: All machines will be operated by at least one of the team members. There will be one round for grading purposes done in the lab to evaluate 'droid performance. The public tournament is purely for entertainment purposes (though if you have not yet checked off, successful completion of the min-spec tasks during the public demo counts as a valid late checkoff).

Grading evaluation: Each machine will be graded based on its performance in the testing before the class competition at the end of the quarter. Each machine will have up to 2 minutes to solve the challenge. Grading is not based on point values, but how robustly your robot performs.

Grading Criteria:

1. *Concept* (20%): This will be based on the technical merit of the design and coding for the machine. Included in this grade will be evaluation of the appropriateness of the solution, as well as innovative hardware and software and use of physical principles in the solution.

2. *Implementation* (20%): This will be based on the prototype displayed at the evaluation session. Included in this grade will be an evaluation of the physical appearance of the prototype and the quality of construction. We will not presume to

[††] Yes, we have pictures of students with ping-ping ball induced welts on their backs.

judge true aesthetics (though we might comment on it), but will concentrate on craftsmanship and finished appearance.

3. *Report* (10%): This will be based on an evaluation of the written report. It will be judged on clarity of explanations, completeness and appropriateness of the documentation.

4. *Performance* (20%): Based on the results of the performance during the evaluation session.

5. *Design Evaluations* (30%): Based on check-off completion during the project.

Project Milestones:

Each week, your team will need to achieve a list of check-offs to stay on schedule and each partner will need to work as part of the team. **IF YOU DO NOT STAY ON SCHEDULE WITH THE CHECK-OFFS** you will NOT finish in time and be forced to stay through winter break until your robot is complete: **STAY ON SCHEDULE**.

Your weeks will essentially break into the following (see Canvas for specific dates):
Week 1: Design, Schedule, and Group Order (Design Review I)
Week 2: Electronics and Mechanical Prototyping
Week 3: Working Prototype for moving robot and ball launcher; State Machine (Design Review II)
Week 4: Finalizing robot and getting everything to work together.
Week 5: Competition and Final Check Off (Design Review III)

There will be **weekly checkoffs**, **three design reviews** throughout the project, **one project report**, and **one and only one competition.**

Half of this project is communicating well and documenting progress to stay on schedule. With that in mind, we expect each team to maintain and update a lab notebook with everything you are doing and copious notes.[‡‡] We very (very) strongly recommend that your lab notebook stays with the robot in lab. We will use this to verify your check-offs for each week. We recommend sharing some form of file/team drive/GIT repo to help you keep yourselves on task, but do not require it. That said, each team will need to submit their lab notebook and schedules for the Design Review #1. See "check-offs" section for further details. Note that if you want to use GIT for your

[‡‡] You are welcome to use any online website drive to collect your notes as well as any handwritten papers. You just need to show your readily available notes to the teaching team for checkoff. We highly encourage building a website for this project for your portfolio (just keep in mind how much time things take).

storage for the project, you will be able to create a repo on the UCSC GITLAB server.

A report describing the technical details of the machine will be required. The report should be of sufficient detail that any skilled ECE118 alum could understand, reproduce, and modify the design.

<u>Design Review 1:</u> May 11th (Preliminary Design Review, in class)
Team Concepts, present your best design to the class for three minutes
Come up with 3 team concepts for your design from your individual ideas (from your midterm) and a bit of brainstorming (you will present your best 2). Mix and match between the best of your designs. How are you and your team going to accomplish your project goals? Schedule out your time as well as your team's.

Deliverables are:

- 3 detailed TEAM concepts for solving the project.
- Best team design and backup design.
- Planned team schedule (tasks) for the project.

<u>Design Review 2: Mid-Project Review:</u> May 31st
Full Prototype, presented to the staff for 10 minutes.
Present your currently working parts and your full design to the teaching team for review and insight into potential roadblocks. Every system (both mechanical and electrical) should be prototyped at this point.

Final working (perfboard) prototypes of all sensors and actuators that your robot will use. Fully tested, fully documented.

Deliverables are:

- Prototype of Mechanical components
- Final sensors on perfboard with final schematics
- Final actuators mounted on the robot with final schematics

<u>Design Review 3: Final Check-Off (Grading Session):</u> June 7th
Present your final check-off robot to the staff. You get three tries to succeed on the field in each session.

Deliverables are:

- Robot that meets all requirements and completes the challenge.

<u>Competition/Public Demo:</u> June 9th

The public demo off your finished, operational machines. This fun performance will likely have a large and enthusiastic audience. Demo will be on June 9th at 6:00 pm (Jack Baskin 101 Auditorium).[§§]

Clean-up and Class Review: Monday after Public Demo (time will go out on Piazza)

Lab Report: June 16th
Electronic copy of your lab report, turned in as a group assignment in CANVAS.
Create a section for each design and write an evaluation of each aspect of your design: what went well and what didn't. Make sure to include pictures and links to video as necessary. Also include your final BOM.

Check Off Schedule:
Check-Off's are used to ensure that you are on track and keeping up. It allows the teaching staff to allocate their resources to help teams out in an appropriate way. Treat them seriously and your project will be completed well and on time.

Check-off 1: May 18th

Basic project management and system component design. This is where you define who is primary/secondary on which tasks. How you will coordinate time and schedules, etc.

Deliverables are:

- Time schedules
- Personnel assignments
- System Block Diagram
- Mechanical Design Sketches
- Working beacon detectors on perf-board with LEDs (at least one) with accompanying schematics[***]

Check-off 2: May 22nd

Mechanical and Software Designs. You should at this point have your final robot design completed in appropriate CAD software, and your state machines should be entirely drawn out (neatly). Your mechanical design should easily fit within an 11" cube. While both of these may need to be updated as you progress, they should be in close to final form.

[§§] We expect you to show up with your robot by 5:30PM. We will do everything we can to give you access to the room beforehand so you can test your robot in the tournament environment.

[***] This should be the best one from Lab 2 among your team. If you really, truly, have to build a new one, make sure you use the best of the designs from lab 2. This is not the time to redesign a better filter.

Deliverables are:

- State Machine(s)
- Final Mechanical Design (Solidworks)

<u>Check-off 3:</u> May 26th

Sensors and Actuators. Your full sensor suite should be functional and documented at this point. All ball launch mechanisms should be prototyped and tested for range and accuracy (this gives time to redesign if necessary).

Deliverables are:

- Working sensors (breadboard is ok) and schematics
- Actuators (breadboard is ok) and schematics

<u>Check-off 4:</u> June 5th

Mobile platform with basic reactive navigation. Your platform should be integrated into a moving droid, which can navigate the field and resolve collisions (bump sensors). Your ball launch mechanism should be able to shoot a ball into the goal from a desired zone.

Deliverables are:

- Autonomous platform that can move and sense
- Reverse off of a collision sensor
- Keep itself on the field
- Ball launch mechanism that is able to shoot ball into the goal from a desired zone.

<u>Minimum Specifications Check-Off:</u> June 7th or **June 9th**

Your robot should be able to meet the minimum specifications. To pass the class, you should meet the min spec in Design Review 3 or in the public demo at the latest.

Deliverables are:

- Robot that meets minimum specifications

<u>Notes on successful projects management</u>: There are a few rules of thumb to follow that will make your project much more successful, and keep you working well as a team.

The first rule is a bit paradoxical, but nonetheless important: *Do what you are bad at*. That is, if you are good at software but bad at mechanics, then you take the lead on mechanical stuff, and take a secondary role in software design.

The second rule: Double-team every single task you need done. That means one person is primary/lead the other person is secondary. Note that if you follow the first tip, then likely the secondary is better at the task than the primary. Do **NOT** attempt to split tasks up so that each one of you go off and do it and then come back—this never works and is *always* slower in the long run.

When crunch time comes, you can run a rotation with your three team members such that one sleeps, two work (the just woken up one works under the one who has been up). Then the lead goes to sleep, the secondary goes into lead position (on another task), and the sleeping one gets woken up to be secondary. While this is not sustainable beyond a couple of weeks, you can get an enormous amount done this way.

Be careful about sleeplessness and cars/bikes/etc. There are plenty of couches around to crash on, and a number of students live in GSH (200 ft. from the lab). Don't think you can keep yourself awake long enough to drive/bike home. Be smart about this. We really don't want to see anyone get hurt through a senseless crash.[†††]

PS: With this many people in the lab, it is going to be very important that you keep the lab clean and not leave your things lying around. We will be assigning I/O boards and batteries to each team, and they will be yours until the project is over. You will also get a milk crate to keep your robot in.

People occasionally donate random parts, and if you happen to find surplus printers, or other random electronics that people no longer want, feel free to dismantle and salvage what you want. However, please discard all parts that are not salvageable in an appropriate e-waste container so as to reduce clutter in the lab.

Drive motors have, in general, been a make-or-break part of the project. BELS has two per team in stock, though you will have to give them back after the project.[‡‡‡] I would strongly suggest you consider purchasing some gearhead motors from Jameco, MPJA.com, or Amazon.com. Ordering them early (i.e.: now) would ensure that you have a set that will work by the time you need them.

[†††] If you need a ride home and are too sleepy, call one of the staff—we will come get you or find a couch for you.

[‡‡‡] The motors we spec'd from Amazon are decent, but not fantastic. If you want better, buy better. Note that this is a change from previous years as required by UC admin. Figuring out what you needed and buying it is a good experience for later projects.