ME 210 Winter 2022: Herding Sheep at The Farm
A Stanford Journey

Project Presentation on March 6 starting at 7:00 pm.
Revision 1: 2/10/22

Purpose:

The purpose of this project is to provide you with an opportunity to apply what you have learned so far in ME210 to solve an open-ended mechatronics design problem.

Background:

Congratulations! As an engineering professor and potential mentor to Stanford students, you have the responsibility of "shepherding" your Stanford sheep. Will you usher them towards academia? Endow them with the skills for a lifetime at Google (or at least long enough for their stock to vest)? Teach them how to design circuits at Apple and scoff at their CS peers "higher up on the stack"? Invest in their air taxi idea? The possibilities are endless. Use your mechatronics skills to guide these superbly talented sheep towards their dreams.

The Task:

Design an autonomous robot that aims to move the most sheep to your scoring area. The objective is to shepherd more sheep to your scoring area than the other team does to theirs.

Specifications

Your robot will start in its designated loading area. Here, you can manually pre-load sheep which are represented by balls, 1.6 in in diameter. The objective is to get those balls from the loading area to your scoring area. But beware! There are holes in the field along the way that your sheep can fall into (i.e. finding another advisor). The fallen sheep will not be returned to you.

The Field:

- ☐ The field, seen in Figure 1 is constructed from wood with dimensions of **8 feet by 8 feet**. The field is split in 2: a flat 8 foot by 4 foot surface and an **inclined** 8 by 4 foot surface.
- ☐ The red team's loading zone is located on the left side, in the top left section of the flat surface. It has a size of 12 in x 12 in. The red team scoring zone is located in the bottom-left hand corner; it has a size of 18 in x 18 in. The height of the upper basket is 12 inches from the ground.
- ☐ The blue team loading zone is located on the right side of the board, in the top right section of the flat surface. It has a size of 12 in x 12 in. The blue team scoring zone is located in the bottom left-hand corner, also with a size of 18 in x 18 in. The height of the upper basket is 12 inches from the ground.
- ☐ As seen in Figure 2, half of the field is angled up by an amount θ equal to **about** 5°. This may be changed very slightly (either higher or lower).
- ☐ **4 inch** diameter holes exist throughout the field. The location of these holes will be similar to what you see in the diagram (but more may be added!)
- ☐ Mega sheep are located at the top corners of the ramp and are **4 inch** diameter balls.
- ☐ IR beacons will be placed on the upper basket, emitting at a height of 7 inches. The red team beacon will pulse at a frequency of 3333 Hz, the blue team beacon will pulse at a frequency of 909 Hz.
- ☐ Black tape will be placed for line following. Holes will be placed at least 0.5 feet away from the black line so that your robot will not fall in the hole if it does purely line following.

The Game:

- ☐ We've designed a head to head game of two robots. Each robot will start in its own loading area with an objective of placing more of its sheep into its scoring area than the other robot. For example, if you are team blue, you will start in the blue loading area and score in the blue scoring zone.

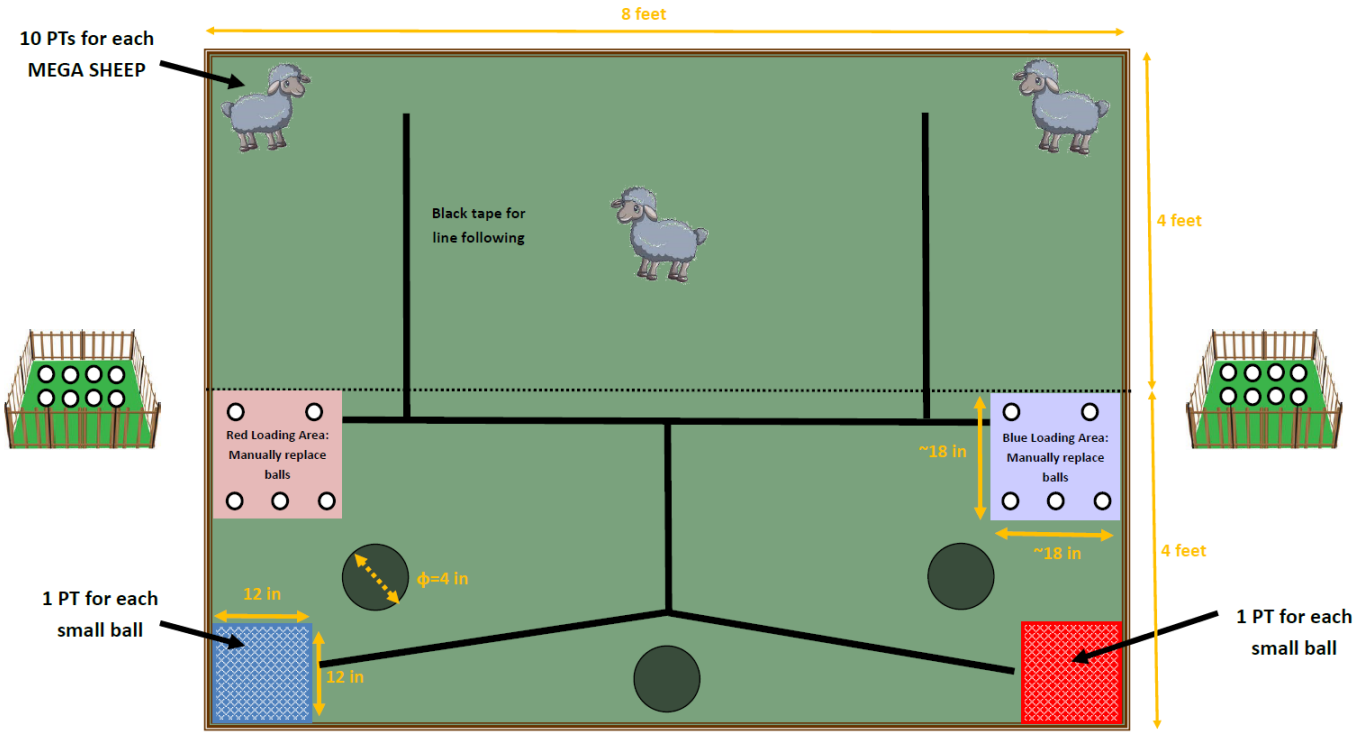

Figure 1: Top view of the field.

- ☐ You can **manually load a maximum of 5 sheep** in the loading area at one time. You can only re-load in your loading zone. You may not enter the other team's loading zone.
- ☐ **"Loading" means placing the sheep on the ground for your robot to pickup or push**, not you placing sheep on your robot. Your robot must be completely within the loading zone (and have scored or lost its balls) in order to be re-loaded. If you score/lose **x** balls, but leave **5 - x** balls on the field for open play, you will only be able to reload with **x** balls. Don't leave the sheep without a shepherd!
- ☐ When your robot is in the loading zone, you may interact with it via a button, a switch or a potentiometer.
- ☐ As seen in 2, there is an upper basket and a ground area (that you can just push or shoot sheep into) in both the red and blue scoring zones. You must navigate the sheep out of the loading area. You can only score once your robot is entirely out of the loading area. You may not play "defense" intentionally against the other team's loading zone or touch any aspect of the scoring zone (e.g. the basket and beacon).
- ☐ If you lose a sheep in one of the holes in the field, that sheep is removed from the game. You have lost a sheep – explain that to your department! Especially when it seems like CS gets all the sheep. Anyways...
- ☐ In the upper corners of the board are mega sheep which can be collected by either robot (you just gotta get to it and figure out a way to shepherd it). **1 mega sheep is worth 10 regular sheep** (some may interpret the mega sheep as overworked grad students). To prevent them from rolling down the field until collected, mega sheep will initially be behind a small barrier. Mega sheep are not replaced.
- ☐ The robot with the highest score at the end of 2 minutes and 10 seconds of game-play wins!

Scoring:

- ☐ Each sheep scored in the ground area is worth 1 point.

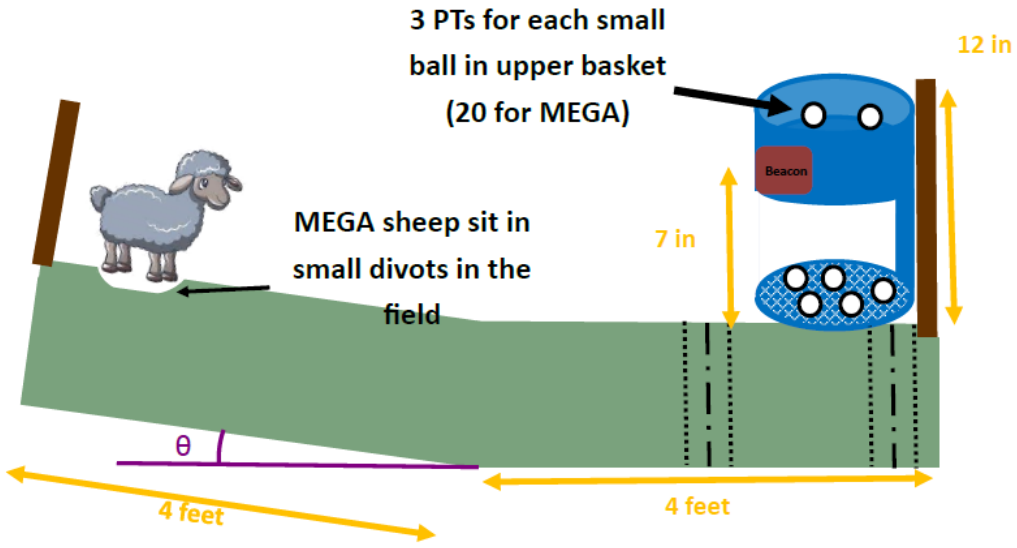

Figure 2: Side view of the field.

- ☐ Each mega sheep scored in the ground area is worth 10 points.
- ☐ Each sheep scored in the upper basket is worth 3 points.
- ☐ Each mega sheep scored in the upper basket is worth 20 points.
- ☐ If your robot gets stuck in a hole, you may manually reset it at the loading zone (trading in 1 sheep) with a penalty of 1 point (you cannot get negative points). If you don't have sheep at that point, you will lose the first sheep you score.

Robot requirements:

- ☐ Each student team will be responsible for designing, building, and demonstrating an operational robot. The robot should be an autonomous machine which will compete according to the specifications and rules defined in this document.
- ☐ Each robot must be a stand-alone entity, capable of meeting all project specifications, and must operate completely untethered during grading and competition.
- ☐ Power for the robot must be supplied by batteries, which are carried on board of each robot. Each team will receive two 7.2V NiMH rechargeable battery packs. The use of circuit breakers is mandatory. We will provide one circuit breaker per team, which will allow you to start your motors (it accepts short current surges).
- ☐ The provided batteries are the only batteries that may be utilized.
- ☐ Each robot should incorporate an easily accessible toggle switch on its exterior, which will serve as an emergency stop switch. The switch must cut all power to the robot when toggled.
- ☐ At the beginning of each round, your robot must fit within a 12" x 12" x 12" cube. Your robot may be dismembered to conform to this specification :)
- ☐ The robot's control software should be executed from the flash memory of one or more Teensy micro-controllers. Tethering of robots to computers during competition is strictly prohibited.
- ☐ Each robot must be constructed as part of ME 210 activities during the remainder of the quarter. It may not be based on a commercial or otherwise preexisting platform. Rulings from a member of the staff

may be requested if there are questions about the content of your robot.

- ☐ Each team must adhere to an expenditure limit of **US $200** for the materials and parts used in the construction of the robot. The cost of the two provided NiMH battery packs, fuses/circuit breakers, and the lab kit components (including a single Teensy per team member) do not count towards this limit.
- ☐ Robots must be robust enough to deal with all normal game interactions including, but not limited to, collisions with any part of the field or debris.

Rules of Engagement:

- ☐ Rounds last for 2 minutes and 10 seconds. The robot that scores the most points wins.
- ☐ In the event of a scoring tie, the staff will preside over the final ruling of the round.
- ☐ Robots must automatically cease game play at the end of a round.
- ☐ The initial orientation of each robot will be either perpendicular or parallel to the wall adjacent to the loading area – each team can decide their preferred orientation. The color of your team will be randomly assigned at the beginning of the round.
- ☐ An auditory start command will be issued by a member of the staff, at which time a member of each team will activate their robot, thereby initializing game play. This is the last human interaction with the robot allowed until the 2 minutes and 10 seconds have elapsed (with an exception being while the robot is in the loading zone).
- ☐ Sideline coaching is strictly prohibited; no information may be passed to your robot during the match aside from the button, switch or potentiometer interactions mentioned above.
- ☐ Intentional destruction, damage, or alteration of any part of the field or other robots is expressly forbidden.
- ☐ Intentional jamming of your opponent's sensing abilities is prohibited.
- ☐ Robots must show good sportsmanship: any celebratory actions or displays prior to the end of the game will be penalized and censured harshly by staff.
- ☐ All machines and devices must be safe to users, to the lab, and to any spectators.
- ☐ Staff reserves the right to require your team to reduce your robot's speed if said speed is considered unsafe.
- ☐ No part of the robot may become ballistic (shoot sheep not metal!).
- ☐ The competition seed position will be determined by the order in which teams perform the graded check off (see performance requirements).
- ☐ Members of your team are not allowed to position themselves (that's you, the humans) in a way that will interfere with the activities of any opponent's robot. Polite, "G-rated" heckling is permitted, of course.

Essential Guidelines for Safety

- ☐ **All projects shall respect the spirit of the rules, as established in this specification and in the culture of ME210. If you are considering something that may violate official sanctions, you must first consult with a member of the staff. Interpretations and rulings are the sole domain of the teaching staff.**
- ☐ All machines and devices must be safe to users, to the lab, and to any spectators.
- ☐ High speed projectiles are not permitted. If your robot has appendages, they should remain tethered to your robot at all times.
- ☐ If your robot stores energy anywhere other than the batteries, you must justify by analysis and demonstration that the stored energy cannot become hazardous. There is no explicit restriction on the amount of energy that may be stored. Any such device must start the round with zero stored energy.

- ☐ The powers of the staff to protect ME210 and its participants are very substantial and shall not be questioned.
- ☐ Tolerances on the dimensions of the field are ± 1 inch unless otherwise specified. (double check this with our field, once its is built).
- ☐ Once the field is constructed, its dimensions may supersede the above tolerances.
- ☐ Although ungraded, teams are encouraged to use creative themes and aesthetics with their robots.
- ☐ Pyrotechnics and combustion of any kind are prohibited.
- ☐ A main circuit breaker/switch will be provided and must be used as a main power shut down. When the switch is in the off position, all power must be disabled, and no subsystems may remain energized.

Performance Requirements

- ☐ For the purposes of grading, the minimum requirement for each robot is to start in the loading zone, orient, navigate to and move sheep to their scoring area. **You will be playing against a brick. You must score at least 5 points.**
- ☐ Your team may check off at any time by declaring[1] your wish to check off to a staff member prior to the check off attempt. If disaster strikes ("Its never done THAT before!?!!"), and your robot fails to check off, your robot's check off requirement will henceforth be raised to two successive, successful check-offs. If either of these consecutive check-off attempts fails, you will be required to perform no more than three successful checkoffs. **Check-off must be completed for all teams no later than 5:00 pm on 3/4/22.**
- ☐ It is important for everyone to remember that the minimum performance requirement is the goal for the class. Student teams are strongly encouraged to strive for demonstration of the minimum performance functionality as early as reasonably possible, so that the members of these teams may return to their regularly-scheduled lives.
- ☐ The results of the tournament held at the public presentation session will not affect grading. The public presentation is purely an opportunity for you to enjoy the devices you've created, and to show your friends and families why you have disappeared for 3 weeks.

Project Advice

- ☐ Start early (now, start now).
- ☐ Spend a lot of time perfecting your state machine, hammering out your design, agreeing on your interfaces, and picking your components. These will be the foundation for your code, and programming your robot will go a lot faster if you do these things well.
- ☐ Get out of your comfort zone. If you don't have experience with a concept or device, working on it during the project will be a great learning opportunity. For example, if you are a CS major, do not spend all of your time coding; instead work on signal conditioning or mechanical design.
- ☐ Work together and communicate. It's tempting to divide and conquer, but your teammates can't help you if they don't understand what you're working on.
- ☐ Sleep. You think you'll get more done if you stay up for 48 hours straight beating your head against a stack of datasheets, but you're wrong.
- ☐ Know where to find emergency replacement parts. If you don't have time to wait for a shipment, then Jameco and Room 36 can save your project, for a price (be wary of, but receptive to, blood contracts).
- ☐ There are other lesser known resources on campus for Laser Cutting or 3D Printing, like Lab64 in Packard building. But accesses to these resources require prior training; so try to get that ahead of time. There

[1] Note that you cannot just state your wish; you must declare it.

are just one or two laser cutters and 3D printers in Lab64, but these can save the day when PRL is overflowing with people.

Milestones

Project Assigned:
February 10 (in class)

Finalize a four person team, and enter your info into the team spreadsheet.

First Checkpoint:
February 15 (in class)

2-4 minute in-class presentation. Show 3 design concepts with sketches, time schedules, project plan, and personnel assignments.

Second Checkpoint:
February 18, 11:59 pm

Turn in physical documentation on Canvas, including schematics, state diagrams, design calculations, and any preliminary testing results.

Third Checkpoint:
February 28, 11:59 pm

Demonstration of all functional subsystems per block diagram: drive train, beacon sensing, tape sensing, navigation, etc. Presented to coach; check-off by teaching staff.

Fourth Checkpoint:
March 4, 3:00 pm

All subsystems functional and integrated. Beat The Brick (your robot can move) check-off by teaching staff.

Public Presentation:
This will take place on **3/6/22** at **7:00 pm** in the Atrium of Building 550. At this event, we will run the tournament with your finished, presentable, competition-ready machines. Guests are welcome!

Project Review:
March 10 (in class)

Brief in-class presentations from each team on project outcome and lessons learned. Bring your sumō-tori!

Project Report:
March 13, 5:00 pm

Report in HTML format, suitable for publishing on the ME210 website.

Evaluation

Performance Testing Procedures:
All robots will be tested by a demonstration, performed by a team member, that should show all of the possible user interactions.

Grading Criteria:

- ☐ **Concept (20 %)** The concept portion of your grade will be based on the technical merit of the design and programming 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.
- ☐ **Implementation (25 %)** The implementation portion of your grade will be based on the machine displayed at the evaluation session. Included in this portion of the grade will be evaluation of the physical appearance of the machine and the quality of its construction. Aesthetics will not be judged, rather, craftsmanship and finished appearance are the focus of this portion.
- ☐ **Performance (25 %)** The performance portion of your grade will be based on the results of the performance during the check-off evaluation session. **To earn the performance points, you must demonstrate at least the core functionality.**
- ☐ **Coach Evaluations (10 %)** The coach evaluations portion of your grade will be based on the four project milestone reviews (see previous section).
- ☐ **Report (10 %)** The report portion of your grade will be based on an evaluation of the final report. It will be judged on clarity of explanations and on the completeness and appropriateness of the documentation. This report should be prepared in HTML format (as a website), and submitted as a compressed ZIP archive on Canvas ready for publication on the Internet. If your report is already hosted on the internet, please include a text file containing a link to the live webpage.

Resources

Websites:

SparkFun (www.sparkfun.com)	Seeed Studio (www.seeedstudio.com)	Jameco (www.jameco.com)
Mouser (www.mouser.com)	ServoCity (www.servocity.com)	Ponoko (www.ponoko.com)
Adafruit (www.adafruit.com)	Hackaday (www.hackaday.com)	DigiKey (www.digikey.com)
McMaster-Carr (www.mcmaster.com)	HobbyKing (www.hobbyking.com)	Newark (www.newark.com)

Local Stores:

Anchor Electronics in Santa Clara	J&M Hobby House in San Carlos
Jameco in Belmont	TAP Plastics in San Mateo

Revision History

Revision 0: Initial release (2/6/22)
Revision 1: Project Release (2/10/22)