FINAL PROJECT:

Autonomous "Basketball" Shooting Robot

Are you excited when the CUE 5, Toyota's basketball-shooting robot, swished throws at the Olympics? Or are you thrilled with the RoboMaster competition? Now, it is your turn to develop an autonomous robot for shooting basketballs, although at a smaller scale.

Figure 1: Toyota CUE5 robot basketball player (https://www.autoevolution.com/).

1. Robot Physical and Cost Constraints

- Actions of the robot on the playing field must be autonomous: no human interventions and no tethers. You are only allowed to interact with your robot when it returned to the home position.
- Your robot must start within a 12 in. x 12 in. x 12 in. space at the home position on the playing field.
- The launcher system of the robot must be home-made. Robot chassis is not required.
- Total cost of each robot is to be less than $400. The course budget provides up to $200 per team and the team members may contribute additional parts up to $200 in value. Current market value is to be used in determining the cost/value of contributed items and not your personal acquisition cost. (All components purchased with university funds remain the property of the University.)

2. Playing Field

The playing field is a square plywood surface (8 ft. x 8 ft.) that has been painted white. Side rails which are made of white foam board will be placed around the perimeter of the field to prevent robots from rolling off the field, shown as bold solid gray lines in Fig. 2. These rails extend vertically upwards with 6 inches beyond the plywood surface, but may not be perfectly perpendicular to horizontal plywood surface.The playing field is divided into left and right courts by a 3/16 inches thick middle wall which is made of white foam board. The middle wall is 6 inches above the plywood surface. Each court is further divided into two regions, marked by 1 and 2 in Fig. 2. The 1 and 2 markings are used to label the regions in this description, and are not marked on the playing field. Black lines in Fig. 2 present the lines on the plywood surface for robot navigation. These lines are physically created by using 3/4 inches width *black electrical tape*. Detailed dimensions of the playing field are shown in Fig. 2 and Fig. 3.

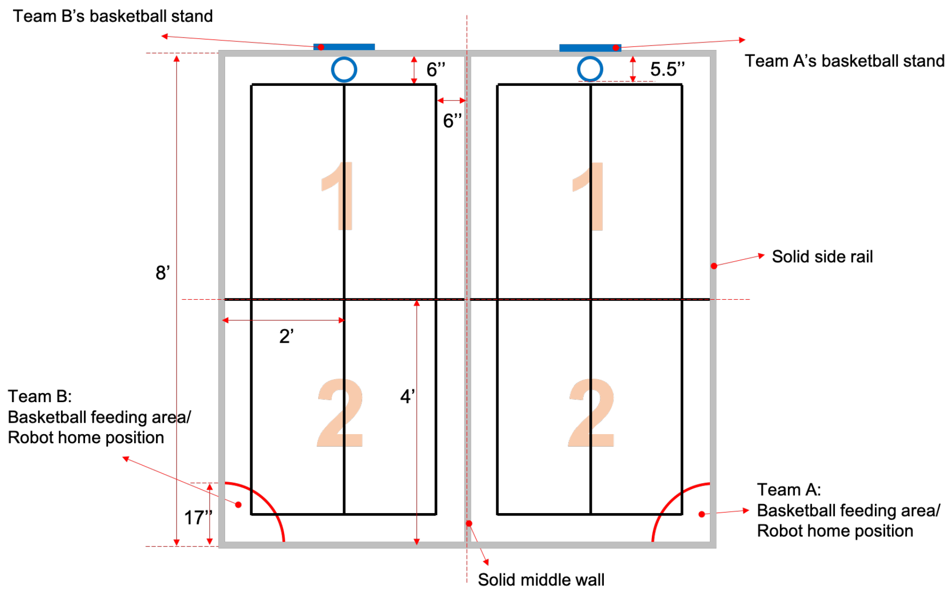

Figure 2: Top view of the playing field.

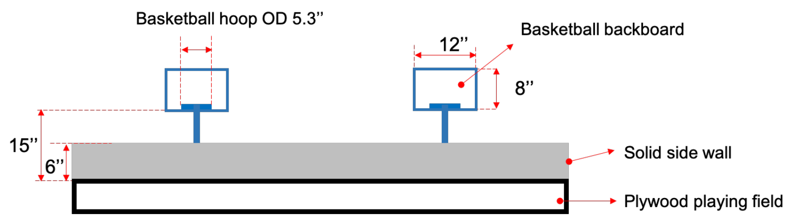

Figure 3: Front view of the playing field.

3. Scaled Backboard and Rim

The backboard is made of plexiglas and is 12 in. wide and 8 in. high. One red-edge rectangle is centered above the hoop on the backboard and the edge of the backboard is covered by 0.7 in. red lines. Figure 4 shows the relevant dimensions.

The rim is a plastic rim with an inner diameter of 4.2 in. and an outer diameter of 5.3 inches. The rim is attached to the backboard via two suction cups. The backboard and rim assembly is mounted from the playing field by an aluminum post. The bottom edge of the rim is 15 inches from the playing field. The rim extends into the playing field by 5.5 inches. A backboard and rim assembly will be made available in the 588 Lab for practice.

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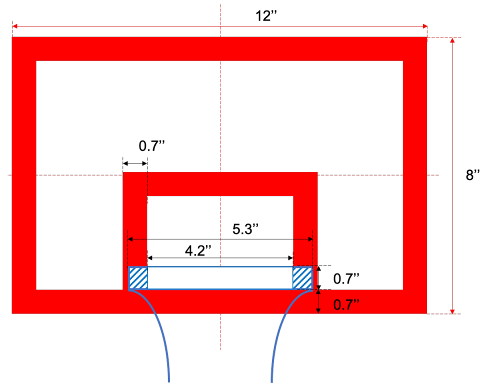
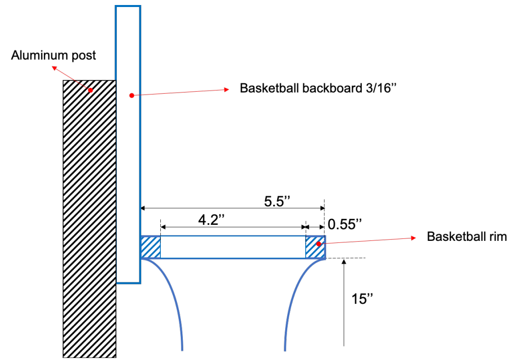
4. Scaled Basketball

The scaled basketballs are 2.5 inches diameter foam balls. Each team will be given 4 balls for practice and testing. During competition/final demo, new foam balls will be used.



(a) Front view of the backboard and rim assembly.



(b) Side view of the backboard and rim assembly.

Figure 4: Sketch of the backboard and rim assembly

5. Competition Rules

Match

1. Two teams will compete with each other on their respective courts during each match.
2. Each match lasts for 3 minutes.
3. During the match, each robot moves autonomously on its own court and places/shoots foam basketballs into the rim on its own court or the rim on the other team's court.
4. Each foam basketball dropped into the rims will receive different scores, depending on the location of the robot. (see the scoring section below for details.)
5. During the match, the robot can move back to its home position autonomously at any time to reload foam basketballs and/or for human intervention. (time will not stop during reloading or human intervention.)
6. At the end of the match, the team with the highest score wins the match. Tie score is allowed.

Rules and Regulations

- The robot starts its match in a 17 in. radius quarter circle area. The quarter circle area is the home position, as shown in Fig. 2. The robot may face any direction at the start, as long as it remains within the home position. At the home position, one team member may briefly contact with the robot to initiate autonomous operation, such as push a button, or flip a switch. Thereafter, the robot must operate entirely on its own. If robot movement does not commence within 30 seconds after the start of the match, the team then forfeits the match, i.e. receives 0 score for the match. "Robot movement" includes any visible change in location, appearance, or configuration of the robot.
- During each match, the robots are limited to operate on its own court.
- No part of the robot is allowed to cross or collide with the middle wall.
- The robot can choose to shoot or dunk basketballs, or even block the shots coming from the opponent.
- Within the limit of the starting robot size (12in x 12in x 12in), there is no limit on the number of foam basketball a robot can carry.
- The robot must stay in contact with the plywood surface at all times. Hovering or flying, although impressive, is not permitted.
- Robots must not affect the color, texture, moisture content, or friction coefficient of the playing field.
- Robots can not damage or in any way puncture or modify the shape or color of the foam basketballs.
- The robot operation must be terminated at the end of the match. Buzzer beater shot will be counted.
- Except to prevent damage to people or equipment, team members are not to touch the basketball backboard and rim, playing field, or any robot (except when robot returned to the home position) during the match.
- It is the team's responsibility to ensure that all robot functions and electronics work properly during each match.
- The instruction team (instructor and TA) may add, delete or alter rules at any time, as they see fit, in an attempt to ensure a safe, fair and enjoyable game. Any violation to the above rules and regulations will be subject to disqualification.

Competition Format and Scoring

Six teams will be placed (by random drawing) into two groups of three teams each. Each group plays round robin matches at the group stage as shown in Fig. 5. Total points each team scored during the round robin phase will determine the ranking of each group. The top two teams from each group will advance into the semi-final round. Win-Loss-Tie records will be used as tie breaker for teams with the same total scores after the group stage competition.

At the semi-final round, the top ranked team from each group is to match up with the second ranked team from the other group. The winners of the semi-final round will compete in the final round for the championship. The losing teams from the semi-final round will compete for the third place.

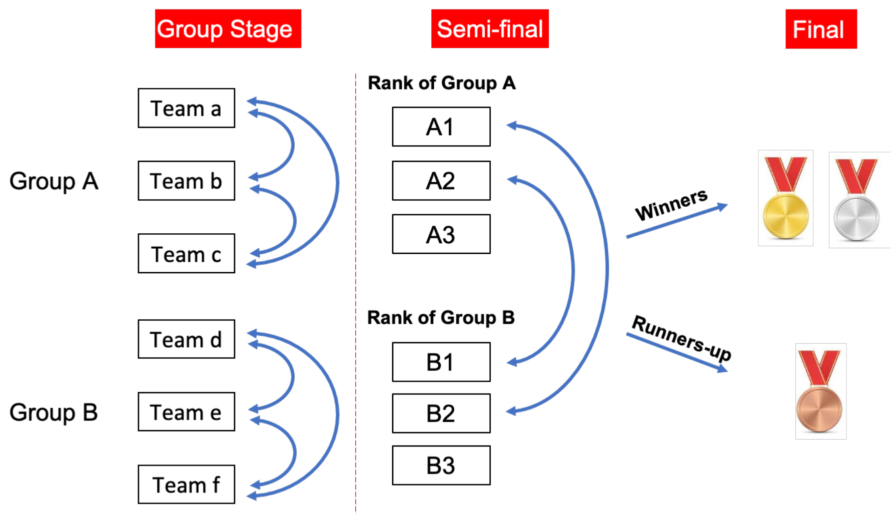


Figure 5: Competition format and schedule.

Scoring

- 4 points: Team at region 2 of their own court shoots a ball into the other team's basket.
- 3 points: Team at region 1 of their own court shoots a ball into the other team's basket.
- 2 points: Team at region 2 of their own court shoots/places a ball into their own basket.
- 1 point: Team at region 1 of their own court shoots/places a ball into their own basket.

If a shot is made when any part of the robot is positioned across the region borders, the shot is taken as made from the lower scoring region.

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6. Deliverable

For the final project, each team will be responsible for providing the following:

Interim Progress Reports

Each project team is responsible for making two 12-minute presentations about the progress of their final project during the second half of the semester. These presentations will take place during scheduled lecture hour, in accordance with a schedule to be posted on Brightspace course website.

Each team member will be responsible for at least one part of your team's presentations. After the oral presentation, the team will be asked to field questions from the audience.

A PowerPoint template for interim reports can be found on Brightspace course website. While you are free to customize the provided template, you will be limited to eight slides containing text: 1) an "introductory" slide with team information and each member's responsibility, 2) a "status" slide with current progress and constraints, 3) a "budget and timeline" slide with cost and timeline, and 4) a "future" slide that highlights changes your team will be making as the project moves forward. You may include additional slides that contain photographs, illustrations, or charts (but not more text!).

You are encouraged to work with your team to ensure that all team members make presentations that are complete, concise, and well-planned. It is up to you and your team to decide the order in which each of you will make the interim presentation. It is not necessary that you attend a presentation period if you are not delivering an interim report. However, you may wish to show up to see what problems other teams have encountered, ask questions of teams that have solved problems that you are currently facing, and to support your teammates in making strong presentations.

A detailed report schedule will be posted on Brightspace later. **Slides need to be submitted to Gradescope for evaluation after the presentation**.

Final Report

The final report should be concisely written and free of grammar errors. The report is limited to 10 pages with figures/plots, excluding appendices. A penalty will be applied for extra pages. The final project grade will consider both the final report and the competition. You are writing for two audiences: 1) readers who want to find out if your solution will solve a similar problem; and 2) readers who want to reproduce what you have done. The report should be in a standard engineering report format, including:

- Cover page - team name and members' name, date of report.
- Title - should be descriptive (and short!).
- Abstract - capsule description of what's in the report, limited to 200 words (In many cases the title and abstract are published without the rest of the report, so they need to stand on their own.).
- Introduction - project objectives, and briefly introduce how you come to the solution method, including robot design, motion planning, sensor and actuator choice, calibration, control strategy, etc.
- Body - Detail robot design, motion planning, sensor and actuator calibration, and control strategy (if applicable) by sections.
- Results - description of experiments or testings done and data obtained.
- Discussion - relate the results to the objectives, and include one or two examples describing what constraints you encountered and how you solved these.
- Conclusion - succinct statement of what was accomplished and what to do next.
- Appendices - relevant material not needed by the average reader.

One team member needs to submit the final report with codes and drawings through Brightspace by **5 pm (EST) on Monday, Dec 13th** .

Code

One team member needs to submit the final Arduino code or any implemented code in an electronic format through Brightspace by **5 pm (EST) on Monday, Dec 13th**, including all library files and all necessary code files. Code should be clearly commented! Compress code into a single ZIP file prior to submission.

Drawings

Final CAD drawings and circuit diagrams are to be submitted in an electronic format through Brightspace by **5 pm (EST) on Monday, Dec 13th**. You may use EAGLE, Fritzing for circuit drawing and SolidWorks, UG for CAD drawing. The drawings should be clear enough for another person to recreate your work. Compress drawings into a single ZIP file prior to submission.

Physical electronic parts

Return electronic parts which were purchased with the university fund to ME 588 lab area at **2:30 - 5:00 pm (EST) on Monday, Dec 13th**.

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7. Purchasing

- University-funded purchases should be requested through the TA. Please refer to the purchase instructions provided on Brightspace.
- Please consider shipping times! Many suppliers may take weeks (or even months) to deliver parts, especially if the component is not currently in stock or the supplier is not at U.S.
- Be aware that the ongoing COVID-19 coronavirus outbreak may have a serious impact on the availability of electronic and other components.
- Personal purchases can be made at brick-and-mortar stores, as well as online stores.
- Personal purchases WILL NOT be reimbursed.
- It is recommended you do not use university funds to purchase batteries. (You are required to turn in materials purchased by the university fund at the end of the semester, and a battery that sits in the parts cabinet for a full year, until next year's course, is generally worthless to anyone. Better that you keep the battery in case you have an opportunity to use it.)
- There are leftovers from past semesters. You may trade these components with the course budget. Details will be posted later.

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8. Working Area

POTR B016:

- Teams can meet in POTR B016 only at the scheduled lab time and when the TA on duty is present.

Machine Shop, Malott Prototyping Suite:

- Please refer to the Project Facility Access Guide on Brightspace for accessing these facilities.

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9. Advice

- Do not wait! Start early! Start now!
- Search the web for components, circuit ideas, and sensors (look for robotic sites).
- Don't reinvent the wheel. Your time is quite limited, so look for concepts and methods that have proven themselves to be reliable.
- Try to limit the number of sensors and actuators. More sensors and more actuators translate to more states in your state machine.
- Try to leverage (use already made) mechanical components as much as possible. You might want to check the Purdue University Warehouse and Surplus Store (Purdue Salvage).
- There are many ways to sense and locate objects. A few minutes of research/planning in the beginning could save you days of work. There are lots of how-to and detail description of subsystems on Youtube and other websites that you can leverage and use.
- Prototype any subsystem you are unsure about. Better to fail early when you have time to recover, than to discover a problem in the final weeks of the semester.
- Make sure you account for robot weight and traction. The most common mistake in previous semesters is that a vehicle does not have enough torque or traction to drive the device!
- Check the sensors that your will be using. Read the datasheet carefully. Make sure you know how they work and how to interface with them! The manufacturers' application notes usually have example circuits for interfacing with the sensors and actuators.
- Beware of grounding, noise, floating inputs, and impedance mismatch type bugs! If you don't know what these mean, look them up in the notes and/or ask questions!
- Think about debugging when you build your circuits. Strategic use of connectors, test pins, LEDs, or external displays can save significant debugging time and agony.

- Don't let your circuity become a rat's nest of wires. Troubleshooting becomes very difficult when you're guessing about which wire does what, or you're unsure whether your connections are still secure.
- Once you have tested your prototype circuit, you will need to build it on a prototype board and solder the components. THIS TAKES TIME! It is best to make use of the dip sockets so that if a component fails, you can change it with minimum rework.
- The lab has a Dremel tool for small part modification. We also have a few soldering stations.

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10. Suggested Schedule

You and your teammates will have to establish a schedule based on your availability and academic obligations. However, it is suggested that each team roughly adhere to the following schedule:

Week of Sep 27th

- Meet your final project teammates.
- Arrange preliminary meeting times and communication methods.
- Discuss and assign subsystem responsibilities.
- Consider initial design ideas.

Week of Oct 4th

- Discuss and sketch your initial concept/design.
- Start looking for key parts and components (sensors, actuators, special chips, etc.).

Week of Oct 11th

- Continue discussing concept/design.
- Start ordering key parts and components (sensors, actuators, special chips, etc.).

Week of Oct 18th

- Finalize conceptual design and look for resources and parts.
- Continue ordering parts and components.

Week of Oct 25th

- Continue ordering parts and components.
- Begin mechanical component construction.
- Begin electronic design, calibration and simulation.

Week of Nov 1st

- Submit interim peer evaluation (11:59PM, EST, Nov 1st)
- Continue building mechanical system.
- Continue building electronics.

Week of Nov 8th

- Test and debug subsystems.
- Begin integrating subsystems and electronic controls.

Week of Nov 15th

- Begin integration of major systems.
- Make final design modifications.

- Test and debug.

Week of Nov 22th

- Continue integration.
- Make last-minute design modifications.
- Test and debug.

Week of Nov 29th

- Test and debug.
- Make final adjustments.

Week of Dec 6th (Dead Week)

- Submit final peer evaluation (11:59PM EST, Dec 6th).
- Project demo (TBD, Dec 9th).

Week of Dec 13th (Final Week)

- Return electronic parts (2:30 - 5:00PM EST, Dec 13th).
- Submit all deliverables by 5:00PM on Monday, Dec 13th.