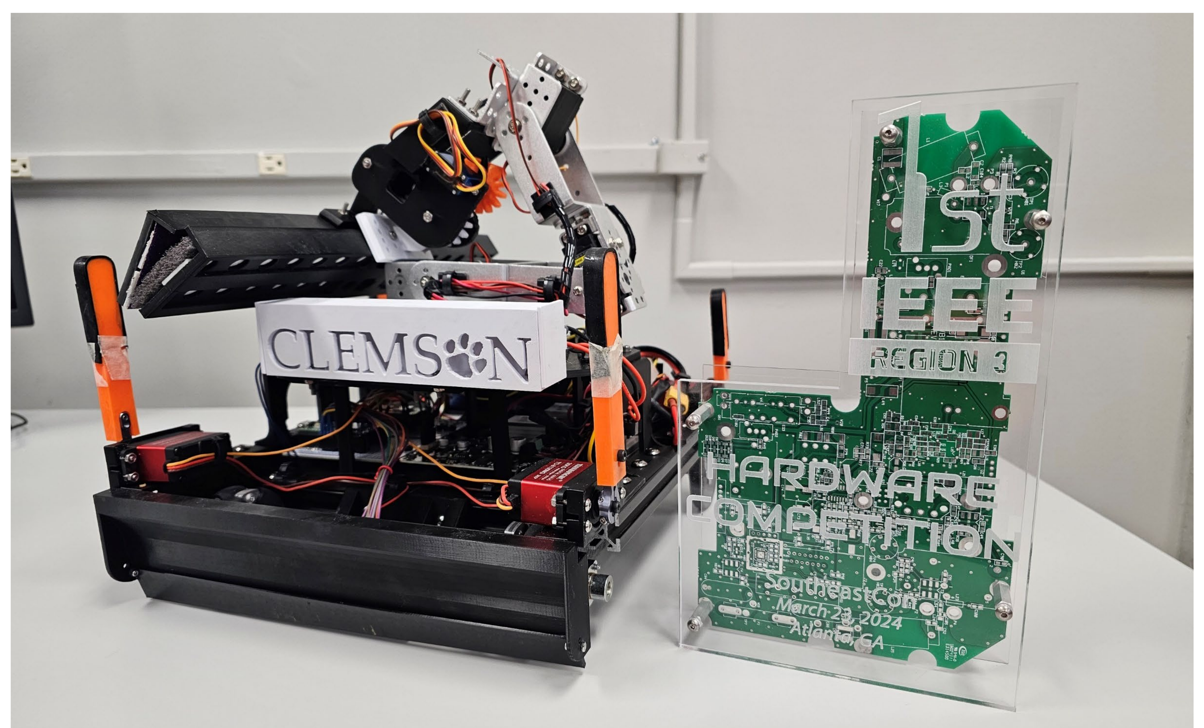
ROAR-E: a Winning Autonomous Robot for the IEEE SoutheastCon 2024 Hardware Competition

Ahmer Raza, Amanda Swearson, Miguel Alday, Connor Belli, Cameron Nowell, Foster Baldwin, Marcelle Gregory, Carter McCauley, Jeff Dale, Juan Paniagua, Alexander Perez, Rodney Stowe, Dr. Hassan Raza, and Dr. William B. Reid III

Introduction

- The IEEE SoutheastCon Hardware Competition is an annual robotic design challenge.
- Competing involves designing and implementing a completely autonomous robot that is able to traverse a challenge course.
- Our team created a robot that won first place among over 50 university teams.



Competition Specifications

Our robot was constrained to be within 12 in × 12 in × 12 in and 25 lbs. The objects on the board were:

- 5 large (1.5 in³) packages and 3 small (1 in³) packages.
- 3 fuel tanks to be placed into 3 thrusters.

A competitor can score a maximum of 120 points excluding bonuses. Specific sources of points include:

- 5pts for being able to move at all.
- 5pts for being able to start autonomously on the green light.
- 2pts per delivered package.
- 1pt per large package placed in the blue zone.
- 3pts per small package placed in the red zone.

Pressed button and finished on time: 30pts
Completely delivered packages: 30pts
Arrived at thruster zone: 20pts
Placed fuel tanks in thrusters: 20pts
Displayed team promotion: 10pts
Miscellaneous: 10pts

Physical Design

Chassis Mechanics

- Our priority was to create something sturdy and reliable, while still not rigid.
- If the chassis was not flexible, the wheels on the chassis would not touch the ground.
- I-shaped base allows for flexibility perpendicular to wheels.
- PLA plastic is naturally slightly pliable in any direction.

Motion

- The robot is 2-wheel-drive instead of 4-wheel-drive.
- Powered rear wheels are traction wheels, and the unpowered front wheels are omni wheels.
- This is to allow for in-place turning: the robot is able to pivot anywhere along the rear axle.
- To get out of the crater, rubbered arms attached to four servos push the robot out.

Navigation

In order to navigate the course, the robot:

- Uses measured distances to determine position.
- Flattens itself along walls to reset the frame of reference.
- Always attempts to move along the central yellow line.

Object Manipulation

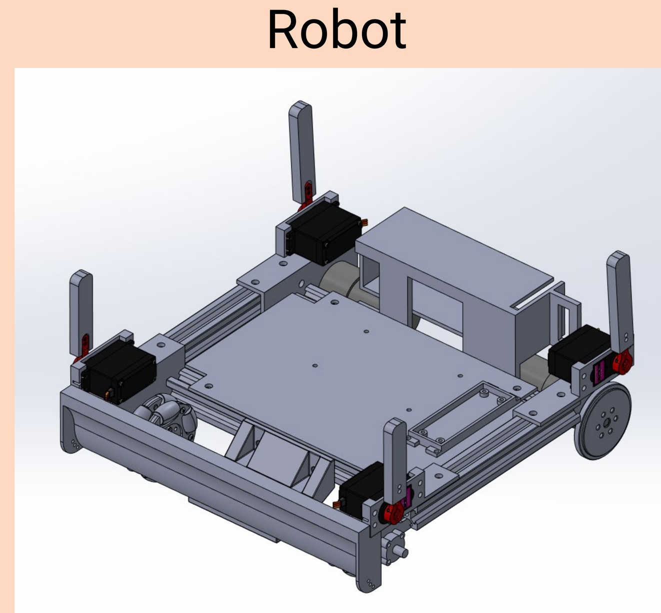
Small packages directly in front of the robot:

- Are pushed across the ramp by a special cubic curve-shaped bumper.
- The concave lower half of the bumper rotates small packages if their corners are caught on the ramp.

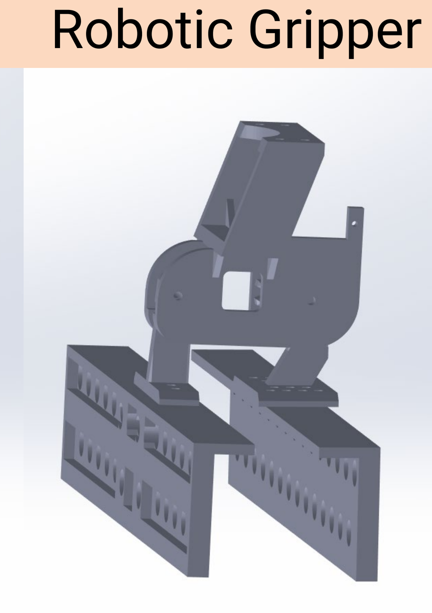
Large packages right next to robot:

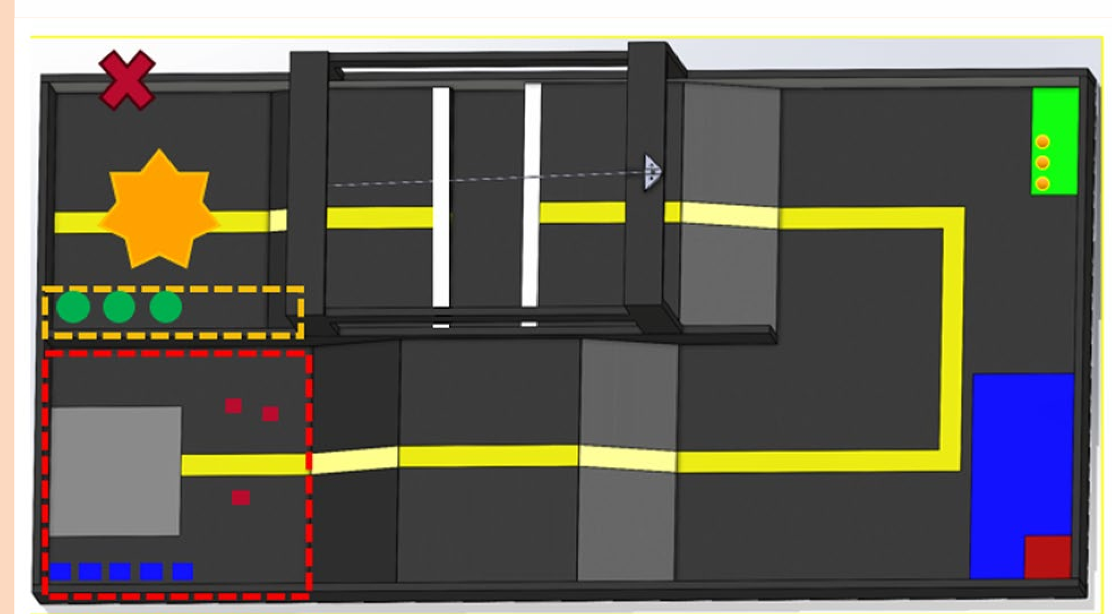
- Are grabbed all at once using a special gripper.
- Gripper is an end effector attached to a 3 degrees-of-freedom robotic arm.

Robot



Robotic Gripper





Game Board

Electrical Design

Modularity

- Our priority was to keep each element of our robot modular and separate.
- We used two Picos to control the arm and crater servos, and one Pico to control the drive and sensors, as well as other Picos using I²C.

Motors

- 3 MG996R positional servomotors are used in the arm.
- 1 MG90D positional micro servomotor is used in the gripper.
- 4 TD-8135MG continuous-rotation servos are used to push the robot out of the crater.
- 2 FIT0186 43.8:1 gear ratio motors are used to drive.

Sensors

- 2 Hall effect rotary encoders to gauge distance; built into FIT0186.
- 1 QTR-MD-08RC line-following sensor to detect line; consists of 8 QTR reflectance sensors.

Controllers

- 3 Raspberry Pi Pico MCUs.
- 1 Cytron MDD10A motor driver/controller.

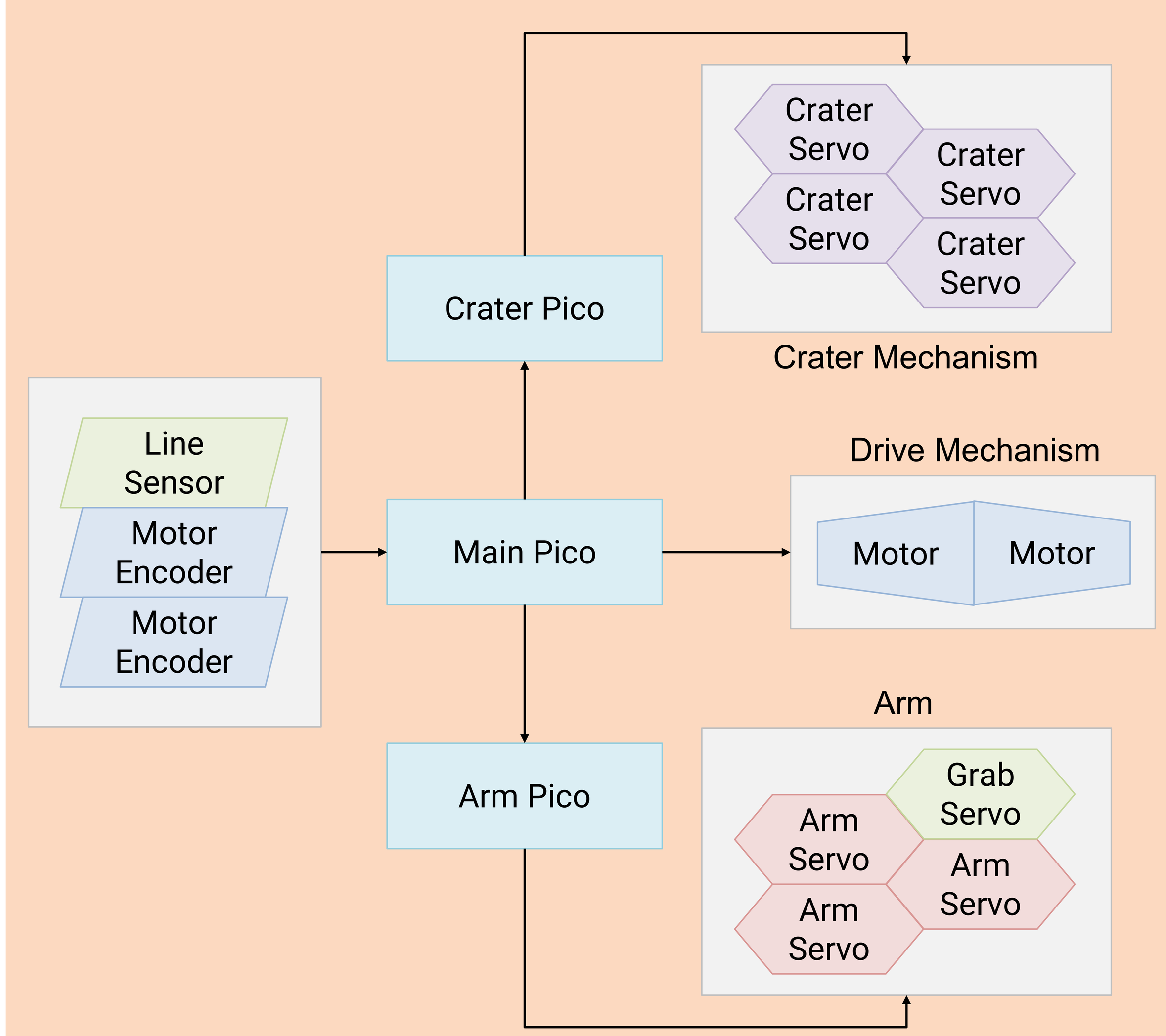
Power Distribution

- The robot is powered by a single 12 V, 5400 mAh battery.
- Power is distributed via one 12 V-to-5 V and two 12 V-to-6 V buck converters.
- 12 V drive motors are powered directly from battery.
- 5 V output from the buck converter powers controllers.
- 6 V outputs power servomotors. Each buck converter does not power more than 2 servos at a time.

Electrical Isolation

When considering our final electrical layout

- Our main goal was to isolate power and signal lines from each other as much as possible.
- Large amounts of electrical interference had previously caused unknown and mysterious behavioral errors.



Software Design

Organization

- The main Pico has been programmed to behave like a state machine.
- At any time, the robot is in one of many predefined states.
- The robot only transitions to next state when certain conditions are met.
- The Picos communicate with one another via an I²C network.

Line Following

- Each QTR sensor in the 8-sensor array gives an analog value, corresponding to brightness.
- To gauge the position of the line, we use a weighted average between the sensor values and the distance of each sensor from the center.

Arm Control

- The three positional servos on the robotic arm are controlled using a linear interpolation (lerp) function.
- Servos move independently and simultaneously, so the arm can perform complex maneuvers.

Acknowledgements

We would like to thank David Bootle and Ella Schafer for their help with 3D printing. We would also like thank David Moline, Gale Black, and Sommer Dobbins for their assistance with order placement and accounting. This project was funded by the Creative Inquiry program. Substantial work was done in the Robotics and Design ECEntials laboratories, recently renovated with funds provided by Hai Xiao, Chair of Electrical and Computer Engineering.