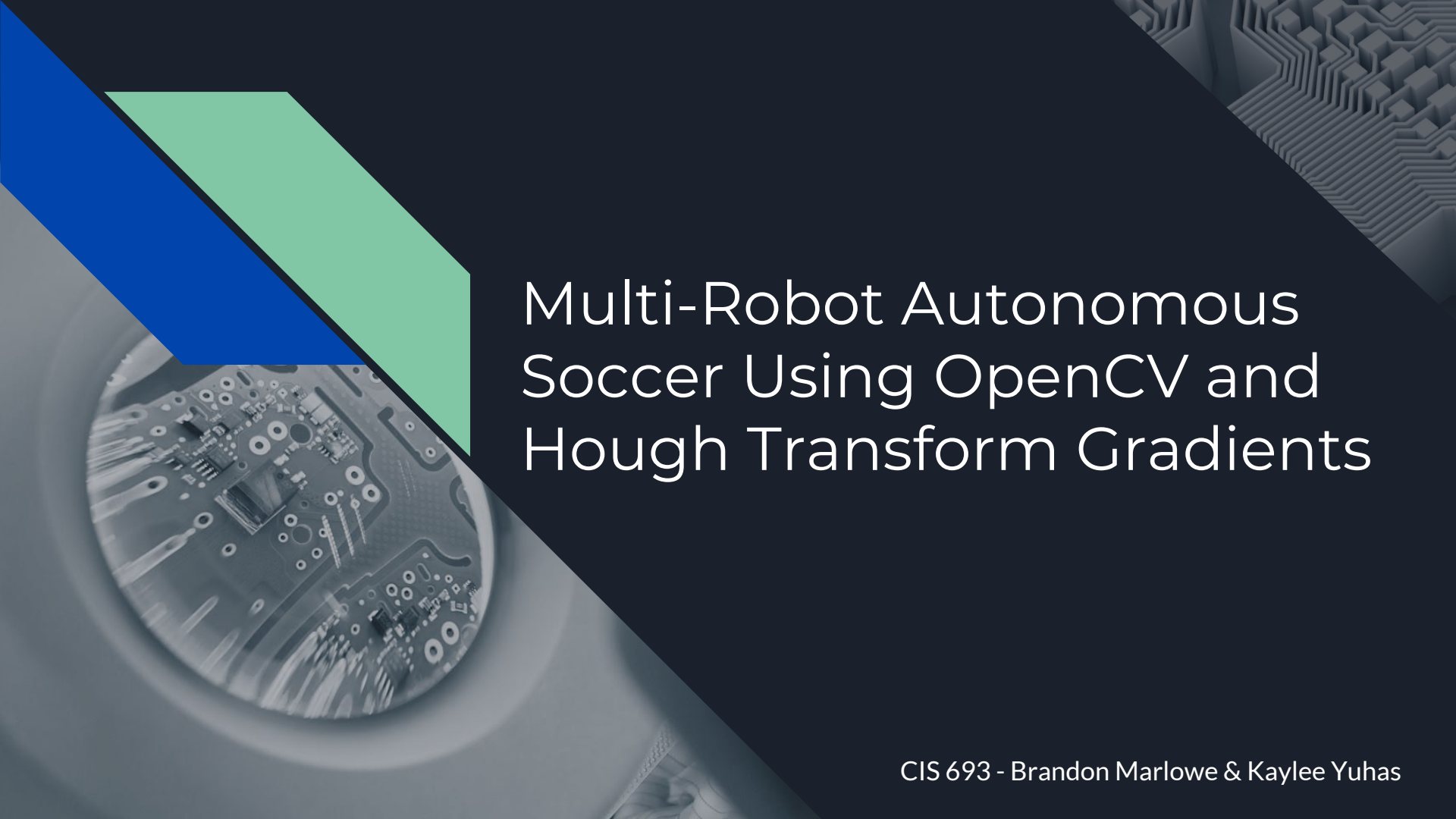
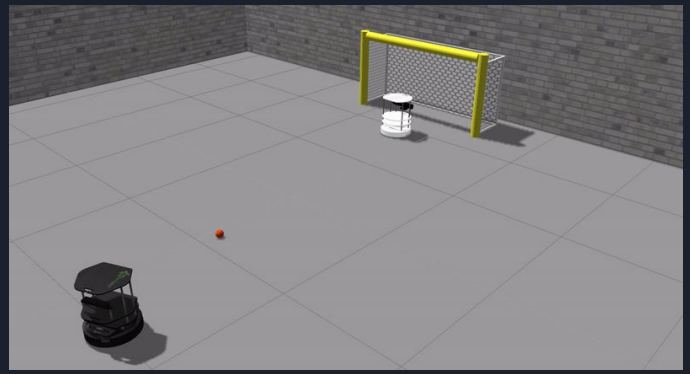


Multi-Robot Autonomous Soccer Using OpenCV and Hough Transform Gradients

CIS 693 - Brandon Marlowe & Kaylee Yuhas

Project Overview

- Autonomous soccer using two TurtleBots
  - Kicker and goalie
- Kicker and goalie maintained at least one meter of separation at all times
- Voice commands triggered behaviors
  - “Start” and “Stop”
- Voice commands processed using PocketSphinx
- Used OpenCV and Hough Transform Gradient extension to detect/track soccer ball



- Annual International Robotics Competition
  - Est. 1996
- Multiple Leagues
  - Humanoid
  - Standard Platform (Shown in GIF)
  - Middle Size
  - Small Size
  - Simulation
- Promotes Robotics and AI Research
- Long Term Goal
  - “By the middle of the 21st century, a team of fully autonomous humanoid robot soccer players shall win a soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup.”

Challenges/Problems

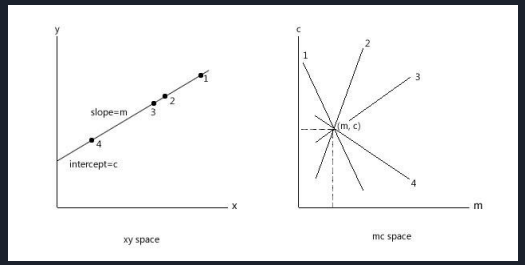
01 The goalie will continually track the soccer ball and block attempted kicks.

02 The kicker must track the soccer ball, the goalie, and kick the ball into the goal.

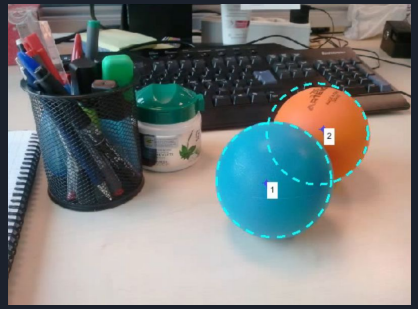
03 Adjust force needed to kick the ball far enough depending on distance from goal.

Circle Detection with Hough Transform Gradients

(Photofrom: http://aishack.in/tutorials/hough-transform-basics/)



(Screenshot from: https://www.youtube.com/watch?v=dgxvBBn_olQ)



Video frame stored

BGR to HSV conversion

Color-range identified

Weighted sum of upper and lower color range matrices and image blurred to reduce noise

Edge detection pre-processing and circle detection

```
cvPtr = cv_bridge::toCvCopy(msg, sensor_msgs::image_encodings::BGR8);
srcIMG = cvPtr->image;

cv::cvtColor(srcIMG, hsvIMG, CV_BGR2HSV);

cv::inRange(hsvIMG, cv::Scalar(0, 100, 100), cv::Scalar(20, 255, 255), redIMG_lower);
cv::inRange(hsvIMG, cv::Scalar(160, 100, 100), cv::Scalar(170, 255, 255), redIMG_upper);

cv::addWeighted(redIMG_lower, 1.0, redIMG_upper, 1.0, 0.0, redIMG);
cv::GaussianBlur(redIMG, redIMG, cv::Size(9, 9), 2, 2);

cv::HoughCircles(redIMG, redCircleIMG, CV_HOUGH_GRADIENT, 1, hsvIMG.rows / 8, 100, 20, MIN_RADIUS, MAX_RADIUS);
```

(Snippet from goalie source code)

PocketSphinx Speech Recognition

- Developed by Carnegie Mellon University
- Open-source
- Our implementation used Python
- Well documented
- Lightweight and fast
  - Written in C
  - Designed for embedded systems
- Reasonably accurate
  - Compared against Kaldi, HTK, and Julius

Error rates on two word detection tests detailed in:

C. Gaida, P. Lange, R. Petrick, P. Proba, A. Malatawy, and D. Suendermann-Oeft, "Comparing open-source speech recognition toolkits," tech. rep., Technical report, Project OASIS, 2014.

recognizer	VM1	WSJ1
HDecode v3.4.1	22.9	19.8
Julius v4.3	27.2	23.1
pocketsphinx v0.8	23.9	21.4
Sphinx-4	26.9	22.7
Kaldi	12.7	6.5

U-Guide Attachment

Kicker and Goalie Behavior

- Kicker
  - Search prioritization
    - Searches for soccer ball first
    - Searches for goal second
  - Velocity logic
    - Proportional velocity approaching ball
    - Maximum velocity approaching goal
- Goalie
  - Simplistic path prediction
    - Tracked ball if further than 1.5 meters away
    - Accentuated alignment error as angular velocity to account for drift of soccer ball
  - Returns to initial position

Alignment Error calculation used by kicker and goalie

```
alignError = -(objCoord[X] - (IMG_WIDTH_PX / 2.0)) / 225;
```

Issues Faced Along the Way

01 Uneven floors in AIR lab

02 Tracking colors with low saturation

03 Map accuracy

04 RVIZ frequently crashing

05 Laptops overheating

Success Criteria

01 Both robots successfully navigate to and from field 

02 Voice commands are heard and correctly interpreted consistently 

03 Both robots track the ball, goal, and each other at all times 

04 The kicker successfully kicks the ball into the goal 

05 The goalie attempts to block shot attempts consistently 

Goalie Performance

Link to view video: https://drive.google.com/open?id=1vtxf1tsaI8Nt99oQxkMdJKq9jJrkhDJP

Kicker Performance

Link to view video: https://drive.google.com/open?id=1JObXAXPmJpa1jKOXJjxTFoyTDS6uMAru

Full System Performance

Link to view video: https://drive.google.com/open?id=1OGPUCeFQ5uk4mx3fLmU5tRnJVGHW6d4T

Bibliography

Mobalegh H., Helgadóttir L.I., Rojas R. (2014) Shape Based Round Object Detection Using Edge Orientation Histogram. In: Behnke S., Veloso M., Visser A., Xiong R. (eds) RoboCup 2013: Robot World Cup XVII. RoboCup 2013. Lecture Notes in Computer Science, vol 8371. Springer, Berlin, Heidelberg

C. Gaida, P. Lange, R. Petrick, P. Proba, A. Malatawy, and D. Suendermann-Oeft, “Comparing open-source speech recognition toolkits,” tech. rep., Technical report, Project OASIS, 2014.

Duda, R. O., & Hart, P. E. (1972). Use of the Hough transformation to detect lines and curves in pictures. Communications of the ACM, 15(1), 11-15. doi:10.1145/361237.361242

Kimme, Carolyn, et al. “Finding Circles by an Array of Accumulators.” Communications of the ACM, vol. 18, no. 2, 1975, pp. 120–122., doi:10.1145/360666.360677.

Fails

Link to view video: https://drive.google.com/open?id=1pJIhqftwzu8qxzfjvgrjwuDvUTgoSsYO