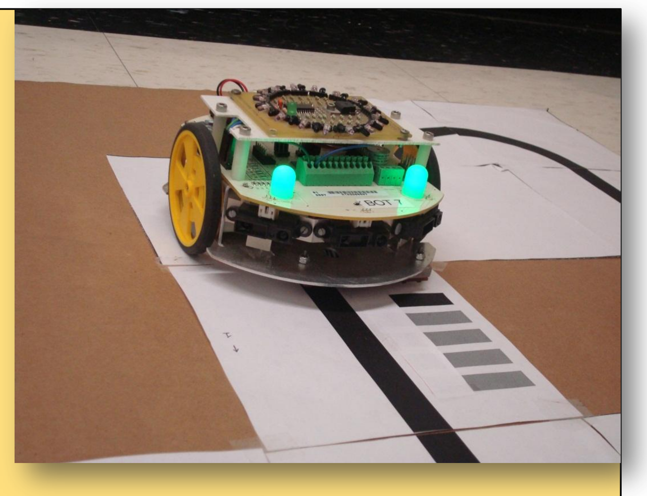
Navigating Dynamic Traffic Environments in a Low-Cost Robot Colony

James Carroll, Daniel Jacobs, Willis Chang, Alexander Lam, Prashant Sridhar, Jeffrey Cooper, Abraham Levkoy, Vinay Vemuri, Priyanka Deo, Matthew McKay, Benjamin Wasserman, Megan Dority, Nicolas Paris, Mark Williams, Devendra Gurjar, John Sexton, Alexander Zirbel, John Howland, Daniel Shope

Advisor: George Kantor

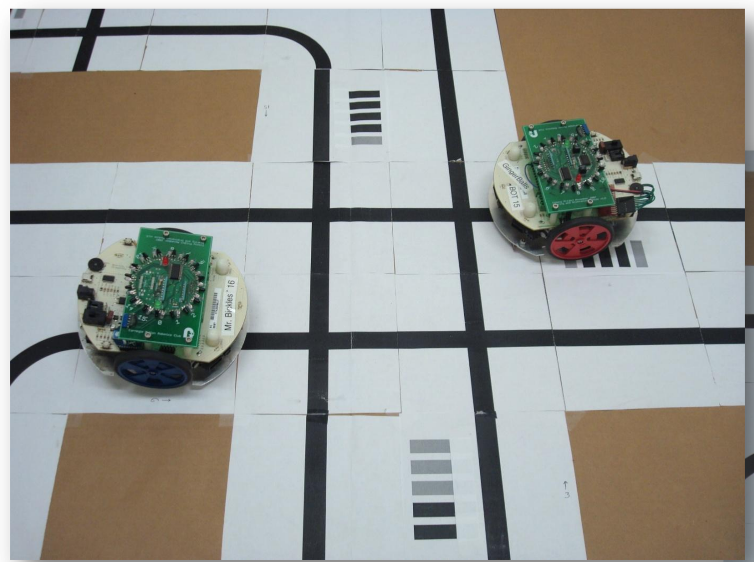
Barcode Reading



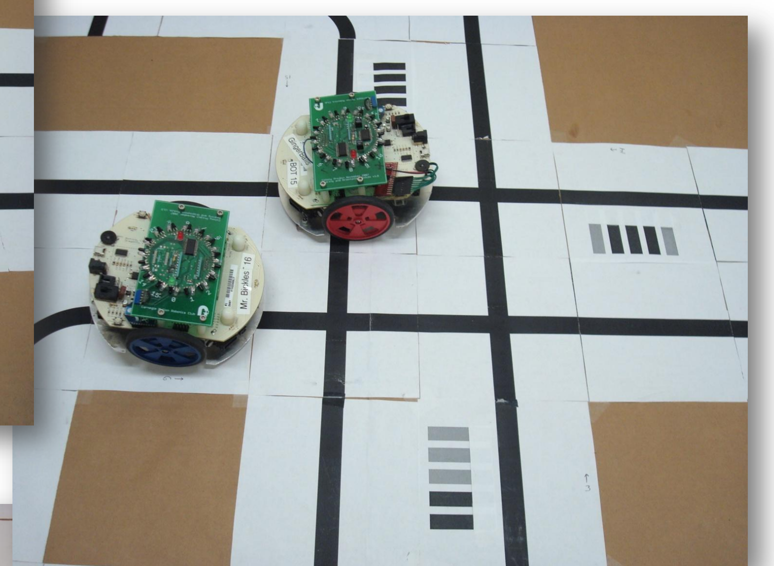
The Colony robots use barcodes to read information while driving, like automobile drivers use road signs

- Barcodes represent indices into an array. This array stores data about the barcode's location: number, position relative to the intersection, and type of the intersection.
- The barcodes are placed along the side of the road, similar to traffic signs. The leftmost line sensor doubles as a barcode reader. This allows the robots to follow the lines and still gather data about the roads.
- A special barcode tells a robot that it can drive on the wrong side of the road for the specific purposes of mapping. This barcode is not used during normal traffic navigation.

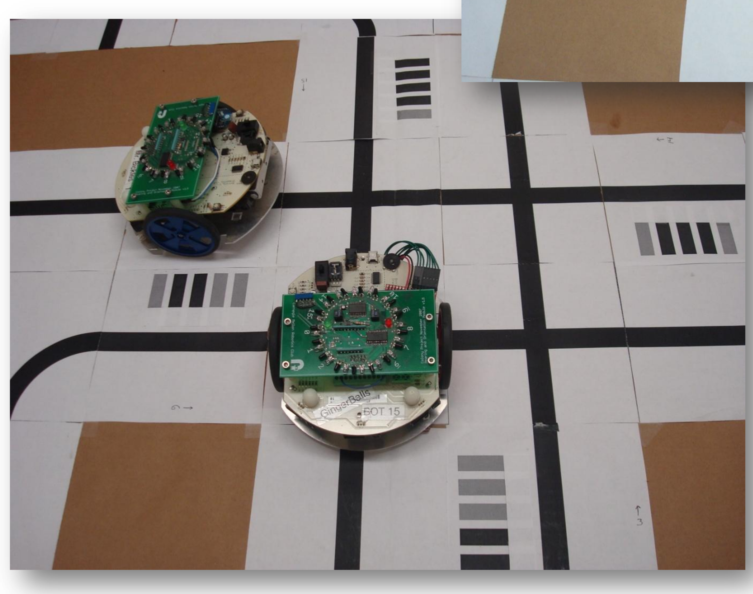
1.



2.



3.



Autonomous Intersection Behavior

At intersections, multiple robots must coordinate their behavior to proceed safely

Problems

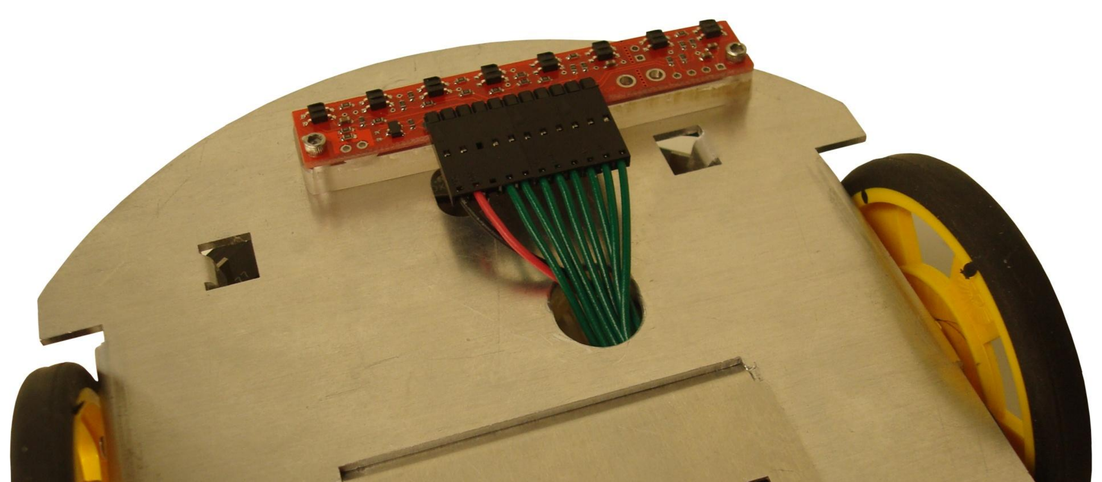
- If two robots enter an intersection at the same time, they will crash
- Race condition: If two robots arrive at the intersection at the same time, which goes first?

Solution

- Use a dynamic linked list of robots at each intersection
- A robot adds itself to the end of the list when it reaches the intersection
- When the robot reaches the front of the list, it traverses the intersection and removes itself from the list

Abstract

The overarching goal of the Colony Project is to maintain a flexible yet inexpensive group of robots for researching emergent behavior and cooperative problem solving. With this research, the Colony Project emulated vehicular traffic in a city-like environment. The development of intelligent, networked cars is a field of growing interest in mobile robotics research, and we will show how we used our robots to study related algorithms and behaviors. Our goal is to enable the robots to autonomously navigate a dynamic environment and to handle interesting traffic objects and events such as lane changes, intersections, tollbooths, and obstacles in the road. This work is a continuation of previous Colony Project research, and it will serve as a foundation for future endeavors. We also hope to contribute to this rapidly growing area of robotics research.



Mapping

One robot navigates the course while constructing a map and makes that map available to other robots

Algorithms

- The robots store the map as a graph with roads connecting intersections
- To explore the map efficiently, the robots use a Depth First Search (DFS):
  - At each intersection, visit a random unvisited neighbor
  - If no unvisited intersections exist, backtrack to the intersection visited immediately before the current one

Future Work

- Another challenge would be mapping with multiple robots simultaneously
  - This is a potential extension of the project
  - The current mapping algorithm violates the rules of the road, so concurrency would require a new algorithm which more rigidly connects navigation and mapping

Navigation

The robots need to be able to follow the roads

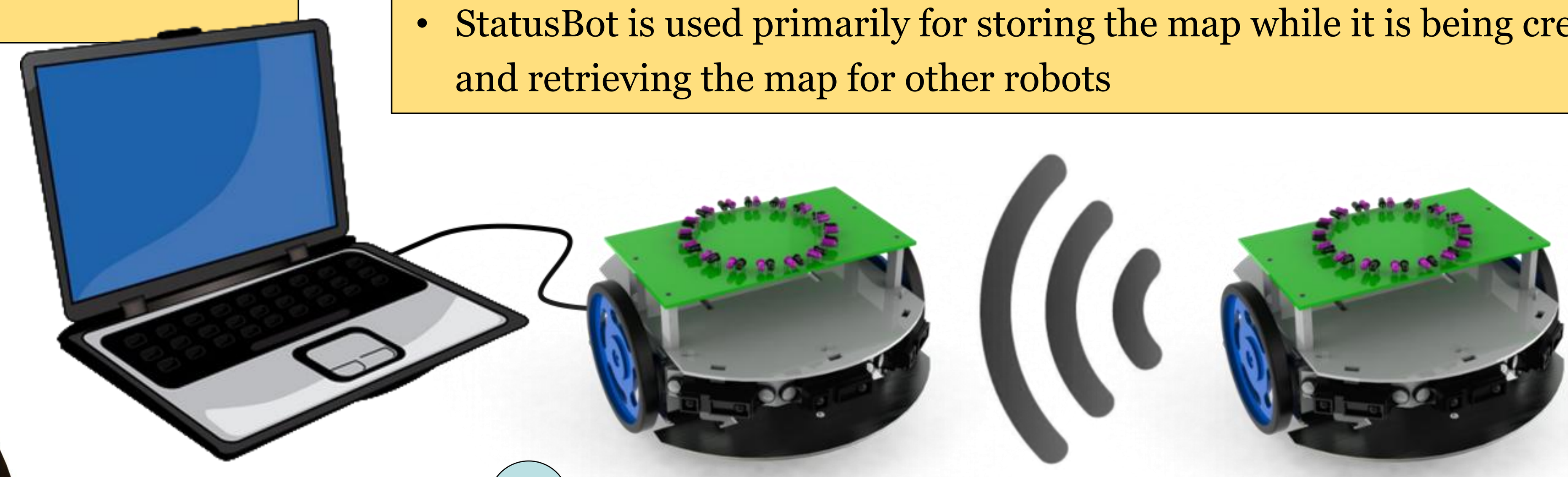
Algorithms

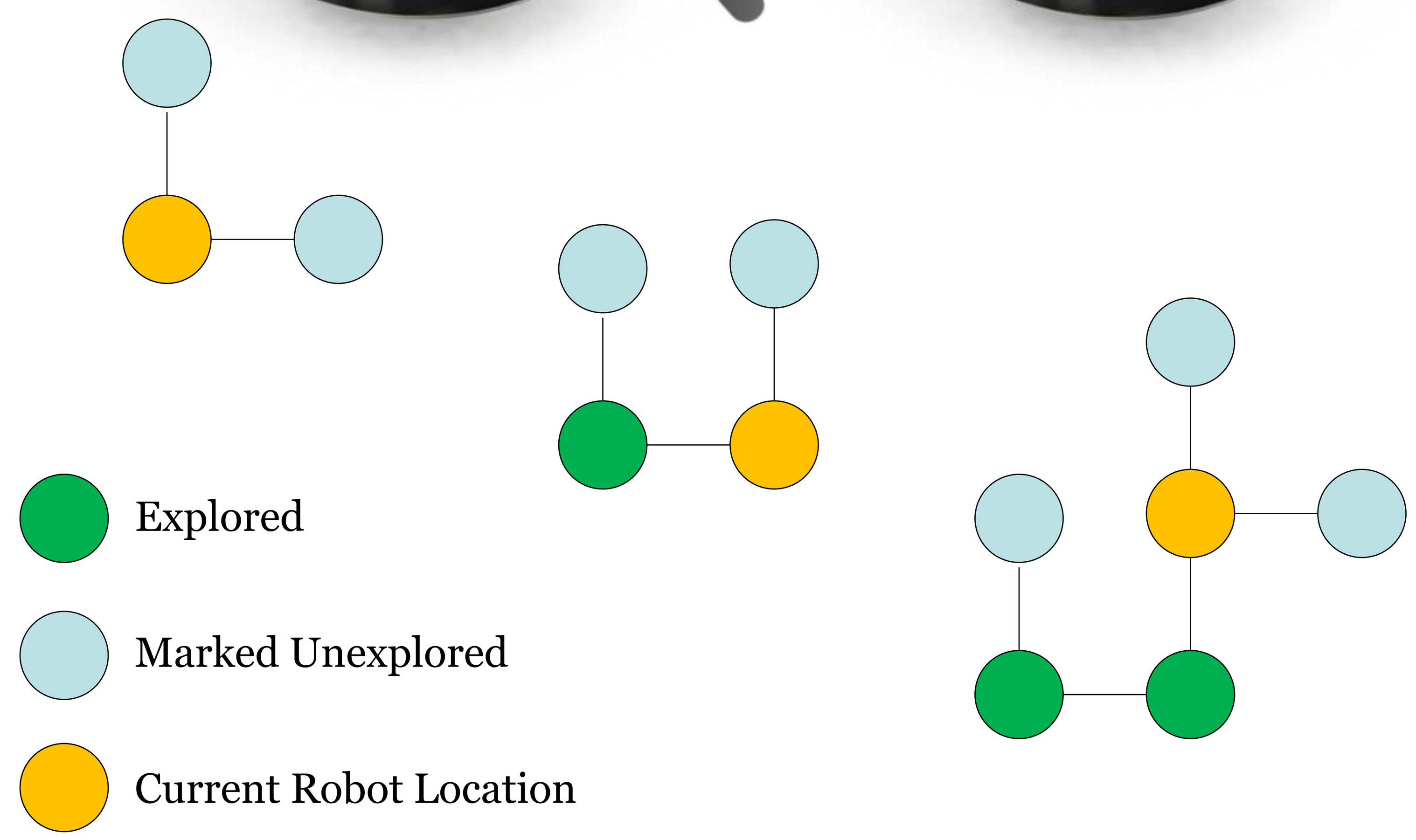
- Each robot has a series of sensors that are used to follow lines.
- They compare the sensors to a threshold to find the average position of the line. Robots use this position to stay centered on the roads.
- Robots can also detect when they have lost the road or when they are crossing an intersecting road

StatusBot

We use a central monitor robot that allows external computers to interface with the swarm

- StatusBot is a stationary robot that monitors all wireless traffic and prints it to an attached computer
- StatusBot is used primarily for storing the map while it is being created and retrieving the map for other robots





Acknowledgements

We first would like to thank our advisor George Kantor. We would also like to thank Peggy Martin for her help and support, as well as Brian Kirby, Tom Lauwers, Prasanna Velagapudi, Steven Shamlian, and Cornell Wright for their contributions to the project.

This project was funded in part by Carnegie Mellon's Undergraduate Office. The results represent the views of the authors and not those of Carnegie Mellon University.