



Autonomous Vehicle Control

via Color Tracking and Ultrasonic Sensing

Abstract

Autonomously controlled vehicles utilize various sensors to survey their environment in order to operate independently of human interaction. Such vehicles can work in conjunction with one another to form a convoy with only one human controlled lead car. This technology could be integrated into various subdivisions, including military, commercial, and industrial sectors. In order to develop such technology, a mathematical model which defines the general motion of a vehicle must be constructed. Also, a set of control laws that guide the autonomous vehicle is needed. MATLAB was used to write a simulation program based on the model and control laws to test the autonomous vehicle's artificial intelligence before implementation onto a physical car. Standard radio controlled (RC) cars are used as the vehicles. The follower vehicles are equipped with Arduino microcontrollers, motor shields, CMUcam2 color tracking cameras, Parallax Ping))) ultrasonic sensors, and servos to carry out all necessary measurements and calculations. Using these components, the distance and offset angle to the vehicle ahead is found and converted to steering angle and motor speed outputs. The process of analyzing, processing, and executing repeats continuously, resulting in efficient function of the autonomous vehicle control systems.

Previous Problems

- Limited viewing angle of the camera
- Changes in lighting conditions altered color, impacting the distance measurement and making the camera lose track of the lead car
- Little flexibility due to preset values: color to detect, and fast/slow motor speeds

Goals

- ☑ Implement a control law which incorporates the rate of change of the distances between the cars for optimal function.
- ☑ Introduce a frontal servo for the CMUcam2 and Ping))) for 180° degree viewing.
- ☑ Utilize a variable steering and speed capable vehicle to lead the convoy for optimal following by the followers.



Sponsors:

National Aeronautics and Space Administration (NASA)
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Theory

The vehicle control system requires a lead car and a follower car. Additional follower cars may be added to create a convoy. The lead car is a radio controlled (RC) car and the major vehicle that the autonomous follower cars pursue. Behind the lead car and subsequent followers is a colored cylindrical object. The follower car tracks the object within its range, processes sensor inputs, and programs outputs to follow as needed.



The algorithm of the microprocessor requires two basic functions: a setup and a loop. Within the setup function, the connected parts are initialized and prepared for performing their respective commands. The loop is essential for the following process. The sensors track the colored object and the car's distance, then the Arduino microcontroller relays the information to be implemented into the control laws, and outputs the necessary values to power the motor and servo to follow.

Parts

Clockwise from top-left

Arduino: Microprocessor where all the subsequent parts are connected to in order to bridge a universal communication between each other. All data is received, processed, and executed with the motor shield here.

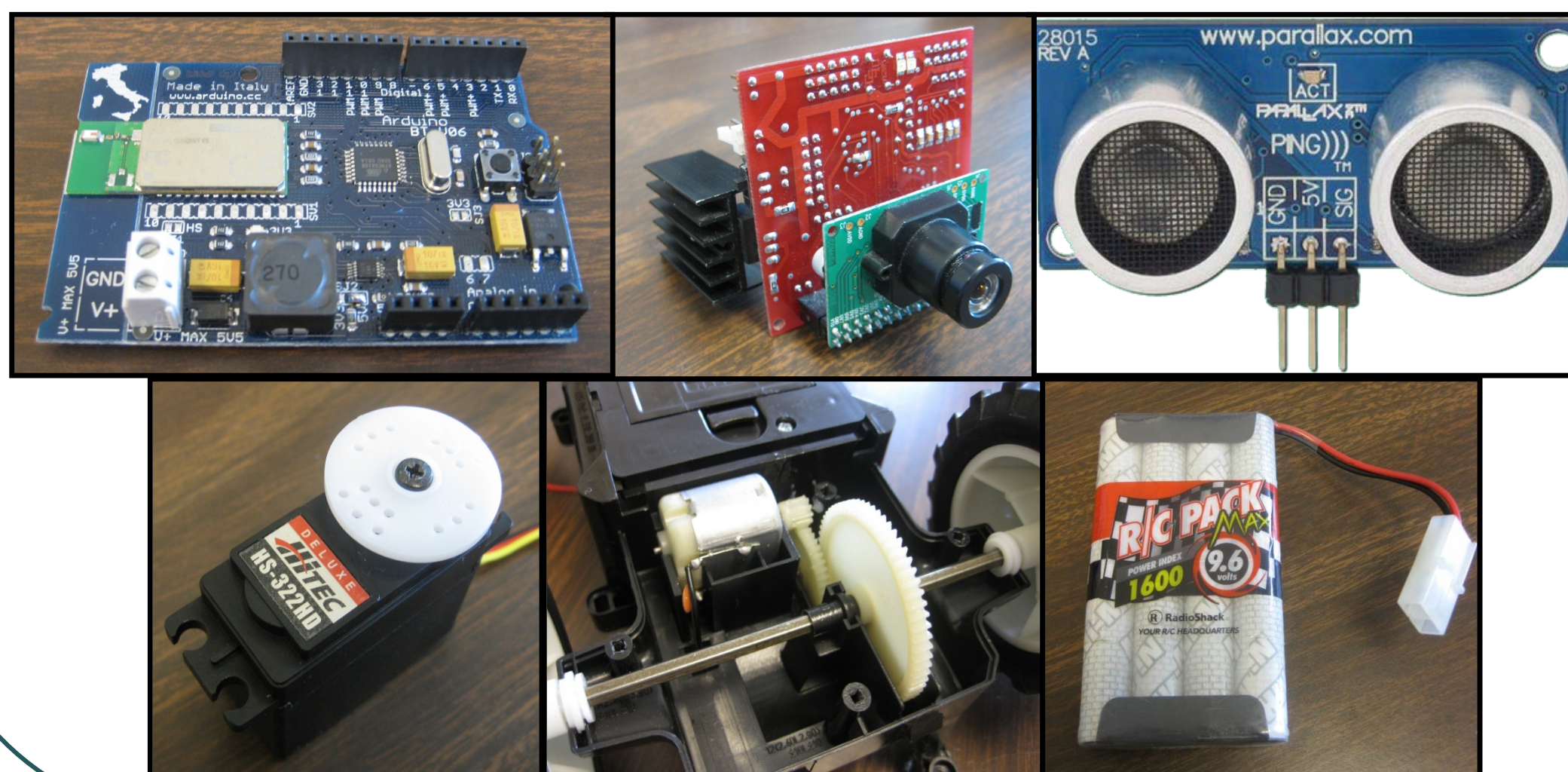
CMUcam2: Color tracking camera which takes the pixels of a determined color and finds center of the color to understand steering angle needed.

Ping))): Ultrasonic sensor which sends and receives ultrasonic waves to analyze distance between the two cars.

Servo: Connected to front wheels to turn car & another to turn sensors.

Motor: Built-in with RC car to allow for rear wheel drive.

9.6V Battery: Standard battery to power RC/autonomous vehicle system.

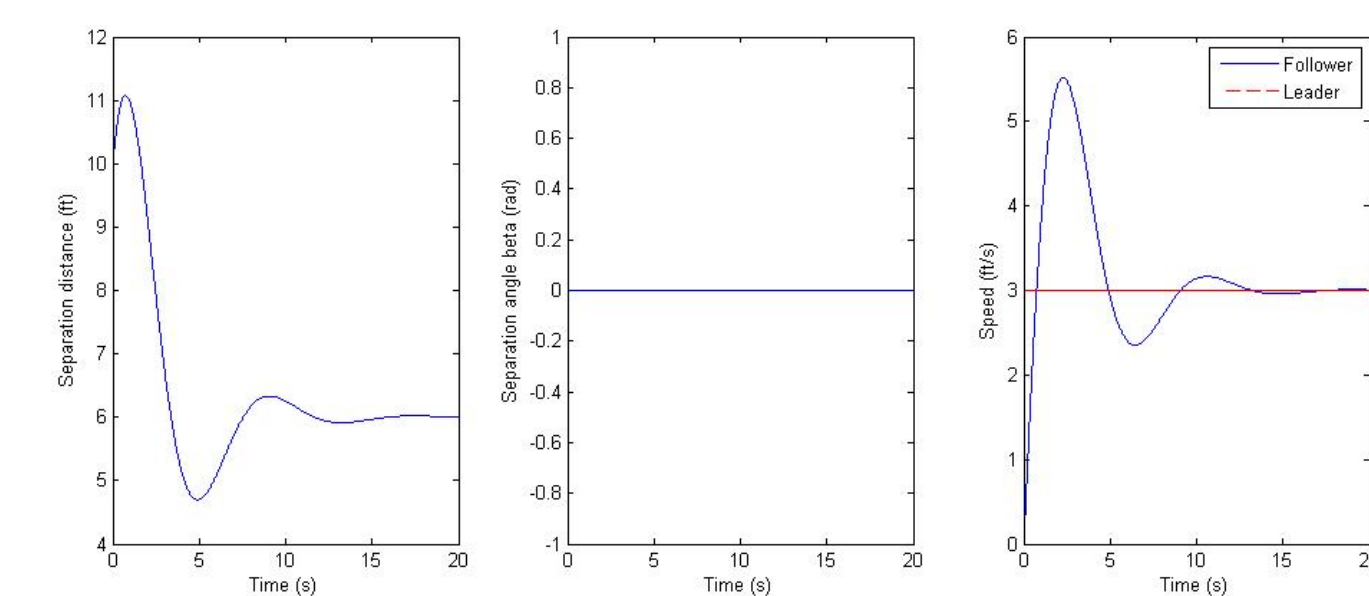


Troubleshooting

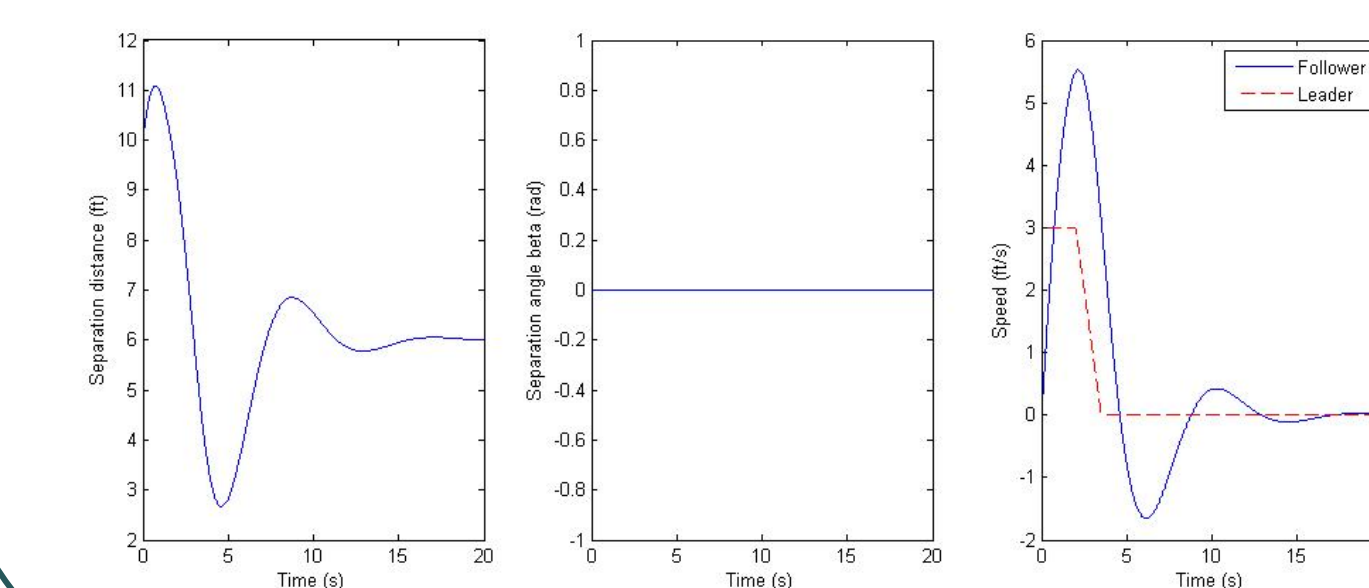
This project has been undertaken by groups prior in an attempt to create a fully functional convoy of autonomous vehicles. We reused many parts and found others to be dead or of no use to our current improvements. Much time was spent early on in the project in order to understand and utilize these parts for optimizing our current advancements. It was also during this time that we realized that the CMUcam2 was not a reliable source of distance measurement due to frequent light changes. We also fixed a problem in the code which caused the steering servo to twitch.

Simulation

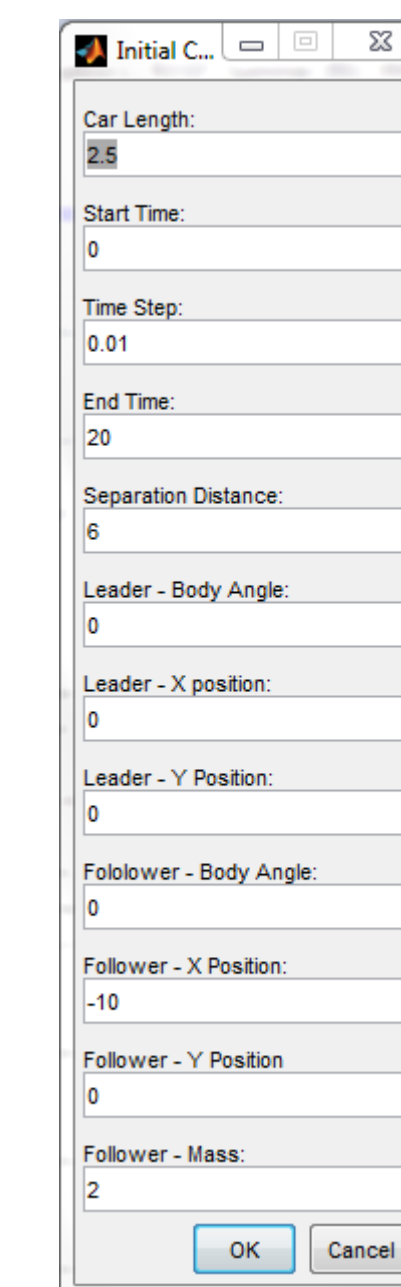
In order to test our new control laws before constructing physical cars, a computer simulation was written in MATLAB. The simulation allowed the user to input the initial positions of the lead and follower vehicles, the desired separation distance, and several other constants. The user can then specify the path of the lead vehicle by defining the turning angle and speed as functions of time. The simulation then utilized our control laws to adjust the speed and turning angle of the follower and animated the result so we can see how the physical cars will behave. Below are some examples of graphs output by the simulation:



Separation distance, body angle, and speed as functions of time - lead vehicle driving at 3ft/s in a straight line



Lead vehicle driving at 3ft/s and braking to a stop



Initial condition setup for the simulation

Approach & Conclusion

With the addition of the ultrasonic Ping))) sensor and a swiveling frontal servo, a few changes to the design and the code were necessary for proper function. The ping pong ball that was originally on the cars ahead would now become a tall cylindrical object since distance measurement is now used with the ultrasonic sensor and not the camera. Not to mention, the swiveling frontal servo added a much greater viewing angle for the follower - 180° were added. This made the follower much more versatile and conquered the problem where the follower would suddenly lose the lead vehicle due to a sharp turn.

Future Goals

- Build this system on a larger scale.
- Implement multiple followers with the newer, more accurate technology and control laws to create a convoy.
- Test mobility on rugged terrain or with multiple obstacles.
- Implement GPS technology and wireless transmitters to achieve a more versatile system.

References

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