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Low Cost Vehicular Autonomy Using RADAR and GPS

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Low-Cost Vehicular Autonomy Using RADAR and GPS

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Abstract

This presentation describes a subset of the systems devised for this year's autonomous golf cart senior design project. Our goal is to explore the possibilities of low cost autonomy using only radar and GPS for environmental sensing and navigation. Although autonomous and semi-autonomous ground vehicles are a relatively new reality, prototypes have been a subject of engineering research for decades [3, 1]. State of the art autonomous ground vehicle prototypes typically use a combination of distance sensors (LIDAR, RADAR, or SONAR) as well as cameras and GPS [2], sometimes also including inter-vehicle communication.

Compared to alternatives, GPS and radar are among the cheapest sensors to implement, with the additional advantage that these sensors operate effectively in the widest range of visibility conditions. Our low cost autonomous ground vehicle project progressed significantly during its first year. The team's achievements include a robust data communication system spanning software and hardware needs, integrated peripheral sensors, and a system-wide interface methodology.

Background

State-of-the-art solutions: examples


(a) Google (b) Tesla

Figure: Existing Autonomous Car Solutions

Major companies are building autonomous cars, two of which are pictured in Figure 1. A typical approach to robust autonomy is to use multiple types of sensors coupled with liberal redundancy.

Our Car

Our Solution

If an vehicle could function with minimal sensors, its cost would be also be minimal. For the purposes of our senior design project, we have attempted full autonomy using only two sensors: GPS for path-finding a RADAR module for obstacle detection. Without sensor redundancy, situation handling in software is a more interesting challenge.

Advantages of our system:

- Extremely low cost
- Low computational processing needs
- Existing data processing libraries for RADAR and GPS

Important assumptions:

- For GPS accuracy, satellites and an ODOT (Ohio Department of Transportation) base station are accessible at all times. This allows the GPS to produce accurate position information.
- The vehicle will not be moving at greater than in-city speeds (less than 30mph).

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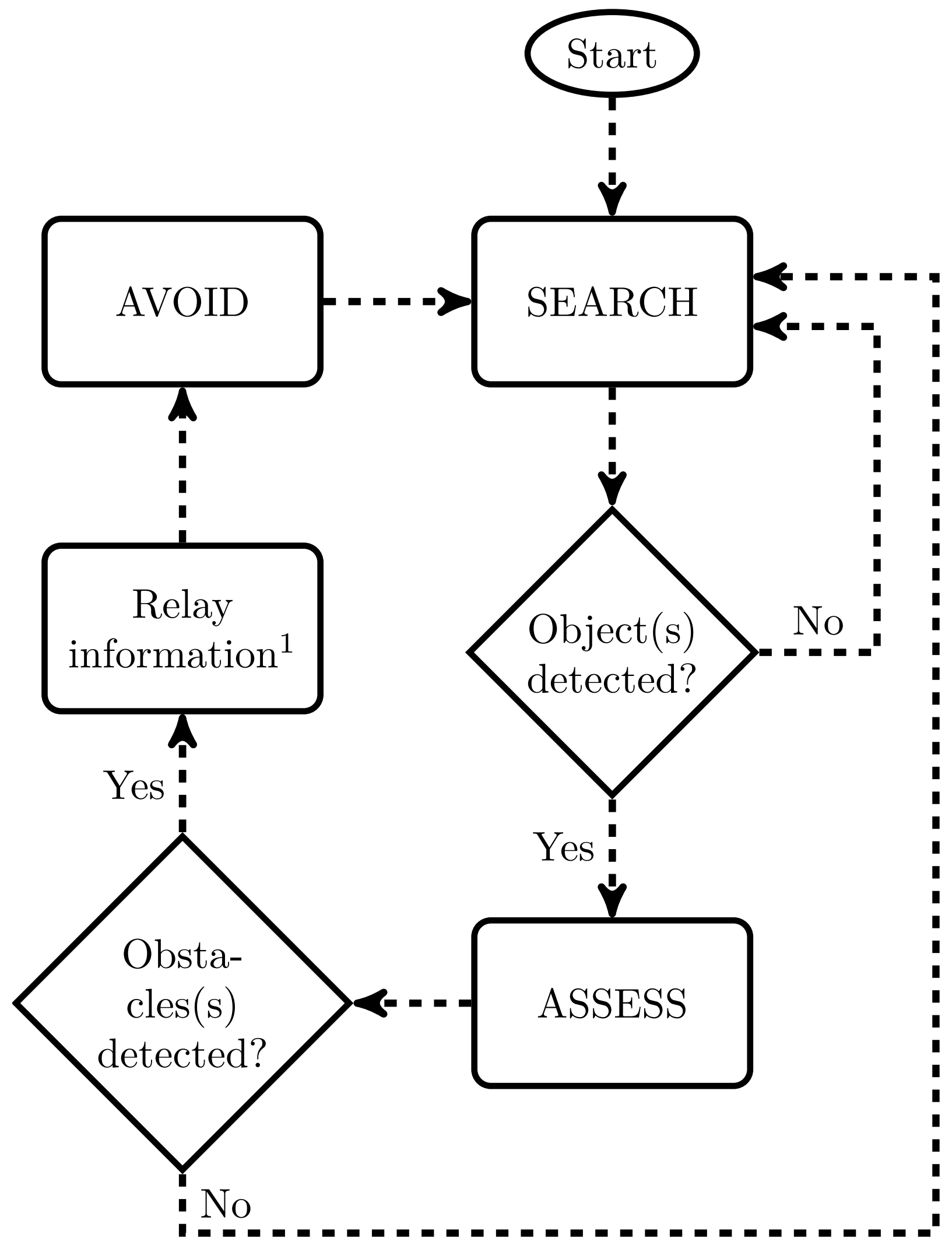
Obstacle Avoidance

- TI AWR 1443Boost
- Serial communication API
- 15°, 20-meter range scanner
- Dynamically reconfigurable scanning parameters

Algorithm

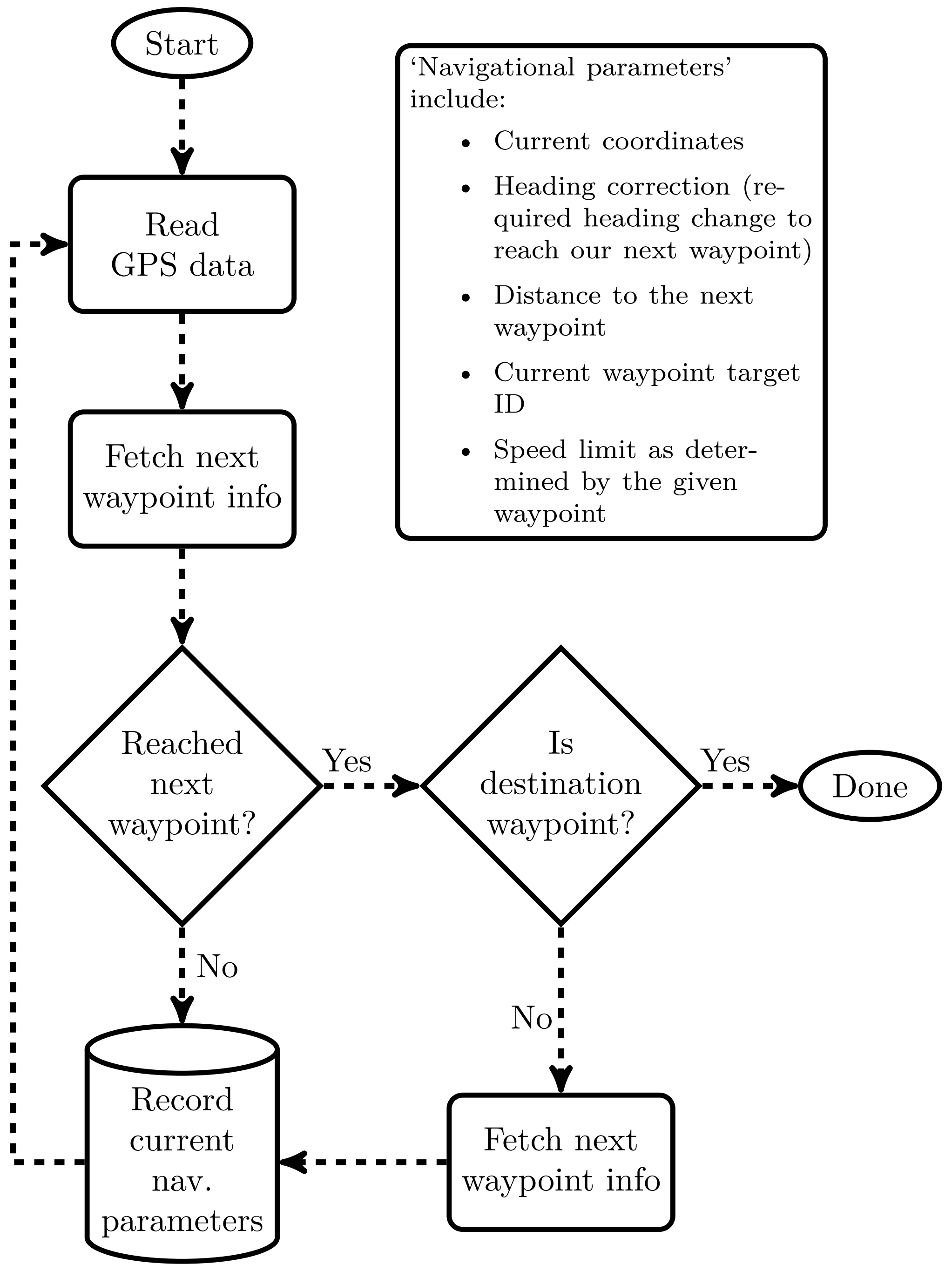

Start
AVOID
SEARCH
Relay information[1]
Object(s) detected?
No
Yes
Yes
Obsta-cles(s) detected?
ASSESS
No

1. Moving obstacle data used by AVOID state, stationary data used by Path system

Navigation

- EMLID RTK+ high precision GPS
- Centimeter-level coordinate accuracy
- ASCII serial logging capabilities provided easy interfacing

Algorithm


Start
Read GPS data
Fetch next waypoint info
Reached next waypoint?
Yes
Is destination waypoint?
Yes
Done
No
No
Record current nav. parameters
Fetch next waypoint info

'Navigational parameters' include:

- Current coordinates
- Heading correction (required heading change to reach our next waypoint)
- Distance to the next waypoint
- Current waypoint target ID
- Speed limit as determined by the given waypoint

Result: total costs

Our autonomous golf cart solution: $3572
In comparison, a single LIDAR costs $319 - $75,000

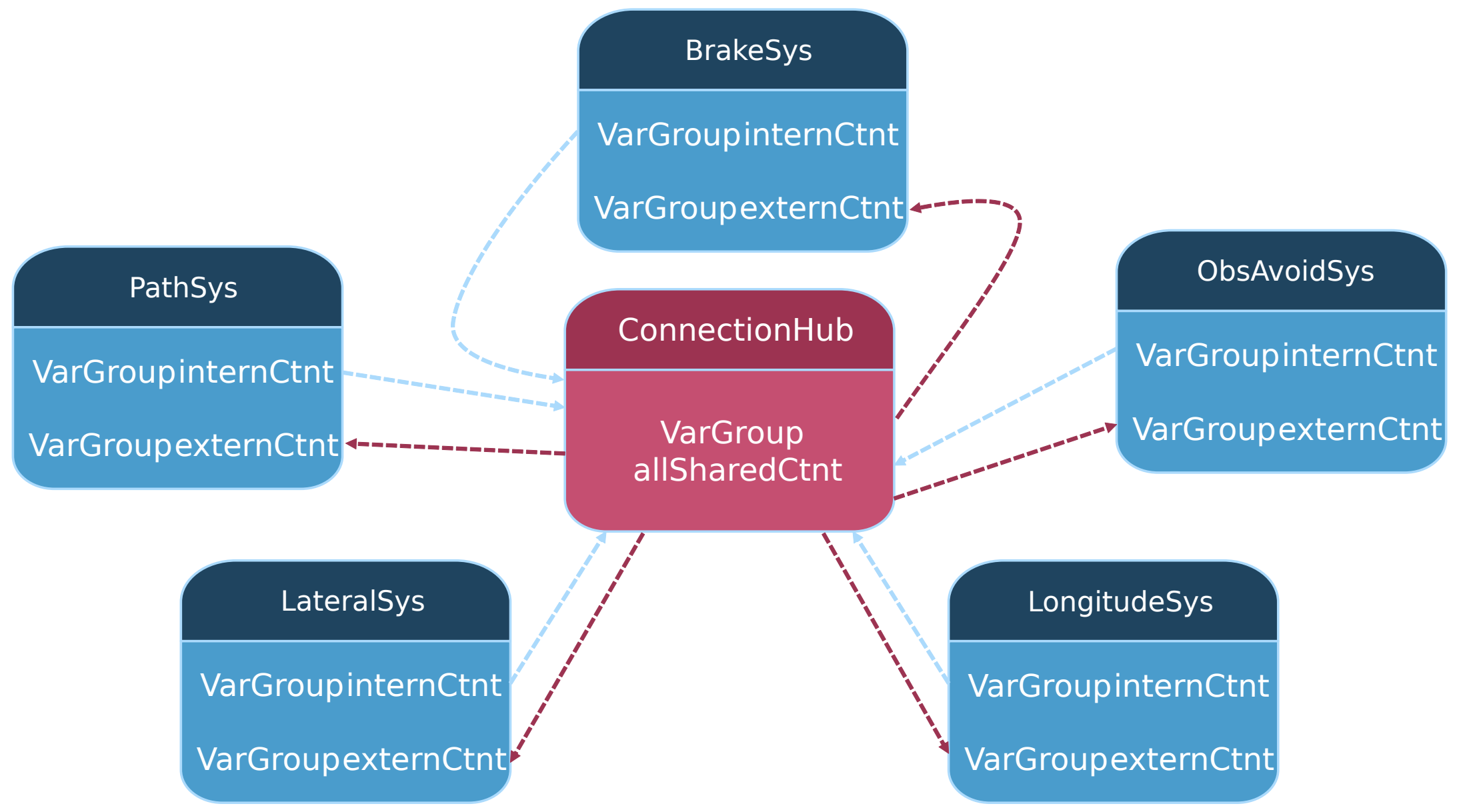
Suggested Improvements

- Dynamic routing
- Improvements to GPS setup
- Improved radar hardware
- Kalman filtering for predicting obstacle paths

Interface Methodology

A primary goal was to create the software to interface between vehicle subsystems. Sensors require separate update rates and perform their own operations, but must communicate to share relevant data. For instance, the lateral control system may be responsible for sending steering instructions to the motor controller, but each heading correction originates in the path system.

Connecting every module to every other module to allow data communication would be time consuming and error prone. Instead, we developed a central system that receives data updates from *all* modules, and pushes updates to each system as the requests are made, as shown below.


BrakeSys
VarGroupinternCtnt
VarGroupexternCtnt
PathSys
VarGroupinternCtnt
VarGroupexternCtnt
ConnectionHub
VarGroup allSharedCtnt
ObsAvoidSys
VarGroupinternCtnt
VarGroupexternCtnt
LateralSys
VarGroupinternCtnt
VarGroupexternCtnt
LongitudeSys
VarGroupinternCtnt
VarGroupexternCtnt

Conclusion

With the demonstrated effectiveness of our algorithms based on minimal sensor needs, we have shown that using RADAR along with GPS could easily provide the low-cost autonomy solution we envisioned.

The TI RADAR we purchased lacked the necessary support packages to provide a robust collision detection demonstration, so we verified the algorithm through simulations. We can accurately classify an object as stationary or moving based on radar data. Furthermore, we determined the time to intersection and sent avoidance instructions accordingly. These simulations validate our obstacle avoidance algorithm.

The GPS sensor was more user-friendly. Test runs indicate its accuracy is enough to guide the car with deviations only on the order of <0.1 meters. Next year's team will be able to build on the algorithms we have developed to integrate high level functionality such as dynamic routing and improved error handling.

References

[1] Ernst D Dickmanns and Alfred Zapp. "Autonomous high speed road vehicle guidance by computer vision". In: *IFAC Proceedings Volumes* 20.5 (1987), pp. 221–226.

[2] K Heineke et al. *Self-driving car technology: When will the robots hit the road?* May 2017.

[3] U. Ozguner et al. "The OSU Demo '97 vehicle". In: *Proceedings of Conference on Intelligent Transportation Systems*. Nov. 1997, pp. 502–507.