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1. What do we want to address with this project?

Self-driving cars are no longer just the stuff of science-fiction; driverless vehicles are already on the roads. As of December, the Ohio Turnpike, not far from Oberlin, has been used for testing autonomous trucks. So far, autonomous vehicles are only allowed on the road if they have a person in the driver’s seat, ready to take over at a moment’s notice. However, the dream of purely autonomous vehicles, capable of driving without any human interference, is not far from reality. That does not mean that all human-driven cars will suddenly disappear from the roads. There will be a transition time - whether it be months, years, or even decades - where human drivers and autonomous vehicles share the roads. To be viable during this transition period, self-driving cars must be able to accommodate human drivers and their many idiosyncrasies. Already, self-driving cars have gotten into accidents with human drivers because they could not adapt to human drivers not following traffic laws exactly. This is an especially big problem because a lot of the appeal of self-driving cars comes from the hope that they will be safer than human drivers - as it stands driving is dangerous.

We intend to create a multi-agent model to address the problems autonomous vehicles face when dealing with human drivers. In particular, we intend to evaluate the effect of the ratio of human-driven to autonomous cars and learning, and communication in autonomous cars on the number of accidents in a model system. Right now, only a few autonomous vehicles are on roads dominated by human drivers. As it is, there is no way to know how autonomous vehicles will fare when they make up a larger proportion of the drivers on the road. They may be safer because most of the cars they interact with will be other autonomous cars, but they may also be more dangerous when they do encounter human drivers because they may not be as accustomed to them.

Autonomous vehicles are so promising in part because they can do so many things that human drivers cannot. They do not have blind spots, can communicate efficiently and without distraction, and are capable of highly specialized learning. Human drivers are limited to hand gestures and using signal lights to indicate their intentions to nearby drivers. Most of these aren’t automatic: the driver must decide when to signal and how, and they inevitably do so in an inconsistent and inaccurate manner. Autonomous vehicles, on the other hand, are capable of communicating their intentions clearly to all of their neighbors. However, in a world of both autonomous vehicles and human drivers, not all of an autonomous vehicle’s neighbors will receive their signals, so the vehicle would have to be capable of interacting flexibly with its autonomous and human neighbors.

Humans are capable of learning, but we are generalists; everyone has to be able to fully function in society, not only through basic functions like sensation, but also through socializing, holding a job, cooking, etc. Autonomous vehicles, on the other hand, don’t have to be generalists. Instead, they must only specialize in is driving. That gives them the opportunity to learn more about driving than any human has the capacity to in their busy life. Machine learning has enabled artificial experts to notice things that human experts have missed across a wide variety of fields from medicine to board games. Autonomous cars may be able to learn to predict the actions of their human and autonomous neighbors to minimize the number of accidents. We hope to model a means by which autonomous cars can learn to adapt to the driving patterns of the human drivers with whom they share the road.

2. Literature Review

More so than any other corporation, Google has led the charge to develop and test artificially intelligent vehicles. Due to the high number of traffic deaths each year in the United States and other similar countries, Google sees a strong imperative to develop this technology to improve roadway safety. However, even as more and more cars gain certain artificially intelligent features, there is much work to be done before the technology will be commercially available: for instance, the ability to adapt to diverse road and weather conditions and a lack of detailed maps for most roads. Google’s driving algorithm functions on the basis of four main questions the agent must answer: “Where am I? What's around me? What will they do? What will I do?”

Self-driving cars have not been accident-free. Their main issue is that they follow traffic rules too closely in situations in which their human counterparts do not. For instance, it is very difficult to merge into a chaotic, speeding line of cars while maintaining a legal speed the entire time. In this way, Google’s fleet of self-driving vehicles has accumulated an accident rate of about double the national rate. Almost none of these accidents were the fault of the driverless car, but they bring up an interesting conundrum: ought programmers teach their vehicles to break the law from time to time to better deal with erratic human drivers?

It is also useful to consider probabilistic-based algorithms when programming a driverless vehicle. We can never assume that we are fully correct about our place in the world (emission probability) and neither can we assume that we have complete and correct knowledge about the location and behavior of other agents in the world (transition probability). Therefore, it is useful to track the probability of certain states existing, but never to assume the infallibility of detected information. The uncertainty here is another cause of accidents, perhaps more so in the human agents who will have a more restricted picture of the world as compared to the improved visibility of agents.

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3. A proposed solution intended to solve the identified problem

The Simulation

We will create a simulation to model a system of cars with artificially-intelligent behavior and cars with more human-like behavior. Our idea is to create a GUI with, say, 4 roads that stretch from the left to the right side of the screen. Each road will have lanes and entrances and exits to merge onto and leave the ramp. The roads will be connected, meaning that if a car leaves the screen on the top-most road on the right it will reenter the screen on the second to the top road on the left. Cars will enter randomly from an entrance and then be assigned a random exit, which will force them to navigate the flow of traffic and make lane changes.

There will be distinct differences in the behaviors of human drivers and automated drivers. Human drivers will exhibit some poor driving behaviors such as tailgating, speeding, and sudden lane switching. Automated cars will behave consistently and potentially be able to communicate with each other and learn. Automated cars will follow traffic laws closely and try to predict human behavior.

Some of the variables we will consider include the ratio of automated cars to human cars, number of vehicles on the road, learning vs. not learning in automated cars, communication vs. no communication amongst automated cars, and how aggressive human drivers are. The ratio of automated to human cars, as well as total number of cars, could possibly be implemented as a changeable variable. That way we can experiment with different outcomes and see if there is an ideal ratio. Learning ability in automated cars is important to consider, as that could be a key distinguishing factor between automated cars and human drivers. If our cars don’t implement learning, then we will have to make sure their prediction and behavior is well modeled to prevent accidents with humans. Communication among automated cars could also be important to minimizing accidents between two automated cars. With communication, automated on automated collisions may virtually never happen, whereas they’re much more likely without communication. Lastly, we need to consider if all human drivers are equally aggressive, and if so, how aggressive are they. If we create them to be too aggressive, then there may be no way to prevent accidents.

Different possible algorithms

Driving is a complex problem; it is very difficult to plan in advance exactly what a driver should do at every given moment. As a result, our best option for implementing both human-driven and autonomous cars may be to use a domain general learning or decision making algorithm. We could use Markov Decision Processes to plan each step of a given vehicle’s path, either in advance or while they are driving. However, it will be difficult to take other agents into account, especially if we do offline planning. Reinforcement learning is somewhat more flexible, though it requires many iterations of training in advance to enable the vehicles to learn to drive to their destination, let alone evade accidents. Furthermore, we want to distinguish between the behavior of human and non-human drivers in particular ways. Though we may be able to accomplish that by adjusting the reinforcement function, parameters, or what the cars are “capable” of doing. If, instead, we decide to code the agents’ behaviors by hand, we may run into situations we could not have anticipated, even in the simple model environment, however we may be able to differentiate between human-driven and autonomous cars more effectively.

4. An outline and description of the project components necessary to complete the project

The main components of our project will be the human car simulations, the driverless car simulation, and the GUI to represent it all visually. We will first want to create one type of driver simulation and create the environment that it will drive in. Then, we can create the GUI in which it will be represented, so we can make sure it is working as intended. Then, we would create the other type of driver and adjust the behavior of each driver in order to work as intended.

5. A description of any existing progress towards completing the project

Our progress to this point includes the literature review, the plan of implementation, the schedule for completion, and other information listed in our proposal. We have not yet started coding, but will begin it following spring break. We have agreed to work in Java.

6. A remaining timeline for the successful completion of the project

In the first week after break (March 27th through April 3rd) we will present our proposal and begin deciding how to implement our project.

In the following week (April 3rd through April 10th) we will figure out exactly how we want to implement our project, including which algorithm to use for the agents.

The next two weeks (April 10th through April 24th) will be spent implementing the project; implementing the agents and the environment. If we have time we will begin implementing the GUI.

After that we will finish the GUI, clean up our implementation and run experiments to present during the week of May 1st.

We will work on the write up of our presentation during the following week to hand it in on May 11th.