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Control and Parameter Estimation Problems of Autonomous Transport Robots

Final Project

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Preface

Autonomous vehicle technology offers the possibility of fundamentally changing transportation. Equipping cars and light vehicles with this technology will likely reduce crashes, energy consumption, and pollution and reduce the costs of congestion, as well.

This technology is most easily conceptualized using a five-part continuum suggested by the National Highway Traffic Safety Administration (NHTSA), with different benefits of the technology realized at different levels of automation:

- **Level 0:** The human driver is in complete control of all functions of the car.
- **Level 1:** One function is automated.
- **Level 2:** More than one function is automated at the same time (e.g., steering and acceleration), but the driver must remain constantly attentive.
- **Level 3:** The driving functions are sufficiently automated that the driver can safely engage in other activities.
- **Level 4:** The car can drive itself without a human driver.

Careful policymaking will be necessary to maximize the social benefits that this technology will enable, while minimizing the disadvantages[1].

1 Introduction to Autonomous Transport Robots

1.1 History of transportation

Since the early days of the human civilization, one of the most common problem has been the transportation. The first major development was the domestication of animals what made it possible to transport more and heavier loads or humans themselves in order to achieve greater speed and duration. The next substantial invention was the wheel which increased the efficiency of animal transport introducing the concept of vehicles. Until the Industrial Revolution, the water transport facilities proved to be the most effective way. With the development of the combustion engines and automobiles around the end of the 19st century, road transport became competitive again. Today trucks transport cargos over thousands of miles, but light items are still being carried in wheelbarrows or trailers attached to more compact vehicles.

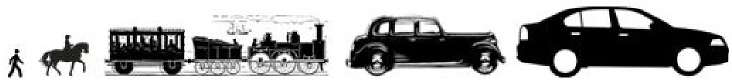

Figure 1: Evolution of Transportation

One of the most dominant development tendency in almost every field of the industry is the automation of processes and procedures. Automation means the reduction of human intervention in the operation of machines. The benefit of automation include labor savings, savings in electricity costs, savings in material costs, and improvements to quality, accuracy and precision. The conventional ways of transporting could be appropriate for most of the cases but not in those when repeated passages to specific locations in small distances have to be taken.

1.2 Autonomous vehicles

An autonomous car which is also known as a self-driving car or a driverless car, is a vehicle that can operate without a certain amount of human control using its sensors to monitor the informations coming from the environment. Great variety of techniques are used to detect the surroundings, such as radar, laser light, GPS, odometry and computer vision. The collected information provides a decent input to the control system which is the soul of the self-driving cars. Several control problems have to be solved continuously during driving on the roads, such as identifying obstacles and avoiding them, following transportation rules or navigating along a predefined path.

Autonomous vehicle technology offers the possibility of fundamentally changing transportation. Equipping cars and light vehicles with this technology will likely reduce traffic collisions, thus the resulting injuries and the related costs including less need for insurance. Autonomous cars are predicted to increase the traffic flow and the mobility of citizens. Reduced traffic congestion and the improvements in traffic flow due to widespread use of autonomous cars will also translate into better fuel efficiency and reduced pollution in cities.

In spite of the various benefits also several issues exist such as technology challenges, disputes concerning liability, customer concerns about the safety of driverless cars, risk of loss of privacy and security concerns against hackers, risk of negative effects on the society and economy and finally moral issues when car's software is forced to choose between multiple harmful alternatives during an inevitable accident.

The autonomous driving technology can be most easily conceptualized using a five-part continuum suggested by the National Highway Traffic Safety Administration (NHTSA), with different benefits of the technology realized at different levels of automation:

- **Level 0:** The human driver is in complete control of all functions of the car.
- **Level 1:** One function is automated.
- **Level 2:** More than one function is automated at the same time (e.g., steering and acceleration), but the driver must remain constantly attentive.
- **Level 3:** The driving functions are sufficiently automated that the driver can safely engage in other activities.
- **Level 4:** The car can drive itself without a human driver.[1]

From engineering point of view, the most important issues are the technological challenges, i.e. how to design a driverless vehicle system which is capable of handling vehicle's performance like human in all possible conditions. An autonomous vehicle is a combination of sensors and actuators, sophisticated algorithms executed as a software on a processor. The sensory system can be classified into three different classes:

- **Navigation and guidance:** the system which determines – where you are, where you want to go, and how do you get there. In the most common applications different techniques such as GPS, compass and dead reckoning are used.
- **Driving and Safety:** Directing the vehicle and making sure that vehicle follows the rules of the road. The autonomous car must be able to see and interpret what is in front of it when it is going forward (and behind when in reverse). It is also necessary to see what is on either side, in other words, it needs a 360° view. A set of video cameras is an obvious choice by which location of lanes and surrounding objects or markers on the road can determined.
- **Performance:** managing car's internal system. Several application specific, unique circuit boards and subsystems are added to a conventional vehicle to provide the functions needed for autonomous operation. Much of the system-level operation involves measuring and managing the power requirements to control power, overall consumption, and thermal dissipation.

The concept of driverless cars made a lot of attention over the past ten years. Generally speaking it can be said that one of the most determining development directions in the automotive industry are related to automated solutions. Many people still do not believe that there could be such a possibility with fully driverless vehicles due to the fact that there so many parameters in the driving function that have to be controlled simultaneously and continuously and even a single failure could cause catastrophy. Nowadays after a lot of research and experiments self-driving cars can be seen as a reality, or at least close future. Still, there are many challenges in designing a fully autonomous system for a self-driving car. The challenges of driverless cars can be sorted into five groups:

- **Road conditions:** Road conditions can be unpredictable and varying, i.e. in some cases they are smooth and well-marked while in other cases there are no lane marking. On some roads there can be potholes, in case of mountainous and tunnel roads the visibility of external signals for direction are poor.

- **Weather conditions:** It can be sunny and clear or rainy and stormy weather. Autonomous cars have to work in all weather conditions, there is no scope for any failure.

- ***Traffic conditions:*** *Autonomous cars would have to get onto the road where they would have to drive in all sorts of traffic conditions. They would have to drive with other autonomous cars on the road, and at the same time, there would also be a lot of humans. Wherever humans are involved, there are involved a lot of emotions. Traffic could be highly moderated and self-regulated. But often there are cases where people may be breaking traffic rules. An object may turn up in unexpected conditions. In the case of dense traffic, even the movement of few cms per minute does matter. One can't wait endlessly for traffic to automatically clear and have some precondition to start moving. If more of such cars on the road are waiting for traffic to get cleared, ultimately that may result in a traffic deadlock.*

- ***Accident Liability:*** *The most important aspect of autonomous cars is accidents liability. Who is liable for accidents caused by a self-driving car? In the case of autonomous cars, the software will be the main component that will drive the car and will make all the important decisions. While the initial designs have a person physically placed behind the steering wheel, newer designs showcased by Google, do not have a dashboard and a steering wheel! In such designs, where the car does not have any controls like a steering wheel, a brake pedal, an accelerator pedal, how is the person in the car supposed to control the car in case of an untoward incident? Additionally, due to the nature of autonomous cars, the occupants will mostly be in a relaxed state and may not be paying close attention to the traffic conditions. In situations where their attention is needed, by the time they need to act, it may be too late to avert the situation.*

- ***Radar Interference:*** *Autonomous cars use lasers and radar for navigation. The lasers are mounted on roof top while the sensors are mounted on the body of the vehicle. The principle of radar works by detecting reflections of radio waves from surrounding objects. When on the road, a car will continuously emit radio frequency waves, which get reflected from the surrounding cars and other objects near the road. The time taken for the reflection is measured to calculate the distance between the car and the object. Appropriate action is then taken based on the radar readings. The principle of radar works by detecting reflections of radio waves from surrounding objects. When on the road, a car will continuously emit radio frequency waves, which get reflected from the surrounding cars and other objects near the road. The time taken for the reflection is measured to calculate the distance between the car and the object. Appropriate action is then taken based on the radar readings. When this technology is used for hundreds of vehicles on the road, will a car be able to distinguish between its own (reflected) signal and the signal (reflected or transmitted) from another vehicle? Even if multiple radio frequencies are available for radar, this frequency range is unlikely to be insufficient for all the vehicles manufactured. Challenges are many even today for rolling out the autonomous cars on the road. But so is the determination of our scientists, engineers and problem solvers from various disciplines. The collective effort of the industry will definitely make the autonomous car on the road a reality one day, and the benefits will be huge. Not only it will save fuel, encourage efficient transportation and shared services, but will also help in saving many lives that are regularly lost in road accidents.*

1.3 Application of autonomous transport robots

One of the latest trends in technology is to create such driverless robots that can help people in their everyday life, i.e. bringing any kind of products to customers. A company called Starship launched a several self-driving robotic vehicles on the streets of Washington, D.C. that can transport food and other small items to customers ordering via app. The robotic vehicles move themeselves along sidewalks using camera and tracking

Figure 2: Starship Technologies

technology to avoid any obstacle and its location can be tracked from the distance in order to know the time of arrival. The six-wheeled electric machine sits about a half-meter high having a lockable cargo bay to carry food products up to nine kilograms in weight.[3]

A company called SMP Robotics made automated guided vehicles that can remove grass clippings and fallen leaves or construct garbage collection in a garden.

Figure 3: SMP Robotics

These small-sized mobile robots have a trailer attached to the back. They are powered by electrical engines, thus noise and smell emission is minimized which allow for operation around people. The built-in accumulators stores the needed energy and can last for several days of cyclical operation. Two ways of route following method is available. The first option is to choose a root in advance with the help of the attached PC tablet. The second way is to set the robot in its 'follow me' algorithm whereby it is going to follow the operator and learn the path. The collected goods on the trailer can be unloaded automatically using a mechanism without any human intervention. The trailer can be fitted with a water tank which can be used for watering of grass and other plants, furthermore automatic water refill algorithm is implemented. This kind of automatic self-moving watering system suits really well such occasions when a fixed irrigation systems are not worth being built due to climate characteristics.[2]

A firm named NEOBOTIX made autonomous transport system for daily use in industrial applications. The robots are equipped with laser scanners that permanently detect landmarks and obstacles what allows the robot to react dynamically to unexpected changes of their surrounding, i.e. to safely operate between human and other moving objects. This flexibility makes them suited for dynamic transportation tasks with frequent changes. For instance, they can complement roller or belt conveyors and take parts to machines or workplaces that are not connected to the conveyor system. [4]

Figure 4: MT-400

Figure 5: MT-500

Possible applications are taking parts to and from workplaces, transporting in direct interaction with humans or dynamic picking of parts for later assembly

BMW logistics also uses autonomous transport robots similarly in industrial environment. The well-known car manufacturer has been working hard to reduce emissions in all steps of the manufacturing process of a car, not only in the final product. This application shows really well that the autonomous developments in the automotive industry is not just about the autonomous driving on the roads but the manufacturing processes as well. Smart Transport Robots (STR) transport components through logistics at the Wackersdorf plant. They measures the distance to wireless transmitters which are located at in the logistics hall to calculate its exact position and route. Using sensors to identify and react to critical situations, it is able to share the route with humans and other vehicles. [5]

Figure 6: BMW: Smart Transport Robots

Another interesting field of application of transportation robots is the military. By putting humans to this work they are often exposed to a risk that could be avoided.The Autonomous Platform Demonstrator is a military transportation robot developed by the U.S. It has a hybrid-electric drive train with six in-hub electric motors powered by li-ion batteries charged using an on-board diesel generator. From control point of view it can be controlled in real-time by a soldier or it can operate autonomously. Autonomously it can operate at speeds up to 50 mph. It can travel along a GPS way point route and avoid obstacles in its way. [6]

Figure 7: Military transportation robot: APD

2 Mobile Robots

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