

Automated Snow Plow

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Abstract

In North Dakota alone, the North Dakota Department of Transportation is responsible for plowing snow on 17,000 miles of roads during the winter. These operations take over 350 snow plows and with even more crew to operate and maintain them. The NDDOT states that the crews stop operations in heavy snow which can cause delays in clearing the roads which cause unsafe travel conditions. Recent advances in driverless vehicles have enabled large vehicles to possibly drive in deteriorating conditions. The Tesla semi has multiple sensor suites that create a digital picture. It is equipped with an enhanced autopilot that allows the truck to stay in its lane and brake for emergency situations. These advances open the door to driverless plows that can be activated in heavy snow storms to clear the roads without endangering human lives or slowing the process of clearing the roads. Studying new sensor technology such as LIDAR and looking into driverless technology, these systems could improve efficiency and help reduce the danger of operating snow plows in dangerous weather where crews stop operating due to white out conditions. With GPS and sensor like LIDAR, an autonomous plow can potentially work through the dangerous weather instead of allowing the snow to accumulate dangerously.

Keywords: snow plow, autonomous, driverless, sensor suite, road conditions

Introduction

In between the years 1981 and 2010, North Dakota averaged approximately 50 inches of snow fall. (Current Results, 2018) This snow fall was over the course of winter time that can last for as many as six months. During these snow falls, the highways and roads can shut down due to the heavy snow and white out conditions. To clear these roads, snow plow crews must drive in the harsh weather to clear the way for regular vehicles to travel. This can take time as the crews are required to cover over 17,000 miles of highways and roads. (NDDOT, 2018) When the weather begins to deteriorate, the snow plow crews will stop due to low visibility because it may be too dangerous to operate. (NDDOT, 2018) This delay in clearing the roads can leave motorists with closed highways or lengthy commutes due to snow covered roads.

A solution to this problem lies in the recent developments of autonomous vehicles such as the Tesla Semi. This semi-truck comes with multiple sensors to include a LIDAR sensor and cameras that create a 360-degree view around the vehicle. (Gene, 2017) This type of sensor suite allows the enhanced autopilot to control the large truck on the highway and maintain a safe driving condition while moving across the country. (Tesla, n.d.) Another example of a self-driving vehicle with sensors is Stanford Universities DARPA Grand Challenge vehicle. This vehicle is a Toureg R5 that is equipped with 5 laser range finders pointed in all directions, a color camera for long range perception, two forward mounted Radars, and GPS/IMU units onboard for location accuracy. (Montemerlo et al., 2006)

The sensor suite on these two examples show that technology in AI and machine learning along with hardware technology has come along enough to utilize them in a conventional way. By importing this hardware with lessons learned, Autonomous Snow Plows (ASP) have the potential to increase productivity and reduce safety concerns for operations in dangerous conditions. The ability to remotely monitor these vehicles while they autonomously operate in the zero-visibility weather would allow for only a hand full of workers to deploy multiple vehicles while monitoring the health and status of the plow. This would allow for the ASP to operate at any time during the day or night and in any weather to clear the roads for the motorists that will use them once they are clear. This would fill the gaps that are left when the crews stop working due to unfavorable conditions.

Literature Review

The literature review for this topic is focused on the sensor capabilities that are available. The biggest requirement for this system is the sensor suite that allows it to see outside and determine its surroundings. Software is another area in which the ASP is required to have for safe and efficient operations. Another portion of this literature review is based on the current technology used in driverless cars such as the winners of the DARPA Challenge. The requirements for snow plows are also covered to determine the viability of the ASP vehicle.

In the Q & A titled “Where’s my snow plow?” by Robert Thomas in 2015 from the Washington post, he explained that snow crews have jurisdictions in which priorities are set for which areas would be cleared first in the event of snow fall. This includes prestaging the snow plows in different areas that are higher priority so that they can immediately start clearing the roads and highways when the weather hits. Robert explains that plows these days are tracked by their headquarters to monitor their progress as they flow along their route. (Thomas, 2015) This Q & A is relevant to the ASP from the perspective of Washington D.C. who received enough snow to

cause issues for their residents. The Department of Transportation (DOT) for the area was utilizing a plan to clear the roads, however, the traffic in the area and the continuous weather caused delays in clearing the neighborhoods and highways.

In a paper written by Lasky et al (1999), they discuss the Advanced Vehicle Control and Safety System (AVCSS). This system is built into the snow plows to give lane positioning warning and lane departure warnings to the driver (Laskey et al, 1999). A lane positioning system would benefit and an ASP while running operations in poor visibility. The paper explains that snow plows are expected to operate in the worst weather conditions for their respective area to include completely snow covered roads, areas with very low traction, and complete visual whiteout (Laskey et al, 1999). The AVCSS also includes forward and side collision warning systems for the driver to help avoid wrecks during these operations (Laskey et al, 1999). The AVCSS include forward radar and magnetometers for sensing the road and using known areas to determine its location on the road (Laskey et al, 1999).

In a patent numbered 5,219,036 titled “Navigation system and process for guiding unmanned industrial trucks without guide wire” by Schwager et al, 1993, there is an explanation of a system that would allow for large industrial work trucks to operate without a driver in a work setting. This patent explains the possibility to put small markers on the road in which the truck virtually knows where these markers are location and uses them to drive along a path (Schwager, 1993). This is a great example of a possible navigational system for the ASP. If the roads in which the ASP would operate were marked with some type of magnetic marker, the ASP could use it to figure out exactly where the road is and combine this type of system to GPS to accurately measure its location on the road. This type of accuracy would be needed to avoid crashing into parked vehicles or other obstacles on the sides of the road during operations. The patent explains that an onboard computer would measure its speed and distance between markers to know exactly where it is located on the road and how much further it can expect to travel before encountering a curve or turn to move to the next road (Schwager, 1993).

In a paper titled “Vehicle Control of Unmanned Dump Trucks” by Okawa et al (1992), there is a description of using unmanned systems to drive dump trucks along predetermined paths using memory onboard the vehicle. This is relevant to the ASP due to the fact that the ASP would be driving the same route during every snow storm to ensure the roads are cleared appropriately. Okawa explains that a person can get into the vehicle and drive the path that is determined to be the most efficient path for the ASP to drive. As the driver is driving the truck, the onboard computer watches the path and location and records it. This path can then be driven by the truck by itself. This technology is older, however, if combining this type of technology with GPS systems, it would allow a vehicle like the ASP to drive predetermined routes without concern of driving anywhere it has never seen before.

The final paper for literature review is the paper titled “Winning the DARPA Grand Challenge with an AI Robot” by Montemerlo et al (2006). This is an extremely relevant source of literature due to the fact that this team was the winner of the DARPA grand challenge where only a few vehicles were able to complete a 132 mile course (Montemerlo et al, 2006). The challenge was completed using basic sensors, however, their focus for the system was software. This is a great example of how we can use existing snow plows and upgrade them with sensors that are available today, and use software to ensure they can operate safely while performing their tasks.

The vehicle that was entered was called Stanley. Stanley was equipped with five SICK laser range finders, a long range color camera, and two forward-pointed antennae for RADAR (Montemerlo et al, 2006). The system all included two GPS antenna and an Inertial Measurement Unit (IMU) in the trunk (Montemerlo et al, 2006). The computer and processors were located in the truck area of the vehicle. Stanley was able to drive through the 132 mile course at approximately 38 mph. This is relevant to the ASP in that Stanley used software along with sensors to determine the best course of action and which areas to travel. The ASP would utilize an almost identical set up that Stanley used for the DARPA course. These sensors along with the software allowed Stanley to work itself through obstacles while thinking on its own. An ASP would need to travel along the road and know when to drop the plow and remove the snow. This is a great indicator that software may be the underlying key to the creation of an autonomous snow plow.

Design Overview

The ASP would start with a snow plow vehicle that exist today. The intent of this technology is to allow for the transformation of previously purchased snow plows to be converted to an ASP. The design of the ASP would begin retrofitting the vehicle with parts that would allow it to be driven by a computer. Emphasis would be put on the sensors. This would be the eyes of the ASP while it is driving in poor conditions. The next item would be the computer system. Computers today are much smaller than they were in 2006. The DARPA challenge showed large computers required to ingest and crunch the variables required to complete the challenge. Most of the technology then has been upgraded to fit in the palm of our hands called cell phones. Another critical item to be installed on the ASP is GPS sensors. The system would need to be able to locate itself on the highway.

Once the snow plow has been given the appropriate equipment to operate autonomously, the software would need to be created and loaded into the computer. The software would be the key component to ensuring the success of the ASP. The sensors on this vehicle would not be very useful without a solid foundation of software to utilize and fuse the data. A virtual world needs to

be created in the brain of the computer using the sensors. This would allow the machine learning of the computers to determine when to drop the plow and where to physically drive on the road to clear the snow and avoid obstacles

Sensors

The main sensor for this type of vehicle would be Light Detection and Ranging (LIDAR). LIDAR gives the ability to have remote sensing using light pulsed from the sensor (NOAA, 2012) LIDAR consists of a laser, scanner, and GPS receiver. LIDAR comes with two types of sensing in which one of them allows the sensor to see through water. This is relevant because it would make it possible to try and look through the snow as it is falling to draw a clear and visible picture of the world around the ASP. Utilizing a system like LIDAR would help the ASP determine its location and avoid obstacles while looking for snow to plow in the process.

The LIDAR sensor would also be combined with millimeter wave detection. Millimeter wave radar is being used in many vehicles today for parking assistance. This type of radar can also be used for looking forward to see obstacles that may cause a collision while driving. Some adaptive cruise control features from millimeter wave radar is Adaptive cruise control which allows the vehicle to see 200 meters in front of it for other vehicles on the highway (Manz, n.d.). This would work well with the ASP to ensure the plow is avoiding collision with other vehicles on the road.

Design Decisions

Design decisions for this system are focused on safety and heavy equipment. The ASP would operate in the same environment as humans. The system would need to work alongside other drivers while operating a heavy vehicle that can be very dangerous if not utilized appropriately. The primary concern for the design would be the navigation system. The LIDAR sensors along with the GPS system would give the ASP a very accurate understanding of its location in space. The LIDAR sensor would also give the ASP a clear picture of the surrounding vehicles during operations. Great care would need to be taken to ensure the computer system is programmed to keep a safe distance from human drivers.

The heavy equipment aspect would need to be understood and designed appropriately. The ASP would be operating in conditions that are well below freezing due to the nature of their job. This type of wear and tear on a system would require the vehicle to have strong protection for the computing systems. There would also need to be great protection of the sensors during heavy operations. If the sensors are damaged or are covered from the snow or bad weather, this can

cause the system to lack the required capability to determine where it is physically located on the road. Secure coverings with clear cases would solve these concerns by giving them a clear view of the road while keeping them protected during operations.

Another design decision for this system would be remote access and monitoring by an operator at the headquarters. A man out of the loop but monitoring is a compromise that should be made to ensure that these vehicles are being watched during operations. It is possible for them to get into a situation that the computer could not predict. These type of situations could be seen and a remote command can be executed by the operator to ensure the ASP is making the right moves to safely and efficiently work through their tasking. This type of design would require an extra communications link to the vehicle during its operations.

Design Limitations

Design limitations for the ASP would be largely focused on the inability to use cameras to look outside in whiteout conditions. The system is intended to operate in harsh weather due to manned crews stopping for safety reasons. If the sensors are incapable of detecting the world around them, they would not function correctly and therefore would stop working or they could feed inaccurate data to the computer which can cause unsafe operations.

The limitation of the lack of a man in the loop needs to be understood and accounted for. If the vehicle doesn't have a driver, there is no way for a human to intervene in the ASP gets into a unique situation that may be difficult to determine the best course of action. A great example of this is the DARPA challenge vehicles that either got stuck or crashed into other vehicles. One of the vehicles was stuck in a berm and burned its tires out while trying to recover itself.

If the ASP is put into a situation in which a human would need to intervene, a design must be put into the software to ensure that it simply stops on the road or pulls over to allow crews to approach it and fix the issue. Another option for this limitation is the ability to remotely operate the ASP. A link would already be implanted into the system to allow operators to monitor the plow during its scheduled operations. Giving the ability to remotely drive would allow the operator who is monitoring the system to intervene if the ASP is acting abnormal.

Conclusion

Human drivers are incapable of operating motor vehicles safely in poor weather conditions such as whiteout from snow. These operations are required for normal drivers to operate on roads and highways. If the operators of the snow plows stop working due to poor weather, the drivers will have to make the commute with snow covering their neighborhoods and highways. This can lead to unsafe conditions and stranded drivers across a recently snow covered area.

The innovation of today's technology has allowed for upgraded computer systems and upgraded sensors that allow for heavy equipment to operate without a driver. This leads to the creation of the Autonomous Snow Plow. An ASP would be capable of activation from their home base and drive pre-determined areas to clear snow without concern about weather or human factors when clearing the roads. Upgraded sensors such as LIDAR and millimeter wave radar enable computers to determine where they are and where obstacles are while driving along a route that may be covered in snow or obstacles. This was proven to be capable in 2006 with the DARPA Grand Challenge. This technology would allow us to remove humans and allow computers to use multiple sensor suites to complete what was a dangerous job while maintaining safe and efficient operations.

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