# Introduction:

Driving through snow is dangerous, especially if the roads were not prepared properly the night before. Sudden snow storms can result in hazardous conditions where driving in slippery snow results in the operator losing control of the vehicle. Around 17\% of all car accidents occur in winter conditions and annually, over 115,000 people are injured and 1300 people are killed in car accidents on snowy or icy roads \cite{carsurance2021}. The snow can be packed and safe to drive on, thin and safe to drive on, or it can be slippery or icy and not safe to drive on. Knowing where to drive is difficult, with traffic lanes falling apart as vehicles form new lanes based on where previous vehicles have driven.

These new lanes consist of a narrow safe zone where the snow has been crushed into either packed snow or melted, surrounded by semi-safe zones. The width of these zones is formed by, and defined by how many times a vehicle has driven over the area. Outside of these zones are areas vehicles have not driven on, which are very dangerous. Driving in these areas results in the vehicle losing control, being unable to turn or stop. This can result in the vehicle colliding with other vehicles or ending up in ditches. This can further snowball the danger to the driver, as they may be injured in the crash, or stranded in the snow, now at risk for hypothermia.

One difficulty in this problem is the small room for error. Each vehicle does its best to follow the tracks, making them narrow. The penalty for making a mistake is also very severe, just a small exposure to unpacked, slippery snow will cause the vehicle to lose control. Finally, time is also an important consideration. Snow is still falling, and the vehicle needs to get home as soon as possible. The more time out on the dangerous streets also increases the chances that another vehicle loses control and collides with the vehicle. This tradeoff of safety, narrow margins, and minimizing the time exposed makes this a difficult task.

We intend to solve this problem by training an algorithm to be able to drive within the areas cleared out by previous vehicles. The algorithm will attempt to drive as quickly as possible, while maintaining safety by not traveling over slippery areas where other vehicles have not traveled. The algorithm will treat areas cleared by vehicles to have a small negative value to encourage speed, a larger negative value to represent slush covered areas of the road and a very large negative to represent the areas covered by fresh snow. The algorithm will return speed up/slow down values as well as right/left/straight directions based on the values of the map surrounding the vehicle.

Image processing will be considered out of the scope of this work. Our assumption is that issues with perception have already been addressed, and images of tracks in the snow are likewise processed. While this is a rather significant assumption to make, it is necessary due to the time frame in which this work is done.

# Background

## \subsection{Challenges in Driving in the Snow}

Autonomous driving in the snow is very challenging for a variety of reasons. Snow creates difficulties in being able to drive by reducing the friction between the vehicle’s wheels and the pavement resulting in an inability to control the direction of the vehicle or to change the velocity of the vehicle or stop. A further issue is that snow creates numerous perception issues ranging from covering up obstacles and signs to creating false positives. \cite{venturebeat2020}. For the sake of this work, we will be dealing primarily with the driving challenge, assuming the sensing challenge is already solved and processed images can be provided to our algorithm.

## \subsection{Solutions to Problems}

The primary way we plan to deal with the problem of slippery snow is by avoiding the extremely slippery snow, and minimizing the contact with slushy snow. This is done through use of a trained on-policy reinforcement learning algorithm.

Another challenge is in procuring enough training information to train a system. To work around this problem, simulations are often used, whether they be the Cityscapes dataset\cite{cityscapes}, CARLA simulator\cite{carla} or custom solutions. Another option would be to modify clear images, rending them foggy or snowy to increase the size of the dataset \cite{Bernuth2019}.

## \subsection{Previous Work}

The majority of the previous work done has involved obstacle detection and landmark detection in snowy conditions. To the best of our knowledge, no previous work has been done in following snow tracks of other vehicles.

## \subsubsection{Sensing}

The ability to accurately sense the environment surrounding an autonomous vehicle is one of the most important parts of this field. In most normal weather conditions, autonomous vehicles are able to do this with relative ease. However, in rainy or snowy conditions, the accuracy of the sensors is degraded significantly. Work done in this area showed that the range and accuracy of LIDAR and Radar sensors is decreased by up to 45\% when driving in these conditions \cite{impactsensor2019}.

Due to this, there has been a significant amount of research done in the area of cleaning up sensor readings in rainy and snowy conditions. Previous work in sensing involved detecting objects, and cleaning images for increased clarity \cite{michaelis2019benchmarking}. Other work focuses on how to use landmarks in snowy landscapes to perform localization on the autonomous vehicle \cite{aldibaja2018lateral}.

Other work involves evaluating the quality of the road conditions \cite{pan2018winter} or improving the response from LIDARs degraded by snow \cite{aldibaja2017robust}. Rawashdeh et al, fused sensor data from LIDARs, Radars, and camera data to detect drivable paths in snowy conditions \cite{rawashdeh2021drivable}. However, this work largely focused on identifying open areas when the vehicle could drive, rather than focusing on how drivable the ground is.

## \subsubsection{Driving}

Previous work by Ozturk et al \cite{ozturk2021investigating} used curriculum RL to address different driving scenarios such as driving in inclement weather. Their work included simulating the effects of different types of weather on the simulated vehicle. One important consideration is that they treat the road as having uniform values per section (e.g., the rainy parts are equally wet across the road), whereas our work assigns different values to the road.

Other work has developed algorithms to use a human to train an algorithm to navigate through bad conditions \cite{peng2020imitative}.

More work in this area involves using a reinforcement learning algorithm to train a vehicle to drive on a road on varying conditions including snow, coast, and cliffs as well as different types of turns \cite{endtoend2017}. This work is similar to ours in that it involves autonomous driving adverse conditions but differs from our work since it assumes that the car will be driving on a road and not always in snowy conditions. Their work also differs from ours in that they plan on driving on the slippery portions of the snow, where our work aims to avoid that danger.

## \subsubsection{Lane Following}

TODO: Look up lane following algorithms

## \subsection{On-Policy Reinforcement Learning}

Reinforcement learning is used to train our vehicle by rewarding desired behavior, such as driving on car tracks, and punishing bad behavior such as driving through fresh snow or taking too long to reach the end goal. Through trial and error, the vehicle learns how to react to its readings of the environment, in this case whether to adjust the vehicle's speed and if turning will be required.This method of learning separates reinforcement learning from supervised learning, in that the vehicle learns the correct actions to take on its own, rather than at the command of the human driver. On-policy means that the optimal policy is found through the actions of the vehicle.