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Utilising Weather and Terrain Data to Improve Autonomous Navigation

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***Abstract*—Autonomous vehicles are progressively arriving on our roads following a wealth of research on autonomous driving on roads. Autonomous off-road driving is also being researched, but aspects such as the effect of weather conditions on the terrain has been largely ignored. Anyone who drives will likely have experienced the effects that heavy rain or ice can have on ground conditions, and yet the effect the weather has on ground conditions is not incorporated into autonomous systems. This paper will outline the benefit of incorporating weather and terrain data together into autonomous navigation and will then go on to discuss how a proposed system will be designed and developed to test the benefit these types of data can bring when used together.**

***Index Terms*—autonomous, weather, terrain, ground-conditions, navigation**

I. Introduction

Autonomous navigation has been investigated and used for decades [1] and is being used both on and off our planet [2]. It is now becoming far more common place with autonomous cars appearing on our roads and even used for racing [3]. However with fractured political and economic systems, ongoing wars and an unstable climate, the face of the world is more changeable than ever and therefore, as these systems are further developed, adaptability must be a fundamental consideration [4]. This is particularly true when it comes to off-road navigation as the possible routes are far more changeable and chaotic than road or track based navigation. While a lot of research goes into navigating in this type of terrain [5]–[7], there is one area which is drastically lacking in research which this project aims to highlight. While terrain data is investigated and used, to some degree, it is generally only used to classify the terrain as traversable or non-traversable. While some do investigate interaction on loose surfaces [8], this is only a handful of the types of surface a rover could encounter. In addition, weather is not looked at whatsoever, except in how it affects the sensors directly [9]. However, as any driver will report, weather conditions change how a vehicle will interact with a surface and therefore the driver should change their approach to different situations. This only becomes more pronounced when driving off-road as a wet slope will require a different approach to climb it than a dry slope. This paper will go onto discuss a preliminary investigation to prove the concept, followed by the proposed methods and testing.

II. Preliminary Investigation

In order to verify that each set of conditions would require a different approach a simulator was used during preliminary testing to drive a vehicle up a slope at varying speeds and adjusted the friction of the ground with each run. As can be seen from Fig 1, the lower the friction the more speed is required for the vehicle to climb to the top of the hill. There are also a few occasions where the rover makes it to the top of the hill at lower speeds, but at the higher speeds the wheels spin forcing it to climb with only inertia. This shows that knowing the ground conditions in advance would help an autonomous system to adapt and take the best route with the most optimal driving style, ultimately saving either time or energy, which can both be precious commodities for autonomous rovers.

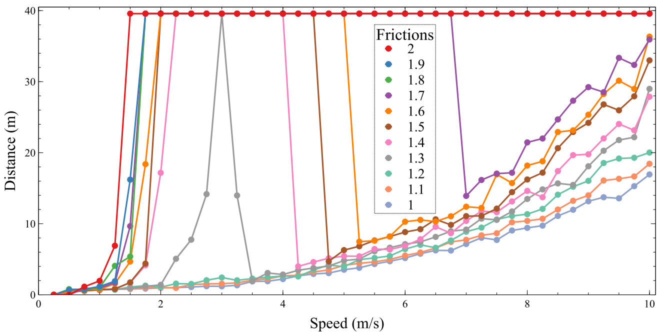

Fig. 1. Distance travelled up an incline for different frictions and vehicle speeds

III. Proposed Method

The first aspect to tackle is the evaluation of the topography of the terrain in front of the vehicle. The data gathered for this part of the system will be in the form of a point cloud gathered from a depth camera. There are several different approaches to using this data, such as segmentation [10], neural networks [11] and three-dimensional template matching [12] which help to tackle it. However, in the end it was decided to convert the gathered point cloud into a height map, then proceed to use template matching on the two-dimensional image, allowing the system to recognise slopes, ditches and other points of interest. The two-dimensional template matching has been developed and is being tested, however the method for converting the point cloud to a height map is still being researched.

The second part of the process, recognising the terrain, is a complex task. It is generally overlooked in favour of classifying the traverseabilty of the terrain rather than the specific material [13]. However, the type of terrain is a key piece of information vital to optimal autonomous navigation, as a rover will interact with differing terrains in a number of ways and being able to recognise that beforehand and adapt can only be a benefit. There are a few options for this method, one being to analyse the spin of the wheels to calculate the traction of the surface [14], but this would only allow for the rover to adapt to a surface once already on it. The only option to analyse a surface before reaching it relies on vision-based approaches and so a neural network was chosen [15]. This takes the images captured by the camera and segments them into the different surfaces or objects found in the terrain. In order to improve the performance of the network it is currently being retrained with a second data set. This new data set was found, but it contained more classes [16], which were added into the existing network as they would only help differentiating between terrains.

The final section of this work concerns weather data; several routes were investigated for capturing weather data, from passive microwave sensing [17], to ground penetrating radar [18] which measure the dielectric constant. Finally it was decided to upload weather data beforehand as a base line for the ground conditions and to then monitor how the weather changes as the rover progresses along its route. The data uploaded to the rover beforehand would be a combination of both forecasting and data from weather stations that are in or around the area the rover aims to navigate. The upload of recent data is necessary in this method as merely detecting moisture in the air does not mean the ground has become slippery; it will depend on the recent weather activity. The rover will be fitted with an automatic weather station, consisting of a thermometer, an anemometer and a Present Weather Sensor (PWS). These detect temperature, wind speed and the size and velocity of water droplets in the air respectively. Some of the data from these sensors will need to have their values adjusted, such as the wind speed to take into account the movement of the vehicle. This will allow the system to monitor any changes in weather that the rover can then adapt its driving to. These three systems can be brought together within the local planner to add their own weighting to any possible routes and allow the system to better choose its driving style for the conditions.

IV. Proposed Testing Approach

Once these systems have been developed and brought together, they will be tested by navigating between two points in differing weather conditions and at varying locations. For each location and condition the system will run, as just a navigation system, then again with terrain analysis and finally with both terrain and weather analysis to investigate how these systems can help improve the efficiency of the navigation, by either time or energy consumption. These tests will be conducted in the real world (Fig 2) rather than in a simulator to better show the effects of the terrain and weather.

Fig. 2. Potential Rover to be used for testing

V. Conclusion

This paper has introduced a concept that could improve all-terrain autonomous rovers to better adapt to their surroundings. Although testing is yet to occur, this research predicts that it will be advantageous to take terrain and weather into account as a pair. This will hopefully lead to further research into this field, gathering more direct measurements of ground conditions. Overall this paper should prove that weather and terrain data are required in tandem to allow a rover to better handle adverse conditions and terrain and is not an area to be overlooked.

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