Plan for Research Studies

Title of the study: *Exploring the effect of using snow poles for detecting snow covered roads in a simulated environment*

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This plan is based on the 6Ps of research as described in Oates, Dr Briony J (2005). *Researching Information Systems and Computing. SAGE Publications*, enhanced based on Creswell, J. W. (2014). *Research design- Qualitative, quantitative, and mixed methods approaches (4th ed.). SAGE Publications.*

Purpose

The field of autonomous driving has seen rapid progress over the last years. Impactful players in the automotive industry such as Tesla and Google are publicly pushing the technology towards a common goal of fully self-driving cars [1, 2]. An EESI issue brief from last year mentions that around half of new vehicles could be autonomous by 2050, and by 2060 half of all vehicles [3]. Still, multiple studies highlight challenges for autonomous driving in adverse weather conditions, such as rain, snow and fog [4, 5]. These challenges need to be solved before cars can become fully autonomous, especially in countries prone to these weather conditions. Motivated by this, our research project will focus on one of these challenges, namely snow covered roads. More specifically our objective is to find out whether snow poles can assist autonomous cars in recognizing snow covered roads.

Autonomous vehicles map raw data from sensors like cameras, LIDAR[1] and GPS into actions such as acceleration, steering and braking. Snow covered roads will therefore harm the car's ability to navigate, since spatial indicators like road markings and pavements can be partly or fully covered by snow. Recent studies attempt to counteract this through a technique called multi-modal sensor fusion [6, 7]. The hope is that different weather-degraded sensors will complement each other to provide good enough predictions of where the road is. While they see promising results in their models, they still conclude that improvements can be made to the road detection system. Another study proposing a similar technique explains that there is a lack of both training data and accurate simulations in which to test the solutions [8]. Indeed, an open-source state-of-the-art simulator for autonomous driving; CARLA [9, 10], does not include snow covered maps [11]. Additionally, none of the aforementioned papers experiment with snow poles, giving motivation to pursue our objective.

While there is one concept study of self-localization using snow poles and other tall objects around roads [12], it focuses more on accurately placing the snow poles on a map, rather than how they help for road recognition during autonomous driving. The proposed algorithm also only detects snow poles on the left side of the road. The gap in research regarding the use of snow poles for autonomous driving has therefore inspired the following research questions:

- **RQ1:** Can snow poles assist autonomous vehicles in recognizing snow covered roads in a simulated environment?
    - **RQ1.1:** How does the current state-of-the-art model for autonomous driving in CARLA perform on a snow covered map?
    - **RQ1.2:** Can this model be modified to detect snow poles?
    - **RQ1.3:** What are the effects in measurable driving performance of introducing snow pole detection to this model?

Contributions

Our project will contribute with research of the knowledge gap in road detection using snow poles. More specifically, we will provide a report documenting experiments and results of adding snow pole detection to a current state-of-the-art model for autonomous driving in CARLA. This includes modifying a built-in map to include snow covered roads and snow poles, as this does not currently exist. The map can also be used to generate training data which can be useful for researchers such as [8]. Both the new analysis and CARLA contributions will

[1] LIDAR is a method for determining distance to objects using lasers.

be made publicly available to motivate further research and discussion around the topic of autonomous driving in adverse weather conditions.

Research Method

The project will use an experimental research strategy. Design and creation could also be a relevant research strategy for this project, but our research questions focus more on observable experiments rather than development of new models or methods. Other strategies such as case studies and surveys are not found relevant for this project.

Our hypothesis is that adding snow pole detection to autonomous vehicles will improve driving performance on snow covered roads. To test this, we will conduct experiments using CARLA benchmarks [13] on the snow covered map. As a baseline we will use the Interfuser model [14], which is the top open-source performer on the CARLA leaderboard [15]. Using the built-in performance metrics for lane intersections and collisions [16], we create a performance baseline in which to compare experiments introducing an independent variable in the form of snow pole detection. Using a simulated environment to generate data makes it possible to control variables that might affect the outcome of the experiments. It also enables us to repeat experiments in different conditions, where we for example vary the traffic, fog level and amount of snow.

As we will use the observation data generation strategy through measurements from benchmarks, it is natural to perform a quantitative analysis of the results. We will analyze performance metrics before and after adding the independent variable in the different experiment conditions, and use this to test our hypothesis. The performance results can then be used to answer our research questions. Since we use a simulator environment with no human interaction, there are not many potential internal validity threats. Factors such as time, experimenter effects and faulty instruments are irrelevant in a controllable and reproducible simulated benchmark.

Participants

I am a master's student in computer science and will be responsible of planning and executing the project. I need to be careful of my own confirmation bias when analyzing the results, and therefore it is helpful to work with two supervisors from the Department of Computer Science: Professor Frank Lindseth and Associate Professor Gabriel Kiss. Lindseth is the main supervisor, and he is responsible for monitoring the research project, hosting recurrent meetings and providing insights into the field of autonmous driving. Kiss is the co-supervisor, and he will provide his expertise on the topic of image processing. Both will help me ensure I stay on track and work towards answering the research questions.

There is no need to involve non-researchers on this quantitative study based on simulation data. We should however still be aware of ethical issues regarding the deployment of autonomous vehicles, especially in adverse weather conditions. We will therefore be careful to note that our experiments were done in a simulated environment, and that they should not be reproduced in the real world without further considerations.

Research Paradigm

The underlying research paradigm for our project is positivism. The three basic techniques of the scientific method described by Oates all apply to this research project [17]; it breaks a complex problem into smaller and more interpretable experiments, the experiments are repeatable and the hypothesis is refutable. Other characteristics of positivism that apply to our research questions are objectivity, quantitative data analysis and measuring.

Final Deliverables and Dissemination

The results of the research project will mainly be the written master thesis along with source code for the experiments and implementation of the modified CARLA map. In addition to being shared through NTNU's channels, the master thesis and code will be openly available on GitHub. With this we hope that the topic will be further experimented with and discussed by the research community. We will also contact the team behind CARLA about including the snow map in the simulator, hopefully reaching more of the community.

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