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WEATHER SERVICE TO SUPPORT AUTONOMOUS DRIVING IN ADVERSE WEATHER CONDITIONS

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Summary

Autonomous driving can be challenging especially in winter conditions when road surface is slippery, covered by icy or snow and visibility low due to heavy snowfall, fog or blowing snow. Also, in summertime the driving conditions can be reduced by heavy rainfall, dust, or smoke. These harsh weather and road conditions set up very important requirements for the support systems of autonomous cars. In the normal conditions autonomous cars can drive without limitations but otherwise the speed must be reduced, and the safety distances increased to ensure safety on the roads.

Finnish Meteorological Institute has developed a weather-based support system for autonomous driving. The system considers weather and road condition and makes an estimation what level of automation is possible while driving. The system is tested in the Sodankylä Arctic vehicular test track environment.

Introduction

Autonomous driving has gained a lot of interest within the recent years. With improved traffic safety and travelling convenience, it is expected to be a common part of the traffic within next 10 years. The key objective is the safety of driving, maintained in all conditions and especially in winter [1].

Autonomous driving needs very precise and real-time information about weather, road condition and other driving related information nearby (like other cars, obstacles, flooding, or other unexpected situations). Data can be collected from different sources, like (road) weather models, fixed road weather station network, weather radars and vehicle sensors. Autonomous driving is strongly dependent of several sensors (camera, LiDAR, radar) detecting the driving circumstances (obstacles, edge line etc), see Fig. 1 [2]. All these instruments have their vulnerabilities in harsh weather, especially in winter conditions [3].

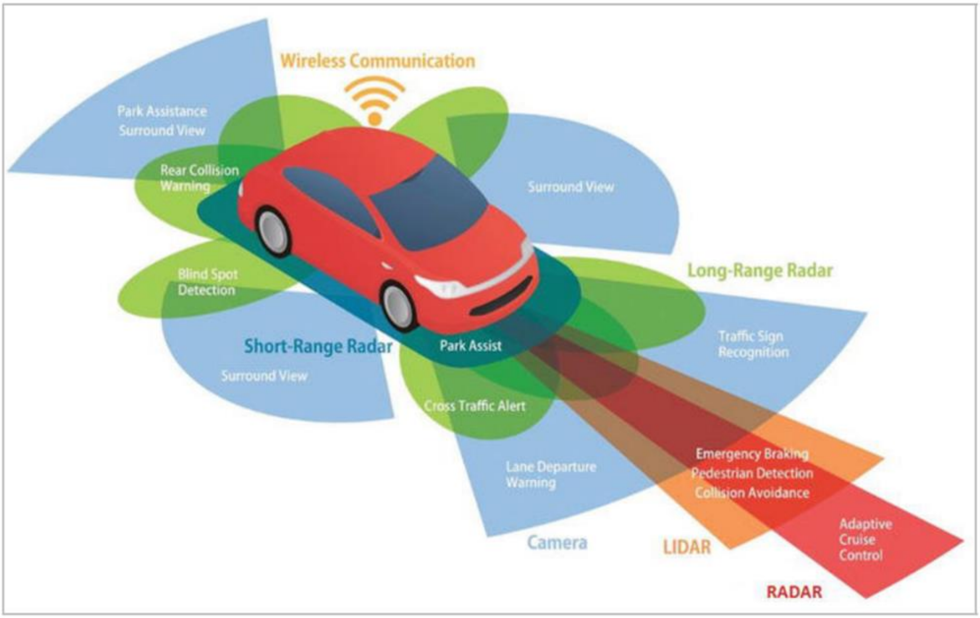

Fig. 1. Wireless communication and sensors in autonomous cars [2].

By combining the relevant weather and road condition information a weather-based autonomous driving mode system is developed to help and support autonomous driving. The driving mode system is dividing the driving conditions from perfect conditions to very poor conditions. In between there are several steps with slightly alternate driving mode depending for example snow intensity and friction. In the most challenging weather conditions, automatic driving must be stopped because the sensors guiding the driving are disturbed by for example heavy snowfall or icy road.

Arctic vehicular winter test track in Sodankylä

Finnish Meteorological Institute is testing autonomous driving in the Arctic vehicular test track in Sodankylä, Northern Finland [4]. The test track is equipped with road weather observation system network including normal road weather stations, IoT sensors measuring air temperature and humidity along with various communication systems. Also, tailored road weather services are produced to the test track, like road weather model calculations and very accurate radar precipitation observations and nowcasting. The developed weather-based autonomous driving system is tested on Sodankylä test track among other arctic autonomous driving testing.

The research work is relying on a miniature autonomous vehicle with capability to carry measurement and communication instrumentation but no passengers. The prototype vehicle is presented in the Figure 2. It has been built on miniature electrical all-terrain vehicle platform, with the size of 0.5x1.0 meter. The current configuration allows the carriage of simultaneous controlling CPUs, stereo camera, LiDAR and radar sensors, friction measuring instrument and 5G/802.11p networks support (see Table 1).

Fig. 2. FMI autonomous miniature vehicle in parallel with normal size vehicle.

Table 1. Miniature/autonomous vehicle sensors.

Device	Detection range	Object detection accuracy	Vulnerability to		
			Rain	Snow	Dark
Video camera *	>100m *	Moderate	Low	High	Low
LiDAR, Velodyne PUCK/ VLP16	>100m	Very high	Mod	Mod	Null
Vehicle radar, Continental SRR 308	>80m	High	Low	Mod	Null
GNSS RTK	∞	Null	Null	Null	Null
Friction, Vaisala MD30, Teconer RWS 431	Spot	Null	Low	Low	Null

**image resolution limited due to real-time interpretation*

Enhanced road weather service for autonomous vehicles

The scenarios envisioned for the autonomous driving are built upon the idea that autonomous vehicle is more vulnerable to the weather conditions, benefiting from more sophisticated weather information. The weather information can be collected from different sources, like weather and road weather observations including weather radar data and supplemented with observations measured by vehicles own sensors. The upcoming road weather and road condition can be forecasted by road weather model [5].

Assuming that the autonomous vehicle is possessing and operating all the instrumentation presented in the Table 1, we can compose the preliminary stepping driving mode table shown in the Table 2. Table 2 also presents weather-related explanations for different driving modes and how weather affects to the sensors. Modes 0 and 5 are straightforward; if the detected conditions are malicious or there is a detection failure, the safe driving is impossible, vehicle must either stop or autonomous driving must be switched to full manual driving. Obviously, if the vehicle's sensors themselves detect an object on the road, driving is impossible as well, but for other reasons. Mode 1 is clear as well, if the weather is fine for driving, there is no need for any adjustments.

Table 2. Concept model of weather-based stepwise autonomous driving mode.

Driving mode	Driving specifics	Road weather and driving conditions	Effect to sensors
0	Must stop	Not defined	Unknown location or other error
1	No need to adjust speed nor driving	Fair weather. Good visibility and dry surface	-
2	Anticipate braking events by lowering speed, increase safety distance	Minor rain or snow / light snowdrift / light fog. Fairly good visibility and friction.	LiDAR not detecting completely, camera detecting poorly

3	Halve the speed, increase safety distance	Moderate rain or snow / moderate snowdrift / light or dense fog. Reduced visibility or friction.	LiDAR not detecting completely, camera not detecting
4	Minimum speed, prepare to stop	Heavy rain or snow / high snowdrift / freezing rain / dense fog. Reduced visibility or friction.	LiDAR not detecting completely, camera not detecting, radar not detecting completely, ice and snow on the sensors
5	Must stop	Heavy rain or snow / moderate or long-lasting freezing rain / heavy fog. Very low visibility or friction.	LiDAR and camera not detecting, radar detecting poorly, ice and snow on the sensors

Modes 2-4 represent the stepping modes, where the detection systems (camera, LiDAR and radar) are one by one losing their capability to detect objects, finally losing the ability entirely. Driving specifics defined for these modes are the concept inherited from the autonomous miniature vehicle we are operating; each autonomous vehicle model possesses their own set of sensors, requiring slightly different countermeasures. However, when we ultimately have accurate definition of “operability” for each type of sensors, each manufacturer can tailor their driving system reactions accordingly.

The next step is to determine the local driving conditions from vehicle cameras and LiDARs. That information could be used as a supplementary material to assume the prevailing driving conditions. Reduced visibility can be detected from analysed camera data. Also, precipitation can be detected from LiDAR data, at least to some extent. Vehicle radar as such has been studied the least in this sense, but it could be used to get some information about precipitation intensity.

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