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ROADVIEW: Perception for Autonomous Vehicles in Adverse Weather Conditions

Abstract: ROADVIEW is an EU-funded Horizon Europe Innovation Action aiming to develop robust and cost-efficient in-vehicle perception and decision-making systems for connected and automated vehicles with enhanced performance under harsh weather conditions and different traffic scenarios. In ROADVIEW, researchers from Finnish Geospatial Research Institute FGI develop two novel perception methods: 1) Environment-aware high-definition mapping method for real-time positioning of an autonomous vehicle, and 2) Optical measurement of road grip and road surface conditions in front of the vehicle.

Keywords: autonomous driving, road surface, lidar, machine vision, positioning

1 Background

Autonomous vehicles require an accurate position and orientation to operate safely. Inertial assisted satellite navigation systems that combine global navigation satellite system (GNSS) and inertial measurements (INS) can provide accurate position and orientation estimates in good conditions. However, relying solely on one positioning solution makes the system vulnerable to malicious agents, e.g. satellite signals can be subject to jamming or spoofing [1] and they the visibility of satellites may be limited (e.g. in forest [2], tunnels or urban canyons [3]). On the other hand, the inertial estimates drifts because of errors accumulated from noisy and biased inertial measurements. Therefore, an alternative solution is preferred. We propose that a prebuilt map can provide accurate absolute position and orientation independent of satellite systems.

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In arctic adverse weather conditions, although the vehicle would know its exact position, the driving conditions create a risk if the vehicle is not able to adjust its driving for changing conditions. The road slipperiness is challenging to estimate and not studied much [4]. The variable slipperiness of road surface, packed ice and snow on the road, and accumulated snow during snowfall need to be taken into account. Solving these is essential to allow automated vehicles to operate safely also in difficult weather conditions common in northern countries. Solutions to these challenges are studied and demonstrated in ROADVIEW [5].

2 Aims

The goal of our positioning development is to provide a map representation, automatically made from laser scanned point clouds, that provides robust and accurate positioning while being memory efficient at the same time. Memory efficiency is crucial for mobile robots, such as autonomous vehicles, due to the limited on-board storage capacity and the limited bandwidth of wireless connection.

The goal of road grip and road surface conditions estimation is to improve safety of autonomous driving in challenging weather conditions. By providing a novel capability of estimating the road surface conditions before driving over the road allows the vehicle to adjust its velocity and control behaviors to take into account low-grip conditions or uneven icy surface in front of the vehicle.

3 Materials and Methods

The HD Map representation developed in ROADVIEW project is based on a registering technique called Normal Distributions Transforms (NDT) which models the dense point clouds produced with lidar sensors as sets of 3D normal distributions to compress the information. By using the NDT, we are able to use existing point cloud registeration methods with our map, but at the same time we utilize information from semantic segmentation to define which points should be used in the map and how the points should be divided into distributions. We call our method Environment-Aware NDT or EA-NDT [6]. An example of EA-NDT map with 3D distributions is shown in Fig. 1
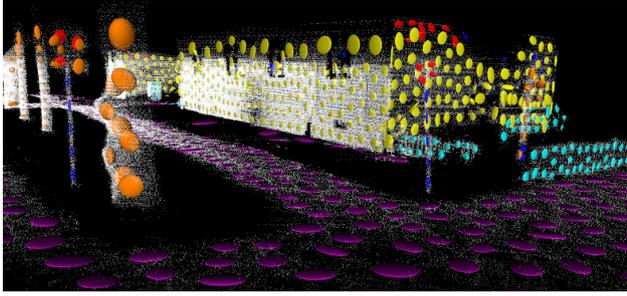
Fig. 1: An illustration of EA-NDT HD map representing the original point cloud (white). The 3D distributions are visualized as ellipsoids (mass within a standard deviation), semantic information is shown with colors: building (yellow), fence (cyan), ground (purple), pole (blue), tree trunk (orange) and traffic sign (red) labels.
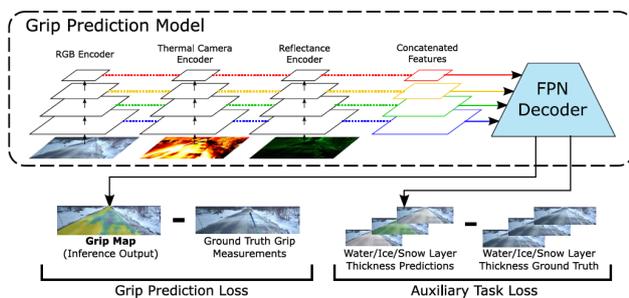

Fig. 2: In the model architecture each input data modality has a separate encoder and their features are concatenated within each feature scale before the FPN decoder. The loss is evaluated both for the grip and the auxiliary surface layer thickness prediction tasks simultaneously. See more details in [7].

The road surface grip estimation is based on a deep-learning solution using a Feature Pyramid Network (FPN) (see Fig. 2) The method fuses lidar, thermal camera, and color camera data streams and predicts road grip as well as, water, snow, and ice layer thicknesses [7]. It is the first real-time capable method providing a dense road grip estimate from the road surface.

4 Results

In [6], we have shown that the developed EA-NDT HD map representation can provide $1.5\times$ higher descriptivity with the same amount of data than the traditional NDT which means that the same accuracy can be achieved with less data. In ROADVIEW deliverable [8], we have shown that the accuracy of positioning wiht EA-NDT is very similar compared to the original NDT but with less data.

Our recently published article [7] demonstrated how road grip can be estimated by fusing lidar with thermal

and color camera information. The method has been successfully used to predict road grip from the sensor fused input with root mean square errors (RMSE) of less than 0.06 (from the unit-less friction values ranging between 0.1 and 0.82).

5 Conclusions

In this work we highlighted the importance of research and development done in ROADVIEW[5] and the perception related research by Finnish Geospatial Research Institute (FGI) for the project to allow safer automated traffic in adverse weather conditions common in northern countries. In this work we showed how automated vehicles could in future position themselves using point cloud producing lidar sensors and high-definition maps and better take the road surface properties into account in their driving.

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