Intelligent Provisioning of High Definition Street Maps for Highly Automated Driving Vehicles

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***Abstract*—High definition street maps are necessary to ensure the passenger safety of future highly automated driving vehicles. The map serves as a virtual representation of the surrounding of the car. Thus the vehicle itself is able to compare its on board sensors with this "virtual" sensor. Therefore it achieves precise and robust information about the actual current traffic situation, which would not be obtainable otherwise. To stay operational, the high definition street map has to receive constantly updates about the newest traffic conditions. The creation and transmission of such highly detailed map updates generates several key challenges. So this PhD thesis focuses on the development of new intelligent concepts to ensure the robust and efficient operation of such a map.**

I. Introduction

Highly automated self-driving vehicles are currently subject of intense research. They enable the drivers to become passengers and spend their time with other tasks while travelling. To ensure the safety of its passengers the car therefore has to track constantly its surrounding by relying upon a variety of different sensors like cameras, radar, lidar, ultra-sound and more. The inbuilt sensor setup however is not enough to ensure the safety and comfort of the passengers in all occurring traffic situations. Especially when travelling with highway speeds the onboard sensors fail to ensure safe and comfortable braking and steering manoeuvres. To solve this problem current research approaches rely on a so called high definition street map. This map is a tremendously enhanced representation of the street infrastructure. It is actually a virtual model of the environment. The map contains detailed information of each geographic element (e.g. traffic signs, lights and curbs) that can help the car to locate itself in the surrounding and to fulfil its personal driving task. High definition street maps thereby achieve an accuracy within the range of centimetres. The map serves as an additional virtual and robust sensor with which the car can continuously compare it's own sensor readings. Standard navigation maps tend to get outdated over time. This is due to the continuously changing characteristic of the road network infrastructure. This effect is even more sever for high definition street maps. The map data information, they contain, has to be updated often within minutes (e.g. the current status of dynamic traffic signs or the position of mobile road works). Both mentioned aspects, the high detail of information and the requirement of constant map updates make a continuous stream of update information necessary. This fact is explained in the following section II.

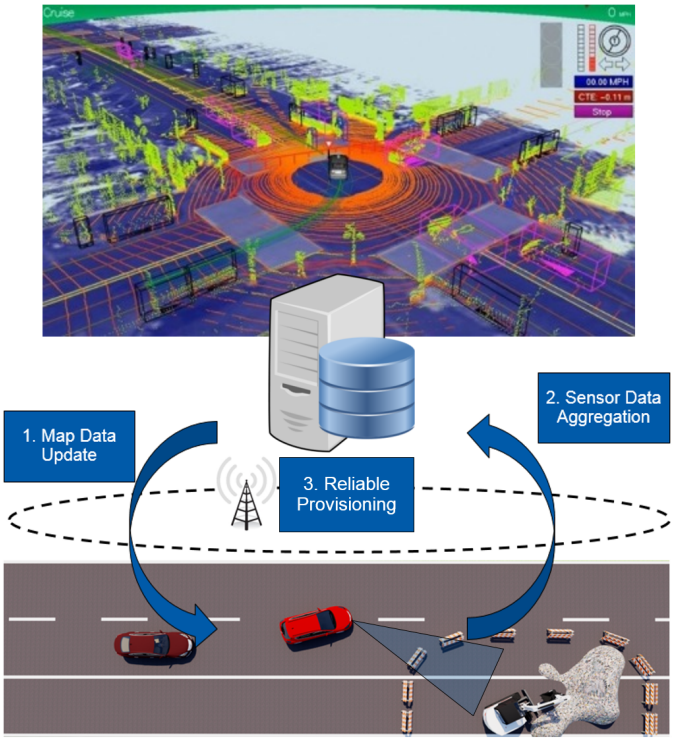

Fig. 1. General working principle of a high definition street map for highly automated driving vehicles.[2]

II. Functionality of a High Definition Street Map

The general working principle of a high definition street map is explained in the following with reference to figure 1.

To ensure the reliability of its high definition map the car has to be provided with a continuous flow of map updates over a wireless data connection (1.)). Such map updates cover events like road works or current speed limits. Information about such events are provided from various data sources, like federal transport authorities or urban administrations. These update information from different data sources have to be gathered together in a central server entity, which integrates them into the existing map material by updating its personal map database. Thus a dedicated map server is able to provide all vehicles with constant map updates and ensures their reliability by the aggregation and therefore verification of different input

[2]Included image source: http://mappingignorance.org/fx/media/2014/04/Google%E2%80%99s-cars-localize-themselves-640x359.jpg

source information.
Only the provisioning of updates based on external data sources does not completely fulfill the need to keep the high definition street map updated. Certain traffic situations like accidents or traffic jams cannot be foreseen. To solve this issue the highly automated driving vehicles have to provide additionally their own sensor information back to the map server (2.)). Then the map server itself has to classify the provided sensor readings and create new map updates based upon the received content. Through this way map updates are also provided for previously unknown traffic conditions.
The third key factor to ensure the functionality of a high definition street map is a reliable network connection (3.)). Because of the mobility of the vehicle the available network connection quality is changing constantly. The highly automated vehicles have to be aware of this fact, when requesting or sending data. Robust transmission concepts are necessary to ensure the safety of the passengers, even when there is no wireless data connection available.

III. Approach

The scope of this PhD thesis focuses on the optimisation of the updating loop of a high definition street map as described in section II.

Derived from the presented working principle of such a map I have identified the following three key aspects of my research:

A. Map Data Updates

In the domain of digital maps a significant amount of research effort has already been conducted to provide data efficient updates for standard navigation maps. This includes the works of Ashara [1], Min [2] and Lee [3]. The general approach of all of them is to provide data efficient incremental map updates via over the air transmission. Asahara further developed an approach to ensure the maps consistency while updating. These existing concepts can be used on high definition street maps, too. However the expected increased amount and size of map updates, which have to be conducted, require the investigation of even more sophisticated updating approaches.

B. Sensor Data Aggregation

The collection of sensor data (so called floating car data) of moving vehicles for further processing is already widely used in research. Ide et al. [4] for example base their algorithms for travel time estimation on collected floating car data. The generation of high definition street map updates leads to new challenges. Especially the high accuracy of the map itself requires new concepts to filter and post process the received sensor data.

C. Reliable Provisioning of Data

Cause of its mobility a vehicle experiences continuously changes of its wireless network connection. To ensure the safety of its passengers a robust data connection is yet mandatory. Therefore existing road segments of bad connection quality have to be taken into account by the vehicle. It has to schedule its data transmission accordingly. For this task the available information of providers about their cellular networks is insufficient. One possible solution approach of this problem is the creation of a so called connectivity map, as stated by Pögel et al. [5], [6]. Such maps store detailed information about measurable network parameters and the end to end connection quality. To provide the connectivity map with content, several active and passive measurement approaches exist [7] [8] [9] [10].

I want to adapt these concepts to enhance the transmission of high definition map data. The approach is based on the fact that highly automated driving vehicles themselves are equipped with cellular modems, which are able to measure their local network quality. Then their measured results shall be shared between all vehicles.

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