doi:10.3311/BMEZalaZONE2022-006

On-Site Test Measurements at ZalaZONE Automotive Proving Ground for Aiding Various Research Projects

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Abstract

The ZalaZONE Automotive Proving Ground can provide multiple controlled and safe test environments which becomes essential when various measurements and field tests are required for different vehicle-related scientific research projects. The Motorway and Smart City platforms are detailed models of a real highway section and a densely populated city area. These test sites were used to set up multiple field tests for various Intelligent Transportation Systems related research projects we are working on. Various measurements were performed by deploying multiple sensors of different types along the Motorway module as well as in the SmartCity zone in form of sensor stations. The Smart City platform was used to perform pre-accident specific scenarios and collect corresponding data in order to support the development of methods which are aiming for the recognition of traffic situations where the occurrence of an accident is highly probable.

Keywords: *ground truth powered measurements, multi-sensor measurement, multi-station system*

1 Introduction

To test already developed methods or start the implementation of new algorithms, sometimes test data becomes indispensable. Collection of such data often proves to be difficult, especially when it is related to specific traffic situations or diverse traffic environments. Both cases involve the use of vehicles, which need to be operated in a safe, controlled environment to avoid damage in life or property. Although, the use of a public road section for testing and data collection might be an alternative [1], this solution would require significant preliminary organization work. Furthermore, tests performed on public roads cannot easily be repeated if such demands arise.

To overcome this barrier, numerous automotive proving grounds are built, several of them can offer high detail models of different traffic environments, as well. At these locations the tests are easy to set up and perform, all the participating drivers can be skilled official test drivers, who can safely perform the different traffic scenarios. The participating cars can be altered or equipped with additional test equipment according to current demands.

In Hungary, the ZalaZONE Automotive Proving Ground provides this environment for various tests and related measurements. It has seven main modules, some of them are optimized for technical vehicle tests, like the Dynamic Platform or the Braking Platform. There are also modules enabling to perform testing in diverse environments such as highway, rural road or densely populated areas. During the planning and building, the proving ground was carefully optimized to support wide range of autonomous car tests [2, 3].

2 Measurements at ZalaZONE

Many projects hosted by BME Automated Drive Lab are linked to a cooperative perception system [4], which is currently under development. The research project reached the state of small-scale testing at designated sites appropriate for sensor deployment. However, before the deployment of sensors a lot of questions must be answered regarding the sensor types and sensor setup. Preliminary simulations were performed to find the theoretically optimal configuration for infrastructure sensors. Beside the simulations, real life tests were also needed to identify further potential problems. For the evaluation of our sensor system, the Motorway platform of ZalaZONE was selected. The platform is an actual highway section, with an overpass. This bridge can be seen in Fig. 1 which provided the possibility to set up the experimental sensor system above the road surface in any chosen point in lateral direction.

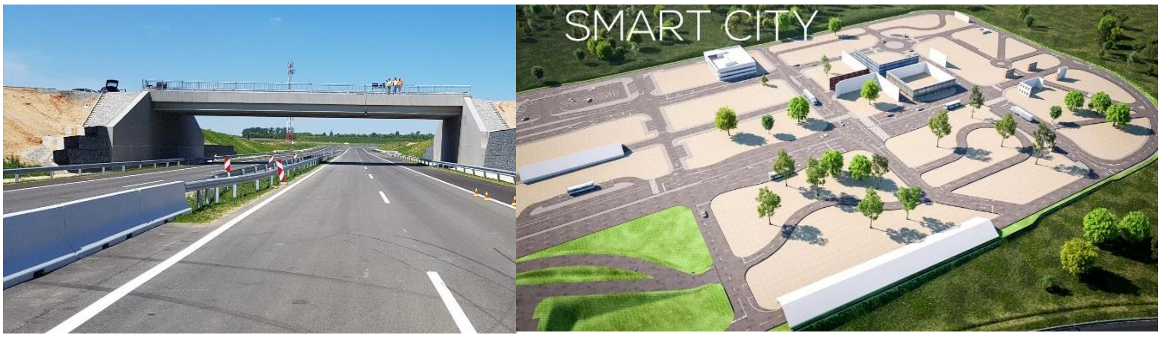

***Fig. 1** Motorway platform with the overpass element (left) and Smart City module (right) of ZalaZONE Vehicle Proving Ground*

One of the planned features of the cooperative perception system is the ability to extract specific scenarios. After the development of this feature, the system will be able to recognize traffic situations where an accident is imminent with high probability and trigger recording. Such recorded data might be useful for automotive companies and accident reconstruction. In order to develop this feature, data covering various scenarios is required. For this purpose, highly dynamic tests were planned and performed to collect the necessary data. The Smart City platform was used to perform these tests. This module represents a densely populated city area, with crossroads, and pedestrian crosswalks. An appropriate crosswalk region has been selected as the location of preplanned highly dynamic scenarios.

Both the Motorway and Smart City platforms were scanned by a high precision digital mapping system, thus high-density point clouds are also available. These models have precise position information wrt. a global coordinate system for every point in the corresponding point clouds.

2.1 Multi-station data recordings

On the Motorway platform, multi-station test measurements were conducted. For the tests, two recording stations were deployed. Each station collected camera images and LiDAR point clouds with its own sensor set. The stations were synchronized in time - by using NTP (Network Time Protocol) [5] - to the clock of the GPS system with Cohda devices. This allowed proper comparison of the two recordings. The first station (Station A) was deployed onto the railing of the overpass element. The sensors were located at approximately 6m height above the ground. In lateral direction, the sensors were in the middle of the left half (incoming traffic direction) of the Motorway section. The second station (Station B) was placed at the left side of the left half of the road. The sensors were near the side railing of the road. The setup is shown by Fig. 2. Station A was equipped with a 4D traffic radar, a camera and a LiDAR unit. The camera was a 2MP unit with 60° FOV (Field Of View) lens. The image rate was 30 frames per second, global shutter mode was used to eliminate the distortion of fast-moving objects in the image. The LiDAR units at Station A were a close-range unit, with 64 laser beams, all directed horizontally in range between 0° and -45°, and a long-range type with 128 laser beams. Station B consisted of a 2MP camera, and a long-range type LiDAR. The data collection at each station was performed by a nearby PC, with RTMaps data logging framework. This framework saves all data with timestamps and can play back the recordings synchronized in time.

Calibration points were selected and measured with a GNSS device in order to estimate the extrinsics of sensors wrt. UTM frame. The marked calibration points have been acquired by cameras as well as by LiDARs of both stations. This information allowed to project the point clouds from each local coordinate system to a global one, merging the separate point clouds into a single cloud, resulting higher point density. For extrinsics estimation the Levenberg Marquardt optimization algorithm [6] and the Iterative Closest Points method [7] were used.

The test vehicles were equipped with high precision GNSS devices to log their precise position and orientation. This information was considered as ground truth. Two of the test vehicles were instructed to drive besides each other and the third vehicle had to follow them in the inner lane. This scenario was performed with different speed levels: 50km/h and 100 km/h.

Fig. 2 *Station B (left) and Station A (right)*

2.2 Multi-sensor perception and LiDAR performance tests

Multiple types of LiDAR sensors are available on the market, but to choose the appropriate type to be used in a given traffic environment additional information was necessary. Simulations were carried out to evaluate the performance of 360° horizontal FOV mechanical rotating units and solid-state technology-based types, with smaller FOV but increased resolution. According to the simulation results, when the sensor set is deployed in a road crossing, the 360° types are far more cost effective, and the available resolution is sufficient for the required detection range. In a highway environment, a solid-state LiDAR can have advantage over the rotating one. Since the region of interest can be defined by two frustums, the points falling outside this region (provided by 360° FOV LiDARs) are neglected. However, the reduced FOV of the solid-state variant comes with an increased resolution, which means, that the objects are represented by more points in a point cloud at a given distance compared to the rotating variant. This phenomenon extends the detection range, as well. Before the final decision regarding the sensors used in the highway environment, the simulation results were verified by various field tests with actual sensors. The field tests were conducted on the Motorway element at ZalaZONE proving ground.

During the tests, we tested a complex perception architecture, consisting of numerous sensor types. Also, different LiDAR devices were evaluated. The perception equipment included a traffic radar, a 2MP camera with 60° FOV lens, a far infra-red thermal imaging camera, and the evaluated LiDAR units. The reference types were a 64-channel variant for close-range, and a 128-channel variant for long-range. The evaluated units were a close-range type with 32 channels and a 128-channel long-range variant. On the second test session, the perception system was a simplified version of the first setup, i.e. beside the 2 MP camera, and the reference LiDAR, a solid-state type lidar was used as the evaluated item. In both cases, the data recorders were synchronized to the GPS time with Cohda devices. Fig 3. shows the two sensor setups.

Fig. 3 *Perception sensor system at the first test session (left) and at the second test session (right)*

2.3 High dynamic traffic situation tests

The development of the scenario extraction feature of the cooperative perception system started with the data collection phase. An appropriate cross walking has been selected, and a mobile sensor setup was deployed. The setup consisted of a 64 channel mid-range LiDAR, a 2MP industrial camera and an IP camera. The recorded scenarios were traffic situations, where a vehicle with high speed is approaching a turning vehicle or a pedestrian who walks across the road and must brake hard to avoid the accident. These scenarios were hazardous for human safety and for the test cars, thus professional test drivers had to perform the scenarios. As pedestrian a controllable dummy was used. Fig. 4 shows the testing scene.

Fig. 4 *The sensor station, the dummy, and the calibration point markers*

3 Results and Conclusion

The recorded data during the above-mentioned test measurements is slightly more than 565GB-s of point clouds, camera images, radar object lists and GNSS information from the test vehicles and the calibration points. The recorded data is useful for testing and validating functions of the cooperative perception system and to give support for various environment perception related activities as for instance the automatic label injection, object detection in point clouds with classical methods, low level sensor fusion-based 3D detector development, etc. For example, the GNSS positions of the test vehicles can be visualized as Fig. 5 shows. The dense areas of the test vehicles are scanned by the nearby Station B. The point cloud from Station A shows the front sides of the vehicles, which are occluded from the other LiDAR sensor, and the second measurement station itself.

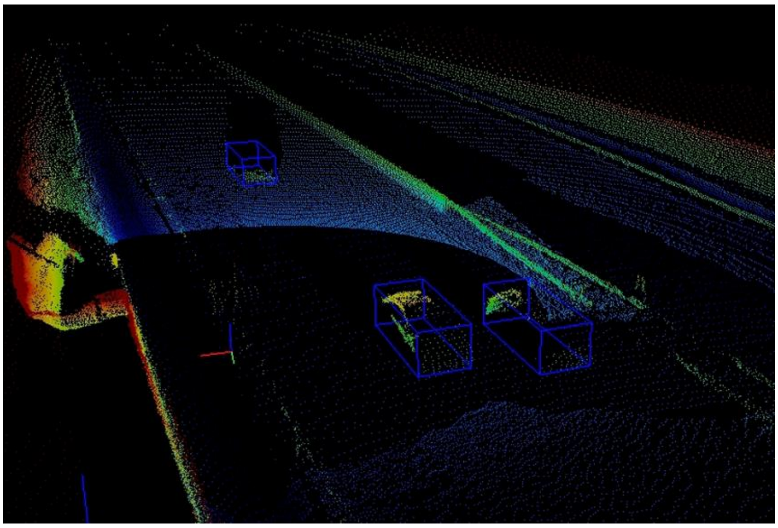

Fig. 5 *Visualized GNSS ground truth in the merged point clouds of LiDAR sensors*

Acknowledgement

The research reported in this paper and carried out at the Budapest University of Technology and Economics has been supported by the National Research Development and Innovation Fund (TKP2020 National Challenges Subprogram, Grant No. BME-NC) based on the charter of bolster issued by the National Research Development and Innovation Office under the auspices of the Ministry for Innovation and Technology.

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