UP-Drive

Automated Urban Parking and Driving

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Evaluation report on integration process and results of first development cycle

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1 Introduction

In order to best tackle the technical complexity of the project, an iterative spiral approach to system development and integration was chosen - as depicted in Figure 1.

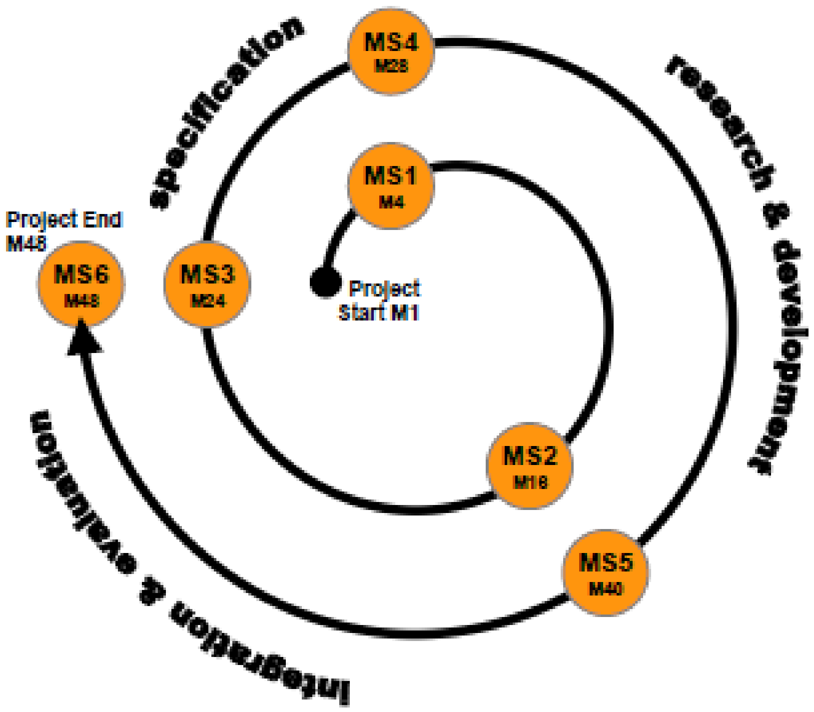

Figure 1: UP-Drive project spiral life cycle model

The spiral life-cycle model supports an iterative process comprised of the following phases: specification, research & development, and integration & evaluation. During the specification phase, initial requirements are gathered. During the research and development phase, new basic research questions are proposed based upon the requirements derived during the specification phase. This is then followed by the design and development of an evaluation platform that realizes these ideas. During the integration and evaluation phase, the evaluation platform is then evaluated and further enhanced in the next iteration based on feedback. The test results provide a new set of requirements, through redefining or completing the old set. With the second set of requirements, a new design and development cycle is performed that eliminates previous problems, and culminating in another evaluation. That process is repeated until a complete set of functions meeting all requirements has been implemented. Note that the specification, research & development, as well as the evaluation phases typically show a certain level of concurrency and small overlaps during one cycle of the spiral.

The UP-Drive system will be built in two consecutive iterations. The main purpose of the first iteration was to have an integrated system early and thus to be able to identify the key issues early enough so that they can be thoroughly addressed within the development phase of the second iteration. In accordance with this approach the first iteration of the system was planned to be ready by month 24 - December 2017. The development phase turned out to be longer than assumed in the initial - and very ambitious - plan and was finalized in month 32 - September 2018. This delay does not have any serious implication on the project development. The first development cycles delivered very promising results, allowing to apply risk mitigation strategies and thus shorten the second development cycle. This document evaluates the integration process of the 1st development cycle and gives an overview of the main results.

2 Evaluation of the integration process

Integration of the software components in the vehicle at the early stages of the development and regular system-wide-tests posed several challenges. Regular system-wide-tests require proper operation of all the system components. This has been challenging, as all main layers of the system (localization, perception, scenario understanding and motion planning) have being developed in parallel. As a result, it was very difficult to achieve the required level of maturity for all modules at the same time and keep that level of maturity throughout the development process. Taking into account the complexity of the UP-Drive software stack as shown in Figure 2, the following strategies have been successfully implemented in order to ensure seamless integration and system-wide-tests in real-world scenario.

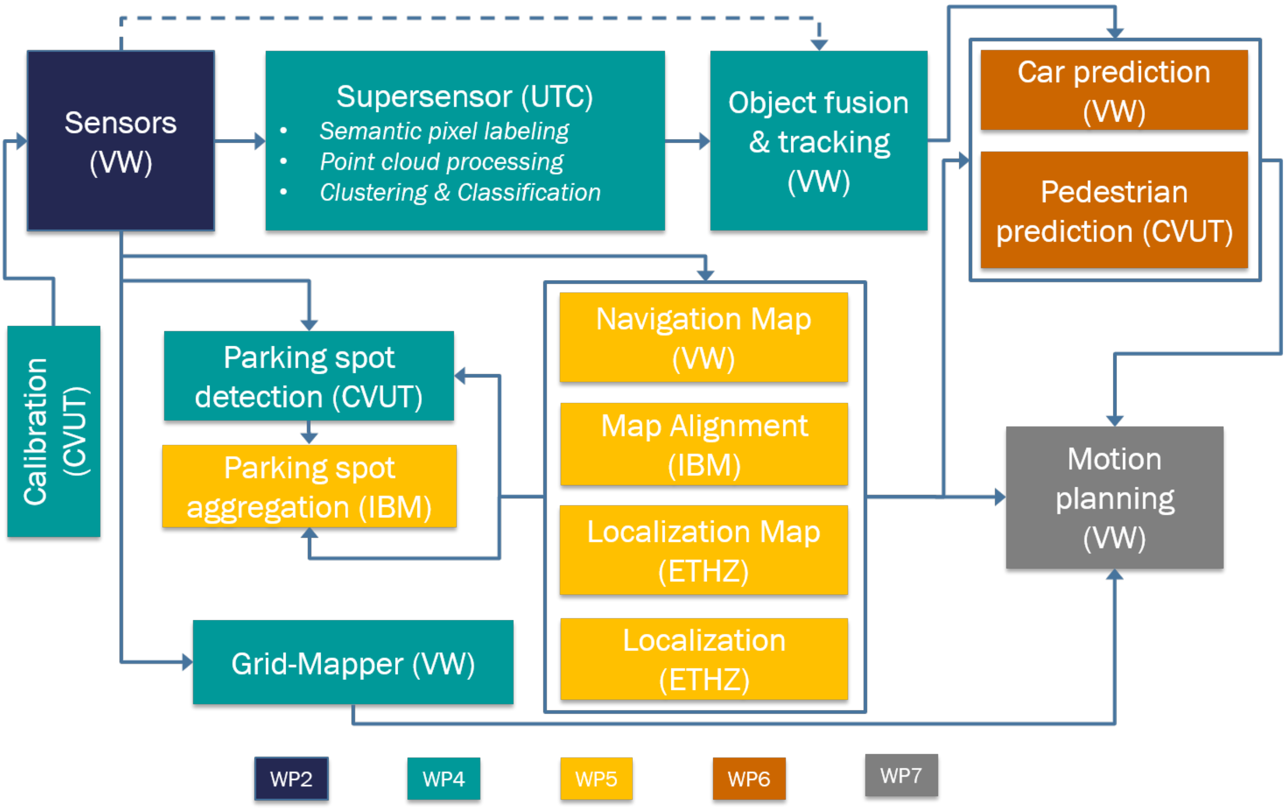

Figure 2: UP-Drive software stack

- Establish a baseline vehicle system allowing step by step integration of the components

The baseline vehicle system was provided by VW and was capable of basic automated driving. Throughout the first integration cycle, the baseline components were continuously updated with the new software releases. This process set in place allowed for testing an integration of the individual partner contributions, without the necessity to perfectly synchronize the development phases for all modules.

- Define clearly the interfaces and provide detailed developer guidelines

VW has prepared a so-called UP-Drive SDK, including execution environment ADTF, all the headers and libraries as well as code samples for all of the interfaces relevant to the project. In addition to that, VW has also provided a visualization module able to display all of the sensor data. UP-Drive SDK includes all necessary software and documentation, thus providing the partners with the toolkit to develop their functionality and test it in playback mode.

- Establish simulation environment and tools

In order to enable thorough testing of scene understanding and motion planning software stack, VW has prepared a simulator able to parse the map data from WP5 and to provide road topology, static and moving obstacles using the interfaces from WP4. The functionality of the simulation environment was continuously improved during the 1st integration cycle, resulting in more realistic behavior of simulated agents and thus seamless integration into the real system. Additionally, tools for data recordings and playback of data were provided. The observed performance and the spotted issues were documented, thus allowing for a fast debugging.

- Implement orderly test procedure

The different modules were tested prior to full system tests. For example, the lower-level layers like perception and localization are mostly tested using the recorded data-sets, whereas higher-level layers like scene understanding and motion planning made extensive use of the simulator. Next step was to continuously ensure that the current software releases of the different system components were installed and thus operational. The system-wide tests in the car in a real-world scenario were followed by feedback-fix loop.

- Organize regular integration weeks

The organized integration weeks proved to be very successful in terms of boosting direct collaboration and to tackle integration issues. This allowed to detect the unexpected problems and solve them ad-hoc. Additionally, a long term hierarchy of priorities could be set up. Within the first development and integration cycle a total of over 30 integration days have been organized, which amounts to approximately 9 % of working days for that period.

3 Results of first development cycle

The development phase turned out to be longer than assumed in the initial - and very ambitious - plan. This is especially true for the new low-level sensor fusion approach developed within WP4. Due to the prolonged development phase, the midterm demonstration has been postponed and aligned with the EC Review in M33. However, due to the applied risk mitigation strategies, the delays in one part of the project had only minor effects on the other parts of the project. Overall, the first development cycle delivered the planed outcomes and further promising results, thus clearly defining the path for further improvement of the system. The results of the first development cycle have been described in detail in the following deliverables D2.3, D3.2, D4.2, D4.3, D5.2, D6.2, D7.2.

Below we present a compact overview of the main results achieved during the first development cycle. Detailed planning for 2nd development cycle will be provided in D8.5.

WP2 Vehicle infrastructure

- Two vehicle platforms fully operational
- The following sensors were updated to ensure improved range
  - Upgraded Trifocal camera and additional two color cameras added
  - Replaced 3 16-layer LIDARs by their 32-layer versions
  - 2 additional 4-layer LIDARs were added
- Computer cluster: all bulky components were replaced resulting in lean & modular construction allowing easy HW-debugging

WP3 Cloud infrastructure

- Setup of hardware stack: extension of physical storage to currently 90TB to accommodate growing project data acquisitions (further extensible based on project needs)
- Design and implementation of the development and deployment tool chain: implementation of a Gitlab, Travis CI, Docker and Kubernetes based development and deployment toolchain. Application of this workflow to a growing set of deployed cloud services
- Setup and implementation of the bulk data storage service: migration to a more extensible cloud middleware based on Kubernetes

WP4 Perception

- The first design, implementation and evaluation of the modules needed to build the spatio-temporal and appearance based low-level representation (STAR) which represents the basis of the virtual super-sensor that perceives the ego-vehicle surrounding environment have been completed.
  - sensor calibration
  - perception adaptation to adverse weather conditions
  - 3D points correction
  - optical flow computation
- Initial design of higher-level perception functions used for 360-degree environment perception has been implemented. It includes the following modules:
  - point cloud based perception module including ground and 3D object segmentation and parking spot detection
  - image based perception module including object semantic segmentation and signaling perception
  - enhanced perception module including road users perception by associating semantic labels to 3D objects, road users perception by using the super-sensor low-level data representation (STAR) and road users tracking and correction of their position

WP5 Lifelong Localization & Mapping

- The visual mapping framework is fully operational
- The visual metric localization pipeline has been integrated and is operational in the both vehicle platforms
- A first version of the reference frame alignment has been developed and integrated on the vehicles
- Initial work on integrating the LiDAR data into the online localization pipeline has been done

WP6 Scene Understanding

- Several approaches to motion prediction and intention estimation has been evaluated and tested: simple physic-based motion prediction, Kalman filters, Bayesian networks (BNs) and heuristics
- Basic pedestrian intention predictor module has been implemented. It processes pedestrian data from the object sensor, predicting their short-term trajectory and based on Bayesian network estimating the intention of pedestrians to cross roads on crosswalks
- AnTool - Object intentions annotation tool, which focuses on annotations of traffic-related data

WP7 Decision-making and Navigation

- Updated trajectory planner based on dynamic programming has been implemented. Important development step was the merge of the two separate trajectory planners (for road following and parking) to just one, thus eliminating the need for orchestration
- Evolvement of the vehicle architecture from one with an explicit decision- making layer to a slim strategy layer feeding routing and scenario understanding output directly to the trajectory layer
- 5 out of 11 use-cases defined in D1.1 have been successfully addressed

WP8 System integration and evaluation

- See Chapter 2 for details.

4 Conclusions

In this document we evaluated the integration process during 1st development cycle and outlined the implemented strategies. A compact overview of the main results achieved during the first development cycle was given. Detailed planning for the 2nd development cycle will be provided in D8.5.