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European Commission

Project Number: [688652]
Project Acronym: [UP-Drive]
Project title: [Automated Urban Parking and Driving]

Periodic Technical Report

Part B

Period covered by the report: from [01/01/2016] to [31/12/2016]
Periodic report: *[*1st*]*

1. Explanation of the work carried out by the beneficiaries and Overview of the progress

1.1 Objectives

The main objective of the project is to build a prototype car system able to perform automated operation in complex urban environments with speeds up to 30km/h. To achieve this goal, substantial progress needs to be made in the key technologies of perception, localization and reasoning.

The project has chosen a spiral approach to system development as depicted in Figure 1. This essentially means that the UP-Drive system will be built in two consecutive iterations. The main purpose of the first iteration is 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.

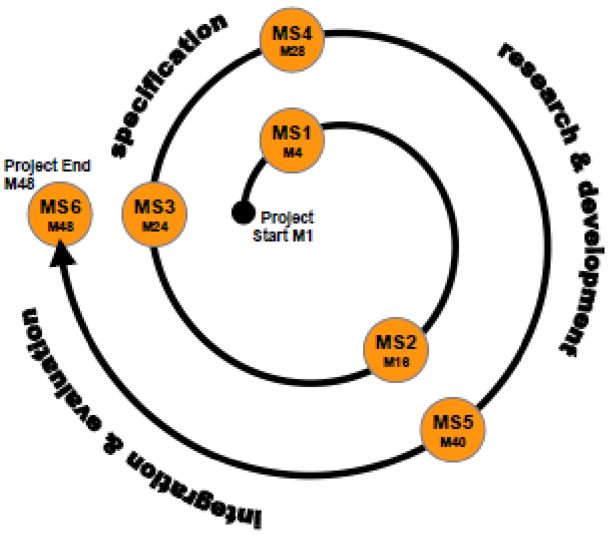

Figure 1 - Spiral life cycle model

Based on that approach, 6 milestones have been defined for the project. These are summarized in the following table.

#	Milestone title	Due month
1	“Work has started, first specification completed”	4
2	“First development phase completed”	16
3	“First integration and testing phase completed”	24
4	“Revised specifications completed”	28
5	“All developments completed”	40
6	“Project completed”	48

In the first year the project has focused on building the foundations for the envisioned system. Thus, the main achievements can be summarized as follows:

- The test vehicle has been built-up. It was equipped with a rich sensor suite, a powerful computer cluster and a drive-by-wire interface. The sensor system has been calibrated and its integrity has been validated. First datasets have been collected.
- The complete system and software architecture has been defined. On a systems level this includes detailed requirement analysis within each work package, followed by defining modules and their responsibilities and possible algorithmic approaches. On the software level interfaces between and within the work packages have been defined and implemented.

In addition to the above, the development of software modules in the respective work packages has started. This development is assisted by validation using simulation or measurement data from the car.

According to the Description of Action – and expressed in more formal terms – the objectives for the first 12 months of the project were to complete Milestone 1 and perform work towards completion of Milestone 2. Descriptions of both milestones are quoted below.

MS1 - "Work has started, first specification completed":

- The consortium has met
- Personnel has been employed and work has been started;
- Management structures are in place
- Web site is operational
- Development repository is in place
- First requirements analysis and requirements specifications complete
- Submitted deliverables: D1.1, D3.1, D5.1, D9.1, D9.2

MS2 - "First development phase completed":

- Initial version of components has been developed and individually tested
- First scientific results published (at least 5 papers have been submitted to relevant conferences)
- Submitted deliverables: D2.1, D2.2, D3.2, D4.1, D6.1, D7.1, D8.1, D8.2, D8.3, D9.3

All of the requirements for the first milestone have been fulfilled and substantial progress has been achieved towards fulfillment of requirements from Milestone 2:

- Initial versions of some components have been developed and tested
- 2 papers have been submitted to relevant conferences
- The following deliverables of Milestone 2 have been submitted: D2.1, D3.2, D4.1, D6.1, D7.1, D8.1

In general the project is on track. The progress of the individual work packages is explained in more detail in the following sections.

1.2 Explanation of the work carried per WP

Work in UP-Drive project has been partitioned into 10 packages. The work package structure is depicted in Figure 2, which is self-explanatory. It should be mentioned, however, that the main effort is placed on the 4 work packages (numbered 4-7 and marked green) which are devoted to what the project believes to be the key challenges of automated driving.

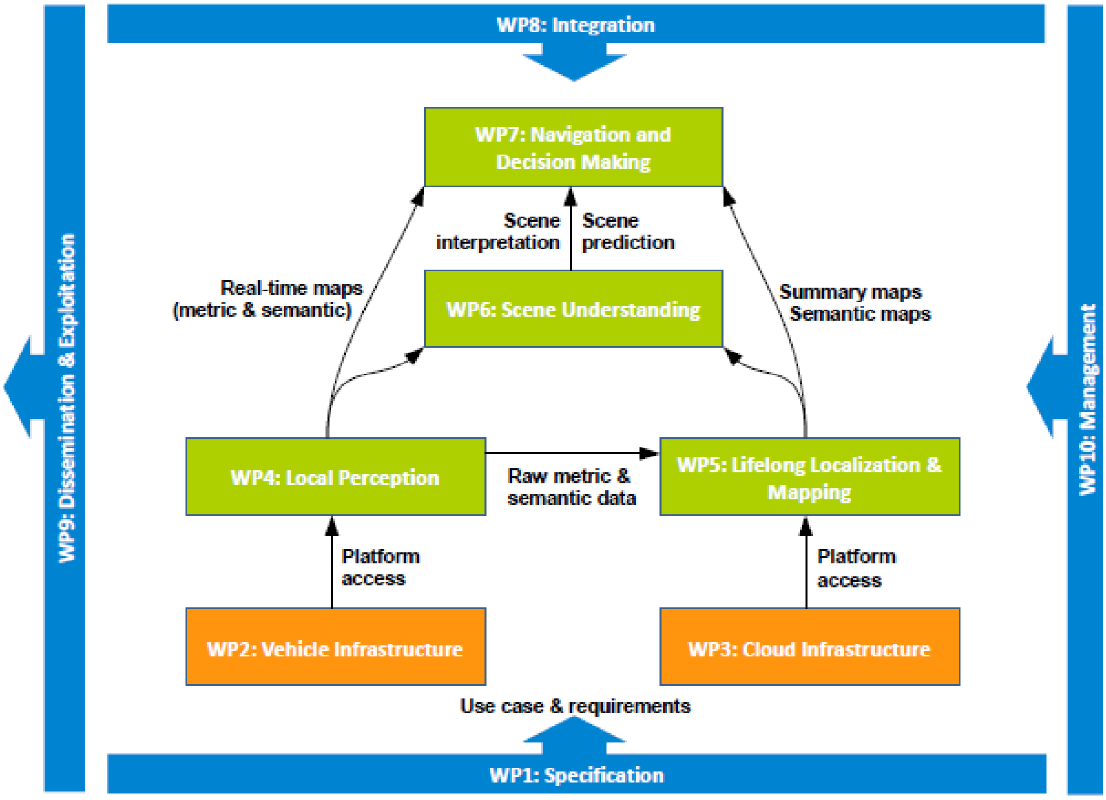

Figure 2 - Work package structure

1.2.1: Work Package 1 – Requirements, System & Components Specification and Architecture

In WP1 end user needs and requirements are analyzed with respect to the proposed applications which in turn lead to a concretized application specification. Based on these requirements, the structural and functional architectures of the system and components are specified. During the project duration two cycles of specification and re-specification are performed: first was done in M1-M4 and the second one will be done in M25 - M28.

Task 1.1 End-user needs and requirements analysis

This task is to identify the end-user needs based on the proposed applications. This is mediated by the industrial partners (VW). The proposed applications and use cases descriptions are illustrated with the identified user needs.

In the first iteration, the function of on-street valet parking from both the customer as well as technical perspective has been analyzed. This global scenario was chosen as potential theme for the demonstration of the project. This is due to the fact that on the one hand the customer function is very appealing and on the other hand that the technical solution requires solving the key challenge of the UP-Drive project: fully automated city driving. All the global use-cases and the system requirements related to this function were clearly defined. They were described in details in Deliverable D1.1 (M4).

In the second iteration (M28) the customer function can be easily applied to other interesting use-cases such as: picking up kids from school or grandparents from train station or groceries from the supermarket.

Work within this Task has been performed by VW.

Task 1.2 Application analysis and requirement specification

The task derives the relevant requirements for the demonstrator applications from the use cases. Both functional and non-functional requirements are derived. The application analysis are focused on the project's main use-cases.

More specific use-cases and scenarios along with the derived requirements have been identified. The requirements are grouped (requirements on perception – WP4, requirements on mapping and localization – WP5, requirements on scene understanding and prediction – WP6, requirements on motion planning and control – WP7) and presented for each subsystem. Scenario-level use cases describe the individual challenges the car might be confronted with and needs to master during the automated operation in urban environment. They were described in details in Deliverable D1.1 (M4). The analysis and specification has been performed in M1-M4 and will be revisited in the second half of the project. Work within this Task has been performed by all partners.

Task 1.3 Definition and specification of system architecture

The goal of this task is to define the global architecture of the overall system. It is based on input from Task 1.2 and covers hardware as well as software aspects on the vehicle and the cloud backend.

The top level architecture has been depicted in Figure 2. It highlights the functional blocks and their inter-connections. There are two functional blocks related to vehicle and cloud infrastructure that have to be developed for the UP-Drive project and four functional blocks related to the key technologies expected to bring contributions beyond the state of the art: local perception, lifelong localization and mapping, scene understanding, navigation and decision making. The architecture was described in details in Deliverable D1.1 (M4).

The definition has been performed in M1-M4 and will be revised in the second half of the project (M25-M28).

Work within this Task has been performed by all partners.

Task 1.4 System hardware and software components specification

This task provides specifications for all relevant hardware and software components of the system. Initially specification for the hardware and high level software components are provided. This work carried out for this task includes both hardware and software specification for all the components: vehicle infrastructure, cloud infrastructure, perception, lifelong localization and mapping, scenario understanding, decision making and navigation, trajectory planning, vehicle control. An initial overview of the data-types that are going to be used to communicate within and across the work packages was also provided.

The initial specification was described in details in Deliverable D1.1 (M4). As the project progresses, this initial specification will be extended and detailed (M25-M28).

Work within this Task has been performed by all partners.

Conclusions:

The objectives for this Work Package have been achieved:

- collection of requirements and their organization and prioritization
- refinement of the architecture from the high-level down to the level of interfaces
- definition of responsibilities, both in terms of module boundaries as well as partner contributions
- the Deliverable D1.1 was compiled and submitted
- Initial requirements, architecture and specifications have been laid out. All partners know what contributions are expected from them and what they can expect from other partners. Consequently, the focus of the project can switch towards solving the scientific and technical challenges of the respective work packages.

As the project progresses, new requirements will be identified, architecture will be adapted and specifications will evolve. This will be done in M25-M28 and will be presented in Deliverable D1.2 (M28).

1.2.2: Work Package 2 – Vehicle Infrastructure

The main objective of Work Package 2 is to provide test platforms for the project. In the first project year the goal was to build the vehicle platform (planned for month 8 – August 2016) and to make it fully usable (planned for month 12 – December 2016). Both objectives have been achieved. Details are given in the following sections.

Task 2.1 Vehicle platform setup

This task involves the hardware buildup of the vehicle, including the mechanical and electrical installation of the computer and sensor systems and their proper configuration. The real challenge lies in the system complexity, as it consists of 14 machines, 22 sensors for environment perception and 4 systems for estimation of vehicle motion.

Nonetheless, the car equipped with all the sensors and the computer cluster was provided to the project at the end of May 2016 – that is 3 months ahead of plan. This enabled the recording and sharing of first datasets – although not all sensors were operational at that time. This also encouraged the consortium to hold the first integration meeting: the 1st Calibration Workshop in Wolfsburg.

The car and the computer system are depicted in Figure 3. The car is a fully electric e-Golf, which already served as test vehicle for the V-Charge project.

Figure 3 - Car with integrated sensors and the computer system

Since that point in time, the sensor and computer systems have been in heavy use, which helped exposing some of the initial flaws. Those have been fixed consecutively, such that the platform is in solid shape and can be used for work within all work packages. Currently the system suffers only from a number of minor issues, which will be solved in the upcoming weeks.

Work within this task has been performed by VW.

Task 2.2 Drive by wire functionality

The goal of this task is to provide the vehicle's computer system with control over the vehicle's actuators like throttle, brakes and steering.This has been achieved by the modification of the topology of the vehicle's Controller-Area-Network (CAN), installation of vehicle-gateways and programming thereof. Of course, safety concerns are of uppermost importance. Among other organizational measures, this translates to the design premise, that the safety operator must be able to take control over the car at all times. For that reason the standard actuators – without any firmware modification – have been used. More details on that have been given in Deliverable D2.1.

Tests have shown that this approach allows for performing all the maneuvers required within UP-Drive. However, some improvements – especially achieving higher steering speeds at driving speeds above 10km/h – are desirable. We are currently investigating options for such improvement.

Work within this task has been performed by VW.

Task 2.3 Low-level data acquisition, processing & communication framework

The main objective of this task is to provide the following capabilities:

- Logging and playback of sensor data
- Communication interface for modules provided by different partners and/or running on different machines

This has been achieved with vehicle delivery in May 2016. The solution is a combination of 2 middleware frameworks widespread in the industry: Automotive Data- and Time-Triggered Framework (ADTF) and Data Distribution Service (DDS) on top of customized operating systems (Windows 7 Embedded and Ubuntu 16.04 LTS). In addition to that, time synchronization has been established within the computer system and the time signal has been propagated to the relevant middleware components. More details are given in Deliverable D2.1.

This task has been performed by VW and is considered completed.

Task 2.4 High level system debugging & maintenance framework

The objective of this task is to provide additional tools that make work with the car easier and debugging system issues more efficient. The following tools have been provided:

- data recorder that can easily be activated by the driver
- system monitor, providing information on health of all system components currently available in the car
- software deployment tool, easing the boot-up of software releases in the distributed system
- interface and tools for distribution of vehicle and test parameters

- live data visualization for the sensor and perception system integrated into the vehicle's navigation screen

The details of the tools are presented in Deliverable D2.2. In the upcoming months, as the number of modules running in the car will increase, this tool-suite needs to be incrementally adapted to reflect that growth. This means mainly integration of status information and live visualization for the new modules. Work within this task has been performed by VW.

Task 2.5 Calibration & data integrity validation of the sensor system

In this task a number of activities have been performed:

1. Precalibration by measuring locations of all sensors with the help of an external 3D measurement system, including the reference 3D point that defines the car coordinate system.
2. Development of a calibration room concept for multi-modal calibration, room setup and experimentation with room geometry and marker distribution. Two calibration workshops in Wolfsburg were conducted.
3. Timestamp analysis of LiDAR and camera data, validation of timestamp consistency and detection of dropouts, analysis of dynamic motion effects affecting LiDARs due to gyroscopic forces.
4. Data export from ADTF to Matlab to support fast prototyping of methods in Matlab.
5. Calibration data acquisition and processing, calibrated parameters shared with the partners (and used by them in data processing experiments)

Please note that within the Work Package 4 a new task (called "4.1bis") has been introduced that deals explicitly with the development of novel calibration algorithms for the multi-modal sensor system.

Task 2.6 Reference sensor integration

This task covers reference systems for ego-motion estimation and environment perception.

The UP-Drive vehicle has been equipped with a high quality Inertial and GPS Navigation System with support of Real-Time Kinematics (RTK). This allows for 2cm positioning precision and for use as ground truth sensor for localization. The system has been properly configured and the data has been used for a short analysis in Deliverable D2.2.

As the UP-Drive's sensor-setup for environment perception is very rich, a lot of evaluation can be done by referencing the different sensors against each other. This is especially true for evaluation in static scenes, for which sensor measurements can be also integrated over time to provide best quality. For those reasons no additional reference sensors have been installed. However a HDL-64E Velodyne is available at VW premises and can in principle be used for dedicated measurement campaigns. Work within this Task has been performed by VW. This task is considered completed.

Task 2.7 Vehicle maintenance and update

As the vehicle has been put into operation quite recently, so far only minor updates have been performed:

- fixing / replacement of defective components
- update of the gripping system for the rear 360°-Lidars, in order to improve stability
- installation of a network switch offering support of Precision Time Protocol (PTP)

Work within this task has been performed by VW.

Conclusions

The objectives for this Work Package for Period 1 have been achieved:

- The test platform is operational: computer system is available, sensor system is functional, most sensors are calibrated, drive-by-wire interface is functioning, and low-level and high-level elements of the data acquisition and processing framework are in place
- The car has undergone relevant testing and many datasets have been acquired
- The deliverable D2.1 has been compiled and the deliverable D2.2 is close to completion

The provided test platform can and is already used as base for efforts in other work packages. In the upcoming weeks, the remaining minor issues will be solved and after that the focus in this Work Package will turn towards building the second test vehicle.

1.2.3: Work package 3 – Cloud Infrastructure

Work package 3 has the aim of providing a project-wide foundational layer for the storage, processing, maintenance and sharing of data across devices, as well as the (automated) compilation, testing, deployment and operation of software modules within the project. When fully operational the framework aims to span hardware and software infrastructure stacks on a dedicated server and the shared areas of the vehicles. It will expose a common front-end allowing the same applications (i.e., mapping, localisation and scene understanding functionality) to operate on either stack.

Within calendar year one of the project, of the five tasks defined in WP3 the following key objectives had to be reached:

- Setup of a project-wide development infrastructure
- Design and implementation of a bulk data storage service that allows for programmatic (i.e., from within applications) and manual access
- Scoping and setup of server side compute hardware components based on the functional and application requirements derived in WP1

These tasks have been fully reached and are described in detail in Deliverables D3.1 and D3.2. Below we provide a summary of key achievements within each task.

In alignment with the Grant Agreement's timeline the following, remaining, tasks of WP3 have begun, but are not yet complete, or have not yet started:

- Design and implementation of a development and deployment tool chain for both software and (versioned) data based on containerization and dependency management. This has been started and is under IBM-internal testing.
- Design and implementation of an efficient and secure communication framework. This has been implemented for the bulk object store, but not yet the publish-subscribe messaging framework.

Both of these latter tasks will be fully implemented and reported in D3.3.

Task 3.1 Setup of project-wide development infrastructure

The aim of this task is the setup of project-wide development infrastructure. Measures for success include the selection, implementation and use of source code development repository, issue tracker, and wiki. As documented in D3.1 source code development repository, issue tracker and wiki have been selected and implemented. In the interest of a single service, the open source gitlab environment has been selected for all three elements. They are readily used by the consortium and form an integral part for intra- and cross-partner communication and documentation workflow. As of December 2016, there are more than 50 users across 25 repositories (projects). The continuously growing wiki maintains close to 100 pages.

Task 3.2 Specification, setup and maintenance of hardware stack

The hardware stack will consist of compute nodes, accelerators, memory, storage and communication infrastructure, and has been scoped based on the functional and application requirements derived in WP1. The scoping is described in detail in D3.2 and the corresponding hardware, including GPU accelerators has been procured. This includes: scalability to a total of up to 200 physical CPUs and 2TB of physical RAM, virtual machine flavours of up to 16 virtual CPUs and 128GB of virtual RAM with a maximum over-provisioning of factor 2 for CPUs (i.e., not more than 2 virtual CPUs per physical CPU) and factor 1 for RAM (i.e., equivalent amounts of virtual and physical RAM). The measures for success have all been reached: backend server is assembled and operational. Vehicle-side machines are under the responsibility of VW and are described in WP2.

Task 3.3 Design and implementation of the development and deployment framework

This task involves a development and deployment toolchain consisting of a configuration management system and a continuous integration system. The configuration management system will allow to declaratively specify and automatically deploy the entire software stack. Deployment will use containerisation and/or virtualisation as key implementation techniques.

Measures for Success include the automatic deployment of server-side and vehicle-side software, as well as the continuous building and testing of project software. Within year one an effort based on Docker and Jenkins has been scoped and partially implemented. The implemented parts are being tested within IBM and upon maturing will be released for general consumption by the consortium. In agreement with the CA, this will form part of the second development and integration cycle and be reported in D3.3

Task 3.4 Setup and implementation of a communication framework

This task aims at ensuring appropriate data exchange mechanisms between the various components and functionality deployed in the cloud and on the car. For lightweight communication an implementation building on the publish-subscribe principle (e.g. ROS, MQTT) featuring precise access control, data encryption, and various forms of Quality of Service (QoS) settings is envisioned.

For larger data sources and software deployment the use of an object store or a distributed file system living in a private network among the cars and the server is envisioned that can be seamlessly accessed or mounted within each container. Measures for success include the setup and operation of the backend server for enabling messaging services, having it accessible, and used as the primary communication medium in the project. As described below, the bulk data storage service, including secure access via a REST API is operational. Lightweight communication based on the publish-subscribe paradigm has not been implemented yet as online test operation of cloud backend services with on-vehicle services does not commence until year two of the project. In alignment with the CA, this service will hence be scoped, implemented and made available in time for D3.3 (second development cycle).

Task 3.5 Design and implementation of the bulk data storage service

In the first development cycle the bulk data storage service has been scoped, designed and implemented in the form of an object store. To this end, OpenStack Swift has been selected, which is ideal for storing unstructured data that can grow without bound at a central server. Measures for success for the first integration cycle include the availability, usage and performance testing of this centralised storage service. All of these targets have been reached as described in D3.2. In particular, the object store reaches up/download speeds of up to 100Mb/s, supports large files via splitting, and deep pseudo-folder structures (for seamless interoperability with partners' expectation for POSIX like directory trees).

1.2.4: Work package 4 – Perception

This work package provides the vehicle-side online sensing functionality required for automated driving in low-speed urban environments. The work package covers the following primary aspects:

- **Specification and design of on-board sensing** (covered by Task 4.1 in M1 - M8 and M25 - M28) [UTC, CVUT, VW]. An on-board 360-degree multi-sensorial perception solution was designed based on a set of well selected sensors including laser scanners, radars, large field of view area view cameras, and trifocal cameras disposed in a configuration offering good coverage, redundancy and good measurement accuracy. In the same time this approach offers access to the powerful perception functions of the individual sensors.
- **Spatio-temporal and appearance based low-level representation** (covered by Task 4.2 in M5-M32) [UTC, CVUT]. The redundancy and complementarity of the individual sensors will be exploited throughout complex calibration, motion correction, temporal and spatial alignment and fusion processes to provide a unified, enriched and more accurate spatio-temporal and appearance based low-level representation. This spatio-temporal and appearance based 360-degree representation integrates at pixel level, both in the 3D point cloud and in the 2D image space, the 3D position, the 3D motion, the 2D intensity or color, the image segment and the image class information.
- **Refinement of detection, tracking, and classification capabilities and environment sensorial representation** [UTC, CVUT, VW].
  We will utilize the richness of the sensor setup and of the unified low-level representation as a building block not only for detection of traffic participants but also for the detection of terrain and road infrastructure (covered by Tasks 4.3-4.7 in M5-M42). Starting from the selected sensors and the associated perception solutions and using the new spatio-temporal and appearance based low level representation new solutions are investigated for objects or object parts better detection, tracking and classification. Word Channel, Multi Modal Filtered Feature Channels and Deep Learning methods were experimented and will be developed for improving the detection, and classification results.

The main goals of WP4 in the first year of the project were to provide an initial specification and design of on-board sensing perception system architecture. Because the sensor setup got much more rich than assumed at the time of writing the proposal our plan from the proposal has evolved a bit.

- Task 4.1 Specification and design of on-board sensing
- Task 4.1bis Calibration, cross-calibration, synchronization (newly introduced)
- Task 4.2 Spatio-temporal and appearance based low level representation
- Task 4.3 Perception adaptation to adverse visibility conditions
- Task 4.4 Road infrastructure perception
- Task 4.5 Real-time 3D terrain perception
- Task 4.6 Road users and signaling perception
- Task 4.7 Sensor fusion based perception refinement

All these tasks will be approached by building the pipeline presented in D4.1 (M8).
Several modules were identified and initially specified in terms of interface (input and output data structures), functionality (their main tasks) and performance (evaluation of the output). Their interconnection and mapping on the above mentioned tasks is further presented. Some possible solutions were studied, evaluated and proposed.

Task 4.1 Specification and design of on-board sensing

The perception system hardware architecture presented in deliverable D1.1 (M4) and D2.1 (M8) relies on a set of well selected on-board sensors disposed in a configuration offering good coverage, redundancy and providing good measurement accuracy. The software architecture presented in deliverable D4.1 (M8) is based on the selected sensors and the associated perception solutions. Because the sensor setup got much richer than assumed at the time of writing the proposal a calibration, cross-calibration and synchronization task was newly introduced. The redundancy and complementarity of the individual sensors will be exploited throughout complex calibration, motion correction, temporal and spatial alignment and fusion processes to provide a unified, enriched and more accurate spatio-temporal and appearance based low-level representation. Using the new spatio-temporal and appearance based low level representation new solutions for objects or object parts better detection, tracking and classification will be developed in a unified but multi-modal manner covering road infrastructure perception, real-time 3D terrain perception, road users and signaling perception. The results of the multi-modal detection, tracking and classification are fused and based on them an enhanced representation of the environment is provided.

The main modules of the software architecture and their mapping on WP4 tasks were specified (see Figure 4 below). This architecture establishes the modules that have to be developed, their functionalities and interconnections. This offers a clear vision about the modules allowing the partners towards the development of all the perception functionalities.

The work for this task has been carried out by UTC, VW and CVUT. As the project advances, improvements in specifications definition and functionalities implementation may occur. They will be presented in deliverable D4.4 during M25-M28.

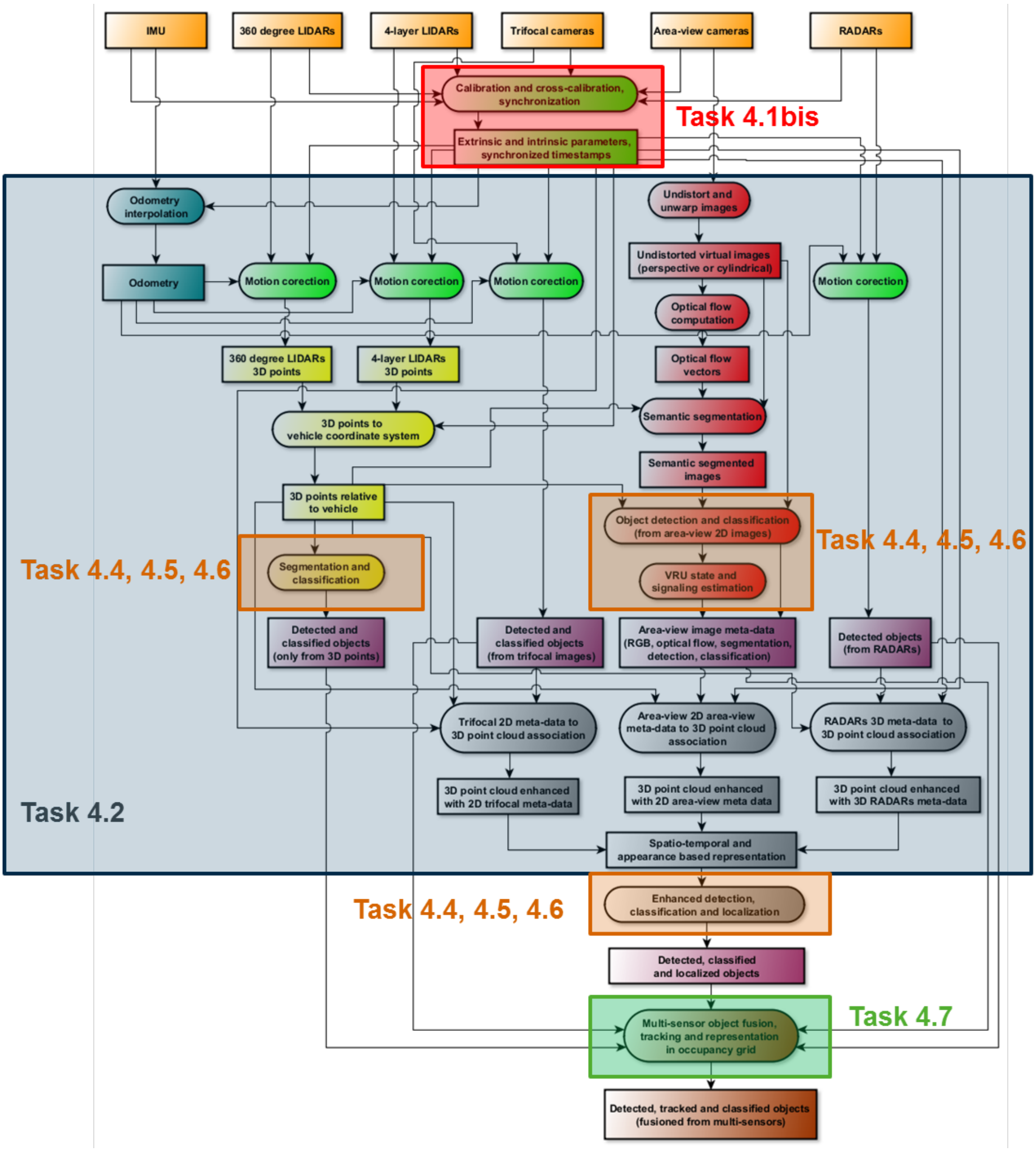

Figure 4 - Software architecture of the perception module (Task 4.1)

Task 4.1bis: Calibration, cross-calibration, synchronization (newly introduced)

This task includes the model of all sensors mounted on the vehicle, computation of intrinsic and extrinsic parameters, offline timestamp calibration, calibration monitoring and adaptation.

A method and a Matlab software for extrinsic calibration of 360-deg LiDARs relative to one of them designated as a "master LiDAR" were developed. The method achieved about 12mm residual root mean square error which is very good considering sensor accuracy declared by the manufacturer. In more details, a Bayesian model and a corresponding Matlab module for 3D point cloud segmentation to non-contiguous planar segments were developed. The inference engine for the segmentation problem is based on pre-existing work. The method uses a Bayesian model selection method for determining the aposteriori-optimal number of segments. Then, a method and Matlab software for plane set to plane set robust matching based on rigid motion invariants were implemented. A Matlab software was implemented for plane to 3D point cloud ICP algorithm for accurate alignment of segmented point clouds usable for both 360-deg and 4L LIDARs (see next).

In future these modules will be used as a first stage of 360-deg LiDAR scan registration between LiDARs and will also be used for finding correspondences for 3D scene tracking, vehicle motion estimation from LIDAR scans, for on-line calibration accuracy monitoring and adaptation, and for aggregation mechanism for incremental building of a detailed map of static road and near-road infrastructure.

A method for extrinsic calibration of 4L LiDAR data was proposed. This is based on matching and registration of 4L scans to 360-deg LiDAR scans. In more details, we developed a new method and implemented Matlab software for the solver of a minimal problem for automatic registration of single-line LiDAR data to 360-deg LiDAR data. The solver seems more stable under noise than the published methods. The solver is used for matching 4L LiDAR scans to 360-deg LiDAR scans.

A method and Matlab software were implemented for automatic mapping from the master LiDAR coordinate system to the calibration room coordinate system based on plane-to-plane matching and tracking. This module enables cross-calibration between cameras and LiDARs. A method and a Matlab software were implemented for optimal registration of extrinsic calibration of 360-deg LiDARs to the precalibrated poses. The positional and angular difference is one of calibration validation criteria. Typical mean positional difference is about 10-25mm and angular difference about 0.2-0.5 degree. The concept, development, and testing of an opto-electronic device for measuring data capture synchronization between LiDARs and cameras were also done.

A method and Matlab software for target point (marker) detection in calibration room for camera extrinsic calibration were developed, implemented and tested.A method and Matlab software for extrinsic camera calibration from target points was also implemented. Currently it is in a testing phase. The work for this task has been carried out by CVUT and presented in deliverable D4.1 (M8).

Task 4.2 Spatio-temporal and appearance based low level representation

This task (M5-M32) includes three prerequisite modules: the motion correction module, the 3D point cloud fusion module, 3D point cloud processing module (tasks 4.4-4.6) and the area view processing module (tasks 4.4-4.6). Their results are used as input for building the spatio-temporal and appearance based representation.

The motion correction module includes the odometry interpolation, the motion correction approach for LIDARs, RADARs and trifocal objects. A generic motion correction solution for the LIDARs, RADARs, and trifocal objects was studied and experimented. It relays on the raw input from sensors, acquisition time stamp information, time stamp of the correction moment, and the 6DoF interpolated ego motion information. ADTF implementations are under development for the Velodyne sensors for the 4 Layers LIDARas, for the RADARs and for the trifocal objects.

The specificity of the sensors imposes the temporal alignment with the area view cameras of all other sensors. The motion correction step will be carried out for each processing cycle.

The 3D point cloud fusion module includes the aggregation and transformation of 3D points in the vehicle coordinate system. Based on the extrinsic parameters of the Velodyne sensors and of the 4 Layer LIDARs a global Point Cloud was aggregated from the motion corrected raw data. The space coverage and the accuracy of the aggregation was investigated.

The spatio-temporal and appearance based representation includes the registration of area view 2D metadata (tasks 4.4-4.6), trifocal 3D meta-data and RADAR 3D meta-data to the fused 3D point cloud and its meta-data. The spatio-temporal and appearance based representation allows the multi-modal enhanced detection, classification and localization of objects.

Experiments for associating (registering) the area view meta-data to 3D point cloud were done. For that a cross-calibration solution between a camera and a Velodyne sensor was developed and experimented. The resulting association was evaluated. The quality of such associations was proved as being accurate.

Trifocal camera 3D meta-data to 3D point cloud association was also studied. For that a cross-calibration solution between the trifocal camera and a Velodyne sensor was developed and experimented. Solutions for correcting the trifocal camera 3D objects localization and orientation are in progress. The work has been carried out by UTC and VW.

Task 4.3 Perception adaptation to adverse visibility conditions

This task (M5-M32) is not approached in this phase of the project.

Task 4.4 & 4.5 & 4.6 Road infrastructure perception, Real-time 3D terrain perception, Road users and signaling perception

The main objective of these tasks (M5-M42) is to provide enhanced object detection, localization and classification. Experiments for objects detection, localization and classification relaying on individual sensors perception were carried out.

The 3D point cloud processing module consists of segmentation, detection and classification steps. Multiple solutions for cloud segmentation were implemented. First step of the segmentation relied on a road object points discrimination and road surface estimation. The second step consisted on individual objects discrimination. The solutions are implemented in C++. A software solution is available in ADTF.

The 3D point cloud processing will provide an independent detection, classification and tracking solution. The raw 3D points projected in the area view images will contribute to a better pixel level segmentation and classification of the images. In the same time the enhanced 2D image metadata related to the 3D point cloud points will improve the 3D Point Cloud level detection, classification and tracking processes.

The area view processing module includes all the processing sub-modules of the images acquired by the top view cameras - image un-distortion and unwarping, optical flow computation, semantic segmentation, object detection, classification and tracking, vulnerable road users state and signaling estimation. The raw fisheye images provided by the area view cameras are not appropriate for further processing since the real world objects are highly distorted in these images. Solutions for image un-distortion and unwarping based on the forward projection model of the camera were studied, implemented in Matlab and experimented. The selected solution represented by virtual cylindrical images was implemented in C and is under integration in ADTF. A solution for pixel level semantic segmentation of the area view undistorted images was developed and experimented. It relies on an original multimodal approach integrating the image information, the associated 3D information obtained by projecting the 3D point cloud points in the area view images, and the optical flow computed from images. The segmentation approach is enhanced by the use of multiresolution filtered channels. The solution was experimented on a training set including pixel level annotated images and depth information. Successful classification experiments and solutions were also developed. A tool for helping the pixel level annotation process of the area view images was developed. It relies on image and depth information obtained from Velodyne data. The annotation process is supported by superpixel based segmentation, conditional random fields based segmentation and some specific segmentation processes. The tool is under evaluation.

The individual findings are fused in the spatio-temporal and appearance based representation (Task 4.2).

Enhanced objects detection, localization and classification is based on the powerful spatio-temporal low-level representation having a multi-modal nature. Experiments were carried out for road infrastructure elements, road users and vulnerable road users providing in this phase results at state of the art level. The work has been carried out by UTC.

Task 4.7 Sensor fusion based perception refinement

The main objective of this task (M5-M42) is the high level fusion and representation of the environment. This includes the grid estimation, object estimation, road estimation and road graph. A first idea for this high level fusion of perceived environment entities was described in deliverable D4.1 (M8). It will be effectively implemented after the results from the previous perception tasks will be available. The work has been carried out by VW.

Conclusions:

The objectives for this work package have been achieved:

- The first perception system hardware architecture described in deliverable D2.1 (M8) and the first perception system software architecture described in deliverable D4.1 (M8) offer a clear vision about the perception modules allowing the partners towards the development of all the functionalities
- A first design and implementation of the calibration, cross-calibration and synchronization (newly introduced task 4.1bis) of almost all available sensors (cameras, LIDARs, RADARs) on the car
- Initial design and implementation of 3D points and 3D objects motion correction, 3D point cloud fusion and processing
- Initial design and implementation of area view data processing including segmentation, object detection and classification
- Initial design and experiments for building the spatio-temporal and appearance based representation
- Initial experiments for enhanced objects detection, localization and classification
- an idea for the high level fusion of perceived environment entities was described in deliverable D4.1 (M8)
- The deliverable D4.1 (M8) was compiled by UTC, CVUT and VW

The work package is on track. All the tasks have already provided some preliminary results except task 4.3 which is currently not a priority. The first iterations of tasks 4.1 and 4.1bis are completed and the Deliverable D4.1 has been complied and submitted. All the other tasks: 4.2 – 4.7 are ongoing (except 4.3) and on track. The achieved results will be presented in deliverables D4.2 (M18), D4.3 (M18), D4.5 (M32) and D4.6 (M42).

1.2.5: Work package 5 – Lifelong Localization & Mapping

The goal of WP5 is to provide a compact, customized, and metrically accurate map representation with which the vehicles can localize reliably in long-term and large-scale operations in urban environments, and where semantic data can be associated, stored and queried. The obtained localization and map representations are furnished to other WPs, which take higher level decisions for the self-driving task. In the first year we have worked towards the following milestones in WP5:

MS1: "Work has started, first specification completed" (M4)

The requirement analysis and specifications for the map representation has been elaborated and reported in D5.1.

MS2: "First development phase completed" (M16)

- Derivation of requirements and specifications for the localization and mapping software layers, data structures, and interfaces.
- Initial version of the metric mapping components and localization have been developed and tested.
- All sensors used for localization and mapping on the vehicle platform have been calibrated. Apart from a minor issue with the data integrity of the TopView images, the vehicle is ready for collecting datasets for localization and mapping on a regular basis.
- Initial work developing internal map representations and interfaces between metric and semantic map components.
- One scientific publication on a state-of-art survey of mapping and localization has been published in an international journal.
- One scientific publication on appearance-based localization under changing conditions has been published to an international conference.

The completed and currently exploitable results are the following:

Task 5.1, Task 5.2, Task 5.3, D5.1 Requirements and Specification

The first phase of work on WP5 was primarily focused on framing and defining the requirements and specifications for both the localization and mapping frontends. This was done according to the expected use-cases and the scope of proposed target scenarios, and driven by thorough discussions between ETHZ and IBM. The complete derivation of these specifications and use-cases can be found in D5.1. To summarize, the following high-level tasks were completed:

- Designing the basic architecture for internal map representations.

- Designing interfaces between the cloud-based mapping backend and location queries (both metric and semantic).
- Defining which functionalities are to be available in the mapping backend.
- Defining both online and offline data exchange, as well as dataset archiving.

The derived specifications on the localization and mapping frontend and cloud-based backend will be used and exploited by work-packages 5, 6 and 7. They define a common ground for future developments by relating various concepts and interfacing various sources of information to each other. For example, this includes high-level project tasks such as life-long mapping and localization, scene understanding and navigation, and decision making.
The primary contributors were ETHZ and IBM. We will now outline important details of the progress that has been made with respect to WP5 over the last year, and document any results which are ready to be used or built upon by upcoming tasks.

Task 5.4 Metric Localization

Building off of ETHZ's previous work on visual-inertial localization and mapping, an initial implementation of metric mapping front and backends are available. The metric localization and mapping framework functions on the basis of sparse 3D landmark-based visual inertial motion estimation, visual loop-closures, and bundle adjustment. This framework is able to provide online localization capabilities, returning 6DoF transformations between the vehicle body frame and a map-based fixed reference frame. In addition to retrieving the vehicle's current pose, the ability to retrieve metric position estimates of historical vehicle poses and mapped landmarks is also possible. Furthermore, the framework is capable of locally storing maps after creation, and has the ability to augment these existing maps with newly acquired data.

In order to begin testing this initial implementation of the metric mapping framework, some work on sensor setup and integration was also required. Successful integration of sensor data from the multi-camera TopView system, IMU, and wheel odometry has been achieved. This includes intrinsic and extrinsic calibration of these sensors. Furthermore, functional metric localization and mapping capabilities on the Wolle (UP-Drive test car) test vehicle sensor suite has been demonstrated in initial test environments, with a qualitative assessment indicating accurate results. Although not originally foreseen in the project, along with the setup on the Wolle test vehicle (which is based in Wolfsburg), we have brought the Kermit test vehicle (which is based in Zurich) from the previous V-Charge project up to an analogous state, albeit with the sensor suite from V-Charge. This additional platform will allow for efficient progress in integration and testing of the localization and mapping software on site of ETHZ in Zurich.

This progress on the metric mapping and localization moves us forward on the track of completing MS2 in the next semester. Further work needs to be done, especially on topics such as long-term robustness and accuracy. A discussion on open challenges in state-of-the-art SLAM frameworks is documented in a related survey paper we recently published, highlighting some of the unsolved problems related to long-term, large-scale localization and mapping which will be addressed within the UP-Drive project. Research on these topics is therefore planned for the next year. Future developments will also be facilitated by thorough testing of the framework on a larger scale. Some initial work in these directions has already begun, and is documented in the form of an international conference paper with the following contributions:

- Development of novel methodology for long-term localization under changing conditions.
- Experiments involving day-to-night and and year-round mapping and localization.
- Initial experiments with larger-scale, multi-mission map creation and localization.

More details on the paper can be found on the project webpage - http://up-drive.eu/appearance-based-landmark-selection-for-efficient-long-term-visual-localization/.

Currently, we are in the process of integrating and testing this novel methodology in the project's vehicles and scenarios for larger-scale and longer-term maps. We will try to push our findings to the limit and continue research into this important direction.

Work in this task was performed by ETHZ.

Task 5.2 Reference Frame Alignment

At the intersection of WP5 and WP6, we have additionally began taking on the task of aligning the semantic map representation with the metric map, which has proven to be fundamental for the proper operation of the localization and mapping framework as well as the scenario understanding effort. This task concerns the alignment of map data between different coordinate frames. Two general types of coordinate frames are maintained within the project:

- Map data that is referenced with respect to GPS, usually expressed in WGS84. The highly accurate dynamic lane models (DLMs) provided by VW are specified in this frame. Certain classes of semantic information, such as road / lane markings, traffic signs and parking spaces are also partially available in this frame.
- Map data that is referenced with respect to metric visual odometry. Certain classes of semantic information, such as road / lane markings, traffic signs, dynamic objects as reported by on-board sensors are translated into that frame.

For the purpose of data fusion and online decision making (i.e., driving decisions), a transform estimate between these two frames is required. In the spirit of the successful RSLAM principle it has been decided that this estimate is maintained at a local level, which ensures maximal local overlap without resorting to the costly and unnecessary deformation of the involved frames further at a global level. This design choice has far reaching consequences and in particular serves as a facilitator of lifelong mapping and continuous atomic updatability of the overall map framework. We have furthermore developed the following components to facilitate development in the coming project phases:

- Writing a parser for VW's DLM format and translation into a standard XML-serializable format using the Boost graph library.
- Tools for visualizing this standard format in ROS' RViz visualizer.

Within project year two, an optimization framework will be implemented that allows for the local optimization between traveled trajectories and the DLM lanes specified in WGS84. This will result in the estimation of transformations that locally bring the GPS and visual odometry frames into maximum alignment, as described above. Work was performed by IBM.

Conclusions

Work on tasks T5.1, T5.2, T5.3 and T5.4 has started without major deviations from the schedule for WP5 in year one. In year two, we will continue to work on all mentioned tasks, as well as begin working on task T5.5 and T5.6.The work package is on track.

1.2.6: Work package 6 – Scenario Understanding

Work package 6 (WP6) is focused on Scenario Understanding in UP-Drive project. The main purpose of the scene/scenario understanding module is to extract contextual information about other traffic participants that are relevant to the particular traffic situation. The data are taken from the UP-Drive software infrastructure. WP6 contributes to understanding the local scene in the surroundings of the car, including driving mode and behavior of other roads occupants.

The aim of scene/scenario understanding is to predict the future state of traffic participants with the several seconds outlook. The Scene/scenario understanding in the UP-Drive project consists of several functionalities, such as object validation & stabilization, Object intention estimation, Set-up of virtual objects and Object motion prediction (Figure 5). The percepts/information come from different sensors as lidar, radar, cameras, GPS receivers, as well as the RoadGraph (a graphical structure representing the traffic infrastructure). These information will be provided by WP4 (perception) and WP5 (lifelong localization & mapping). WP6 will contribute by mitigating the uncertainty before the information is passed on to WP7 (decision-making and navigation).

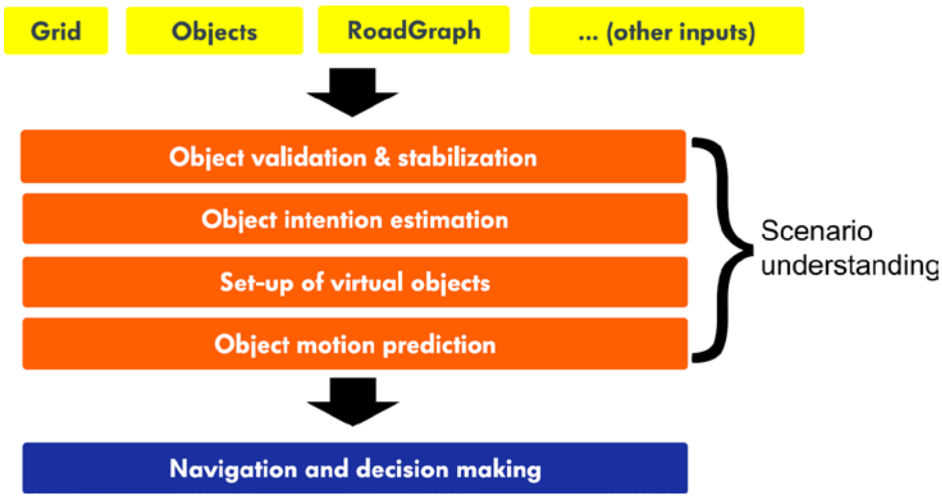

Figure 5 - Scenario Understanding Architecture

The initial requirements for the scene understanding work package (WP6) were presented in Deliverable 6.1. Based on the published works and VW's good practice, the outline of WP6 functionalities and related requirements was listed. WP6 will be closely interconnected with WP4, WP5, and WP7 in UP-Drive.

Task 6.1 Long-term semantic scene understanding

At the intersection of WP5 and WP6, we have additionally begun taking on the task of aligning the semantic map representation with the metric map, which has proven to be fundamental for the proper operation of the localization and mapping framework as well as the scenario understanding effort. This has been reported under T5.2 and forms the basis and essential first part of T6.1. The remaining parts of T6.1 will be approached in project years two and beyond.

Task 6.2 Scenario based scene understanding

Main focus of this task in WP6 is on Scenario understanding architecture and the proposal of the data structure for WP6. The main output of the scenario understanding work package will be the data for WP7. The detailed description of this data structure is presented in Deliverable 6.1.

One important part of the work in the WP6 during the reporting period was to getting know with ADTF system and RoadGraph. For this purpose, several meetings and workshops were organized. The RoadGraph data are crucial for further research and design of the suitable Bayesian network, which can be used to estimate the traffic participant`s current actions and predict their intentions based on the current measurements. The probability distributions for the policy model (for actions and intentions) can be learned from real-world data (RoadGraph), e.g. using the Expectation Maximization (EM) algorithm. Other distributions in the probabilistic network can be modeled either using physics-based models or expert knowledge

Task 6.3 Scene prediction

The main objective of the current work on WP6 was the research in the area of Scenario understanding. During this research period, a lot of different approaches for specific tasks in WP6 were examined.

Based on our study presented in Deliverable 6.1, there are three different approaches for motion prediction and intention estimation tasks, which are part of WP6:

Physics-based motion models, Maneuver-based motion models and Interaction-aware motion models.

- Physics-based models can reliably predict the motion of other traffic participants for up to 1 second into the future. Nevertheless, they are currently the most widely used.
- Maneuver-based motion models are more complex, because intentions of other traffic participants are taken into account. However, they do not consider interactions between traffic participants.
- Interaction-aware motion models are the most sophisticated models. They take into account the interactions between different traffic participants. Therefore, they are most suitable for this task. However, the complexity of these models is very high. We have decided to focus on Interaction-aware motion models and consider the inter-dependencies between maneuvers of multiple traffic participants. Most of these models are based on Dynamic Bayesian Networks (DBN), therefore we have decided to use DBN in our proposal.

We have proposed simple Bayesian network, which serves very well the testing purposes, however it is not sufficient for practical use. The Bayesian network (Figure 6) consists of several parts such as Information about pedestrians, zebra crossings, traffic lights and junctions. Blue nodes represent measured entities, orange nodes are predicted. We have considered simple situations such as pedestrians crossing the street, the stopping car in front of the ego car. The presented network is very suitable for our primary research in the area of scenario understanding. The current research using proposed Bayesian network is performed on simple simulator. The presented Bayesian network will be great help in design of complex system for scenario understanding in UP-Drive project.

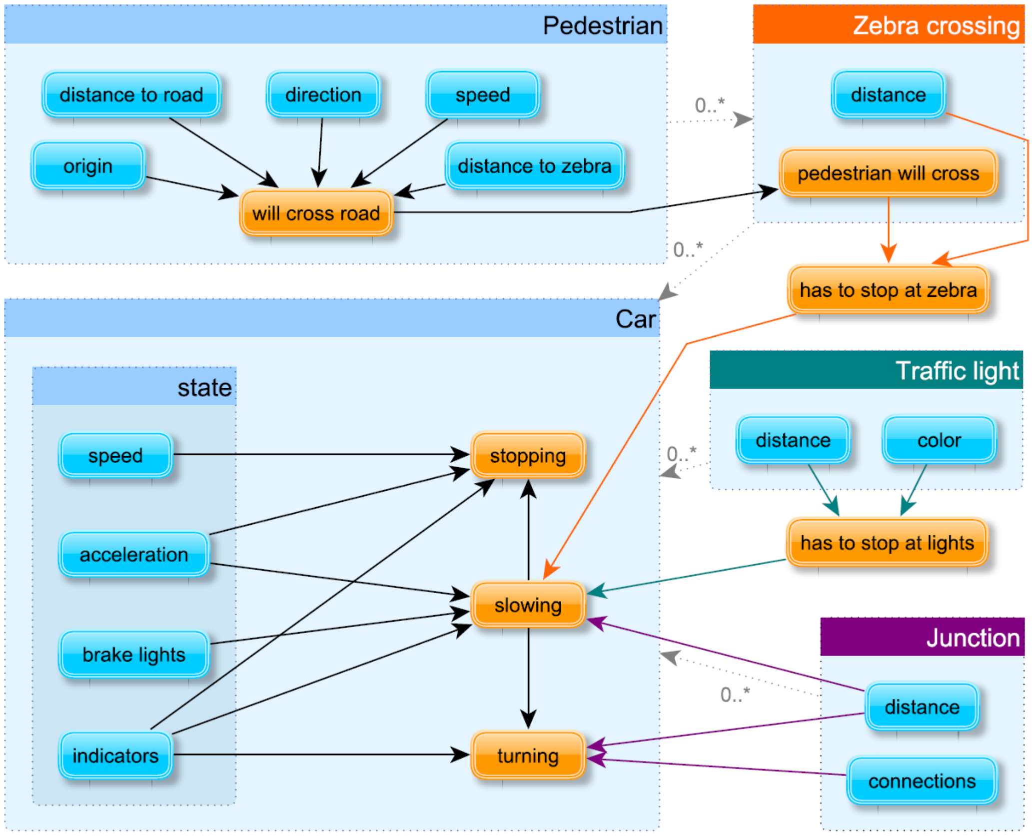

Figure 6 – The schematic of the implemented Bayesian network

Task 6.4 Self-assessment

This task is part of the future work in work package 6.

Outlook

The next steps for WP6 are as follows:

- Continue research in the area of scenario understanding for future use in the WP6. The first scenario studied by CVUT is the narrow street scenario.
- Implementation of possible approaches of scenario understanding, especially intention estimation and motion prediction. CVUT is responsible for this part.
- UTC will focus on object validation and stabilization. This task is closely related to work in WP4.
- VW links WP6 to the experimental car context, provide RoadGraph, experimental data from test drives. VW also explicates the crossings scenarios.

1.2.7: Work package 7 – Decision-making and Navigation

The main objective of WP 7 is to devise a decision making and navigation system providing core planning functionalities comprising logical and physical motion planning layers. Hitherto, the software architecture has already been specified in Deliverable D7.1, which was due June 2016. Moreover, basic versions of the modules required on the different layers are implemented and have proven to be functional in an internal Volkswagen demonstration. Details are described in the following sections.

Task 7.1 Route Planning

According to Deliverable D7.1., this task involves logical route planning on a global as well as local level. Here, global planning refers to a topological path from the current vehicle lane to the target lane. Thus, it is comparable to state-of-the-art navigation systems as no vehicle pose or lane information is taken into account on this level. In contrast, the local path planner maps the global path on a lane level within the local vehicle environment yielding a set of consecutive lanes which need to be followed. Here, local refers to a few hundred meters in order to keep the computational burden manageable.

The following work has been carried out on this task:

- Adaption of the global path planner from previous projects in order to be able to accept mission goals as specified in D7.1
- Adaption of the global path planner in order to provide parking spot information to the mission executive layer
- Adaption of the global path planner to compute very short routes (smaller than 30 meters) for parking spot to parking spot navigation
- Adaption of the local planner to process mission goals

Task 7.2 Tactical Planning

This task connects to the local decision layer elucidated in D7.1, which computes local targets for the trajectory planner. In this context, targets constitute future vehicle states computed by considering the local traffic situation.

This functionality has been tested in the car in the following situations:

- Lane following
- Lane changes
- Keeping target velocity
- Following preceding car

Intersections are currently under investigation and a first version has been tested in simulation. This includes the following capabilities:

- Stop at traffic lights

- Consider oncoming traffic when passing intersections
- Analyze the right-of-way situation

Integration of these modules into the vehicle platform is ongoing work and will be done in the course of 2017.

Task 7.3 Trajectory Planning

Currently, in standard traffic situations we employ a trajectory planner using Frenet coordinates. In parking scenarios in turn, a dynamic programming approach based on motion primitives is used. We refer to this approach as free space planner. Both planners have been tested on vehicle platforms that have been made available by other Volkswagen projects. The scenarios listed in the Description of the task 7.2 are mastered by the trajectory planner. In addition to those scenarios, parking maneuvers have been demonstrated in June 2016 using the free space planner. Adaptation of both planners to the Up-Drive vehicle platform will be performed until spring 2017. In the long term, we aim to consolidate the trajectory planners so that they share a single yet powerful planning engine.

Task 7.4 Trajectory Control

In line with the two-planner approach for the trajectory planning, we also have two controllers running in the vehicle. The control points of the standard trajectory planner are processed by a simple P-controller. However, in low speed parking scenarios, the controller scheme is switched and a controller based on the simulation of electric field lines commands the vehicle. The latter one has been described in more detail in deliverable D7.1.

The following work has been carried out within this Task:

- Porting of the electric field line controller from C++ to a Matlab Simulink environment so that a rapid prototyping hardware from dSpace can be used
- Implementation of seamless switching between the two controllers

Porting of the controllers to UP-Drive vehicle is work in progress. In further future we plan to investigate options for controllers that offer more path fidelity or even trajectory fidelity.

Task 7.5 Mission Executive

The objective of this task is to orchestrate all the relevant actions as well as state transitions of the car system. These include activation and deactivation of automated mode, engine start/stop, computation/ recomputation of the route, triggering of maneuvers, setting indicator lights, etc.

The following work has been carried out in this task:

- Implementation of an orchestration module named mission coordinator
- Definition and implementation of a communication protocol

- Integration of the mission coordinator into the existing software architecture

The mission coordinator provides the following features:

- It is implemented as state machine switching between the states init, driving, parking, shutdown. The active state and the transitions depend on the current mission status. E.g., when approaching a parking spot, the mission coordinator will switch from driving to parking.
- Activation/deactivation of the trajectory planners
- Integration of safety checks. E.g., the standard trajectory planner must not be activated as long as the vehicle still features a large angle to the road direction while parking out. This restriction holds even it has already left the parking spot as the trajectory planner does not consider any vehicle model. However, a bunch of safety checks apply assuring smooth module switches.

We assume that the complexity of the mission coordinator will drop in the future if only one trajectory planner exist. This is still ongoing research and strongly depends on the results of the planner fusion.

Conclusions

The modules of the software architecture defined in D7.1 have been implemented featuring basic or even advanced functionality. The work on tasks T71.1, T7.2, T7.3, T7.4, T7.5 has been performed by VW, is on track and will continue as described above.

1.2.8: Work package 8 – System Integration and Evaluation

Work Package 8 deals with the topics of system integration and evaluation. It can be expected that efforts in this work package will grow as the project progresses. However already in the first year a number of relevant activities have taken place. Those are described in the following sections.

Task 8.1 Integration plan

Currently most modules are in development. Nonetheless, some integration into the car system is already ongoing. A detailed integration plan for the first version of the UP-Drive system has been prepared and documented in Deliverable D8.1. More details on the current state are given in the description of Task 8.4.

Task 8.2 System-wide data acquisition

The acquisition of datasets has started in Month 6, right after the initial car build-up. Since then, the datasets have grown in contents reflecting the expanding functionality of the sensor system. The datasets will be reported on in the Deliverable D8.2.

Here it should be mentioned that partners have prepared tools to extract the sensor data from the measurement files into their prototyping/development environments such as Matlab or ROS.

Task 8.3 Integration and test tools and processes

The interfaces used within the project have been provided by VW. In order to ease the integration work, VW has prepared a so-called UP-Drive-SDK, including 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.

The project plans to perform testing based on datasets, simulation and of course actual automated driving. Software components related to perception will be tested mostly using datasets. Navigation and motion planning components – on the other hand – are best validated in simulation. In order to enable this, VW has prepared a simulator able to parse the map data from Work Package 5 and to provide road topology, static and moving obstacles using the interfaces from Work Package 4. A screenshot from that simulator is shown in Figure 7.

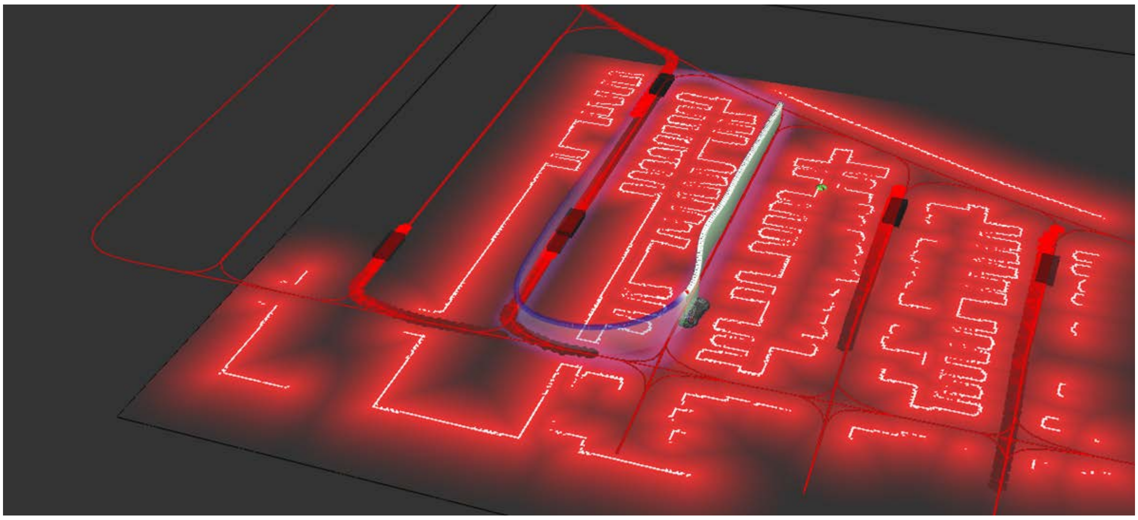

Figure 7 - Simulation environment. Ego vehicle is shown in blue, other vehicles are dark red and static obstacles are glowing red.

A separate simulator for validating scenario understanding components (Work Package 6) has been prepared by CVUT. The above tools will be explained in more details in Deliverable D8.3.

Task 8.4 System integration

Most of the components of the UP-Drive system are in the development phase. However, a baseline system capable of very basic automated driving can already be assembled using the following components:

- the vehicle with its sensors
- VWs WP4 software pipeline – serving as a starting point for the goal-wp4-pipeline – as defined in Deliverable D4.1
- VWs WP7 software stack
- DGPS system acting as the localisation system

The main goal of Work Package 8 can be seen as continuously expanding this baseline system and exchanging the initial components by their more sophisticated versions.

In order to achieve that goal and strengthen the communication in the project a number of workshops have been organized:

- Perception-get-to-know workshop: Wolfsburg, December 2015 (before official project start)
- Kick off meeting with planning workshop: Wolfsburg, January 2016
- Calibration workshop 1: Wolfsburg, June 2016
- Review and planning workshop: Prague, June 2016
- WP6 workshop 1: Wolfsburg, August 2016
- Calibration workshop 2: Wolfsburg, September 2016
- WP6 workshop 2: Wolfsburg, September 2016
- Localisation workshop 1: Wolfsburg, October 2016

- WP4 workshop: Cluj, November 2016
- WP6 workshop 3: Prague, November 2016

The meetings in person have been complemented by very active online collaboration with number of wiki pages and reported issues both approaching 100.

The above efforts have led to the following results:

- Maps provided by VW can be parsed by IBM and converted into the ROS environment, which will be used for development by IBM
- Interfaces for localization defined and pipeline implemented in ADTF (which is the middleware to be used in the project – for details please refer to Deliverable D2.1)
- VWs WP4 software running on UP-Drive car
- Interfaces for the goal-wp4-pipeline defined and skeleton of the pipeline implemented in ADTF
- Interfaces within wp6 defined
- WP7's software-stack running on other cars available at VW
  WP7's controller running on UP-Drive car

Task 8.5 System evaluation and validation

This task has seen only some limited effort – the evaluation of sensor data integrity and calibration integrity has been performed and will be reported on in Deliverable D2.2.

Conclusion

The work package is on track. The most prominent future milestone is the integration of the localization system and some of the perception modules developed in the project - and performing first automated driving with that setup. This is planned to take place in first half of 2017.

1.2.9: Work package 9 – Dissemination, Exploitation & Knowledge Management

Work package 9 has the aim of grouping together all dissemination, exploitation and knowledge management tasks within UP-Drive. The objectives of this work package are:

- To transfer knowledge both within the consortium and to the outside world.
- To set up and maintain a comprehensive set of dissemination tools and mechanisms.
- To promote the results developed within the project.

All WP9 tasks are support tasks for other work packages and tasks. Provision of the content itself will be part of the technical tasks within the related work packages. As such it consists of a variety of tasks conducted with an involvement of all consortium members. Within project year one, activities of this work package were restricted to the setup of the project webpage (D9.1) and the project brochure (D9.2). These tasks are reported here.

D3.1: Setup of project-wide development infrastructure

While not formally part of WP9, this deliverable has setup a project-wide development infrastructure including a source code development repository, an issue tracker and a project wiki. As such it implements the internal, partner-facing part of T9.1 on knowledge management. For further details, please refer to Section 1.2.3.

D9.1: External Project Web-page

The UP-Drive project website implements part of T9.1, as well as T9.2 and forms the public information and dissemination portal for the project. The web site offers basic information about the parties involved and more detailed information about the project and its goals. While the initial version has been reported in Deliverable D9.1, it maintains continued updated access to documentation, scientific reports and project-related papers.

D9.2: Brochure, newsletter

The project brochure has been reported in Deliverable D9.2 and details can be found in there. It implements T9.2 and forms, beside the web-page, the main area of dissemination in the early stages of the project. One thousand copies of the brochure have been printed and distributed among the consortium members, who in turn hand them to external visitors and interested parties.

Outlook

During project year two, the initial exploitation plan (D9.3, M18) and the initial dissemination report (D9.4, M21) will be due. The former will implement Task 9.3. The latter will implement Task 9.2 and focus on both academic and industrial dissemination efforts. Both will be strongly guided by the original specification in Section 2 of the Grant Agreement.

1.2.10 Work package 10 – Project Management

Work package 10 spans the scientific, administrative and financial management and monitoring of the project. The monitoring of project progress as well as project-wide decision making takes place in the Steering Committee meetings. Those are held monthly per telephone conference and twice a year as a physical meeting.

The adopted management structure functions properly. The project has a clear vision of its product and is working toward this goal. In the past 12 months the consortium has managed to lay the foundations for novel research work and has already provided some solid results.

The work package is on track.