Modernized Courses in Automotive Software Engineering

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Abstract - In order to respond to the rapid expansion of the information-communication technology sector and the ever-increasing demands of the automotive industry, universities need to adapt and take active part in creating healthy business environment and provide education to the young generation which will be ready for challenging tasks in this rapidly developed field. The Faculty of Technical Sciences in Novi Sad and Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek have participated in the common project DRIVE as part of the IPA Cross-Border Programme, with the goal of equipping the laboratories and developing the course materials in the field of automotive software engineering. Four laboratories have been set up and four new courses have been developed to support the project goals. This paper describes the newly developed courses covering the most important knowledge and skills for the automotive engineer of the future: functionally safe software design, software verification, machine learning, image and video processing in automotive systems. The developed courses are targeting the upper years of undergraduate studies and graduate studies.

Keywords - automotive, automotive software, cross-border cooperation, laboratories

I. INTRODUCTION

Information and communication technology (ICT) sector is rapidly expanding. Although promising, it does not have a satisfactory business environment support that can adapt fast to trends and demands. In addition, one of the leading European employers, the automotive industry, has included in its focus the software and ICT companies that can respond to the demand [1]-[2].

In order to respond to the fast-growing needs of automotive industry and enhance the competitiveness of the region in education of future engineers specialized for automotive software and hardware, University of Novi Sad, Faculty of Technical Sciences (FTN), Serbia and Faculty of Electrical Engineering, Computer Science and Information Technology (FERIT) in Osijek, Croatia have joined in a cross-border cooperation project “Modernizing Laboratories for Innovative Technologies” (DRIVE) as part of the European Union’s INTERREG IPA program. The aim of this project is to equip the two partner institutions with latest laboratory equipment for development of automotive software and develop the curriculum with study materials for graduate-level education of computer engineers to specialize them for engineering in automotive industry. The project started on 15 July 2017 and lasted for 29 months, until 14 December 2019.

The project DRIVE aimed to increase the competitiveness of the region and make it closer to the already developed parts of Europe. By making the targeted region competitive in the automotive market, it aimed to decrease the difference between European regions, strengthening the entire Europe in the competitive world of automotive industry. Engineering of embedded computer systems applied to automotive systems is a new field within the automotive industry and the engineers working in this field have less than 20 years of experience. Nevertheless, it is one of the fastest-growing fields with a high impact on economy in terms of the Gross Domestic Product (GDP) [3]. The industry faces numerous challenges in infrastructure since the development suffers if the infrastructure does not keep pace with the market demands. Still, the infrastructure cannot be developed without skilled people. Skills are best acquired through formal studies, which stresses the importance of quality education programs.

In addition to increasing the competitiveness of the region, the project DRIVE aimed to allow younger generations to study on state-of-the-art technologies and gain practical skills on modern laboratory equipment which will make them ready for work in the automotive industry. [4]-[6] One of the main project results is the curriculum proposal for the education in the field of automotive software engineering, targeting final years of undergraduate academic studies and the graduate academic studies. Four courses which represent part of the proposed curriculum were fully developed in this project, covering the most important knowledge and skills for the automotive software engineer of the future: functionally safe software design, software testing and verification, machine learning, with the focus on deep learning and image and video processing in automotive systems and systems of autonomous networked vehicles.

The research leading to these results has received funding from the European Union’s Interreg IPA CBC Croatia-Serbia Programme (2014-2020) under subsidy contract no. 2017HR-RS60.
The rest of the paper is organized as follows: section II gives a brief overview of the procured equipment and established laboratories; section III describes the four courses that were developed in the project and section IV provides the plans for post-project activities, as well as conclusions.

II. THE LABORATORIES

One of the main goals of DRIVE project was to equip four laboratories on two locations, two in Novi Sad and two in Osijek, which will serve as laboratories for teaching laboratory activities in the courses within the automotive software engineering field. Laboratories also served to host workshops for engineers which the faculties FTN and FERIT offered to institutions in the region.

At FTN and FERIT the following four laboratories have been established [6]:

- Laboratory for functionally safe automotive architecture and software design,
- Laboratory for hardware-in-the-loop testing, calibration and diagnostics,
- Laboratory for design and testing of automotive-related software,
- Laboratory for image and video processing in automotive applications.

The laboratories are equipped with state-of-the-art equipment for development and verification of software for automotive systems, which consists of:

- equipment that supports automotive application development in Automotive Open System Architecture (AUTOSAR) for automotive electronic control units (ECU) and supporting software, part of which is shown in Fig. 1,
- advanced driver assistance system (ADAS) development boards and supporting software (Fig. 2),
- equipment for automotive application testing based on hardware-in-the-loop (HiL) simulation.

Figure 1. Part of the equipment that supports the fundamental automotive application development based on AUTOSAR architecture

Figure 2. Development board for advanced driver-assistance system automotive application development with the automobile model ready for student use

III. THE COURSES

During the project, the curriculum for automotive software engineering education was proposed [6]. Part of this curriculum, which the project team considered to be the most important for providing the foundational knowledge and skills, was selected for complete development.

The four courses for which course materials and materials for laboratory exercises were developed are:

1. Digital image and video processing for autonomous vehicles,
2. Machine learning in systems of autonomous and networked vehicles,
3. Software architecture in safety-critical control systems,
4. Methods and techniques for automotive software testing.

This section provides description of the course materials that were developed in DRIVE project, and the examples of laboratory exercises the students are learning in the course.

A. Digital image and video processing for autonomous vehicles

The goals of this course are to introduce students to Advanced Driver-Assistance Systems (ADAS) features and to the features of digital images and video signals, as well as to the camera system in vehicles. The goal is to enable students to apply and develop advanced algorithms for processing of digital images and video signals, with an emphasis on algorithms for usage in autonomous vehicles.

Specifically, in the beginning of the course students are introduced to ADAS and in-vehicle camera systems. After that the topics regarding digital image acquisition, representing, filtering and noise removal are discussed. The next step includes the usage of image processing algorithms for edge detection, image segmentation and
object detection. Once students are familiar with how to detect an object, object tracking algorithms are explained. In that way they can practically detect all necessary objects in traffic, e.g. pedestrians, vehicles, traffic signs, etc.

The subsequent area is related to 3D scene reconstruction, where the stereovision and structure from motion (SFM) topics are presented and discussed. The last part regarding image processing explained within lectures is the analysis of complex ADAS algorithms, e.g. lane detection and lane departure warning (Fig. 3), pedestrian detection, surround view, driver monitoring, camera mirror replacement, etc.

At the laboratory exercises, when different image processing algorithms for different purposes are discussed, the real embedded platform (hardware and software) for their implementation is analyzed and explained. After that, the students are working in the lab on the platform in a way that they must implement different image processing algorithms used in ADAS, considering that the implemented solution must work properly in real-time.

B. Machine learning in systems of autonomous and networked vehicles

This course is performed after the previous one. Namely, the goals of this course are as follows: (I) to introduce students to principles of data analysis and machine learning methods; (II) to enable students to apply machine learning methods in intelligent transport systems of autonomous and networked vehicles, focusing on image processing and deep learning; (III) to acquire appropriate skills for work with development tools for data analysis and machine learning, as well as with development tools that enable the implementation of the developed algorithms to the target platform.

At the beginning of the course students are introduced to the different types of machine learning (unsupervised, supervised learning, reinforcement learning) and different regression and classification methods are analyzed. The basics of deep learning followed by architectures and deep learning algorithms are discussed. Different types of deep neural networks, and specifically convolution neural networks, are presented to the students.

At the end of the lectures, different applications of machine and deep learning in intelligent transport systems, like segmentation, detection and classification of objects (signs, lines, vehicles pedestrians, etc.) in the image (Fig. 4), motion planning, centralized and distributed control of networked vehicles, are analyzed. Upon successful completion of lectures, students in lab are implementing different ADAS solutions based on deep neural networks on embedded ADAS platform.

C. Software architecture in safety-critical control systems

Designing and implementing software solutions for autonomous vehicles required special skills which are not required for most of the general software development tasks. This software must be safe and reliable with zero tolerance for errors as lives can be threatened if the software malfunctions while the vehicle is in motion. Therefore, students learning the automotive software must have training in the software architectures for safety-critical systems.

The aim of this course is to teach students to be able to understand and to design the architecture and safety critical software for automotive industry, and also to have a solid basic knowledge about several key concepts and standards necessary for understanding the safety aspect in automotive industry.

The course provides the participants with insights into the concepts and architecture of safety-critical control systems’ software, explains to the participants the basics of AUTOSAR: concepts, architecture, methodology, building elements and ways of migration. The course also provides students with practical considerations: operating systems, software components, communication, input/output handling, handling of states, system services and memory, diagnostics. Students are introduced with the basics of the development of safe automotive software with a focus on ISO 26262 and basic requirements.
D. Methods and techniques for automotive software testing

The aim of this course is to teach students to be able to implement a framework for testing of automotive software and to have a solid basic knowledge about several key concepts necessary for understanding the design of testing process.

The students are first introduced to the testing of hardware-software real-world control loop systems and to the basic concepts of hardware-in-the-loop (HiL) testing, software-in-the-loop (SiL) testing, model-in-the-loop (MiL) testing, emulation, simulation, in-vivo, in-vitro and in-silico testing.

Overview of pros and cons with analysis of models follows in which students are taught about the transition between models: from HiL to MiL. All the models are studied using the examples from the automotive industry. Important components of the automotive system: electronic control unit (ECU), network, sensors and actuators are studied.

Testing process of an automotive system is specific, and the students are introduced to the entire testing process: modeling, configuration, calibration, testing, measuring and evaluation. An overview of existing testing tools is given.

At FERIT, the new study program “Automotive computing and communications” has already been established and more information about it can be found on an institutional webpage [7].

IV. LESSONS LEARNED

The courses were implemented in the winter semester of the academic year 2019/20. FTN introduced the new courses as electives in the current master study program of Computing and Control Systems. FERIT introduced the new study program at the master level.

Since the courses are mainly practically oriented, examination was performed at the lab exercises. In order to examine students’ success and motivation in carrying out the laboratory exercises, the short Lab Feedback Questionnaire (LFQ) was developed, which the students filled at the end of the course.

The survey showed some initial vulnerabilities of the platforms used in the courses, but it is an expected outcome in the pilot generation. Generally, students were satisfied with the easiness of usage of the laboratory platforms (67% responded with “agree” and “strongly agree” to the statement), and the value of learned materials (78% positive responses). The negative side was the time investment in the laboratory exercises and easiness to debug the problems in the solutions. This opens the door to opportunities for improvement in the following years.

V. CONCLUSIONS

The DRIVE project, part of the Interreg IPA CBC Croatia-Serbia program, allowed equipping the four laboratories in two institutions which will lead to the increase of competitiveness of the region and increase of the quality of teaching in the field of automotive software development.

DRIVE project has completed, but the results of the project will be applied in the years to come as the new study program has been established at FERIT and the complete set of new courses introduced at FTN which could pave the way for future accreditation of the corresponding study program there as well. Future research will be focused on expanding the set of courses and the set of laboratory exercises to cover more topics important for software development for automotive system. This field is rapidly developing nowadays, therefore it is necessary to regularly update the course materials to keep in pace with the state-of-the-art.

In addition, DRIVE project allowed establishing the collaboration between enterprises and academic institutions in the region which will create a positive feedback loop, benefiting both sides, as the better trained students will enter the workforce making the companies more competitive in this rapidly expanding industry, which will allow companies to offer even better opportunities for student internships and joint research with academia.

REFERENCES