User Experience design of further training on 'Test automation of an AI self-driving robotic car powered by a Raspberry Pi'

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ABSTRACT

In this study, we discuss the implementation of interactive continuing training in test automation of autonomous vehicles (AVs). The most important characteristic is that the training should be appropriate for introducing new project members to an existing project within that domain. Therefore, we conducted user experience (UX) tests with professionals in software engineering, software quality assurance, IT education, and similar fields. All potential stakeholders, such as lecturers, subject matter experts, developers, or testing and quality assurance experts must be incorporated from the very beginning of the implementation of the continuing training. The UX test focuses as well on the proposed curriculum of the training as a whole, as also on two lectures on the basics of a Raspberry Pi and the installation of the Raspberry Pi operating system on Windows, which will be provided as an optional lecture for persons with no or only a few experiences in microcontroller boards, and finally on the main part of the course, a group assignment on implementation of a test automation suite for testing of the autonomous robotic vehicle. The implemented UX test aims to make the interactive continuing training appropriate for the individual needs of professionals to ensure fast familiarization in the test automation of autonomous vehicles.

CCS CONCEPTS

• **Applied computing → Education**; • **Human-centered computing → Interaction Design**; • **Software and its engineering**;

KEYWORDS

user experience (UX) testing, curriculum design, autonomous driving, test automation, Raspberry Pi, robotic vehicle

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1 INTRODUCTION

The approval of the first level 3 autonomous vehicles revolutionizes public road traffic in that way the driver partially gives up control of his or her vehicle to the car's system [22]. Car systems need to be trained to imitate human behavior through artificial intelligence. Monitoring of the surroundings and reaction in different situations are partially completely transferred to the system [20, p. 2]. However, the driver retains full responsibility for his or her vehicle. To create public acceptance and trust in autonomous vehicles, a wide variety of requirements need to be achieved [31] [12]. For this reason, quality assurance will be more important than ever before. The focus of this study is on the development of virtual training for testing the embedded software of an autonomous vehicle. Therefore, we use a simulated robotic vehicle that fulfills the criteria of the Internet of Things (IoT). It is equipped with sensors, actuators, and processors that communicate with each other and exchange data via a cloud. For this purpose, the vehicle must establish a connection to the Internet. Unless the target audience for the proposed virtual training is software testers and software engineers in general, at least primary knowledge of the hardware that is controlled by the embedded software, is essential. Consequently, we provide two trial learning units on the structure of a Raspberry Pi microcontroller board and the installation of the Raspberry Pi Operating system on a Windows PC. We intend to analyze what exactly the target audience expects of interactive training to benefit from it in their day-to-day work. The number of requirements a self-driving vehicle needs to fulfill is enormous. For this reason, we decided on a modular course that consists of building blocks, whereby each building block builds on another. The main part of the training is a group assignment that needs to be completed in a team of three to six learners. To ensure equitable competition conditions for each learner, preparatory course units are provided to catch up on lacking knowledge. In Chapter 2, we discuss the background and motivation for this study. Chapter 3 describes the educational context. In Chapter 4, we introduce the test object for continuing training, the Sunfounder PiCar-X, a robotic vehicle controlled by a Raspberry Pi. In Chapter 5 we define the research questions that will be evaluated in the course of a user experience test with professionals in Chapter 6. For this purpose, we provide a prototype of an interactive learning platform with an incorporated assignment based on a case study.

2 BACKGROUND, MOTIVATION AND OBJECTIVE

Before the launch of a project in the testing of autonomous vehicles (AV), all stakeholders need to be aware of the required skills and experiences of the people who are working on that project. Continually re- and upskilling is indispensable. Therefore, continuing training needs to be customized to real-world engagements. These trainings need to be seamlessly integrated into the development process. Existing training providers still focus mainly on classic lecture formats and video trainings. But especially in the field of test automation of autonomous vehicles, interactive learning approaches need to be pursued. Training's need to reference clearly to challenges a quality assurance team is confronted with. This includes not only technical, but also security, privacy, and ethical aspects. Concerning autonomous driving, in particular, there are, for example, legal regulations in different countries and ethical issues that need to be considered [9] [17] [21]. The ethics commission of the Federal Republic of Germany, for example, specified strict requirements[1]. Tests with real autonomous vehicles on public roads face many hurdles. AV needs to comply traffic rules of each country in which they are used in public road traffic, e.g. the StVO[2] in Germany [21, P. 24/25]. Existing learning platforms as Coursera[3] [7]or Udacity[4] [2]

3 EDUCATIONAL CONTEXT

The educational approach consists of confidentially determining the level of knowledge of professionals within the framework of an assessment center and guiding them step-by-step through modular learning blocks to a common level of knowledge. Candidates for the course discuss, together with an experienced subject matter expert, why training want to join this training, what they expect of it regarding their current project and for future projects, and what individual features should be incorporated in the training they can benefit in their day-to-day work, as tools, products, and standards, programming languages, operating systems, and methods.

3.1 Structure of the course curriculum

The curriculum builds on modular building training Candidates for the training develop an appropriate learning path together with a subject matter expert so that they have the opportunity to catch up lack of knowledge that is required to participate in the assessment we describe in **??**.

The curriculum incorporates optionally preparatory courses to bring potential participants in the assignment to a common level of knowledge. These are, in particular, the basics of Raspberry Pi, but also the scripting language Python, the Robot Operating System, the OpenCV library for computer vision, the Tensorflow library for artificial intelligence, machine learning, and deep learning, or appropriate integrated development environments for test automation of robotic vehicles, like PyCharm [5] or Visual Studio Code [6]. With the inception of education 4.0 it is possible to customize courses on real-time learner profiles by the inclusion of the Internet of Things, Virtual Reality (VR) and Augmented Reality (AR) [1].

3.2 Assignment - Case Study on 'Implementation of a test automation suite and automated end-to-end regression testing of autonomous vehicles'

Our approach for interactive continuing training is a course on test automation of autonomous vehicles on the example of the robotic vehicle Sunfounder PiCar-X[7] [30]. The course is designed for software testers, test automation engineers, QA experts, and software engineers, to specialize in the testing of autonomous vehicles.

The course incorporates a case study on testing of an autonomous robotic car. Within that case study, learners have the opportunity to take up different roles, like test engineer, test analyst, test automation engineer, test administrator or test manager. The members of the learning team organize themselves. They discuss together with the instructor the individual learning objectives of each role and of the team as a whole.

The assignment for the learning team is to implement a test automation suite for end-to-end regression testing of the robotic vehicle. The learning group is expected to analyze appropriate integrated development environments, design a high level test automation concept, design appropriate test cases for automation, implement a test automation suite and automate the test cases. The test automation concept should include at least the following artifacts:

Description of the test object and its scope, including requirements for test automation, test project description and delimitation, definition of the test automation objects and agreed test volume. The test automation status needs to be documented and a final report for each customer requirement needs to be prepared. It needs to be defined who are the respective contact persons and who performs which role. Furthermore, an infrastructure concept including the design of the test automation structure, deployment, and roll out, continuous integration, test data management, test management, version management, change and release management, risk assessment and avoidance, and maintainability, is expected.

The fictitious client is a manufacturer of autonomous vehicles.

The case study includes four customer requirements: Basic movement, obstacle avoidance, line tracking and color detection.

Test object is a robotic vehicle, the PiCar-X.

The test object as well as the hardware and software required for the training will be provided in a simulated testbed[8](Figure2) [3].

For the following use cases, which correspond to fictitious customer requirements, an automated end-to-end regression test set needs to be implemented.

[1]Situation in Germany, Renata Jungo Brüngger, member of the Daimler AG Executive Board, responsible for the integrity and legal issue: https://group.mercedes-benz.com/innovation/case/autonomous/legal-framework.html
[2]StVO: Straßenverkehrsordtrainingd traffic regulations)
[3]Coursera: http://wwwtraining.com
[4]Udacity:http://www.udacity.com
[5]PyCharm: https://www.jetbrains.com/pycharm/
[6]Visual Studio Code: https://code.visualstudio.com/
[7]Sunfounder PiCar-X:https://docs.sunfounder.com/projects/picar-x/en/latest/
[8]https://iotstrem.com/course/test-automation-of-autonomous-vehicles-with-sunfounder-picar-x-and-pycharm/lessons/case-study-test-automation-of-a-robotic-vehicle/

Customer Requirement I - Basic Movement:
The vehicle needs to start and stop automatically.
The vehicle needs to move forward normally.
The pan/tilt camera looks straight ahead with no left or right tilt.
The pan/tilt camera looks straight ahead with no up or down tilt.

Customer Requirement II - Obstacle Avoidance:
While moving forward, the vehicle needs to detect an object and/or a person ahead less than 0.5 meters.
In the case the object and/or the person is less than 0.5 meters ahead, the vehicle needs to turn left.
In the case the object and/or the person is less than 0.3 meters back, the vehicles needs to turn right again.
If there is an additional obstacle left ahead of the vehicle, it needs to stop and wait until the obstacle ahead or the obstacle left ahead leaves.

Customer Requirement III - Line Tracking:
In the case the right (and the first) probe detects a black line, right is returned.
In the case the middle probe detects a black line, return forward.
In the case the left probe detects a black line, left is returned.

Customer Requirement IV - Traffic Light and Traffic Sign Recognition:
The vehicle needs to detect the status of traffic lights.
In the case it detects 'red', the vehicle needs to stop.
In the case it detects 'red' and 'yellow', the vehicle needs to start.
In the case it detects 'green', the vehicle needs to drive.
In the case it detects only 'yellow', the vehicle needs to slow down.
Furthermore, the vehicle needs to detect the following traffic signs: 'STOP', 'Give Way', and 'Priority Road'. In the case the vehicle detects a 'STOP' sign, it needs to stop. In the case the vehicle detects a 'Give Way' sign, it needs to observe the priority road to check if another vehicle is passing. In that case, it needs to stop and wait until the vehicle passed. It might happen that someone disregards the priority rule. To avoid serious accidents, autonomous vehicles need to be trained to act like anticipating human drivers.
Consequently, even in the case the vehicle detects the traffic sign 'Priority Road', it needs to observe the environment before crossing the road.

The assignment should be completed in a learning group of four to six people. Each member of a learning group performs an individual role. This can be, for example, a test manager [10], a test automation engineer [15], a test analyst [8] [23], a test administrator, or a test engineer.

According to iSQI[9] [29, P.205ff.], the tasks of the individual roles are as follows:

The **test manager** is responsible for test planning and controlling, design and coordination of the test concept, procurement of the test resources, selection and introduction of testing tools, introduction and optimization of supporting processes, as error handling and configuration management, decision about test environment and test automation, introduction, application and evaluation of metrics defined in the test concept, controlling of the test plan according to test results and the test progress, development and communication of the final test report.

Test automation engineer is the primary role of the assignment. For this role we recommend at least two or three people. It is expected that they design automated test cases in Python [18]. Furthermore they should get familiar with the computer vision library for computer vision 'OpenCV' [24], the open source library for artificial intelligence, deep learning and machine learning 'Tensorflow' [32] and the 'Robot Operating System (ROS)' [19]. For those who have no or only little prior knowledge in Python, OpenCV, Tensorflow and/or Robot Operating System (ROS), specific trainings are provided as additional modular building blocks to prepare for this role in the course of the group assignment.

Test analysts are responsible for reviews of requirements, analysis of specifications and system models for derivation of appropriate test cases, development of the test specification, determination and preparation of test data.

Test administrators are responsible for installation and operation of the system environment, implementation and supervision of the test environment.

Test engineers are responsible for the test implementation and error reports, review of test plans and test cases, application of testing tools and test monitoring tools, test execution and logging of tests, reporting of test results and deviations identified.

4 DESCRIPTION OF THE TEST OBJECT

Test object is an AI-driven self-driving robot car controlled by a Raspberry Pi 4 Model B 8GB Single-Board Computer, the Sunfounder PiCar-X1. This vehicle is equipped with the Robot HAT board2 [10], [14] [28, P.1], a multifunctional expansion board designed by Sunfounder, that enables to control the robot car by a Raspberry Pi. With the Robot HAT, the robot car integrates left and right driving motors, servo motors for steering, and a camera with pan and tilt functions. The Robot HAT has furthermore a built-in Bluetooth chip for remote control of text-to-speech and sound effects.

5 RESEARCH QUESTIONS

The primary goal of this study is to figure out what exactly the target audience needs to complete the assignment on 'Test automation of an autonomous vehicle' successfully. As we assume that potential participants in this course have already basic skills in software test automation, but not with microcontroller boards to control robotic vehicles, we focused also on the fundamentals thereof. Concerning this matter it is essential to analyze what instructions people with no or only very little knowledge in this fields need to get familiar with it. To perform test automation of the robotic vehicle those

[9] iSQI: International Software Quality Institute

[10] https://docs.sunfounder.com/projects/picar-x/en/latest/about_robot_hat.html

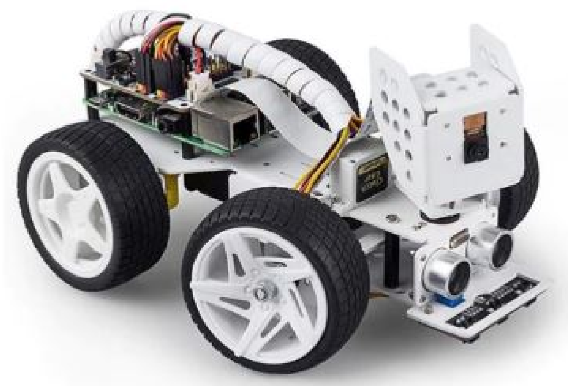

Figure 1: Sunfounder PiCar-X, *Source: Sunfounder*

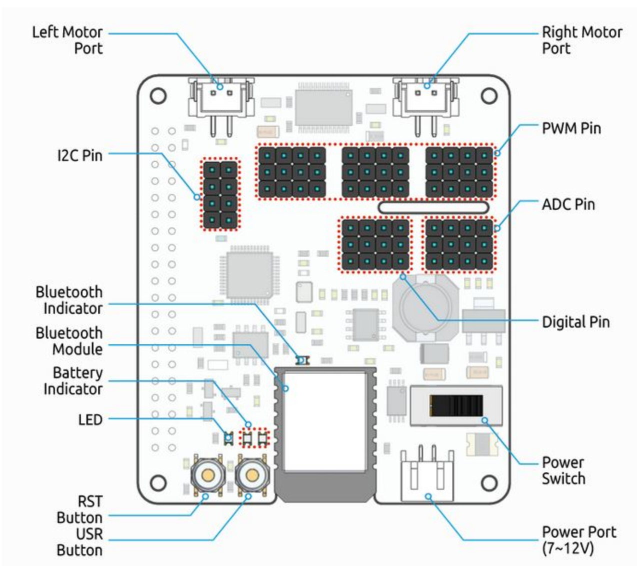

Figure 2: Robot HAT, *Source: Sunfounder*

fundamentals are indispensable. Furthermore, we assume that potentially course participants have different previous knowledge and it is essential to bring them to a uniform level of knowledge to cope with the assignment. To pick up potential course participants at their current skill level, we provide a proposal for a curriculum including preparatory courses to analyze, which additional preparatory courses we need to provide to bring participants of a learning group to a common knowledge level. For these reasons we structured the research questions as follows:

RQ I - Is the structure of the proposed curriculum 'Test automation of autonomous vehicles with Sunfounder PiCar-X' [4] clearly evident? Which additional preparatory courses should be incorporated that even beginners are able to complete the course successfully?

RQ II - Is a beginner with no prior knowledge able to know exactly what a Raspberry Pi is after watching the learning video on *Raspberry Pi (Overview)* [5]'? If not, what crucial aspects should be incorporated in the video or what additional learning material should be provided that it is easily visible what exactly a Raspberry Pi is?

RQ III - Is the requirement level of the lecture *Installation of Raspberry Pi Operating System on a Windows PC* [6] appropriate for a beginner with no or only basic knowledge of a Raspberry Pi or any other microcontroller board? If not, what crucial aspects should be incorporated additionally, or what additional learning material should be provided that persons with no or only basic knowledge of Raspberry Pi or any other microcontroller board are able to complete the provided lecture successfully?

RQ IV - Is the structure of the proposed assignment on the implementation of a test automation suite and automated end-to-end regression testing [3] visible enough and are the instructions clearly comprehensible? If not, what additional information or learning material should be incorporated that a person or a learning group with no or only prior knowledge is able to complete the assignment successfully?

6 USER EXPERIENCE (UX) TESTING WITH PROFESSIONALS

As stated in [33, P. 123], user experience defines human's perception and anticipation of the usage of a product, a system, or a service, including their emotional performances, beliefs, preferences, cognition, physical and psychological reactions, behavior and achievements. As described in [11, P. 13 ff.], the main goal of user experience testing of instructional design of virtual trainings is to improve the learning experience of each individual and as a consequence to simplify the learning process. To complete a training successfully, their is always a certain degree of motivation required. That can be intrinsic motivation, if someone participates in the course because he/she is personally (very) interested in the topic, or extrinsic motivation, in the case someone needs special incentives to participate in the training [16]. From our standpoint, the most efficient precondition is if someone who specializes in autonomous driving is at least rudimentary personally interested in this topic. User experience tests can contribute to arouse precisely this interest. But therefore, the topics provided and the questions posed need to inspire the consulted user experience testers so that they will be motivated by themselves to participate in further stages of a user experience test and finally decide to participate in the course we present in this study.

6.1 Interviews with Professionals

In the first step we conducted interviews with team members of a Center of Excellence Automation Integration of a multinational technological consultancy. We asked them the following questions:

- What do you expect of an ideal interactive virtual learning environment?
- Which learning approach(es) do you like most? Do you prefer video tutorials, hand-on-sessions, audiovisual trainings, coursebooks or others?
- What is the ideal location for an online training from your point of view? Do you prefer classroom trainings, learning in small learning groups, learning individually or in a hybrid environment?
- What device(s) do you prefer to use for online learning? (PC, tablet, smartphone, wearables, etc.) and why, for example because you are familiar with it)?

Most challenging of the interviews was to bring different ideas of the interview partners together to design a proposal for an e-learning platform that considers the different expectations in an overall concept The results of the user experience tests were used for the evaluation of the research questions.

- The interview partners would especially appreciate a gamified learning concept. This means that they can select a course in a course database that matches exactly their individual needs to reach their career goal. If they reached an interim goal or the final career goal, they get a credit point in their personal skill meter.
- They prefer especially using laptops and smartphones.
- All the interviewees insist on a mixture of learning approaches dependent on the subject. A proved concept therefore is VARK [13]. It is important, that the course lecturer can be contacted anytime and gives feedback within a reasonable time span.

6.2 Point of View(s)

The IoT domain is divided into various application domains. One of these domains is smart mobility that includes autonomous vehicles [26]. The requirements on software quality assurance between the different application domains divide significantly. Therefore, it is appropriate to provide a learning platform that enables lecturers as well as subject matter experts in IoT related real-world projects to share their experiences within interactive virtual trainings.
In fact, a variety of approaches therefore are already existing. In the past, we conceptualized a training on test automation with Lego Mindstorms for Education and extended it to a gamified approach with a digital twin of a physical and a simulated environment. However, the big challenge of virtual training is that it really contributes to a successful implementation of a real-world project. None of the existing platforms meet that requirement so far. As a consequence we developed the prototype of a continuing training we presented in 3. To verify if this prototype fulfills the requirements of the determined target audience, we conducted user experienced tests in the course of an interactive online survey.

6.3 Survey

In the course of the online survey the UX testers were consulted to assess the curriculum of the continuing training as a whole, and three individual lectures. the first lecture consists of a video training on the introduction in a Raspberry Pi [5]. The second lecture is a hands-on training on the installation of Raspberry Pi operating system on a Windows PC [6]. The third lecture includes the assignment described in Section 3.2. [3]. Thereby the UX testers need to assess the assignment and the case study individually. The goal of the survey is to evaluate the development of the training as a whole as well as that of the individual lectures. This approach supports to improve the training iterative so that it finally fulfills exactly the expectations of each individual learner as well as that of each individual project or sub project. If these requirements are fulfilled, it can be provided for the familiarization period of new team members in an individual role in a project or a sub project.

6.4 Results

We consulted six people as User Experience Testers (UX Tester) that answered all questions. All of them are professionals in software engineering, (software) quality engineering or education in these areas. We consulted as well young professionals with up to two years of professional experience, experienced professionals with with two to five years of professional experience and senior professionals with more than five years of professional experience. However, all of them have no or only basic experience in IoT related topics so far. For this purpose they are exactly the target audience for this study.

The reason why we decided for user experience testing is that this method is appropriate to pick up professionals at their current level of knowledge and professional experience, analyze what type of lectures they need to provide the best possible learning environment that fits exactly their individual needs.

The persons we consulted as UX Testers are as follows.
UX Tester I - Systems Engineer (>10yrs. professional experience)
UX Tester II - IT Teacher (>10yrs. professional experience)
UX Tester III - IT Apprentice (1-2yrs. professional experience)
UX Tester IV - Software Developer (2-5yrs. prof. experience)
UX Tester V - Automation Consultant (2-5yrs. prof. experience)
UX Tester VI - Automation Advisor (5-10yrs. prof. experience)

The UX test consists of two question groups. In the first question group, they evaluated the efficiency of the course curriculum. In the second question group they evaluated the assignment with the two basic lectures on *Raspberry PI Overview* and *Installation of Raspberry Pi Operating System on a Windows PC*, and a group assignment, which includes a case study on end-to-end test automation with the *Sunfounder PiCar-X robotic vehicle*. The UX Testers evaluated the comprehensibility of both lectures and the case study.

6.5 Evaluation of the research questions

RQ I- Is the structure of the proposed curriculum 'Test automation of autonomous vehicles with Sunfounder PiCar-X' clearly evident? Which additional preparatory courses should be incorporated so that even beginners are able to complete the course successfully?
The foundation for the decision to participate in continuing training is that it matches the expectations of the respective professional. They predominately expect that they can benefit from it in their career, and what concerns software engineers and software quality

Job Title	Level	Ratings			
		C	L1	L2	L3
Systems Engineer	Senior	2	1	4	2
IT Teacher	Senior	3	3	4	1
IT Apprentice	Junior	1	2	2	3
Software Developer	Experienced	1	1	3	1
Automation Consultant	Experienced	1	1	4	1
Automation Advisor	Senior	1	2	4	4

Table 1: UX Test Ratings

engineers, especially also in their individual specialization and their current project. The familiarization period for new team members in projects is usually very short. In the ideal case, they can use the interim period between two project assignments for target-oriented training. Therefore, we provided a prototype of the curriculum 'Test automation of an autonomous robotic vehicle with Sunfounder PiCar-X and PyCharm'.
UX Testers III, IV, V, VI completely agree with the proposed curriculum. Also UX Tester I agrees, but he or she recommends additionally that the navigation pane should be folded when loading the page. Otherwise, the subsections hide too much information displayed at the beginning. UX Tester II expects additional buttons, e.g. to allow users to expand and collapse all toggles with a single click.

RQ II- Is a beginner with no prior knowledge able to know exactly what a Raspberry Pi is after watching the learning video 'Raspberry Pi (Overview)'? If not, what crucial aspects should be incorporated in the video or what additional learning material should be provided so that it is easily visible what exactly a Raspberry Pi is?
UX Testers III and IV outline that the 5-minute video makes pretty clear what a Raspberry Pi is. User Testers V and VI complimented that it vividly explained what exactly a Raspberry Pi is and what components it consists of. However, UX Tester VI added that the quality of the sound should be improved, and if possible also subtitles should be added. UX Tester IV mentioned additionally that it should be referred to the official page of the Raspberry Pi foundation [11]

RQ III- Is the requirement level of the lecture 'Installation of Raspberry Pi Operating System on Windows' is appropriate for a beginner with no or only basic knowledge of Raspberry Pi or any other microcontroller board?
UX Tester III mentioned that a timeslot of at least 60 minutes would be beneficial to complete this lecture successfully, even if there is an instructor available who can help anytime when questions occur.
UX Tester IV expects the lecture is continually updated according to changing and extended requirements for the respective project or sub-project. Learners should also be referred to the official site of the Raspberry Pi Foundation because in the future it is important to be able to extract information from there. UX Tester IV suggests additional download links for the required components. UX Tester VI would also prefer additional video training on this lecture.

[11] Raspberry Pi Foundationhttps://www.raspberrypi.org/

RQ IV - Is the structure of the proposed assignment on implementation of a test automation suite and automated end-to-end regression testing visible enough and are the instructions comprehensible?
UX Tester III and IV outlined that the assignment is comprehensible. However, an incorporated virtual lab would make the case study even more visible. Thereby it is important, that it can be built on each performance module. The current status of the achievements of each individual should be saved so that he or she can continue learning exactly to the point the individual learner or the learning group stopped the last session. This would make the assignment even more adapted to a real-world project. Furthermore clear instructions and a step-by-step user guide would be beneficial because especially for pure beginners it might be challenging to figure out where to start and what exactly the individual achievements are expected of each role. UX Tester VI noted additionally that the figures should be designed more visible. An accompanying video including best practices might also support to comprehending the case study.

The rating of the answers of the consulted UX Testers is as follows. The ratings are depicted in **??**.

- 1 - fully comprehensible
- 2 - comprehensible
- 3 - less comprehensible
- 4 - not comprehensible

6.6 Expert Heuristic Evaluation

Heuristic evaluation is a usability engineering method defined by the Danish web usability consultant and researcher in the field of human-computer interaction, Jakob Nielsen [25]. Originally, this method has been applied in the course of the design of user interfaces. In this study, we apply it to the design of interactive continuing training. Nielsen recommended three to five evaluators to find different usability problems from the view of different experts in the same or a similar domain. We apply this method to derive suggestions for improvement based on the feedback of the UX testers. The results are depicted in 2. Nielsen defined the grades for severity rating as follows:

- 0 - I don't agree that this is a usability at all
- 1 - Cosmetic problem only: need to be fixed unless extra time is available on project
- 2 - Minor usability problem: fixing this should be given low priority
- 3 - Major usability problem: important to fix, so should be given high priority
- 4 - Usability catastrophe: imperative to fix this before the training can be released

6.7 Discussion

We place the highest value to take all feedback of the user experience testers into consideration for the further development of the training on *Test automation of autonomous vehicles with Sunfounder PiCar-X*. From our standpoint, such continuing training can only be successful if the people who participate in it can benefit from

Section	Violated Heuristic	Description	Suggestion for Improvement	Severity Rating
Curriculum (C)	Recognition rather than recall	Hidden information on sub sections	Folding navigation; additional buttons	3
Lecture I (L1)	Flexibility and Efficiency of Use	Sound quality	Higher sound quality; additional subtitles, reference to Raspberry Pi Foundation	3
Lecture II (L2)	Flexibility and Efficiency of Use	Timeslot for exercise too short	Extended processing time of 60 minutes	2
Lecture II (L2)	Visibility of System Status	Topicality	Continually updates; additional download links for required components; accompanying video training	2
Lecture III (L3)	Match between system and the real world	Adaptation to real-world project	Virtual lab with storage of intermediate states	3
Lecture III (L3)	Visibility of System Status	Comprehen-sibility of the case study	Step-by-step user guide; interactive figure; accompanying video training	4

Table 2: Heuristic Evaluation

it in their day-to-day work. Unlike conventional online courses, the training needs to focus on the requirements of real projects in testing autonomous vehicles and it should prepare the participants to work for long-term success in such a project. To make this possible, the training needs to be dynamic. To realize this it has to be customized to the individual needs of learners, which must also be incorporated into more advanced courses.

Potentially threats to the validity of the user experience tests are the different professional backgrounds and prior skills of the UX testers consulted. Someone with more than ten years of experience in software test automation has usually completely different prerequisites than a young professional who is just working on his first test automation project. One piece of evidence, therefore, is the feedback of an IT apprentice on the proposed assignment, that it might be challenging to figure out where to start. Therefore, the learners need step-by-step instructions. But regardless of this, the previous technical knowledge of test automation in general, scripting languages, and appropriate integrated learning environments are indispensable. There are, in fact, several trainings on these topics already available. However, it needs to be verified that finally members of the learning group have the same preconditions. Therefore, it is essential that we provide customized preparatory trainings in collaboration with learners and subject matter experts. For this reason, we focused our UX test first of all on the fundamentals. But finally, a learning group that implements the proposed assignment needs to collaborate closely and they need not explicitly have the same prior knowledge, but such that complements that of each member of the learning group.

To verify this, we will supplement the proposed curriculum with trainings on the implementation of various integrated development environments appropriate for test automation of robotic vehicles, so that potential participants in the assignment can analyze for themselves, ideally in a team, which of these approaches they are most comfortable with.

Furthermore, we just prepare the launch of a real-world engagement in the testing of autonomous vehicles in collaboration with a car manufacturer. That will also support improving the presented case study step-by-step so that it is finally as close as possible to the real requirements of car manufacturers and automotive suppliers.

7 CONCLUSION

A user experience test has been implemented with professionals to analyze the acceptance of a new interactive continuing training on 'Test automation of autonomous vehicles with Sunfounder PiCar-X'. At first we analyzed existing trainings on autonomous driving. We recognized that these training's usually treat the topic in general. But there is a lack of appropriate trainings that are based on real-world projects that has been implemented in a similar approach in industry. Our approach therefore is a course that builds on modular building blocks. Professionals who are interested in the course first of all analyze their individual prior skills confidentially together with a subject-matter expert and define, together with him/her, an appropriate learning path to acquire the prior skills that are required to complete the assignment successfully and to contribute actively to the group result. The outcomes of the user experience test can be consulted for the further development of the continuing training. This concerns as well the incorporated assignment on the implementation of a test automation suite and perform end-to-end test automation for the autonomous robotic vehicle as also for the preparatory lectures therefore to bring participants of the proposed group assignment to a common level of knowledge. To motivate professionals to participate in the proposed course the challenge is that we can enable a unique learning experience and they can finally benefit of the course in a real project in industry.

8 FUTURE WORK

The next step is to conduct the continuing training proposed in this study in a first iteration with test learners. The goal is to analyze

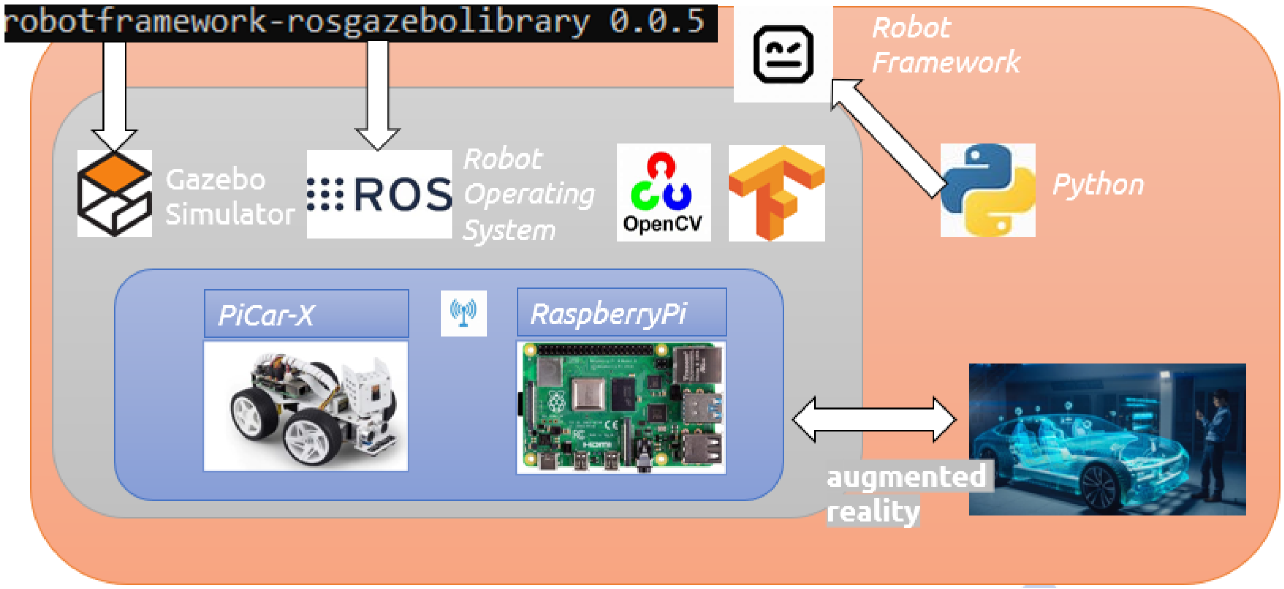

Figure 3: Future Work - Test lab

the extent to which professionals are familiar with those continuing trainings. This approach will eventually help to iterative improve the training and identify further expectations of both the professionals and the projects they are working on. We will complement the proposed curriculum with trainings on how to implement different integrated development environments by applying different learning techniques suitable for robotic vehicle test automation so that professionals can self-analyze which individual learning techniques are best suited for them. An auspicious approach is furthermore to incorporate augmented reality into the virtual lab [27]. To enable this, we are currently preparing to build a prototype of a simulated test lab for testing embedded software in autonomous and connected vehicles in collaboration with an automotive manufacturer to simulate testing in real physical test environments and with real vehicles. Furthermore, all the required tools, frameworks, simulators, and components will be incorporated into the virtual lab, so that the learners or the institutions they are working for or for them they are commissioned, don't need to obtain it by themselves. That will furthermore support us to improve the presented case study step-by-step so that the staff of automotive manufacturers, suppliers, and service providers have to opportunity to attend the training in the course of a initial training for new team members in related projects.

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