Augmented Reality System for Training and Assistance in the Management of Industrial Equipment and Instruments

Edison A. Chicaiza(✉), Edgar I. De la Cruz(✉), and Víctor H. Andaluz

Universidad de las Fuerzas Armadas ESPE, Sangolquí, Ecuador
{eachicaizal, eide, vhandaluzl}@espe.edu.ec

Abstract. This article proposes the development of a smartphone application on the Android platform as a recognition tool, focused on the digitization of real objects using image processing techniques. The application is oriented to the process of training and assistance in the handling of equipment and industrial instruments within the field of engineering such as electronics, mechanics, electromechanics, mechatronics, being a technological tool that allows users to interact in the reality environment Increased, it presents a friendly and intuitive environment, thus improving the process of handling industrial equipment and changing the paradigms of the use of physical manuals and giving use to new technologies such as smartphones with digital information.

Keywords: Augmented reality · Object recognition · Characteristic points

1 Introduction

The ever-increasing use of TIC has produced a new scenario that is affecting the most important elements in the development of the society being the industrial fundamental mainstay destined to develop the economy of a nation with intellectual capacity, moral and emotional people who contribute to the development of society [1, 2]. These technological developments have influenced the industry very strongly through the creation of new diffusion tools, and new structures of creation and advancement in prisoner of training and personnel within the industrial sector [3]. Within the system of management and assistance have been implemented new ideas, methods and lines of action that are related to the technology, instead of theoretical - practical that are aimed at improving the traditional production process [4]. The technological tools for training and assistance in the management of equipment and Instrument in comparison to the usual techniques present better result when applied, because the technology combined with the work or study increases the effectiveness of the knowledge acquisition processes [2, 5].

Augmented reality (AR) has been defined as a system that fulfills three characteristics [4, 6]: first, it combines the real and virtual world; second, it allows interaction in real time; third, align real objects or places and digital information in 3D. AR technology has existed for more than 50 years, but only the recent proliferation and consumption of

G. Bebis et al. (Eds.): ISVC 2018, LNCS 11241, pp. 675–686, 2018.
https://doi.org/10.1007/978-3-030-03801-4_59

smartphone technologies (for example, smartphone, tablets) have been available AR systems available to the general public. In parallel, another technology that has been highlighted by the advances are the smartphones [7, 8], these smartphones require features that allow the processing of information to develop the app with augmented reality, before it the basis to generate the AR environment is the recognizing of the site or object with which it will interact. Currently the AR is developed in 4 levels; the first level includes applications that hyperlink the physical world through the use of bar codes and 2D, these codes only serve as hyperlinks to other content, so there is no record in 3D or tracking of markers, at this level they have been developed "Mobile Augmented Reality of Tourism-Yilan Hot Spring", which uses QR fast response codes [9, 10]; in the second level consists applications that use markers, black and white images, quadrangular and with schematic drawings, usually for the recognition of 2D patterns, more advanced form of this level also allows the recognition of 3D objects, at this level they have developed works such as: "Authorship and Analytics of Multimodal Educational Mobile Applications", which handles recognition of 2D and 3D objects [9, 11]; the third level has applications that substitute the use of markers by the GPS and the compass of the smartphones to determine the location and orientation of the user and superimpose points of interest on the images of the real world, this level of the AR, this level of consists of works such as "Digitalization of Tourist Destinations: Tool for Government Planning and Management, "based on geposing, and" Augmented Reality and Pedestrian Navigation through its Implementation in M-Learning and E-Learning: Evaluation of an Educational Program in Chile "which is based on smartphone maping [9, 12]; The fourth level consists of devices such as Google Glass, high-tech contact lenses or others that, in the future, will be able to offer a fully contextualized, immersive and personal experience, such as: "An Augmented Lecture Feedback System to Support Learner and Teacher Communication ", which is based on Google Glass [8, 13].

Within the technology for learning is the fusion of the real environment and an environment with augmented reality, promoting the interaction of the operators with the contents for the training and assistance of the handling of industrial equipment, and thus improve the performance in the production process [2, 14]. For the use of the AR the success is the recognition of the objects or the environment with which one is going to interact there are several techniques as it was described in the levels of AR, according to the levels of AR, the development of our work is it is immersed in level 3, through the use of image processing for recognition, being the most efficient and effective process with smartphone due to its low data processing capacity [9, 10, 14].

This research proposes the development of an AR application aimed at supporting the process of training and assistance in the management of industrial equipment and instruments within engineering, taking advantage of the technology available to the smartphone and exploiting its benefits to the maximum by incorporating TIC in production processes [11, 15], and immersion with AR, using image processing techniques, aimed at recognizing objects and presenting multimedia content, creating a space in AR, with the aim of facilitating training and assistance, providing interactive, user-friendly training environments [16, 17].

This article is divided into 4 sections: the first section consists of the introduction, then the second section consists of the recognition and development technologies of the

multimedia environment; in the third section the results are presented and their respective analysis of results, the fourth and last section consists of conclusions of the work developed.

2 Development of the Application

The development of the proposed application is shown in Fig. 1, which considers four main stages in which a specific task is defined, in addition, one or several processes that allow executing the workflow tasks of the application for smartphone: (i) *Layer 1* in this layer allows the creation of the 3D Object Target and the digitization of the industrial instrument, with the Vuforia Object Scanner application; Vuforia is the popular SDK for the creation of applications in a wide selection of smartphone, provides tracking, image recognition, recognition of objects encompassed patterns in which the categorization of input data into identified classes, by means of extraction of significant characteristics or attributes of the data extracted from a medium containing irrelevant details.

The extraction of characteristic points is a step frequently used to get to define the object itself within an image. The obtaining of the characteristic points of the object that allows to identify again the object from these points. The first step is to detect the position of each characteristic point. Subsequently its content is define by one or more characteristic regions. More specifically, two tasks are use, namely:

Detection: The detection consists of finding the place of the image where typical points exist; the detection is the process in which there are located the regions of the image that contain a few certain characteristics, due to his form or texture.

Description: The description is realized after the detection, once located the place, one proceeds to describe by means of one or more characteristics the region placed about typical detected point. These characteristics are stored frequently in a vector for his later use.

Vuforia Object Scanner is based on image processing determining points and regions characteristic of objects, image processing is based on the algorithm Speeded up Robust Features (SURF), and it is the accelerated algorithm of characteristic points providing better results in terms of repeatability, distinction and robustness.

SURF uses an algorithm based on the hessian matrix for detection, which looks for a balance between the approximation of methods and the conservation of good results, managing to create a rapid algorithm and with high repeatability. The utilization of Gaussian for the creation of the space of scales; concretely, in an approximation of the determinant of the hessiana matrix. By means of this approximation there is obtained a much more rapid calculation of the space of scales. To understand the approximation of SURF one must show before what aspect they have the partial derivatives that compose the hessiana matrix.

After locating the position and size of the characteristic points, the next step is to describe those points; this process is carried out by calculating the characteristic region surrounding each point, a concept known as local description. This process of obtaining characteristic points is achieved with the application Vuforia Object Scanner, as the

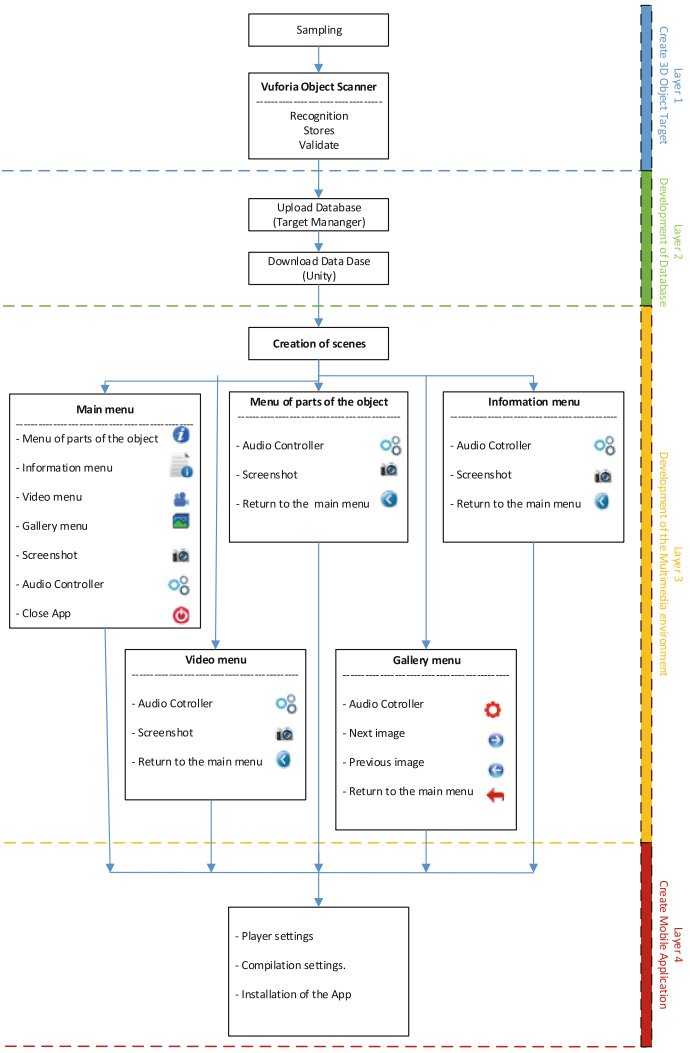
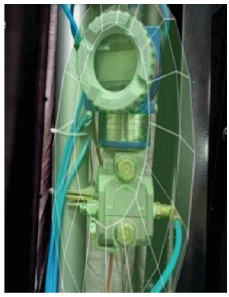


Fig. 1. Multilayer scheme of the application.

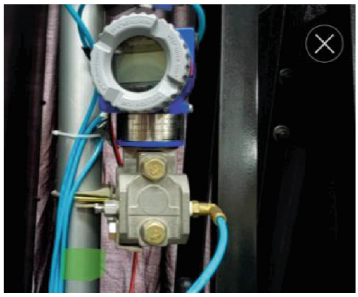
first instance it is essential to determine the objective of scanning objects, the objective of object exploration is used to establish the position of its object objective in relation with its local origin. This origin is represented by (0, 0, 0) in the lower left corner of the grid region of the object exploration target and corresponds to the local (0, 0, 0) of the bounding box of the prefabricated instance of Object objects, this is observed in the Fig. 2, the positioning of the instrument in the bounding box.

Object recognition encompasses patterns in the category of input data in identified classes, through the extraction of features or data extracted from a medium containing irrelevant details; The validation of the 3D Object is carried out by means of the

(a) Point of origin for the creation of the 3D Object



(b) Taking of characteristic points of the 3D Object



(c) Object validated as 3D Object

Fig. 2. Positioning of the instrument in the delimiter and the process of obtaining characteristic points.

Vuforia Object scanner application and the camera of the smartphone for to verify the correct creation of our pattern, this can be seen in the Fig. 2(c).

(ii) *Layer 2* is responsible for generating the database in the Target Manager and provides 3D Object files with compatible features to use in the development of the application; the type 3D Object pattern is stored in the database, of the Vuforia platform to be used according to the user's needs. The Target Manager allows the download of stored patterns with an extension compatible with the Unity platform.

(iii) *Layer 3* consists of the development of the application where three scenarios were created which consist of: main menu, menu of parts of the object, and general information menu of the whole object that it recognizes, within which, in the main menu, as well as in the other menus, a label of text type is included that will indicate the name of the recognized object that is shown in the upper right part of the screen of the smartphone, the information button will appear that will direct to the corresponding scene, the options button for the audio control that is found by default, the information button of parts of the object that will direct to this scene, and the close button which closes the application.

In the information menu of parts of the object a script is developed for the handling of the Box Collider that will detect the AR Camera when it is located above the object's position, showing the name with the corresponding text color in the upper left, it also presents the return button that will direct you to the main menu scene.

In the Information menu, textual information is presented with 3D text showing characteristic content of each object, the Lean Touch script is also included to rotate and scale the information presented on the smartphone screen. For the presentation of the video, the Video Playback Controller script is used to manage the video shown on the screen through the AR Camera, allowing starting, pausing, and resuming the playback of the displayed video, also adding the Lean Touch script to rotate and scale the video.

Last, (iii) *Layer 4* is observed in Fig. 3, the Player Settings in Unity is configured prior to the compilation of the application, selecting the left orientation by default, placing parameters such as the name of the company and product developed, the version number of the application, and the minimum API (Application Programming Interface) level from which the application will work.

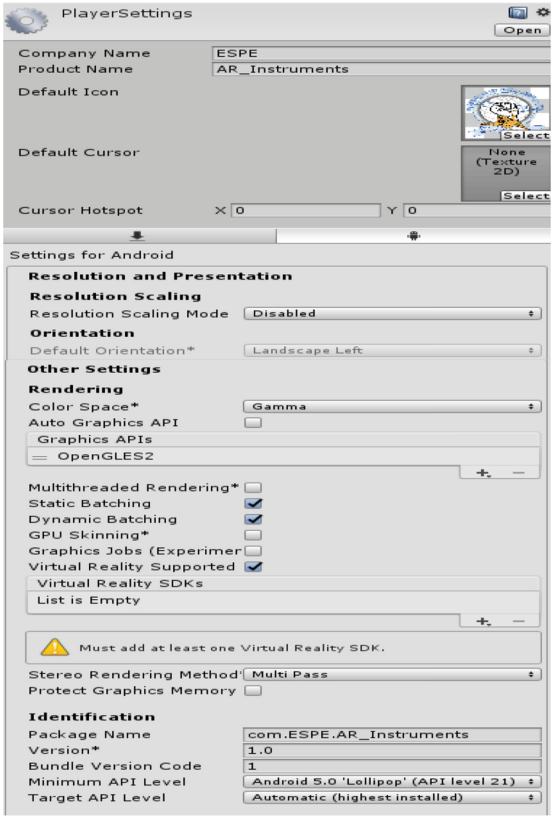


Fig. 3. Configuration of the Player Settings in Unity

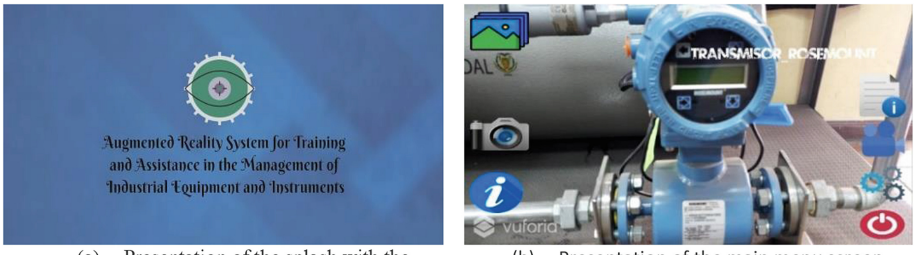
After the configuration the Android application is compiled, generating an APK file (Android Application Package), the file is copied to the smartphone and the installation is carried out.

3 Experimental Results

This section presents the experimental performance of the application of augmented reality oriented to the process of training and assistance in the handling of industrial instruments, the application is used as a tool to improve the process of training and management of industrial equipment and changing the paradigms of the use of physical manuals and the use of new technologies such as smartphones with digital information.

In this section, it shows how the application of augmented reality facilitates the process of recognition and interaction with the recognized object by providing relevant information of industrial instruments. In this case the user can make use of the application to obtain specific information of the industrial instruments, to start with the application of recognition it is necessary that previously the APK is install on the smartphone.

When the application is running for the first time, a welcome splash of the application is show, as shown in Fig. 4(a); later the start screen appears where you can see the main menu of the application, such as it is show in Fig. 4(b). The application recognizes objects that are in the database, from the Industrial Instrumentation Laboratory, as shown in Fig. 5(a), the user uses the augmented reality application on his mobile device, as shown in Fig. 5(b), the Foxboro IAP 20 instrument is from the Pressure Station of the Industrial Instrumentation Laboratory, as shown in Fig. 5(c).



(a) Presentation of the splash with the theme of the application

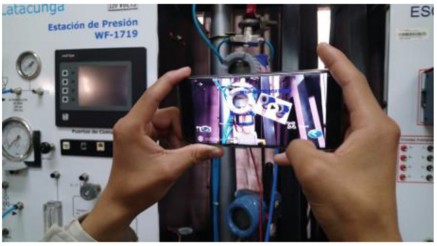
(b) Presentation of the main menu screen

Fig. 4. Start and presentation of the application.

Once detected the desired object, allows the interaction with the object for it in the information icon, allows showing information about the object, this information can be text or graphic, by means of which general information of the Foxboro Transmitter IAP 20 is provide, as shown in Fig. 6(a). The information presented can be rotted and scaled according to the needs of the user, as show in Fig. 6(b).

By means of the audio configuration buttons, we control the predefined audio of the application that allows us to stop - play the audio and upload - lower the volume, and with the button, return to the main menu of the application. With the information menu provided by the application allows you to obtain the possibility of observing a multimedia video, related to the object that is detected according to the

(a) Pressure station of the industrial instrumentation laboratory



(b) Use of the application on the smartphone by the user

(a) Foxboro IAP 20 Pressure transmitter information

Fig. 5. Use of the application in the pressure station in the Industrial Instrumentation Laboratory.

(a) General information about the Foxboro Transmitter IAP20

(b) Information rotated and scaled by the user

Fig. 6. General information about the Foxboro Transmitter IAP 20, with its characteristics and operation.

database, in this menu we can see the video with possibility to put play, raise - lower the audio volume, zoom and rotate the video with the next button , allows you to configure the audio options and return via a button to the main menu , this menu is shown in the following Fig. 4(b). Using the textual information button , allows showing information in augmented reality of the detected objects as shown in Fig. 6.

The information is present in augmented reality on the mobile device as shown in the following Fig. 7(a), textual information of the Siemens S7-1500 PLC is present as show in Fig. 7(b), the audio information and video of the recognized device is show in Fig. 7(c).

(a) Presentation of information on the smartphone

(b) General information of the Siemens S7-1500 PLC

(c) Video in augmented reality of PLC S7-1500

Fig. 7. General information about the Siemens S7-1500 PLC, with its features and audio and video information.

Within the options of the application allows the recognition of specific parts of the objects detected, as show in Fig. 8, another of the benefits provided by the application is the ease of making screenshot using the button , through this button you can save images in a local database of the same smartphone which is accessed through the button , this gallery of images is specifically for this application, when entering the gallery you can browse the images by means of the following buttons , this is show in Fig. 9, finally with the button we abandoned the application.

The results presented below indicate the validity of the usability of augmented reality environments, to carry out an industrial instruments management, in our specific case: in the training process and operator, assistance in the handling of equipment and

(a) General recognition of Rosemount 3051s transmitter parts

(b) Detection of Rosemount 3051s transmitter parts

Fig. 8. Detection of detected object parts.

(a) Screen captured from the Foxboro IAP20 Transmitter (b) Screen captured from the S7-200 PLC

Fig. 9. Gallery of images of the screenshot.

instruments immersed in the industry. For this purpose, the SUS summary evaluation method is used [17]. Generally providing the style scale that generates a single number, represented by an average composed of the usability of the smartphone application, as shown in Table 1.

The total number, obtained from the sum of the operation in each question, results in 31. Based on this result, the SUS score is calculated and expressed by a multiplication of 2.5, which means that the application is feasible for training and assistance in the handling of industrial equipment and instruments, provides assistance to the operator, obtaining a percentage of 78.43%, representing a high usability of this type of technological tools.

Table 1. Results of the questionnaire.

Questions	Punctuation					Operation
I would like to use often the application				2	9	3.82
I found the App with increased reality it is unnecessarily and complex	9	2				3.82
It was easy to use the App with augmented reality				3	8	3.73
You need the support of a technician to be able to use this application	11					4
The different functions of the application are well integrated		1			10	4.1
There was too much flexibility in the application			1		10	0.18
I imagine that most people would learn very quickly to use the application				1	10	3.91
I found the application very difficult to use	9			1	1	0.27
I felt very confident in the navigation of the application				2	9	3.82
I need to learn many things before using the application	8	3				3.73
Total						31.37

For the precision in the detection of the objects, the same object was focused with the smartphone in 10 different angles, of which in 9 of them the detection is fast and instantaneous providing the information corresponding to the scene in which it is inside. The application, thus being 90% accurate in the detection of objects, this appreciation depends on the lighting in which the tests are performed and the focus of the smartphone camera, the environment must have a natural or artificial lighting higher than 100 lx.

4 Conclusions

The increased reality contributes to the training and assistance of the managing equipment and industrial instruments, providing benefits that they contribute to the suitable use of the equipment's in the industrial field, offering a training to the users and orientating to the correct managing and utilization of the equipment's, increasing the useful life of the equipment's, this way also omitting failures of functioning for erroneous maneuvers. The work shows the development of the application Assistance. AR that offers relevant, adaptable information of the equipment's and industrial instruments to the environment in which they are. In turn, the application allows the interaction of the user for the managing of the information presented in the recognition of the objects, from the screen of the mobile device. Finally, the application presents options of managing of the audio and video in the graphical interface developed of agreement to the needs of the user.

Acknowledgements. The authors would like to thanks to the Corporación Ecuatoriana para el Desarrollo de la Investigación y Academia – CEDIA for the financing given to research, development, and innovation, through the Grupos de Trabajo, GT, especially to the GTeTURISMO; also to Universidad de las Fuerzas Armadas ESPE, Universidad Técnica de Ambato, Escuela Superior Politécnica de Chimborazo, Universidad Nacional de Chimborazo, and Grupo de Investigación en Automatización, Robótica y Sistemas Inteligentes, GI-ARSI, for the support to develop this work.

References

1. Joo-Nagata, J., Abad, F.M., Giner, J.G.B.: Augmented reality and pedestrian navigation through its implementation in m-learning and e-learning: evaluation of an educational program in Chile. Elsevier Transl. J. Comput. Educ. **111**, 1–3 (2017)
2. Wu, H.-K., Lee, S.W.-Y., Chang, H.-Y., Liang, J.-C.: Current status, opportunities and challenges of augmented reality in education. Elsevier Transl. J. Comput. Educ. **62**, 41–49 (2013)
3. Zhanga, C.J.: The development and evaluation of an augmented reality-based armillary. Elsevier Transl. J. Comput. Educ. **73**, 178–188 (2014)
4. Blum, J.R., Greencorn, D.G., Cooperstock, J.R.: Smartphone sensor reliability for augmented reality applications. In: Zheng, K., Li, M., Jiang, H. (eds.) MobiQuitous 2012. LNICST, vol. 120, pp. 127–138. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-40238-8_11

5. Gallardo, C., et al.: Augmented Reality as a New Marketing Strategy. In: De Paolis, L.T., Bourdot, P. (eds.) AVR 2018. LNCS, vol. 10850, pp. 351–362. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95270-3_29
6. Huamaní, J.A.: Augmented reality: a digital resource between the real and the virtual world. Hamut'Ay **2**, 50–57 (2016)
7. Iván Ruiz, D.: Autoría y analítica de aplicaciones móviles educativas multimodales, vol. 1, pp. 1–6. Springer, España (2016)
8. Almenara, J.C.: Productions of learning objects production in Augmented Reality: the experience of SAV of the University of Seville. Int. J. Educ. Res. Innov. (IJERI) **6**, 110–123 (2016). España
9. Olivencia, L.: Tecnologías de Geolocalización y Realidad Aumentada en Contextos Educativos: experiencias y herramientas didácticas, RACO Transl. J. Didáctica, Innovacion y Multimedia, p. 31, Abril 2015
10. Espinosa, C.P.: Augmented Reality and Education: Analysis of Practical Experiencies, EBSCO, Enero, pp. 187–203 (2015)
11. Cabero Almenara, F.R.J.: Mobile devices and augmented reality in the learning process of university students. Int. J. Educ. Res. Innov. **20**, 110–123 (2016)
12. Sevilla, A.V.: Realidad Aumentada en Educación. Int. J. Educ. Res. Innov. **77**, 39 (2017)
13. Hui, L., Hung, F.Y., Chien, Y.L.: Mobile augmented reality of tourism-Yilan hot spring. In: 7th International Conference on Ubi-Media Computing and Workshops (UMEDIA), Mongolia, pp. 148–152 (2014)
14. Acioly, S.G.: Mobile augmented reality systems applied to food packaging—a heuristic evaluation. In: IEEE Transaction on Realidad Virtual y Aumentada (RVS), pp. 127–131 (2017)
15. Acosta, A.G., et al.: Digitalization of Tourist Destinations: Tool for Government Planning and Management. In: DePaolis, L.T., Bourdot, P. (eds.) AVR 2018. LNCS, vol. 10850, pp. 162–170. Springer, Cham (2018)
16. Torres, D.R.: Augmented reality and Cultural Heritage: new perspectives for the knowledge and dissemination of the cultural object. IEEE Trans. Realidad Virtual Aumentada **2**, 78–86 (2015)
17. Andaluz, V.H., et al.: Multi-user industrial training and education environment. In: De Paolis, L.T., Bourdot, P. (eds.) AVR 2018. LNCS, vol. 10851, pp. 533–546. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95282-6_38