

Virtual Industrial Robot Palletizing Workstation Based on Augmented Reality Technology

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Keywords: augmented reality; virtual simulation; industrial robot; palletizing

Abstract: In view of the defects of expensive equipment, complicated structure and safety risks in the experimental teaching of industrial robots, this paper proposes the use of augmented reality technology in the experimental teaching of industrial robots for the construction of virtual industrial robot workstations. In this paper, taking the existing industrial robot palletizing workstation of Southeast University Chengxian College as the actual object, first of all, it analyzes the teaching contents that cannot be completed in the existing practical experiments, and formulates the main contents of virtual experimental assistant teaching. Secondly, 3ds Max modeling software is used to build a 1:1 three-dimensional virtual simulation model according to the actual industrial robot palletizing workstation. And then the virtual interaction is realized by programming based on the Unity 3D software development platform. Finally, through scanning and touch operation of specific identification maps, multi-angle, authentic and three-dimensional display of the virtual simulation model of the industrial robot palletizing workstation is realized on the mobile device, to assist practical experimental teaching. With the integration of augmented reality technology into the experimental teaching link of the industrial robot palletizing workstation, a new model combining virtuality and reality can be created to solve the bottleneck of the industrial robot experiment teaching.

1. Introduction

Along with the advancing Made in China 2025 and Industry 4.0, the application of industrial robot rapidly increases. According to the data from International Federation of Robotics (IFR), in 2016, about 290,000 industrial robots are sold globally, with year-on-year growth of 14%, and 90,000 industrial robots are sold in China, with year-on-year growth of 31% [1], higher than other countries. In the future, the average annual growth rate of sales of Chinese industrial robot will remain double-digit.

However, there is a great shortage of talents in robot industry. In 2017, *Guidance on Development Planning of Manufacturing Talents* issued by Ministry of Education, Ministry of Human Resources and Social Security of the People's Republic of China and Ministry of Industry and Information Technology of the People's Republic of China predicates that, by 2020, there will be a shortage of 3 million talents in high-end CNC machine tool and robotics, and 4.5 million by 2025 [2]. Based on the market demand for talents, colleges and vocational colleges gradually introduce theoretical teaching and training teaching of industrial robot in teaching course. Southeast University Chengxian College also establishes two training workstations of six-degree-of-freedom industrial robot palletizing, and carries out practical teaching of industrial robot.

There are some teaching problems in the teaching of industrial robot palletizing training workshop. First of all, industrial robot is a cross-disciplinary subject, involving mechanics, control, instrument, automation, electronics, computer and so on, with complex mechanical structure, electronic connection and operational control. Besides, theoretical courses are boring and abstract, so it is hard and arduous for students to understand complex structure and principle; secondly, due to the expensive price, the industrial robots are too less to ensure that every person has a set of equipment in training; thirdly, there is a certain safety risks when operating industrial robot at short

range, especially when many students gather around one robot workstation; fourthly, industrial robot workstations cover a large area and cost many teaching resources; finally, the human-computer interactive effect of industrial robot is poor, which cannot stimulate students' interest and innovative thinking.

These problems have an influence on the experimental teaching of industrial robot, so it is necessary to improve teaching method and innovative teaching mode to solve these problems.

In recent year, virtual reality (VR) technology and augmented reality technology (AR) develop rapidly and is widely applied. AR technology performs analog simulation and overlapping of substance message that cannot be experienced in a certain time and space in real world through sensor, computer, electronics and information technology, including vision sense, auditory sense and tactile sense, combines three-dimensional virtual object produced by computer and real world, integrates virtual information and realistic environment, and improves the perception and cognition of users to realistic world. It has characteristics of virtual-real combination, good interaction and strong realism [3-8]. Compared with VR technology, AR is suitable for experimental teaching due to its unique convenience and universality without space and time limitations.

In 2017, Ministry of Education, on the basis of experimental reform and information construction of experimental teaching project, decides to implement demonstrative virtual simulation experimental teaching project from 2017 to 2020. By 2020, 1000 demonstrative virtual simulation experimental teaching projects have been built [9]. Therefore, the virtual simulation industrial robot workstation built by AR technology can strengthen the human-computer interactive effect, decrease experiment equipment costs, reduce safety risk, reduce the consumption of teaching resources and stimulate students' creative thinking by innovating teaching form and integrating high-tech element, which is the best choice to break the bottleneck of industrial robot training and solve problems.

2. The Design of Experimental Teaching Contents Assisted by AR

2.1 The construction of virtual simulation experimental system

The virtual simulation experimental teaching system is built according to realistic experimental teaching process, shown in Figure 1.

First of all, it is requires to analyze the experimental objects of realistic teaching, conclude and summarize relevant professional knowledge points and teaching objectives that corresponding experiment can reach, analyze experimental teaching contents can be reached and cannot be reached, and formulate the main contents. Based on this, the modeling objective can be chosen from realistic experiment according to teaching contents of virtual simulation, and the virtual model of realistic experiment can be displayed vividly, appropriate three-dimensional modeling software can be chosen to perform three-dimensional 1:1 scene modeling according to characteristics of modeling objective, usually 3ds Max by Autodesk. Lastly, virtual simulation software development platform such as Unity 3D and Unreal, comprehensive knowledge and three-dimensional model and the function of adding three-dimensional scene navigation and human-computer interaction are used to produce virtual simulation experimental teaching system targeted for objects [10].

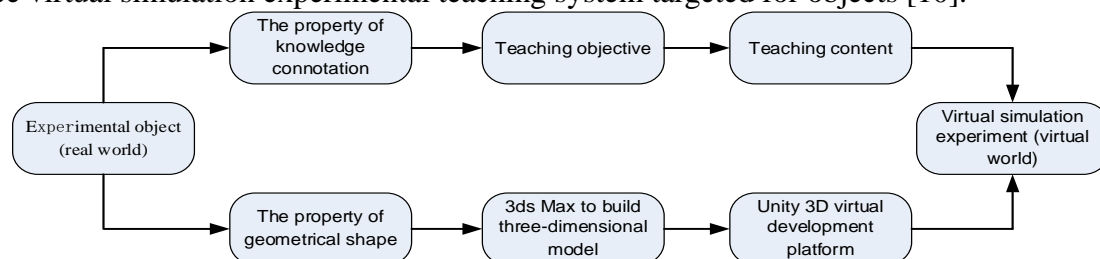


Figure 1 The construction of virtual simulation experimental teaching system

2.2 The teaching content of experiment assisted by AR

The main characteristics of AR technology is to strengthen users' perception and cognition of

realistic world by the virtual-real combination. AR software adopts more mobile devices to display, such as mobile phone or tablet computer. The virtual simulation experimental system based on AR technology is more to assist experimental teaching. Thus, it is necessary to combine the teaching content of realistic experiment and characteristics of AR interactive display to formulate the teaching content of virtual simulation experimental system.

Combining with the teaching objective and teaching content of six-degree-of-freedom industrial robot palletizing workstation, the teaching content of virtual simulation experimental system is analyzed. The realistic six-degree-of-freedom industrial robot palletizing workstation is composed of Essington ER16 six-degree-of-freedom industrial robot, robot control cabinet, ERT70 robot teaching-programming, robot end effector, conveyor belt, and workpiece tray [11]. It can replace manual work in the end of logistics production line, pile up workpieces according to a certain order and layers and complete the automatic palletizing of workpiece. In the teaching of actual experiment, the gripping position and robot motion trace can be determined by demonstration operation, so as to complete the process of depalletizing and palletizing.

Table 1 Teaching contents of virtual simulation experiment

No.	program	Teaching contents
1	Main menu	To display equipment component of industrial robot palletizing workstation by highlight flashing and name tag of equipment, play cyclically, and match corresponding background interpretation voice consisting of the function of industrial robot palletizing workstation and equipment component.
2	robot	To display internal structure and work principle of each axis of robot, realize the simulated operation of each axis through touch interactive operation. When clicking each axis, corresponding axis will be displayed by highlight flashing. After displaying, each axis will be in simulated operation according to its own motion range, along with the motion sound effect of robot. Besides, the simulated dismantle is practiced by touch interactive operation to grasp the internal structure of robot.
3	demonstrator	To display part component of robot demonstrator and detailed function description of menu key, function key and axis operation key by highlight flashing and name tag of equipment, play cyclically, display detailed operation procedures of demonstrator and match corresponding background interpretation voice.
4	Control cabinet	To display part component of robot control cabinet and detailed operation procedures by highlight flashing and name tag of equipment, including servo drivers, controller, scram button, start stop button and main power switch, play cyclically, display detailed operation procedures of control cabinet and match corresponding background interpretation voice.
5	Technological process	With the background voice interpretation simulated by three-dimensional animation, to display technological process of industrial robot depalletizing and palletizing of workstation. The entire process of three-dimensional simulation is accordance with realistic experiment operation process. The optoelectronic switch on conveyor belt will be highlighted in red color when detecting the signal of workpiece.

Since there are only two sets of actual industrial robot palletizing workstations, the experimental teaching is basically completed by the operation by teacher and observation by student. Students have no real experience, and the internal structure and working principle of the robot cannot be intuitively explained. Students cannot deeply understand and master the relevant knowledge and operational skills of industrial robot palletizing. Thus, the teaching content of virtual simulation experimental system needs to solve problems existing in actual experiment. The determined teaching contents of virtual simulation experimental system include main menu, robot, demonstrator, control cabinet and technological process. In this way, the industrial robot palletizing workstation, device parts component, internal structure and operation steps of robot, control cabinet, the function and procedures of demonstrator and technological process of robot palletizing can be comprehensively and interactively displayed. In addition, the touch operation can also realize the

enlargement, shrinking, rotating and virtual dismantle practice. The detailed teaching contents of virtual simulation experiment are shown in Table 1.

3. Software Design

3.1 The design of three-dimensional virtual simulation model

It is necessary to establish a three-dimensional virtual scene model in accordance with realistic experimental scene, so that virtual simulation experimental system can be effectively displayed. In order to fully restore the entire component, part structure and material, and work principle of industrial robot palletizing workstation, the method of manual field measurement is mainly adopted, and the materials of three-dimensional model can be obtained by collecting part details of site by high-definition camera.

Filed measurement mainly includes the length, width and height of each part, and the distance between parts. The camera capture mainly includes the overall layout of workstation, photos of each angle of part and video of workstation. It is also necessary to capture the material in three-dimensional modeling software from the front angle without sundry. The follow-up mapping mainly adopt mapping materials collected in filed to ensure the realistic simulation of scene [12].

Combining with materials collected in industrial robot palletizing workstation and realistic data from field measurement, computer 3D software is applied to establish 1:1 three-dimensional virtual simulation model. 3D modeling is to build a specific 3D image by virtue of geometry described as real object, to reach a realistic effect by light, color and texture rendering. In this paper, Autodesk 3ds Max 2017 is adopted for modeling. 3ds Max is an excellent professional three-dimensional animation software, integrating the functions of three-dimensional model required in this project, including modeling, mapping, animation and rendering. In addition, FBX document saved in 3ds Max can be directly loaded into game engine such as Unity 3D, to provide convenience for producing AR virtual simulation experimental system.

After three-dimensional virtual simulation model, it is necessary to combine materials to examine information such as size, arrangement and details. When determining model finally, it is required to conduct realistic mapping of model by using photos shot on site. After the captured materials are processed by Photoshop software, these become model mapping materials that can be used, and then mapped according to the correct position and after being imported into 3ds Max. After the mapping, the UV normal is adjusted to be correctly arranged in the model. Then, the animation system of 3ds Max can be applied to produce palletizing technology animation.

3.2 The realization of interactive software

After completing three-dimensional model and animation, it is required to adopt software programming to realize the virtual human-computer interactive operation of three-dimensional scene. In this paper, Unity 3D is applied for interactive software development. It is a multi-platform comprehensive game development tool for users to create interactive contents such as three-dimensional video game, architectural visualization and real-time three-dimensional animation.

In order to realize the software effect of augmented reality, it is necessary to use AR framework of Vuforia SDK by Qualcomm Incorporated. The detailed operation process is presented. First, it is required to apply for a License Key on the Qualcomm Vuforia platform. This Key can be used multiple times in multiple projects. It is to grant engineering permission to call the resources in the Vuforia SDK package. Then, to create the database of the identification object, which is actually to add specific identification picture in advance. An industrial robot picture is used as the identification picture in this project, and the Vuforia server to produce the identification database of the picture; the database needs to be downloaded and imported into the project.

After completing these steps, enter the Unity implementation process of the entire interactive software. First, create a new project file, save the three-dimensional model and animation created by 3ds Max as FBX file, import it into Unity 3D software development platform; further adjust the

position, size and animation parameter settings of the imported model in Unity 3D; import the downloaded Vuforia SDK Assert database package containing the specific identification map into Unity project file, then delete the original Main Camera and add the ARCamera, adjust the lighting, try to simulate the real environment light of the laboratory and enhance the experience; Add the three-dimensional model to be displayed when recognizing the image in the field of view; use the C# programming language to perform script editing according to virtual experimental teaching content; finally, set the application icon, name, and adaptation device information to the software according to requirements to be packetized as apk file, so as to complete the realization of interactive software.

The software implementation process is shown in Figure 2, and software interface is shown in Figure 3.

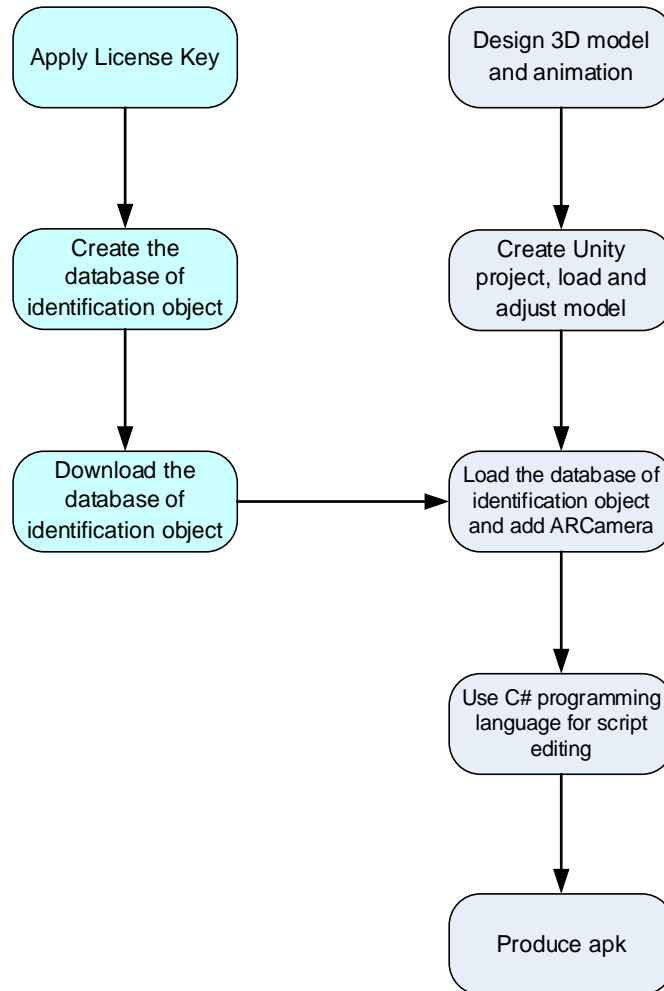


Figure 2 The software implementation process

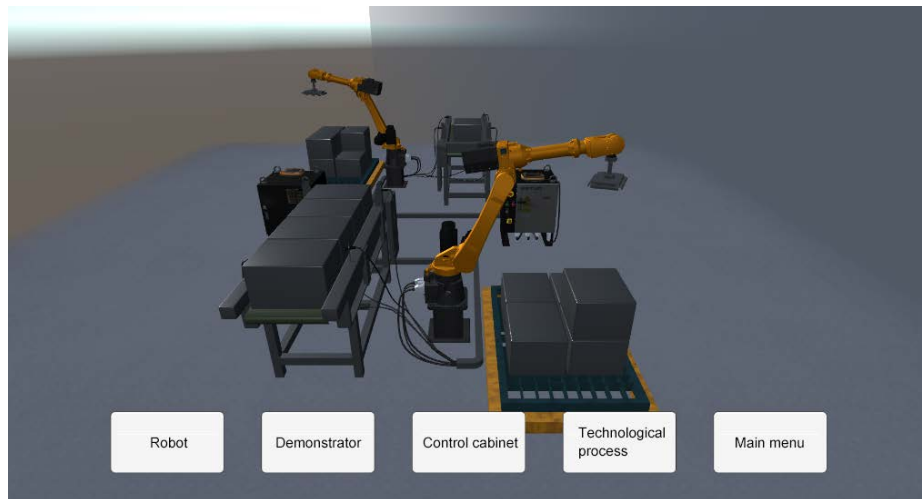


Figure 3 Software interface of virtual simulation experimental system

3.3 The teaching assisted by AR virtual simulation experiment

In the teaching assisted by AR virtual simulation experiment, students need to scan specified QR code by smart phone or tablet computer [13], download and install apk program of virtual experiment, open corresponding application icon and scan the corresponding identification pictures to virtual simulation experimental system, automatic identify 3D virtual simulation model and perform the touch interactive operation of 3D simulation model.

Through the interactive operation of AR virtual simulation experimental system, students can quickly grasp the function of industrial robot palletizing workstation, equipment part component, internal structure of robot, work principle and operation procedures, and robot palletizing technological process. In addition, they can practice the robot enlargement, shrinking, rotating and virtual dismantle.

After the examination of practical course, this virtual simulation experimental system of industrial robot palletizing workstation can greatly mobilize students' interests in learning and improve teaching results.

4. Conclusion

This paper, taking industrial robot palletizing workstation in Southeast University Chengxian College as an example, displays the construction of virtual simulation experimental system of industrial robot based on AR technology. It combines virtual simulation and realistic experiment scene and stresses the realistic sense of experience. Students can use mobile APP to perform scanning recognition and finger touch operation, and obtain a new interactive experience of virtual-real combination, which enhances the attractiveness of industrial robot experiment teaching, enhances students' interest in learning, and helps teachers better conduct on-site teaching. Students can carry out AR-assisted learning at the experimental site, or experience the interactive experience of virtual simulation experiments at any time and anywhere in the spare time, and strengthen the mastering of professional knowledge and skills and accumulation of experience.

The virtual simulation experimental system of industrial robot palletizing workstation built in this paper can solve the bottleneck of industrial robot talent training through the auxiliary teaching effect, truly solve the difficult teaching of industrial robot, high risk coefficient, and the boring teaching mode, and realize the immersive experimental teaching of industrial robot.

AR technology brings great opportunities for traditional education to realize teaching innovation and upgrading in the new normal. The method proposed in this paper is strongly representative and inspiring in the field of industrial robot experimental teaching. It can play an inspiring and a guiding role in subsequent industrial robot and even the entire experimental teaching and talent cultivation of intelligent manufacturing.

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