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Research Article

Virtual Reality Applications in Industrial Automation Systems: Industrial Robot Station Application

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Abstract:

Throughout the history of technological development, production is expected to bring more output with less cost perpetually. In order to compete in ever-changing market conditions, it is an inevitable requirement to increase productivity and reduce costs. As a result of the efforts to respond to this need, industrial robots emerged in the production systems. The aim of this contribution is to give a focus on the virtual reality technology usage with offline robot programming and to emphasize its advantages on design, programming and commissioning phases of robotic production lines. This paper presents application of a virtual reality tool in aid of robot programmer in industrial robot station environment. The proposed system aims to provide information in industrial robot station as well as to enhance the robot programmer concentration in the safety mechanisms in industrial workspace. The proposed virtual reality application in industrial robot station has been applied to a case study from the automation sector, resulting in enhanced robot programmer integration with the industrial environment.

1. Introduction

Industrial robots are basically designed to take people's places in the routine work that people do and increase productivity. The main advantages such as the ability of working under heavy weights, speed, high quality and long working times as long as periodic maintenance is done correctly, have made it possible for them to rapidly increase their usage areas in the industry. The robots have found a wide usage area in a variety of sectors in our country and in the world. In automotive sector such as welding, paint, assembly, quality control; in FMCG sector such as production, packaging, quality control and similar fields in pharmaceutical sector are also examples of this.

With offline robot programming, robotic production lines can be designed and simulated before the line is physically established. [1] In this way, the design errors and the improvement opportunities can be observed before making any investment. Besides, offline robot programming can be used as an effective training tool for maintenance people and students. When the online robot programming method was used in the past, the robot and so the production had to be stopped for a long time. In offline robot programming, robotic production lines can be designed, programmed, and simulated in a computer in the office environment. Today, robotic production lines are first designed and programmed in the computer environment, then the line is physically installed and the robot programs are fine-tuned. In actively working production lines, cycle time improvement projects are designed, programmed and simulated in the office environment without stopping the production for a long time, and then the improved program can be commissioned during scheduled maintenance periods.
In the literature search for offline robot programming, the use of ABB RobotStudio software

for offline robot programming [2-6], arc welding application in RobotStudio software [7], palletizing application in RobotStudio software [8], an application with an imported CAD model into RobotStudio software [9] were observed. In the literature search for virtual reality technology, a study on historical development of virtual reality [10], application fields of virtual reality [11], virtual reality applications in education sector [12-14], virtual reality applications in tourism sector [15], virtual reality applications in clinical therapy [16], comparison of virtual reality and augmented reality in technological aspect [17-18] were observed.

This study aims to examine the use of virtual reality technology in order to improve the design and programming processes of robotic production lines in terms of time, cost and work safety. In this context, in the first part of this study, the use of ABB RobotStudio software was examined, and then gripper robot application, which is used extensively in the automotive sector, was programmed and simulated. In the last part of the study, the simulation prepared in RobotStudio software was experienced with HTC Vive virtual reality system and the results were shared.

2. ABB RobotStudio

RobotStudio is software developed by ABB and is used for offline programming and simulating of robot stations. Its main advantages can be defined as follows:

- ✓ The behavior of the system can be observed by designing the station in the virtual environment before physically installing it and the system can be optimized in this stage.
- ✓ In cycle time improvement projects for production lines, program improvements can be done offline in the office environment without stopping the production.
- ✓ Technical skills such as the design of the robot station, programming of the robot, etc. can be achieved by project and maintenance teams with securing work safety and gaining experimentation as much as desired.

In order to experience the virtual reality technology with offline robot programming, a gripper robot application was designed and simulated in ABB RobotStudio. The aim of choosing gripper robot application is that it has a wide usage area in automotive and many other industries.

2.1 Gripper robot application

Gripper is a tool that is simply used to move a part from a place to another place. This is widely used in production lines, warehouses, logistics, etc. In order to design, program and simulate a gripper robot application, the process steps are defined as below respectively:

- Creating a station
- Adding a robot and setting up its system
- Designing a gripper and defining it as a mechanism
- Designing a table with suitable dimensions
- Designing the work piece to be gripped
- Adding the Smart Components
- Adding the necessary I/O signals in the robot system
- Configuring the Station Logic
- Defining the robot's path
- Program code writing in RAPID
- Simulating the program

In the sample application, an empty station was created and then IRB 140 model robot has been added in the station. After that, a system was installed in the robot. In order to utilize in the program, a PROFIBUS device has been selected in system configuration as well.

2.2 Designing a gripper and defining it as a mechanism

To design the gripper, as it is seen in Fig. 1, a base was first designed. It is important to position the midpoint of this part at the center of the coordinate system. Because this piece, which will later become the base of the gripper, will be connected from the center point while connected to the tip of the robot.

Then two pieces those are required to be opened sideways on the base were formed to be positioned on the base piece. After that, the parts to grip the work piece were designed and placed on the opening and closing parts. Subsequently, the "Union" command was used to connect the gripping part to the opening and closing part. The "Create Mechanism" selection under the "Modeling" tab should be made to convert this designed part into a moving mechanical object. When this selection is made, as it is seen in Fig. 2, a page titled "Create Mechanism" is opened. In this page, the settings of the mechanism were made. In this step, the links, joints and tool data are defined. After that, the home and end positions of the tool were defined. Home position is used when the gripper is closed and end position is used when the gripper is open. Finally, the gripper tool definition was completed and the tool was attached to the robot. Considering the application, two tables and one work piece was designed and added in the station, as it can be seen in Fig. 3.

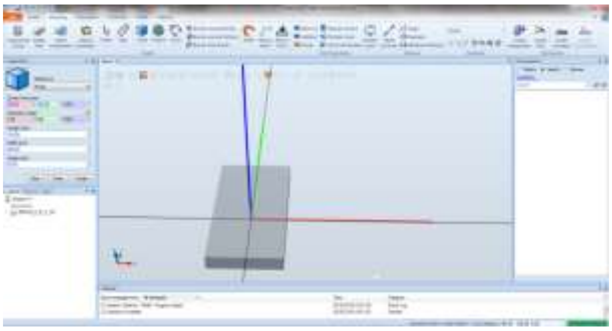

Figure 1. *Creation of base for gripper*

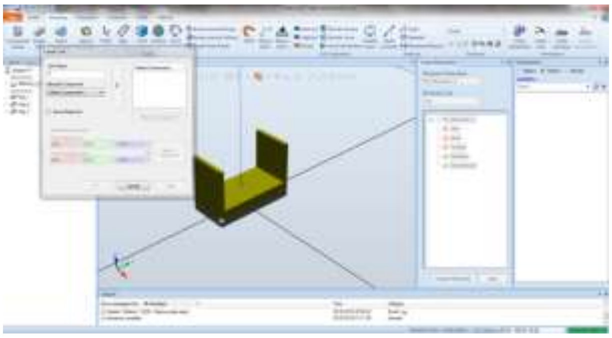

Figure 2. *Definition of the mechanism*

Figure 3. *Designing the tables and the work piece*

2.3 Adding the smart components

When parts are required to show complex behaviour other than routine movements, the "Smart Component" feature is used. In the gripper application, the work piece is waited to be sensed by a sensor on the gripper, then to be attached and to be travelling with the gripper. In order to manage the open and close actions of the gripper, “JointMover” was used. In order for the work piece to be sensed by the gripper, “LineSensor” was used. In order to attach the work piece to the gripper when the sensor senses it, “Attacher” was used. In order to detacher the work piece from the gripper when the sensor does not sense it, “Detacher” was used. In order to use in the block diagram, “NOT” and “LogisSRLatch” gates were used. After that, in the “Design” tab of the SmartComponent, input and output signals were defined. The input signal was named as “GrpAlBirak” and the output signal was named as “ParcaBagli”. After making the necessary connections in the “Design” tab, the situation has been achieved as it can be seen in Fig. 4.

Figure 4. *Completion of SmartComponent block diagram*

Figure 5. *Completion of Station Logic block diagram*

A new PROFIBUS card has been defined in the system so that the signals defined to be uses in the program could be collected on a separate card. At first, the PROFIBUS card with the name "Kart1" was defined. Then a warm restart was performed in order to complete the new card definition in the system. After that, an output signal with the name “PB_GrpAlBirak” and an input signal with the name “PB_SmartComponent” were defined in the “Kart1”. Besides, an additional input signal with the name “Start” was defined in the “Kart1” as well. In order for the changes to be valid and active, a warm restart was performed again. Then, on the "StationLogic" screen that can be seen in Fig. 5, the necessary connections were made between the signals. In this configuration, the system’s “PB_GrpAlBirak” output signal was connected to the SmartComponent’s “GrpAlBirak” input signal. Then the SmartComponent’s “ParcaBagli” output signal was connected to the system’s

"PB_SmartComponent" input signal. The system's "Start" input signal was then used in RAPID code page. After that, the target points were added and then the robot path was defined.

2.4 Program code writing in rapid and simulating

RAPID is the ABB robot programming language. In the next stage of the program, the necessary codes were written in the RAPID code editor. The main program was started under "main". In order to start the cycle, input signal "Start1" should be set to 1 and then to "0" with the push button algorithm. The commands "WaitDI Start1,1;" and then "WaitDI Start1,0;" were used for this. The commands "Set PB_GrpAlBirak1;" for the grip program and "Reset PB_GrpAlBirak1;" for the release program have been used. The "WaitTime 1;" command was used after the set and reset commands to wait 1 second when the gripper is opened and closed. Then grip and release programs were added in the required locations under "Path_10". The screenshot of the program in this phase is seen in Fig. 6. When "Kart1" was selected in the "Device" tab of the "I/O Simulator" screen, it was observed that the I/O signals that have been defined on Kart1 were filtered out. After that, the "Play" key under the "Simulation" tab was pressed and the simulation was started. Then, it was observed that the program was running when the "Start1" signal was turned 1 and then 0.

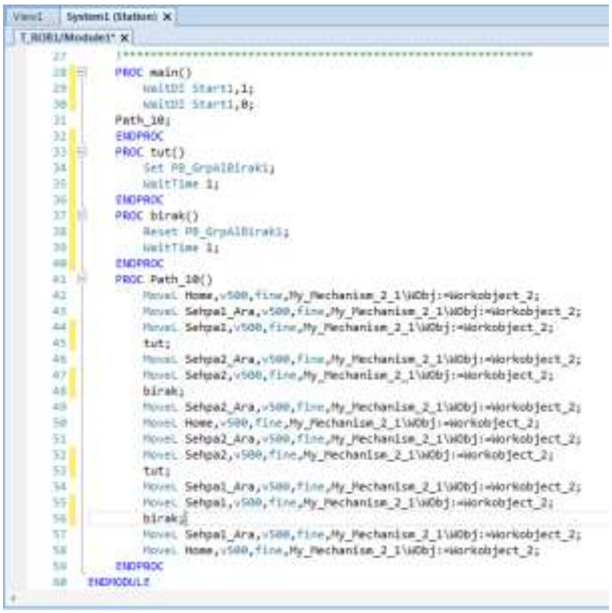

Figure 6. *The program code in RAPID code editor*

3. Virtual Reality Application

ABB RobotStudio software is compatible with the HTC Vive virtual reality system. Thus, a simulation prepared in this software can be experienced in 3D by connecting the HTC Vive virtual reality system. HTC Vive system provides virtual reality experience with the compatible software's. HTC Vive VR system consists of main stations, controllers and headset as shown in Fig. 7. The headset and the hand controllers are tracked devices. With the help of the main stations, they can locate themselves in the virtual world [1].

In order to be able to display with the virtual reality set, it is necessary to create a station viewer application from the station. At the same time, Station Viewer provides the ability to view the designed robot station and simulation even on computers without the Robot Studio software installed. In order to create the Station Viewer application of the designed robot station, the "Save Station as Viewer" must be selected in the "Share" section under the "File" tab. The screen image of the Station Viewer application which is saved on the desktop can be seen in Fig. 8.

Figure 7. *HTC Vive main components [19]*

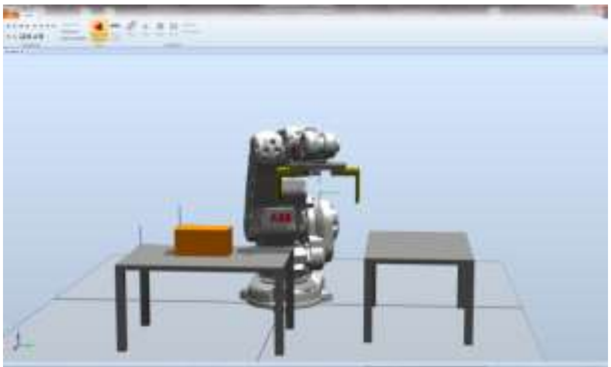

Figure 8. *Station Viewer screenshot*

"Virtual Reality" button can be seen under "Home" tab. When the HTC Vive virtual reality system was connected to the computer, the button had been activated. Then, when this button was clicked and HTC Vive headset was worn, the virtual environment was experienced as it can be seen in Fig. 9. However, when any point was marked with the sensors in the hands, the user was teleported to that point in the virtual environment and observed the station from that point, as seen in Fig. 10.

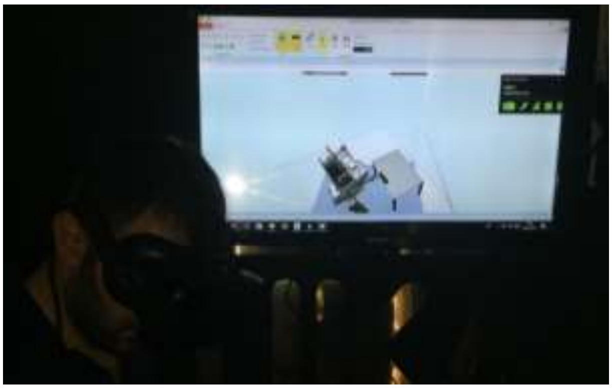

Figure 9. *Watching robot simulation with HTC Vive VR – 1*

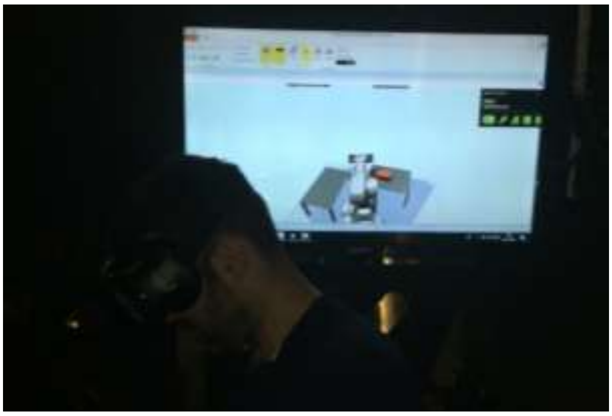

Figure 10. *Watching robot simulation with HTC Vive VR – 2*

4. Conclusion

Robotic production lines are very expensive investments. For this reason, all stage from project design phase to commissioning and also prototype and serial production stages are conducted under great cost and time pressure. It is expected that the line installation will be completed as quickly as possible and the outputs will be achieved at the desired quality level. In this study, it was preferred to use virtual reality to improve the offline robot programming process. First of all, a robot application which is used extensively in the automotive sector was programmed and simulated in ABB RobotStudio software. Then this simulation was experienced with the HTC Vive virtual reality system and it was confirmed that the program works as desired.

It was observed that the biggest advantage of using virtual reality technology was to be able to enter into the designed system almost as if it was in the real world and to examine the virtual system from any desired direction. In this way, the designed system behaviour was observed much more clearly. This has been confirmed to have a positive impact on the duration and quality of offline robot programming. Virtual reality technology is foreseen to be used more intensively in the upcoming years to improve the offline robot programming processes, to respond effectively to the training needs of maintenance staff, and to improve robotic sales and marketing processes. In the future, it is emphasized the importance of focusing on integrating augmented reality technology into robot programming and even into robot maintenance processes as well.

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