Gamepad Control for Industrial Robots
New Ideas for the Improvement of Existing Control Devices

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Abstract: In the scope of this work, a frequently used gaming device—the gamepad—is investigated as a control device for industrial robots in order to extract new ideas for the improvement of existing control devices. Thus, an approach for the integration of a gamepad control in a common industrial robot system is developed and implemented. The usability of the gamepad control is improved by adding a smartphone to the gamepad, which serves as a display to show information to the user. Finally, the developed gamepad control is compared with the operation via conventional control device.

1 INTRODUCTION

The sales of industrial robots reached the highest level ever recorded in 2015 (IFR, International Federation of Robotics, 2015). At the same time, modern products offer a lot of variety and diversity. Thus, small and varying batch sizes are in the focus. In doing so, a high flexibility becomes more important for industrial robot systems. This requires a quick and easy programming of the robots in order to lower the costs. For this purpose, an intuitive Human Machine Interface (HMI) for the robots is important as it lowers the qualification skills needed by the user. In addition, the time needed by inexperienced users to get started with the robot is reduced by an intuitive interface.

Common control devices for industrial robots have hardly changed in the past few years. Usually, the user input is still done via buttons, whether they are physical or virtual. Alternative devices exist in the gaming industry. One of the most frequently used gaming devices is the gamepad. In the scope of this work, we investigate the gamepad as a control device for industrial robots to obtain new ideas for the improvement of existing devices.

This paper is structured as follows: In Section 2 the related work on control devices for industrial robots and on gamepads is shown. The approach for the use of a gamepad as a control device for industrial robots is explained in Section 3. The implementation of this approach and a usability test of the gamepad control is presented in Section 4. Only initial trends are pointed out because of a currently low number of test candidates. Finally, Section 5 concludes the paper with a short summary and an outlook to future work.

2 RELATED WORK

This section shows the related work on control devices for industrial robots. Furthermore, the gamepad is explained in detail.

2.1 Industrial Robot Control Devices

The commonly used control device for industrial robots is called Robot Teach Pendant (RTP). Almost every robot manufacturer offers such a control device included with the robot. The RTP varies from manufacturer to manufacturer, but most of the time the control is done through physical or virtual buttons. Some devices have an additional joystick, 3D or 6D mouse to achieve a more intuitive controlling of the robot. Most applications can be accomplished with a RTP. The usability can be improved by an extended interface, as shown by Dose and Dillmann (Dose and Dillmann, 2014). Usability tests have shown that this method can be used without expert knowledge in robotics and additionally reduces the set up time of a new task dramatically.

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Another method for moving the robot is the manual hand guidance. With this method the program is taught by positioning the robot to the desired place by hand. Modern lightweight robots offer such a function, but with larger robots, this is not yet available. For heavier robots the movement can be supported by the robot motors, as shown by Colombo et al. (Colombo et al., 2006). The robot has a force and torque sensor that recognizes an outer force and moves to the desired position accordingly.

Guiding a robot by vocal input has been realized by Pires (Pires, 2005). The user has a fixed set of commands to guide the industrial robot through tasks. The operator uses his voice and tells the robot when to stop, open or close the gripper or start welding. The huge advantage of this interface is the natural communication since it is the same interface humans use to exchange information. Secondly, it is easy to change from one robot to another by simply saying the appropriate command. Furthermore, it reduces complexity as the set of existing commands is smaller.

Hand gesture and face recognition has gathered a lot of interest lately and many different approaches of gestures can be recognized. Some approaches utilize color information of camera images, as shown by Brèthes et al. (Brèthes et al., 2004) and by Malima et al. (Malima et al., 2006). The identification of body parts based on depth sequence data is considered by Liu and Fujimura (Liu and Fujimura, 2004). The main problem in the context of gesture recognition is the gesture spotting, which means when a gesture command is starting or ending.

Modern motion control devices like the Nintendo Wii Remote have also been used successfully for the guidance of an industrial robot, shown by Neto et al. (Neto et al., 2010). It provides a user easy means to control a robot without expert robot knowledge and a wireless and intuitive way to deal with common industrial tasks such as pick and place. This approach has been compared to the manual guidance of a robot and showed, that the manual guidance was faster in completing given applications.

Some gamepad controls for robots have already been realized. Especially for mobile robots the gamepad is a popular control device, e.g. used by Caccamo et al. (Caccamo et al., 2015). Colombo et al. used a gamepad for an industrial robot arm, but there is no approach and no further investigation explained (Colombo et al., 2006).

2.2 Gamepad

Gamepads were first developed within the video gaming industry (Cummings, 2007). The first gamepads consisted a D-pad and two buttons. The D-pad is a plus shaped button, which can be tilted in four (up, down, left and right) or eight (plus the diagonals) directions. Thus, it is ideal for simple movement controls. As the possibilities within games became more complex, the movement control within the game had to be easier and more intuitive. When the videogames started to become three-dimensional the D-pad was starting to lose its meaning. In order to give the user more control, the analog stick was introduced. Its sensitivity and intuitiveness as well as the possibility to choose between more orientations made it popular and the analog stick became the dominant control for three-dimensional problems.

3 APPROACH

In this approach a gamepad is used for the control of an industrial robot. Usually, directly controlling the robot from an external device is not offered by the robot manufacturer. Thus, further components are necessary for the communication (cf. Figure 1). One part of the system is the robot arm connected with its controller. Furthermore, the gamepad is connected to the control computer. A wireless connection is preferred to improve the movability of the user. In addition, there is a smartphone attached to the gamepad to show information to the user. It is used as a display and also connected wirelessly to the control computer by Wi-Fi. The control computer and the robot controller are also connected to each other.

The main software part of this approach runs on the control computer. The control software continuously receives the state of the gamepad (cf. Figure 2). All changes of the state—the pressing of a button or the deflection of an analog stick—are processed fur-

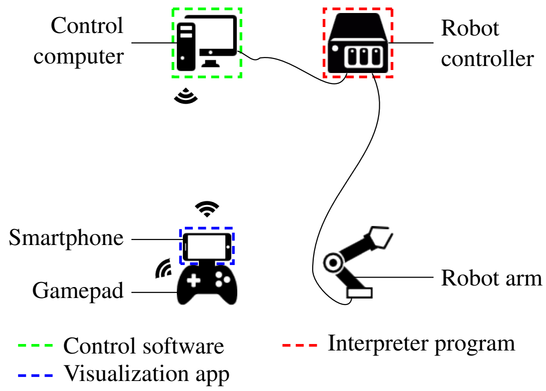


Figure 1: System overview for the gamepad control for industrial robots.

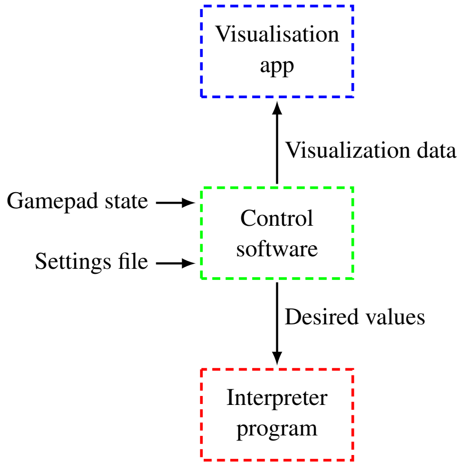


Figure 2: Software overview for the gamepad control for industrial robots.

ther. Similar to conventional robot control devices, a safety function is also integrated in order to prevent unintentional entries. Thus, buttons can be used as release buttons and a robot action is initialized only if these buttons are pressed. The resulting action for each input is defined in a settings file. Each line of the file contains a setting consisting a button or axis parameter and a robot action parameter. The axis parameters also consist a modifier to regulate the sensitivity. Thus, the settings can be changed quickly by editing the settings file. The desired values for the robot are estimated from the combination between the gamepad state and the settings. They are sent to the robot controller by the control software. The interpreter program reads the information and executes the appropriate robot commands. To provide the user with information, the software sends the relevant data to the visualization app.

Notheis et al. (Notheis et al., 2014) suggested that visual hints for the movement of robots were helpful for the participants. We adopted this idea and integrated a visualization which would help the user to understand the controls and shorten the learning process for operating the industrial robot. Since an industrial robot can quickly cause damage to the equipment when it is used by an inexperienced user, we were seeking an opportunity to avoid collisions. Most collisions and problems happen because of a lack of robotic-human awareness. Drury et al. (Drury et al., 2003) described that many users collided with objects even though sensors indicated them. We assumed that this might be due to an abundance of input data which might lead the user to involuntarily ignore certain information. Based on this assumption the app is modified to only show the input options that are currently necessary to conduct a certain movement.

4 EXPERIMENTS AND RESULTS

In this section, the implementation of the approach described above is presented (cf. Section 4.1). It begins by outlining the used hardware. Furthermore, the software implementation is described in detail. Finally, the usability of the realized approach is examined (cf. Section 4.2).

4.1 Implementation

For the implementation of the approach four main hardware components are necessary: a robot with its controller, a control computer, a smartphone and a gamepad. A KUKA KR 6 R900 sixx industrial robot arm is used as robot for the implementation. It has six axis and a separate robot controller. A software package for the XML communication via Ethernet offered by the robot manufacturer is installed on the controller. The control computer has an Intel Core i7 CPU and 16 GB RAM. Its operating system is Windows 8.1. A Google LG Nexus 5 smartphone with Android 6.0.1 is used as a display for the user. It is fixed to the gamepad by a self-constructed adapter. A Microsoft Xbox 360 Wireless Controller for Windows is used as gamepad. As the name already indicates, it is a wireless controller and connected to the control computer by an usb-transceiver. The gamepad is equipped with two analog sticks and one D-pad. Furthermore, the gamepad is equipped with two triggers and ten buttons. Two of these buttons are integrated in the analog sticks.

The control software is realized with C# and the .NET Framework. All connections are initialized from this software. The open source framework SlimDX is utilized for the connection with the gamepad. For the network connections the data is sent to a connected socket by the System.Net.Sockets namespace. An user interface for the configuration of the settings file is implemented in the software to simplify the configuration process (cf. Figure 3). Through this interface the settings can be changed by clicking on the robot parameter and subsequently entering the accompanying gamepad button or axis. The modifier can be changed by a slide control next to each axis setting. The specific settings selected for this implementation are explained in the back of this section.

An XML file is utilized for the communication between the control computer and the robot. It is transfered by the control software via Ethernet continuously. It contains parameters for a target robot position and robot axes values, a gripper state and a mode parameter to select between cartesian and axes movement. Inside of the interpreter program the XML file

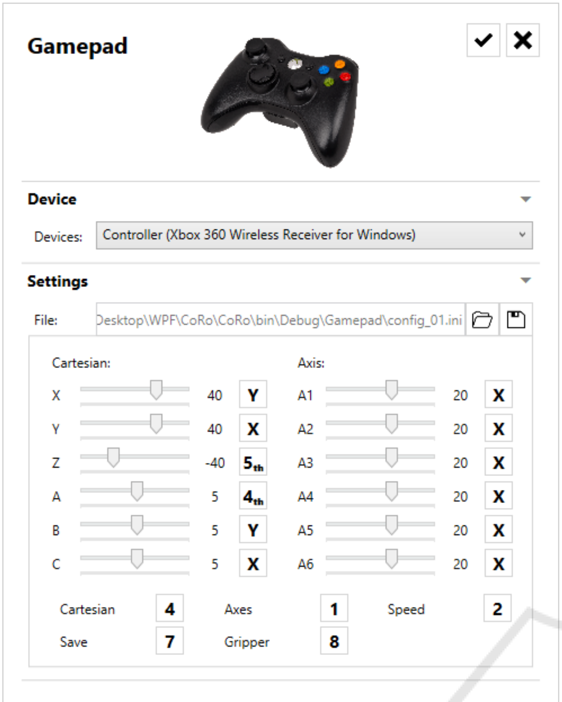
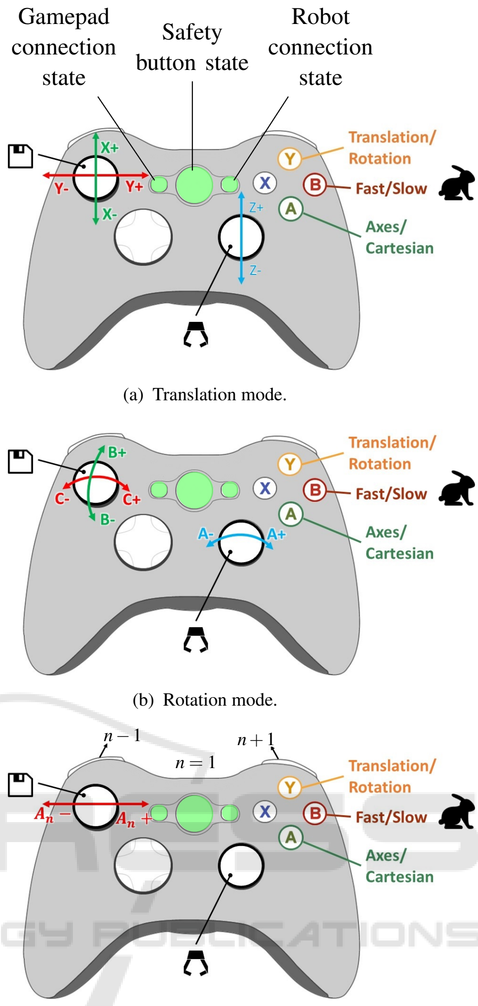


Figure 3: Settings window in the control software for the gamepad control.

is read and subsequently robot actions are executed based on the parameters. This is also done continuously to ensure a rapidly execution.

The main part of the visualization app is an image of the gamepad (cf. Figure 4). It contains information about the action connected with each button. Depending on the selected mode it contains also information about the actions connected with the analog sticks. There are three modes defined: two cartesian modes (translation and rotation) and an axes mode. The switching between the two cartesian modes is done by the Y-button. The A-button switches between the cartesian modes and the axes mode. The selected axis can be changed by the two buttons on the top of the gamepad. The left button reduces the axis index by one and the right button increases the index by one. Two speed levels (fast and slow) are implemented for a regulation of the movement speed. A switching between these two levels can be done by the B-button. The two speed levels are visualized by a turtle and a rabbit icon to achieve a better perception. Furthermore, the states of the connections between robot controller and control computer as well as between gamepad and control computer are visualized by colored areas. Thus, the user can easily check the connection states of the system. In addition, the safety button state is visualized in the same way to give a feedback of the pressed safety button. The two



(a) Translation mode.

(b) Rotation mode.

(c) Axes mode.

Figure 4: Different modes in the visualization app.

triggers are used as safety buttons. They need to be pressed to achieve any kind of action. The gripper can be opened and closed by pressing the right analog stick. A robot position is added to a program by pressing the left analog stick. We were considering to use the D-pad as well but decided against it since it is suggested by Cummings that a D-pad performs worse for 3D tasks (Cummings, 2007).

4.2 Usability Test

With the implemented gamepad control for an industrial robot arm a usability test is conceived. Thus, two tasks are defined which represent frequent sequences of industrial robot applications. The first task is a simple pick and place task (cf. Figure 5). An object has to be moved from a position $p_1 = (500 \;\; -500 \;\; 0)^T$ to a position $p_2 = (500 \;\; 500 \;\; 0)^T$, all units are in mm.

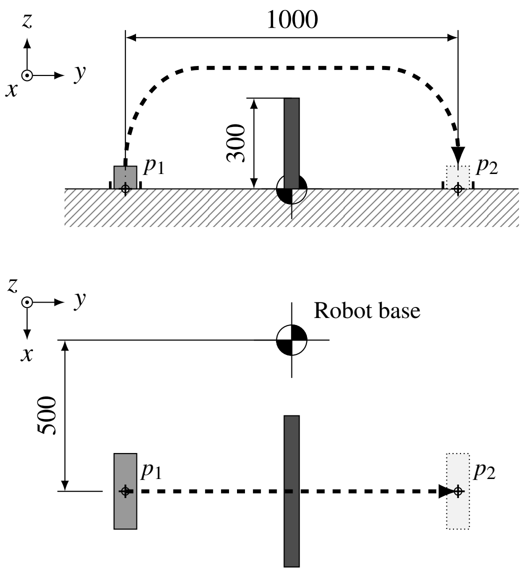


Figure 5: First task for the usability test of the gamepad control for industrial robots.

In doing so, an obstacle at y = 0 mm with a height of 300 mm must be overcome. The two positions are marked by bars which support the positioning. Between these bars the object has a clearance of 1.5 mm. The exact path points are not specified. For this task a gripper, fitting to the moved object, is mounted on the robot arm.

For the second task the robot has to be moved along an s-shaped path (cf. Figure 6). The linear part of the path has a length of 300 mm in y-direction. The neighboring linear parts are linked by an arc with a radius of 50 mm. A pen is attached to the robot arm to achieve a visible path by drawing on a plane. All points of the path are marked by a circle with 5 mm radius. Before the first position and after the last position of the path the tool has to be moved up in z-direction to get a distance between the tool and the plane.

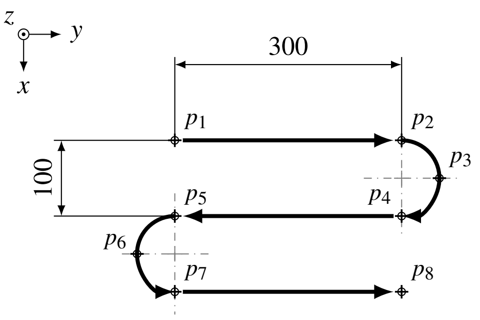


Figure 6: Second task for the usability test of the gamepad control for industrial robots.

These two tasks are performed with the conventional RTP and with the gamepad control by ten test users so far. The time required for each performed task is recorded. In order to avoid understanding related errors each task is done twice with each of the devices. Thus, eight time values result for each test user, four with the RTP (t_P) and four with the gamepad (t_G). The mean values of all users are summarized in Table 1. It appears that lower average times are achieved with the gamepad control. Due to the smaller difference between first and second attempt, the game pad appears to be more intuitive to learn. In addition, user data about the age, the experience and the perception of the usability is documented. Because of the above-mentioned low number of test candidates a more detailed evaluation does not make sense until now.

5 CONCLUSIONS

Within this paper we have developed a software, which reads inputs from a common gamepad device, translates these inputs and refers them to the robot controller, which commands the movement of an industrial robot. In order to simplify the guiding process and to reduce the training time of the user, we have integrated an easy and self-explanatory interface, which has only the necessary functionalities included. The method of robot manipulation with a gamepad is tested in two different tasks. Every user had to perfom every task twice with the RTP and twice with the gamepad. In the first tests, lower times are achieved with the gamepad control. In addition, all users strongly preferred the gamepad as a manipulator over the RTP.

From this we are inclined to suggest that the gamepad seems to be more intuitive to users then the RTP. However, due to the small number of test users, no valid statement can be determined until now. Thus, the usability test should be extended to more users with different ages and levels of experience to conclude if the gamepad is faster and more intuitive then

Table 1: Mean time values for the usability test tasks.

Task	Attempt	$\bar{t}_P$ (min:s)	$\bar{t}_G$ (min:s)
Pick and place	1	7:57	5:29
	2	5:27	4:16
Path	1	7:11	4:38
	2	5:45	4:07

the RTP. In addition, the hardware could be improved by constructing a smartphone adapter that results a center of mass in the middle of the gamepad and not infront of it. Thus, the handling of the device could be improved.

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