Integration of a 2D Vision System into a Control of an Industrial Robot

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Received: 18 April 2014; Accepted: 30 April 2014; Published online: 27 June 2014

Abstract
Industrial robots play an important role in today's production. They are mostly tied to the production process by teached orders. To make industrial robots more flexible and more interesting for the industry, they are often additionally equipped with a vision system. Thus, they are not bound by their fixed program and able to adapt their path to each object individually. This paper explains the cooperation of a six-axis industrial robot and a 2D-Vision System. Here, the precision of the robot and the accuracy of the vision system are combined. The vision system In Sight Micro 1100 acquires quality and localization tasks. It locates the object, inspects it and judged its quality. These results are finally send to the robot controller of KUKA KRC 2 Edition 2005 in the form of coordinates and are ultimately put into action by the industrial robot KUKA KR 16-2. With the software In Sight Explorer 4.8.0 a visual order can be created and adapted to the existing conditions. It offers a variety of preset localizing and qualitative tools. Alternatively, there is the possibility to created special tools in a spreadsheet program. The paper describes the interface between vision system and robot. Finally, an inspection station for work piece quality control is created from the derived results.

Keywords: *Integration, Vision system, Robot controller, Quality inspection*

1 Introduction

"Robots sales slightly decreased in 2012 by 4% to 159346 units, the second highest level ever recorded for one year" [1]. In almost every industry, the number of industrial robots is increasing. They are not generally bound to a process, but can take individual actions and decisions. Hence, it is necessary to equip them with sensors. Under an automated process, which is used in mass production, may not ultimately suffer the quality. However, the result must be at least of the same quality as with manual production. In addition, vision systems usually work faster and more accurately than the human eye.

To be able to convey this development to students, the Robotics Laboratory of the Bochum University of Applied Sciences was established. In this laboratory the stuff, including students work, research and develop with a variety of industrial robots of the *KUKA Robot Group*. One task is the integration of a vision system to control an industrial robot. The aim was to create an inspection station for work piece quality control, where the students are able to create a variety of automated processes. The main task is to establish the communication between the vision system and the robot controller *KRC 2 Edition 2005*. Furthermore a workstation should be created for interested students where they can expand their knowledge in the field of robotics and image processing. In the following, this communication between the robot and the camera is described, as well as specifics on the program structure and ultimately the inspection station for work piece quality control is illustrated with an example application.

Please cite this article as: M. Stepien and R. Biesenbach, "Integration of a 2D Vision System into a Control of an Industrial Robot," *KMUTNB Int J Appl Sci Technol*, Vol.7, No.4, pp. 67-71, (2014), http://dx.doi.org/10.14416/j.ijast.2014.04.006

2 Robot System

The robot system used here consists of the industrial robot *KUKA KR 16-2*, the robot controller *KUKA KRC 2 Edition 2005*, the gripper *Schunk SWG 50* and the vision system *In-Sight Micro 1100* with the *In-Sight CIO-Micro-E/A-Module* from the company *Cognex*. These components built up the known robot system and will be described briefly below. For safety reasons, the robot system is enclosed by a safety fence.

2.1 *KUKA KR 16-2*

The *KUKA KR 16-2* is a six-axis articulated robot, weighs approx. 235 kg and has a medium load bearing capacity up to 16 kg. With a range of approx. 1611 mm he has a repeatability of ± 0.05 mm [2]. With the *KCP* (KUKA Control Panel) the robot can be controlled and programmed. In addition, the robot is bounded in his working area through software and hardware limits. This ensures that he remains in his work space and people between the robot and solid objects cannot be injured. A safety fence around the robot cell protects against unauthorized access.

2.2 *KUKA KRC 2 Edition 2005*

There are various interfaces, such as: PCI slots, USB, serial, parallel and Ethernet interfaces as well as a serial real-time interface (COM3) in order to connect to different sensors. The operator has either so called inline forms or the proprietary programming language *KRL* (KUKA Robot Language) available.

The robot controller has in addition to the software components *KSS 5.5* (KUKA system software) and *KUKA HMI* (Human Machine Interface), two operating systems. On the one hand, *Windows XP Embedded 2.0,* which was tailored to the requirements of the *KSS* and is responsible for the visualization and on the other hand, the concurrent real-time operating system *VxWorks*, the real-time control of the robot system.

2.3 *Vision system*

The vision system of the Company *Cognex* consists of the camera *In-Sight Micro 1100* and the *In-Sight CIO-Micro-E/A-Module*. The 1/3 inch CCD sensor of the camera has a resolution of 640x480 pixels and has a color depth of 8 bits [3]. The *CIO-Micro-E/A-Module* offers multiple connectivity options, such as digital inputs and outputs, RS232, PoE (Power over Ethernet), LAN (Local Area Network) and trigger connections.

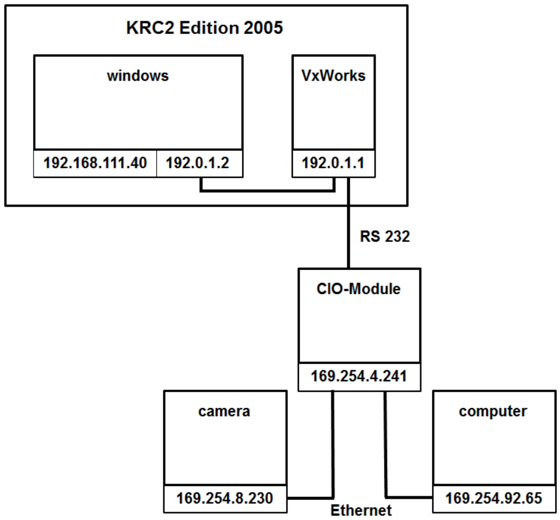

Figure 1: Communicational schema.

3 Connecting the Components

In this system, the *CIO-Micro-E/A-Module* forms the knot of the communication. The *In-Sight Micro 1100* is integrated via PoE to the module. A computer, on which the image processing software *In-Sight Explorer 4.8.0* is running, is connected to the normal LAN port. Communication takes place via Ethernet with the TCP / IP protocol. Finally, the module is connected to the RS232 serial real-time interface of the robot controller, as shown in the Figure 1. Here, the data transmission runs over the 3964R protocol.

4 Communication to the Vision System

4.1 *Implementation of the interface*

Before it is possible to send commands, the serial port has to be configured in the robot controller *KRC 2 Edition 2005*. The interface used here must be assigned for the real-time operating system *VxWorks.*

The parameters of the serial interface are in the system file “SERIAL.INI”. In the section “[COM3]” the basic settings for the RS232 communication will be established. It must be ensured that the transmission rate, the number of data and stop bits, and the parity are matched to the settings of the vision system.

In addition to the basic serial port settings, the 3964R protocol also can be configured. Here, the timeout values (CHAR_TIMEOUT, QUITT_TIMEOUT, TRANS_TIMEOUT) can be set, as well as the maximum number of receive and output buffers (MAX_TX_BUFFER, MAX_RX_BUFFER). In order to avoid an unnecessarily long cycle time during a test phase, the timeout values are in the ms range.

4.2 *Serial interface with 3964R protocol*

The communication is an asynchronous and a bit serial transmission method. This means that only one data stream is generated when data is produced, for example due to a fingertip. If data is to be sent, they are provided in the output buffer (TX_BUFFER) and then forwarded by the interpreter to the protocol. Also received data in the receive buffer (RX_BUFFER) is stored and then passed to the interpreter that they processed. When the transfer is done with a character length of 8 bits, bit 7 is zero. The control characters for transmission of the 7- bit code are taken from the DIN 66003. The following Table 1 shows an overview of how data with the 3964R protocol is sent.

Table 1: Data flow with 3964R protocol

Robot controller		Vision System
STX	→	
	←	DLE
Character 1	→	
Character 2	→	
…	→	
Character n	→	
DLE	→	
ETX	→	
BCC	→	
	←	DLE

The connection begins with a STX character (START OF TEXT), that is sent from the robot controller to the vision system. This is the signal of a beginning text. If the vision system answers within the adjustable acknowledgment (QUITT_TIMEOUT) with a DLE character (DATA LINK ESCAPE), a connection is established successfully and the 3964R protocol begins to send the control data with the specified transmission speed. Through the character delay time (CHAR_TIMEOUT) the vision system checks whether the time interval between two characters is not exceeded. If the output buffer (TX_BUFFER) is empty, the DLE, ETX (END OF TEXT) and BCC (BLOCK CHECK CHARACTER) are sent and the robot controller waits for an acknowledgment. These BCCs are the longitudinal parity of payload bits of all data bytes. If the acknowledgment by a DLE character is carried out, the transfer is considered as successfully completed.

4.3 *Reading and writing with CREAD/CWRITE*

CREAD and *CWRITE* are two flexible commands of the *KRL*, which allow the user to communicate with another control system or within the robot system. In this case, the robot controller communicates with the vision system and receives the position data. Communication takes place over serial interfaces, as described in section 4.2.

In the structure of the communication, the communication characteristics of the camera have to be taken into consideration. The *In-Sight Micro 1100* is not capable of communicating with the robot controller itself. Therefore, the use of the *CIO-Micro-E/A-Module* is unavoidable. Nevertheless, it is important that the camera does not send data by itself, but always waits for a command from the partner controller. Accordingly, all data, which will be processed by the robot, must be requested by *CWRITE* command. The realized operations by the camera, such as create a new image, also need an appropriate command of the robot controller. After each received command, the camera sends an integer to the robot controller, so that it can be checked whether the command was successfully performed by the camera. Hence, the communication characteristics of the camera must be regarded in the program design of the robot in order to avoid potential failure.

With the two commands *CREAD* and *CWRITE* it is possible to communicate inside and outside the robot controller. Here, a *HANDLE* variable must be passed on to the commands, to clarify on which interface they have to communicate. Furthermore,

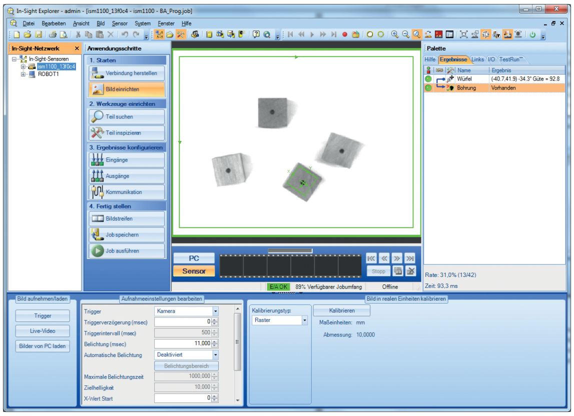

Figure 2: In-Sight Explorer 4.8.0.

Figure 3: Inspection station for work piece quality control.

the commands must be assigned to an independent variable, which receives the status return value of the command. Possible error messages respectively a successful processing about this status return value of the command, can be inquired.

In order to create a new image, the command *SE8* (SET EVENT 8) was chosen. This is a programmed order of the camera, which only needs to be called up. In order to request individual settings or coordinates, the command "*GVcell*" (GET VALUE date cell) is used, which requests the individual data from the table view.

5 Image Processing

Image processing operations like edge detection or texture description were performed by the software *In-Sight Explorer 4.8.0*. At the beginning, the image must be set up and calibrated, so that the correct coordinates are transferred. The transition from the world coordinate system to the camera coordinate system occurs by translation and rotation. [4] In the next step, the tools provided by *In-Sight Explorer 4.8.0* are selected. In the first place, a localizing tool is used, which locates the object by means of a memorized image. Subsequently, the localized object is examined for its characteristics, whereby the quality of the objects is observed and quality differences are made visible. Due to the radiometric study the objects can be reliably detected. As an example cubes were localized, sorted by the quality and picked up automatically. In Figure 2 the EasyBuilder view of the Image processing Software ist shown with a located object.

If the camera is in an online mode during the implementation of the program, various statistics are recorded. All set properties and tools can be found in the tabular view of the *In-Sight Explorer 4.8.0*. Thus, the operator gets a quick overview of all existing data, which can be requested via a *GET VALUE* command.

6 Summary

In this work, an industrial robot has been connected with a vision system, as this becomes increasingly relevant in the industry. The following Figure 3 visualizes the considered experimental setup.

Objects, which should be scanned, must be located in the image area of the camera. The image area is located within the workspace of the robot. Due to safety, the working area is limited, so that stationary objects are not touched and people do not get in danger. After the experimental setup, the necessity of robot programming and image processing has been described. During the implementation of the vision system, settings must be made in order to avoid an unnecessarily long cycle time. Likewise, the vision system should inspect only key features of the objects and then provide the results to the robot.

7 Results

An individual inspection station for work piece quality control at Bochum University of Applied Sciences was created by the extensive linking of the robot controller *KRC 2 Edition 2005* with the vision system. Students have here the opportunity to familiarize themselves with the communication between two different systems and to delve into image processing and robot programming. A complex work area is available, where they can take on new or additional projects. Furthermore an internship can be offered to the students.

The image processing of the vision system and the necessary data transfer are completed in less than one second. Therefore it is possible to reach a cycle time of a few seconds with the robot. The camera offers quick location and especially a qualitative study of the objects. The investigated objects are sorted by the robot with an accuracy of ± 0.05 mm. In order to improve the cycle time, the system can be expanded in another research project, for example with a fully automated material flow.

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