

Material handling based on object recognition with the help of FANUC delta-parallel industrial robot

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Abstract. The task was made that recognizes objects with the help of delta-parallel constructed pick & place FANUC robot, that can be found at the Mechatronics Department, Engineering Faculty, University of Debrecen. The detection of the different objects was realised by a SONY XC-56 typed industrial monochromatic camera and using the own image processing software component of the robot. To accomplish the material handling a linear drive, an electropneumatic gripper and the digital output system of the robot were used. During the project, the implementation of a material handling operation was the aim that is based on the machine vision of the robot. As a result, the robot used its vision and object recognizing ability based on iR Vision environment, completed object recognition and material handling procedure with the help of a linear drive controlled by robot program code.

1. Introduction

At the Cyber-Physical and Intelligent Robot Systems Laboratory a special laboratory was created, where new industrial solutions are showcased. The laboratory can be found at University of Debrecen's building mechatronics research center [1]. Nowadays we are at the beginning of the new industrial revolution, which is the Fourth Industrial Revolution, or briefly Industry 4.0. One of the results of the new technologies is that they increase the effectiveness of the industrial production processes. The Machine Vision is very important due to the automatization processes. In the industry three essential adaptability goals have been determined, such as object recognition, determination of the size and the position [2], [3]. Related to the importance of the technology and the fact that at the Mechatronics Department it was possible to deal with a robot that is able to use machine vision I studied the material handling based on object recognition with the help of the mentioned industrial robot.

2. Technical overview of the robot

2.1. FANUC M-1iA 0.5A robot and its appliances

The robot that was used, a M-1iA serial 0.5A typed delta-parallel structured robot produced by FANUC Corporation. It is ideal for precise assembly procedures. The number of moveable axes is 6, its maximal reach is 280 mm, the maximal speed is 4000 mm/s, maximal repeatability is +/- 0,02 mm, mechanical weight is 23 kg, and the load capacity of the 6. axis is 0,5 kg [4]. The robot has a R-30iB Mate typed Open Air control unit that can be found on the base construction of the robot. The operating system that the robot uses is the FANUC's own developed operating system, without frame system. It has IP67

protection against the damage caused by the industrial environment [4]. The primary control possibility of the robot is the Teach Pendant that name is iPendant Touch that provides command structured online-indirect programming [4].

The machine vision of the robot the XC-56 type monochromatic camera produced by SONY is responsible for. The resolution is VGA, the maximum scanning speed is 120 pixel/sec, the imaging mode is CCD, maximum illumination is 0,5 lx, and it has IP66 protection [5]. The camera has also a 12VC1040ASIR objective produced by Tamron, that can produce a suitable image quality in the field that is near the infrared (under 850nm). The imaging size is 1,2", it has variable lens type, manual iris type, the focal length range is 10-40 mm and the operating temperature is (-20) – (+60) °C [6]. The machine vision of the robot is existed by the iRVision image analyser developing environment. It has a direct connection with the imaging device, that is the SONY XC-56 camera. The image analyser system and the developing environment can be reached from the Teach Pendant of the robot, or from the Microsoft Internet Explorer browser, the 192.168.0.1. address.



Figure 1. The robot, the control unit, the Teach Pendant, the camera and the objective [4], [5], [6]

3. Optimization of the workspace

3.1. The digital output system of the robot

As a result of my earlier project, the digital output system of the robot was developed. Due to it, controlling different devices by digital signal through the output system of the robot became possible. A switching circuit was made to the robot and its task is to receive the 24 V reference signal voltage that comes from the output ports of the robot. It contains photo-Darlingtons to realise the galvanic isolation and to activate the associated Finder 55.34.9.024.0040 typed miniature industrial relays. For this reason, with the help of the relay connection, it is possible to operate devices from program code. It contains an electropneumatic vacuum gripper that are controlled by the RO1 relay (Robotic Output 1) [7].

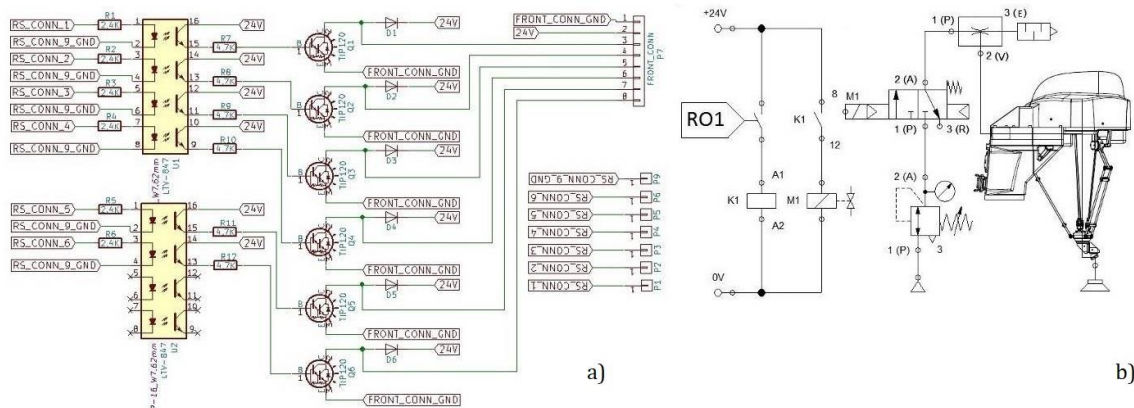


Figure 2. The schematic of the switching circuit (a) and the electropneumatic gripper (b) [7]

3.2. Providing of the optimal lightning

In the interest of the lightning, EGLO typed lamps was equipped on the frame construction of the robot to give enough and well-positioned light against the light pollution. The lamps operate RGB LEDS. They have GU10 typed connection, their performance is 4W one by one. Their minimum lightning intensity is 220 lm, they can be operated via 220-240V AC supply voltage and their current use is 40 mA. Their operation is possible with the help of 6. relay via program code. The lamps were equipped with 2 beholders that were designed printed in 3D.

3.3. Connecting of the linear drive to the robot

During the project, an ISEL LEZ1 type linear belt drive was connected to the robot in its workspace. Its task was the carrying the objects to help the material handling process. The belt spacing is 3 mm, the belt width is 9 mm, the repeatability is ± 0.2 mm, in case of 1:1 transfer the belt feed is 60 mm/revolute, maximum speed is 1,5 m/sec and the step angle if the stepper motor is 1.8° [8]. To control of the belt drive moving stepper motor a Pololu A4988 type motor controller device was chosen, besides Arduino Nano is the applied microcontroller. The operation of the linear drive is in connection with the digital output system of the robot. Due to it, 3 fixed positions were defined for the stepper motor. These 3 positions connect of the 3 output ports of the robot (RO2, RO3, RO4). An RO5 output relay and a potentiometer were defined as well to position the linear drive proportional according to the potentiometer.

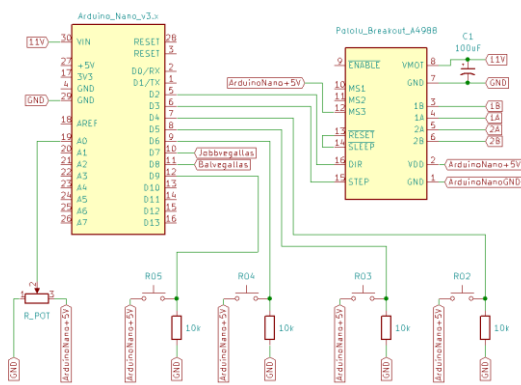


Figure 3. The schematic circuit for controlling the linear drive

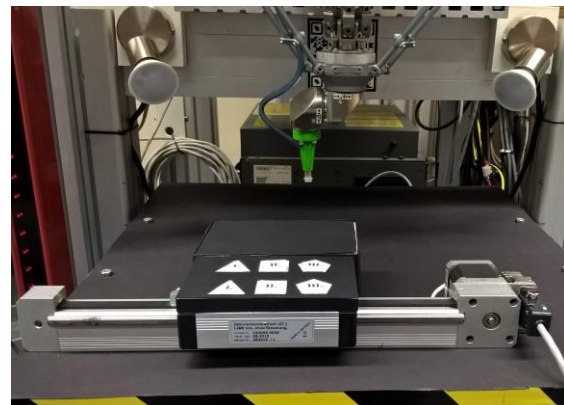


Figure 4. The modified workspace

3.4. Creating new worktable for the object recognition

The stability of the worktable is a basic demand as the procedure works with Z offset = 0 value. In this case the X, Y values and the rotation value to the reference position are detected. Otherwise the displacement along the z line are not detected, because the process claims flat. That is why the vertical displacement of the work table can result the failure of the procedure. For the same reason it is necessary to provide the parallel position with the x and y lines of the worktable. One more important thing that the camera view needs to be perpendicular to the flat of the worktable. In the lack of it, the robot program that recognizes the objects can be inaccurate. It is appropriate, if the background is different from the objects that are recognized. As the mentioned objects are white, the surface of the worktable has been covered with black pasteboard that provides the contrast.

4. The performance of the necessary calibrations

4.1. The tool frame calibration

Determining of the Tool Center Point (TCP) is important when the robot calculates its motion between 2 points itself. In this case the unit controller has to take into consideration the geometrical parameters of the tool avoiding the collision. To calibrate the tool, the Three Point Method was chosen. The

calibrated tool was an electropneumatic operated vacuum gripper. However, due to the geometry of the gripper it was not possible to rotate it accurately around the chosen reference point. To solve this problem a calibration tool was designed in form of 3D model and 3D printing. The geometrical parameters are equals with the vacuum gripper, but it has spike forming which is suitable for the calibration and the calibrated parameters are accurate in case of the vacuum gripper.

4.2. The calibration of the user frame and the camera

During the calibration of the user frame, that user frame is taught for the robot where the target operation will be done. To accomplish that the more accurate Four Point method was used. In the course of this method, four points was thought for the robot. These points are a point along the X line, a point along the Y line, the Orient Origin point, and the System Origin point. As the tool frame calibration was associated with object recognition procedure as well, so it was necessary to accomplish it together with the camera calibration. During the camera calibration, the real physical coordinates and the direction of the user frame is associated with the pixels that represent the image of the camera. Implementation of it happens with calibration grid plate. The calibration grid plate is the multitude of the points that are situated in regular distances. These points are reference and orientation points. The orientation points sign the certain directions. These directions have to be the same with directions and points thought during the calibration of the user frame. The software part of the camera calibration was accomplished in the iRVision environment.

5. The object recognizing procedure

During the material handling the task of the robot is to detect the taught objects that can be found in is workspace using object recognition and then to detect the shaped holes of the object panel that belong the objects. The robot has to determine offset values during the detection, which contain the X and Y coordinates of the found objects and the R rotation around the Z line referred to the reference position. According to the determined offset values, the robot has to fit the objects into the suitable hole that was determined in the robot program. As there are 3 types of objects and 3 types of shaped hole belongs to them, it was necessary to implement 6 different object recognizing procedure that detects the suitable object and shaped hole in the interest of success. The process provides 2-dimensional vision with 1 camera.

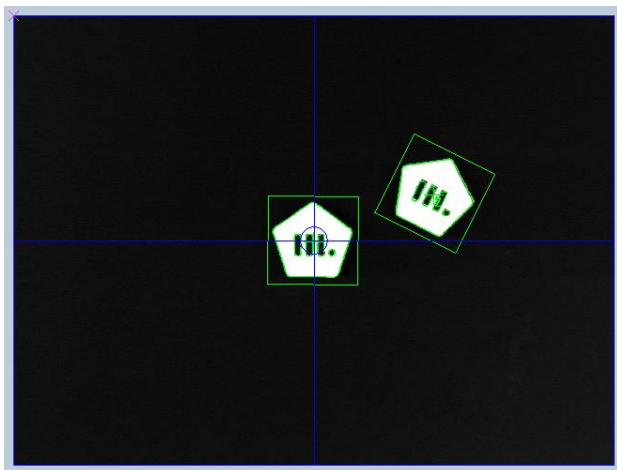


Figure 5. The recognition of the pentagon object

6. The material handling process

It became possible to create the robot programs after the implementation and testing the object recognizing procedures. These programs carry out the desired process of the material handling based on object recognizing. With the help of the subprograms, detection of the objects and fitting them into the right hole happens. The task of the main program is to control the lightning, the linear drive and the subprograms.

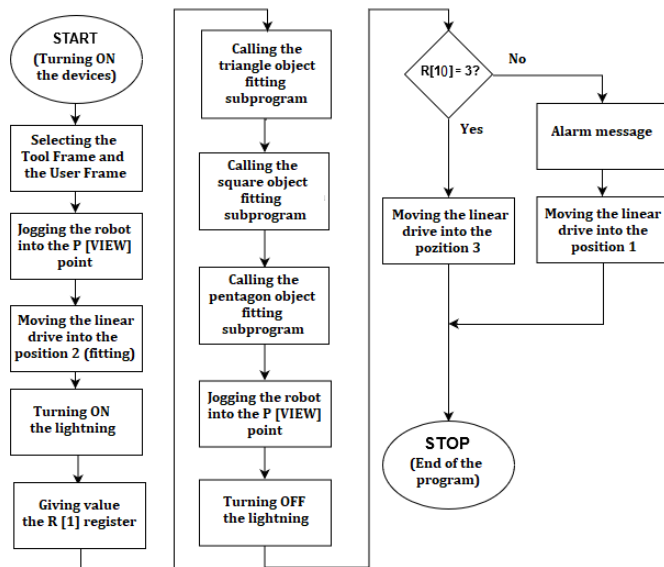


Figure 6. The flowchart of the main program

Conclusion

During the project, the implementation of a material handling operation was the aim that is based on the machine vision of the robot. As a result, the robot used its vision and object recognizing ability based on iRVision environment, completed object recognition and material handling procedure with the help of a linear drive controlled by robot program code. Other developing possibilities are enlarging the robot with other equipment, realising image recognition procedures form more camera standing and developing the digital input and analogue output system of the robot.

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