Design and Experimental Applications of Material Classification Prototype System

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ABSTRACT

Progress in the field of robotics has greatly influenced industrial automation technology. The material classification process is one of the important parts of this technology. Through the experimental system, it was aimed to classify materials in different shapes and properties. Robot manipulator-based system is proposed for the mentioned purpose. The proposed prototype system consists of a fixed rapidly traversing conveyor, 6 DOF industrial robot manipulators, Labview software and Universal gripper elements. On the other hand, Labview is an image processing software developed with the graphical programming language and the camera system is trying to predict the position with the 2D image of the material. Classification process was performed by analyzing the field information and shape properties of the materials to be classified with the developed image processing techniques. In the proposed system, use the universal gripper to hold and move the material. The system basically consists of three units. The first unit is the computer on which the image processing techniques are applied, the belt conveyor where the transport of the second unit materials is made, and the third unit is the 6 DOF industrial robot and the universal gripper where the holding and moving process is carried out.

Keywords: Image Processing, Labview, Industrial Robot Manipulator, Universal Gripper.

Malzeme Sınıflandırma Prototip Sisteminin Tasarımı ve Uygulaması

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ÖZET

Robotik alanında ilerleme, endüstriyel otomasyon teknolojisini büyük ölçüde etkilemiştir. Malzeme sınıflandırma süreci, bu teknolojinin önemli parçalarından biridir. Deneysel sistem aracılığıyla, farklı şekil ve özelliklere sahip malzemelerin sınıflandırılması amaçlanmıştır. Bahsedilen amaç için robot manipülatör tabanlı sistem önerilmektedir. Önerilen prototip sistemi, sabit hızlı konveyör, 6 DOF endüstriyel robot manipülatörü, Labview yazılımı ve Üniversal tutucu elemanlarından oluşmaktadır. Öte yandan, Labview grafiksel programlama dili ile geliştirilmiş bir görüntü işleme yazılımıdır ve kamera sistemi malzemenin 2D görüntüsüyle konumu öngörmeye çalışmaktadır. Sınıflandırma işlemi, sınıflandırılacak malzemelerin alan bilgisi ve şekil özelliklerini gelişmiş görüntü işleme teknikleriyle analiz ederek gerçekleştirilmiştir. Önerilen sistemde malzemeyi tutmak ve taşımak için üniversal tutucu kullanılmıştır. Sistem temelde üç üniteden oluşmaktadır. İlk ünite, görüntü işleme teknikleri uygulanan bilgisayar, ikinci ünite malzemelerin taşıma işleminin yapıldığı bantlı konveyör ve üçüncü ünite 6 DOF endüstriyel robot ile tutma ve taşıma işleminin yapıldığı üniversal tutucudan oluşmaktadır.

Anahtar Kelimeler: Görüntü işleme, Labview, Endüstriyel Robot Manipülatör, Üniversal Tutucu

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1. Introduction

Today, robots are beginning to be used very often in the industry. In almost every factory it is possible to encounter a robot. The robot, reprogrammable; materials, parts, tools, multifunction machines that carry or process according to the work to be done with the programmed movements. Most industrial robots are like mechanical arms and most of them function like human beings. Industrial robots have tremendous applications such as assembly, welding, spray painting, machine loading, manufacturing, construction, manufacturing. The pick and place application can be said to be the most used application in the industry.

The gripper is the necessary element for the pick and place process. The last element of the kinematic chain, the gripper, is the only part that comes into direct contact with the material. However, there is a need for universal grippers that can accommodate different objects with various shape and surface features. Universal robot grippers are robotic end effectors that can grip a wide variety of arbitrarily shaped objects [1]. Most existing designs are based on versatile hands, but this approach reveals hardware and software complexity. The reasons for this complexity include the control of joints, the perception of the force necessary to hold the object securely, and the application of sufficient force to hold the object intact. Instead of the mechanical fingers used in existing designs, a material that will take the shape of the object when it is pressed against the target object, and then a grip that will grasp the object completely and hold it fast with the vacuum process will be very useful.

Figure 1.A universal jamming gripper [1]

In this study Motoman SV3X 6-axis robot manipulator, universal holder and image processing techniques were used to determine the type and position of 3 different types of material coming on the belt conveyor. In this study, materials of different shapes and sizes were classified by image processing and most importantly pick and place was taken from one position with a single robot manipulator and gripper.

John R. Amend and his colleagues described a simple universal gripper in their work. They gave information about the construction of the gripper and informed about the operations that could be

done with these grippers. They have presented the results that universal gripper using both positive and negative pressure are better in terms of reliability and speed. They concluded these results by comparing them with other gripper performances [1]. Ik Sang Shin and his colleagues have developed a system that allows the objects on the moving belt conveyor to be taken without stopping the conveyor. Instead of ultrasonic or infrared ray sensors, object information such as position, orientation, speed and size required for this process has been realized with image processing help. They have worked to ensure that the image processing system is fast enough to allow the holding process to be done without stopping the conveyor. By using the technique of extracting two consecutive image frames from each other, they obtained positive results from this study [2]. Patakota Venkata Prasad Reddy and V V Satya Suresh were interested in the importance of the universal gripper used in industrial robot applications and the handling of various materials. They have come up with some approaches that will increase industry performance and reduce cost [3]. Eric Brown and his colleagues have described the working mechanisms that arise when the universal gripper performs the holding operation in their work. They have separated them by frictional, locking and vacuum modes. When they do what they do, they determine the pressure required for the holding process to take into account. They have come to the conclusion that the universal gripper can perform the holding operation without active feedback [4]. Philip Ronald B. Fajardo and his colleagues have worked to increase the ability of the universal gripper to hold in their work. The calculation of the optimum pressure value required for handling the object in consideration of the width, height, length, and weight of the handled object was carried out with the help of artificial neural networks. They achieved 99.131% successful retention rate [5].

Abdullah Beyaz has done real-time video processing of apples, lemons, and oranges in his work. Measurements were made on the images by software developed in the Labview environment. As a result of the studies, it has been determined that the software developed in the Labview environment can be used effectively for the measurement of agricultural crop size [6]. Ajay Pal Singh and Neeraj Julka have used NI Vision Assistant to improve image processing speed in their work. A system based on machine vision has helped to accurately calculate the results. Screws of different sizes are classified by image processing in Labview. Labview seems to be suitable for automation of classification like this [7]. Suresh Babu Changalasetty and his colleagues have used the Labview program and image processing techniques to set up a system in which moving vehicles are identified and classified for signal control and traffic control in their work. With the Labview, image processing techniques have been applied to this system and positive results have been obtained [8].

Raza Ul Islam and his colleagues have built forward and inverse kinematic models of a robot manipulator with 6 degrees of freedom in their work. In this model, the study area of the robot is obtained. The obtained coordinate information of the object to be retained by the image processing and the robotic manipulator to go to the location of the object holder is provided with inverse kinematics [9].

Fatih Ahmet Şenel and Bayram Çetişli conducted object inspection in the belt conveyor with image processing and five-axis robot arm in their study. In their experimental studies, they have performed classification of 60 products with 100% success rate [10]. E. Utku Senses and his colleagues carried out material classification and storage automation with robot arm in production band [11].

2. Materials and Methods

The system basically consists of 3 units. The first unit consists of the Logitech C270 HD digital camera used for image acquisition, and the personal computer to which the image processing techniques are applied, and the information obtained is sent via Arduino Uno. The second unit consists of a belt conveyor made of transporting work and a reflective optical sensor on it. The third unit consists of a Motoman SV3X robot manipulator, a universal gripper and a mini vacuum pump that allows this gripper to work. The design and implementation of the system in the Solidworks program are shown in Figure 2. Implementation of the system is shown in Figure 3.
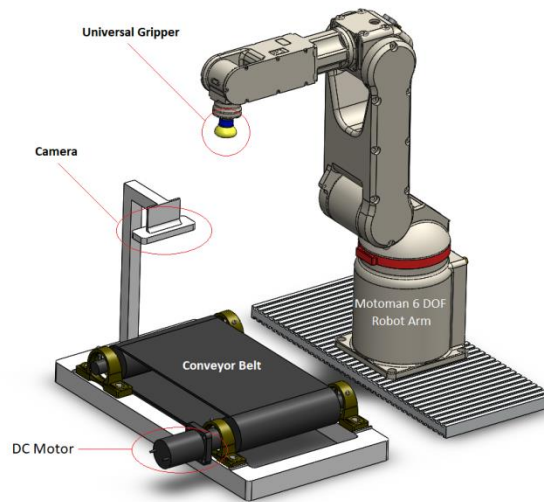

Figure 2. Design of the system in Solidworks

Figure 3. Implementation of the system

All of the software, including Arduino Uno, which is the interface for image processing techniques in the system and communicating with the robot manipulator, has been developed in Labview (Laboratory Virtual Instrumentation Engineering Workbench) programming environment. The software of the Motoman Robot Manipulator was developed with the programming hand control (P-pendant). Labview programs are called virtual instruments (VIs) because they mimic elements such as views and operations, oscilloscopes, and multimeters. Labview is a comprehensive set of tools that includes tools to help you retrieve, correct, analyze, display and store data, as well as any errors in the code you write. In Labview, you create a user interface or front panel with controls and indicators. Controls, buttons, push buttons, dials, and many other tools are different input mechanisms. Indicators, graphics, LEDs, etc. are output screens. After creating the dashboard, the code can be added using VIs and constructs to control the front panel objects. Block diagrams contain these codes. Labview is a graphical programming tool that can be used to communicate with equipment such as GPIB, PXI, VXI, RS232, and RS485 as well as data acquisition, visual and motion control devices.

The materials used in the experimental system are shown in Figure 3 as A, B, and C.
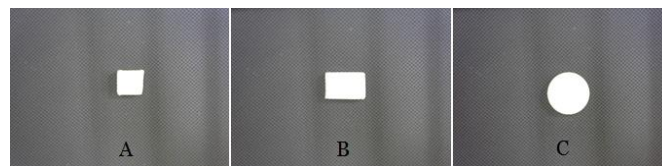

Figure 3. Materials A, B, and C

With the image calibration, the process of transforming the pixel coordinates from the camera into real coordinates was done. With Labview "Image Calibration", the distance between pixel 0 and pixel 1279 on the X-axis, which is the horizontal axis of the image formed by 1280x960 pixels, is determined as 250 mm.

In this work, the image obtained from the camera is in RGB format and the red space is separated by the "Color Plane Extraction" operation.

After the color space conversion process, thresholding is applied to distinguish the background and the object from each other. Thresholding segments an image into a particle region, which contains the objects under inspection, and a background region based on the pixel intensities within the image. The resulting image is a binary image. Use Thresholding to extract areas that correspond to significant structures in an image and to focus analysis on these areas. Thresholding an image is often the first step in a variety of machine vision applications that perform image analysis on binary images, such as particle analysis, golden template comparison, and binary particle classification [7]. The threshold value is set at 150, and when this value is set, it is considered that the result of the threshold determination is close to the actual area of the material.
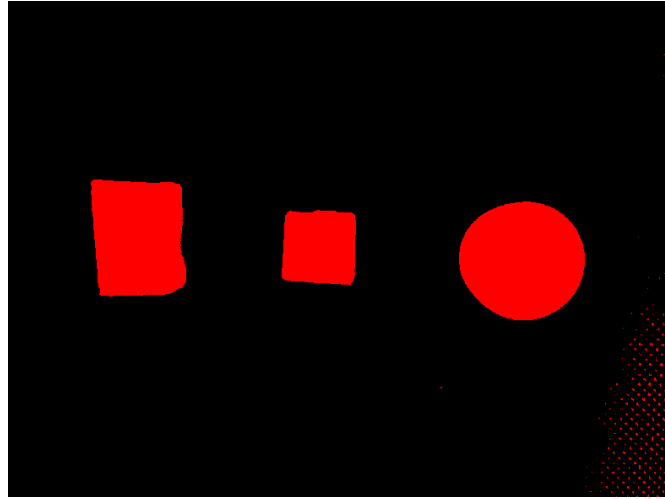
Figure 4. Threshold

There are some errors in the image caused by light reflection after the threshold determination process. The "Basic Morphology" operation is used to remove these minor errors. In this process, small objects were detected and deleted.
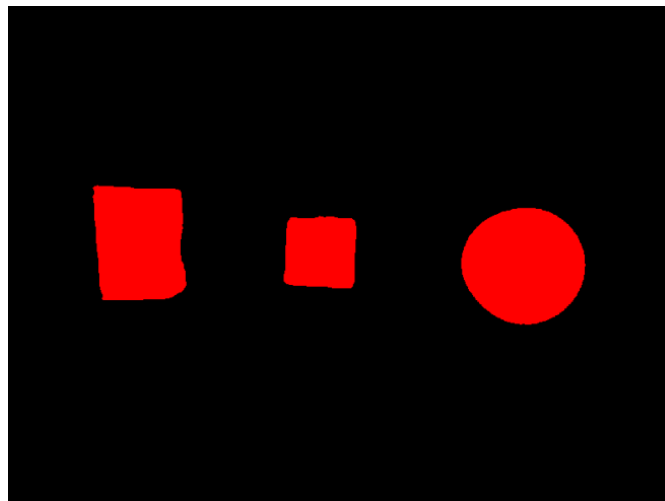
Figure 5. Morphology

Classification identifies an unknown sample by comparing a set of its significant features to a set of features that conceptually represent classes of known samples. A particle classifier uses feature vectors to identify samples based on their shape [7]. The particle analysis process obtains the coordinate and area value of the materials to be distinguished. Classification of the materials was done by using the obtained area value. The Shape Matching process is used to teach the shapes of the materials to be classified and the matching process is applied. In this way, the classification of materials in different shapes and sizes is carried out easily.
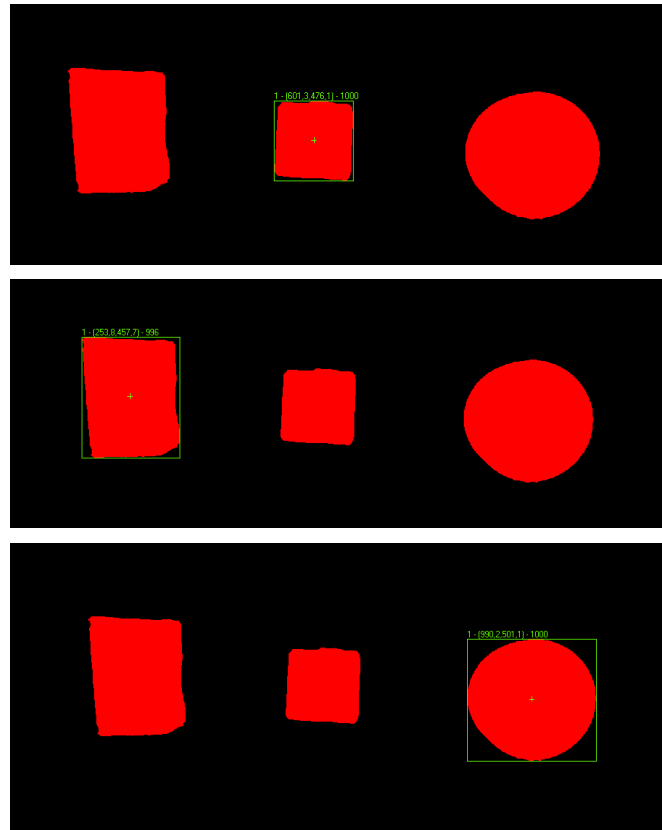
Figure 6. Shape matching

3. Results and Discussion

The results of the particle analysis are shown in Table 1. The materials are classified with the help of the area values. Coordinate information is sent to the robot manipulator. Thus, the material is placed in the pouch with the help of a universal gripper. The results of the shape matching are shown in Table 2.

Table 1. Particle analysis results

	A	B	C
Mass Center X Position	601,34886 pixel	253,76225 pixel	990,50005 pixel
Calibrated Mass Center X Position	117,54278 mm	49,60169 mm	193,60830 mm
Mass Center Y Position	476,12284 pixel	457,71959 pixel	501,09352 pixel
Calibrated Mass Center Y Position	93,06545 mm	89,46825 mm	97,94635 mm
Area	18039.00 pixel × pixel	35904.00 pixel × pixel	42032.00 pixel × pixel

Table 2. Shape matching results

	A	B	C
Center X Position (pixel)	601	254	990
Center Y Position (pixel)	476	458	501
Score (Max. 1000)	1000	996	1000

The system first checks the order information entered from the user panel. Order A, B, and C were created separately for materials. The order information will be processed if at least one of the values entered for the three materials is one. If all of them are zero, the system will not work. The Motoman manipulator allows the material to come by operating the belt conveyor. With the signal from the reflective optical sensor on the belt conveyor, the conveyor stops when the material enters the imaging area of the camera. This is followed by the status information from the Labview program. Meanwhile, the Labview program first checks the orders and if the order is not ready and the material seen by the camera is in order, Motoman Robot manipulator informs the part to be taken. Taking knowledge of the material, Motoman Robot takes the manipulator material and leaves the pouch. After this process, Motoman Robot waits for the signal that the manipulator package is ready. The Labview program returns to the beginning by reducing the amount of material put in the pouch after ordering the pouches of the material and checks the orders to decide if the package is ready. If the package is not ready, the same operations are repeated and the package continues to be put into place. If the incoming material is not in order, but the package is not ready, the conveyor will continue to operate without receiving the material. When the package is ready, the system gives the packet ready signal and the operation is completed.

4. Conclusions

In this study, images were taken from a camera connected to a computer and image processing techniques were applied with the help of a program prepared in Labview and the package creation process was performed by determining the type of products arriving on the belt conveyor.

In this study, two different methods have been tried for the classification of materials. The first of these methods is the classification process by calculating the area of the material and making use of the area differences between different types of materials. The second is to classify the materials by scanning in the instantaneous image of the system which has been taught and taught the images of the materials to determine the type of program. The classification process was carried out without error by two methods. The reason for this is that the field values and the shapes of the materials to be made are sufficiently different from each other. The second method, shape matching, yields more accurate results when the field values of the materials to be classified are close to each other but different in shape. Conversely, if the materials are like each other but have different field values, classification by particle analysis and the field value is more accurate. As a result, the methods should be selected by evaluating the properties of the materials to be classified.

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