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Application of Image Processing and Industrial Robot Arm for Quality Assurance Process of Production

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***Abstract*—Recently, in the new era of highly developed technology, image processing is becoming a more efficient and required sector in the industry, enterprise, monitoring, and other various systems. All these applications lead us to research the image processing techniques in the quality assurance process of production with an ABB IRB 120 industrial robot arm. There are numerous types of image processing methods that are used in the quality assurance process of products. Hence, in our experiment, we attempted to distinguish the normal and abnormal products, which are replaced by 3D objects using the image processing system and ABB industrial robot arm. Therefore, we used the OpenCV library to enhance our image processing system. This paper presents the combination work of image processing methods and usages with modeling the end-effector of ABB IRB 120 industrial robot, their programming and experimental results.**

Keywords— Image processing, Quality Assurance, OpenCV, Industrial Robot, IRB 120, Automatic Control

I. INTRODUCTION

Assurance of product quality, especially checking the safety of food products is the largest issue to solve in the industry. The quality assurance process is not limited to few selected products, but checking all products that have been produced should have the benefit of decreasing the number of poor quality products reaching the customers by several times [1].

Image processing is used to enhance the image quality using mathematical actions to transform into digital format, take enhanced pictures or to extract useful and important information [2]. Surveillance technology is used in numerous fields such as recognition of fingerprints, face, and vehicle plate number, movement of objects, parking system, and restoration of cultural inheritance. Image processing mimics the human ability to recognize any given objects. Humans correctly recognize general images about 94.9 % of the time, whereas Google recognizes 95.18 percent; and Microsoft 95.06%. The methods developed these companies exceed the human capacity [3]. Additionally, the ability of a human to recognize a face is about 99.5% while Facebook's DeepFace correctly contraindicates 99.7% of faces [4]. Facial recognition is a method that not only gathers information, but also adjusts images to recognize certain styles of eyes, noses, etc. When a person is walking on the street, the analyzed portion should be automatically selected from the most complete image. This system is widely used in the checkpoints at airports, colleges, entry examinations, user management, timesheet systems, bank-affiliated branches and other numerous programs [5]. Hence, this research work is performed with the use of image processing, exploitation of ABB made IRB 120 manipulator robot in the quality assurance process. The main structure diagram of the quality assurance process is shown in Fig.1.

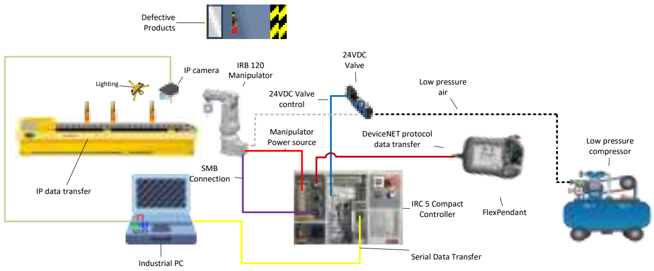

Fig. 1. Structure Diagram of Quality Assurance Process.

II. METHODS OF IMAGE PROCESSING

All objects that are available to human eyes become an image by being captured in the camera lens. Image quality is expressed in DPI (Dots Per Inch) where a higher dot quantity indicates higher quality. In a computer language, the image is specified in the most commonly used format of RGB (Red Green Blue) 256-bit color model. The primary step of image processing is based on the color model system. A computer recognizing red colored objects must filter the RGB values through the upper and lower limits of red color. Color model easily changes with light source, camera specification and other affecting parameters.

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When color models are expressed in computer language and human eyes. Color can be represented by a variety of RGB values rather than having a single numerical definition. In addition, brightness can be affected by many things. Fig. 2 shows the effects on brightness measurements of small black substances and bubbles mixed in bottled water [6], [7].

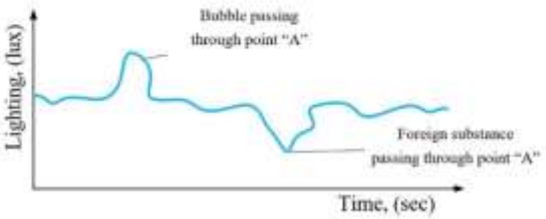

Fig. 2. Brightness distribution of a black substance and bubble [6].

Digital image processing methods are classified into two sections: the image information processing method for human understanding and image data processing method for the embedded machine. One of the first applications of digital image was used in the newspaper industry when pictures were first sent by submarine cable between London and New York [8]. In this study, we used the OpenCV (Open Source Computer Vision) library to enhance our image processing system, which has more than 500 optimized algorithms for image and video analysis. Since its introduction in 1999, the community of researchers has broadly accepted it as the primary development tool of developers in computer vision [9].

A. Fundamentals of Image Processing

The images are expressed in a multi-dimensional system format, which designed in two or more dimensional systems. The purpose of image processing is divided into 5 usages:

- Observing invisible objects
- Creating a photo recovery and detailed mapping
- Seeking interested objects from the image
- Measuring different objects in the picture
- Recognizing objects from the image

Linear algorithmic methods for edging the image are determined by the regression equation. This algorithm depends on the analysis of the four basic types of images. The function of (3×3) digital image is expressed in (1) and fig. 3.

$$f(x,y) = \begin{bmatrix} (x-1,y-1) & (x-1,y) & (x-1,y+1) \\ (x,y-1) & (x,y) & (x,y+1) \\ (x+1,y-1) & (x+1,y) & (x+1,y+1) \end{bmatrix} \quad (1)$$

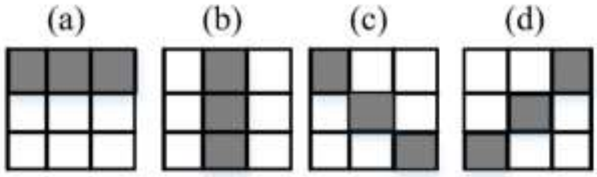

Fig. 3. Four-directional mask (3×3). (a) Horizontal direction. (b) Vertical direction. (c) and (d) Diagonal direction.

B. Fundamentals of Image Processing

There are four basic steps in the image processing, including camera shooting as image acquisition, and image preliminary processing as image enhancement, and image masking as image segmentation and image recognition.

1) Image acquisition: Image acquisition is the first step of image processing and is performed with a video capture system (video camera), lighting and auxiliary devices (microscopes, measurement tables). This step is a key component of the image processing that strongly influences image formats and the implications of further analysis and development [10].

2) Image enhancement: Image enhancement is a step in reducing the unnecessary deviations created during the image acquisition and optimizing the information required for edge enhancements for further processing. The enhancement technique is divided into two categories, based on spatial domain methods and frequency domain methods [11].

3) Image segmentation: Image segmentation is one of the significant procedures, which is used for image processing that distinguishes the objects from the background. Most common usages have been devised to automatically choose a thresholding [12].

Thresholding is the first and simplest segmenting operation. The method of segmentation is an old method, but it is still a widely used because of its ease of use and rapid operation. Thresholding segmentation is defined by parameter T. The selected Y (x, y) value of the image is called the thresholding value. Point-intensity often used here [13].

The result of the segmentation process is expressed in a binary image, as shown in (2).

$$g(x,y) = \begin{cases} When\ 1, & Y(x,y) \geq T \\ When\ 0, & Y(x,y) < T \end{cases} \quad (2)$$

Here: g(x,y)- Result of segmentation
Y(x,y)- Selected matrices
T- Thresholding

4) Image recognition: The image recognition system requires images have to be taken by high-quality camera. First, the image is smoothed by Median filter. After that, images are divided into two different frames using thresholding. Compared to other methods Canny's edge detection method is considered the most appropriate and effective method [14], [15].

C. Main Algorithm of Process

Image processing, especially the quality assurance process, gives precedence to the predefined standard over the captured image. Even so, the quality of the product can be achieved through the use of image processing, as well as by comparing the normal products with others.

In our image processing system, we used to HSV color model, which is useful to separates luma, or the image intensity, from chroma, or the color information, unlike RGB. For instance, to do histogram equalization of a color image, only the intensity data without the color information should be used to avoid results with very strange colors.

In computer vision, there are many other reasons to separate color components from intensity, such as creating robustness to lighting changes, or removing shadows.

The HSV is one of many color spaces that separate color from the intensity. HSV is often used simply because the code for converting between RGB and HSV is widely available and can be easily implemented [16].

The main algorithm of the our quality assurance process example is shown in Fig. 4.

III. MODELING OF ACTUATING SYSTEMS

The modeling of the actuation system is divided into three steps. The first step is creating 3D models in SolidWorks drawing program, the second step is inserting a tool into RobotStudio program that is cooperating with significant parameters and the third step is teaching pathways and programming robot actions in RAPID programming language.

A. Technical Specifications of IRB 120 Robot

Robot controller IRC5 has 16 analog and 16 digital input/output ports, which are managed in DeviceNet as well as Serial, LAN, WAN, and USB ports for transmitting data and an additional Profibus port is optional. Full control and management of the device is available with the FlexPendant control with HMI screen. In addition, the interconnection of pneumatic and electrical systems inside the robot prevent damage by robot movement [17].

Movement type and speed of the IRB 120 Robot arm is shown above in Table I.

TABLE I. ROBOT MOVENT SPECIFICATIONS

Location of Motion	**Type of Motion**	**Ranges of Movement**	**Maximum Speed of Movement**
Axis 1	Rotation motion	+165° to -165°	250 °/sec
Axis 2	Arm motion	+110° to -110°	250 °/sec
Axis 3	Arm motion	+70° to -110°	250 °/sec
Axis 4	Wrist motion	+160° to -160°	320 °/sec
Axis 5	Bend motion	+120° to -120°	320 °/sec
Axis 6	Turn motion	+400° to -400°	420 °/sec

B. Working Principle of Robot and End Effector Modelling

The work object and tool of the robot can be designed in the RobotStudio program or FlexPendant controller. When Robot does not have any tool or work object, default settings will be wobj0 and tool0. Here is "wobj" as dimensional Robot working object, "tool" as end effector, which is assembled for Robot. It is possible to model work object and tools in RobotStudio in complete detail shown in Fig.7.

In this experiment, we used 3D objects instead of the actual products, which is possible to represent the critical parameters of normal and abnormal products (e.g., product filling, color, shape, and other specifications) are shown in Fig.6.

Besides, the work object is the specified field that designed in RobotStudio for Robot movement pathways. In addition, a simulation in the RobotStudio program is available to verify the Robot movement and catch mistakes in programming shown in Fig. 8 [18].

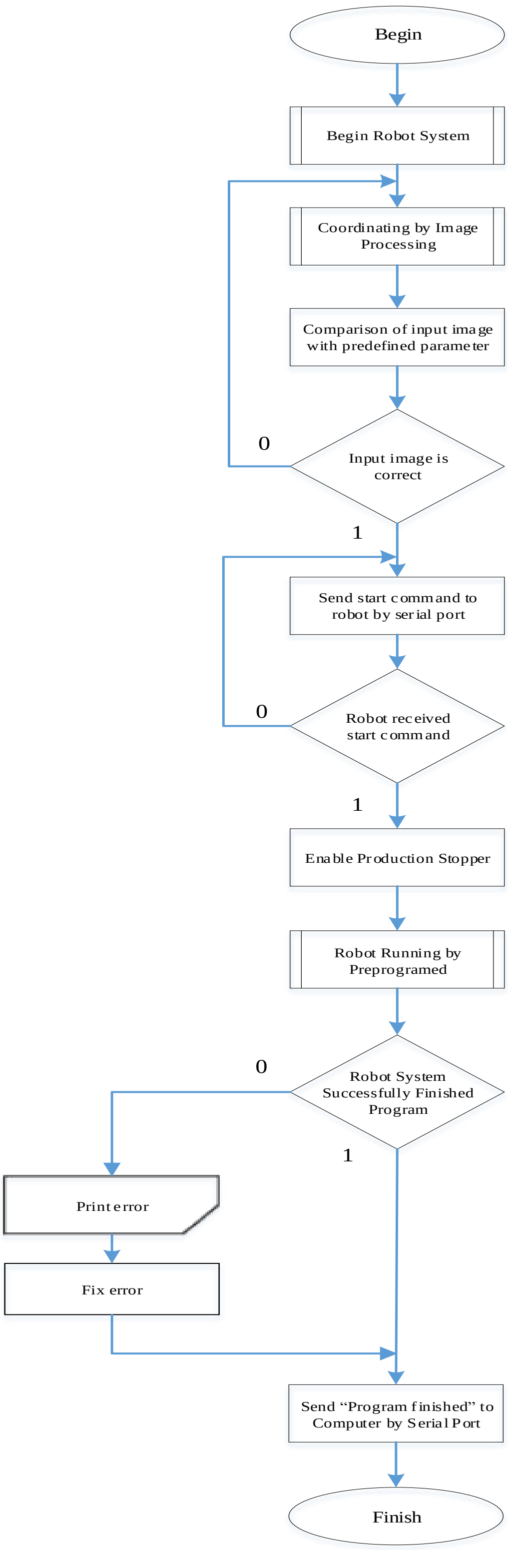

Fig. 4. Main algorithm of quality checking process example.

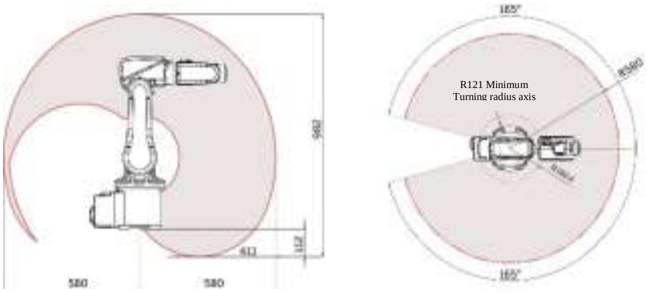

Fig. 5. Robot Working range and turning radius.

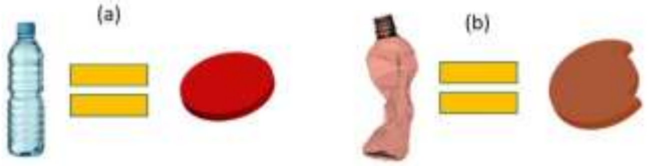

Fig. 6. 3D modeled objects of (a) normal, (b) defective products.

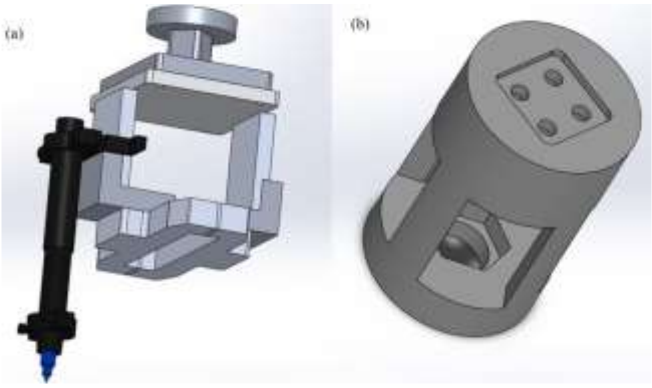

Fig. 7. Modeling of Robot end-effector.

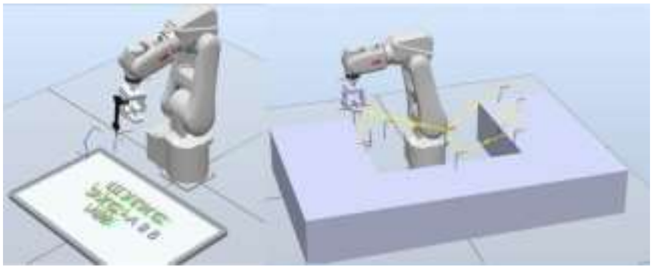

Fig. 8. Robot pathways modeling in RobotStudio.

C. Programming

The RAPID high-level programing language that was introduced in 1994 for control ABB industrial robots. RAPID has similar operators and variables as other programing languages except for movement instruction that teaches the type of movement for the Robot. In the RAPID programming language, there are many opportunities to assign variables, operators and instructions. Therefore, data transfer in Serial and Ethernet port operates by RobotStudio and FlexPendant accurately [19].

IV. RESULTS

The innovative image processing algorithm has been successfully developed, that checks the quality of the product and sorting process with an industrial manipulator.

TABLE II. RAPID PROGRAMING LANGUAGE DESCRIPTION

Function		**Description**
MoveL p10, v1000, fine, tool0;wobj0;	***MoveL***	MoveL is used to move the tool center point (TCP) linearly to a given destination. When the TCP is to remain stationary then this instruction can also be used to reorientate the tool and main task T_ROB1.
	p10,	Determined destination point. It is three-dimensional system defined by RobotStudio and jogging on FlexPendant. If Robot programed to reach x=600, y=-100, z=800; program will look like: CONST robtarget p10:= [[600, -100, 800], [1, 0, 0], [0, 0, 0, 0], [9E9, 9E9, 9E9, 9E9, 9E9, 9E9]];
	v1000,	V as Velocity is the speed of robot movement. Joint of Robot has different maximum speed. In the RAPID program, "Vmax" function used to work with maximum speed.
	fine,	Zone data for the movement. Zone data describes the size of the generated corner path. When zone data = fine robot will move exactly defined pathways. Zone data describes the size of the generated corner path.
	tool0;	An equipment that assembled in Robot arm for grabbing, absorbing and other usage. Name of the tool shown here that Robot using.
	Wobj0;	The work object (coordinate system) to which the robot position in the instruction is related. This argument can be omitted, and if it is, the position is related to the world coordinate system. If, on the other hand, a stationary TCP or coordinated additional axes are used, this argument must be specified for a linear movement relative to the work object to be performed.

In this experiment, we attempted to the incorporation of the image processing system and an industrial robot arm for distinguishing the normal and abnormal products, which are represented by 3D objects. These 3D objects are possible to replace the original product (e.g. Product shape, filling level, color, and other criteria). The results of image processing steps will define normal and abnormal products with the base criterion. Then an IRB 120 industrial robot moves the objects to the right position.

In addition, the manipulator accurate movement is verified on the drawing. As an example, the abbreviation of Power Engineering School - Mongolian University of Science and Technology, "ШУТИС-ЭХС" is written in the Mongolian language. All of experimental results are demonstrated in Fig. 9 to 11.

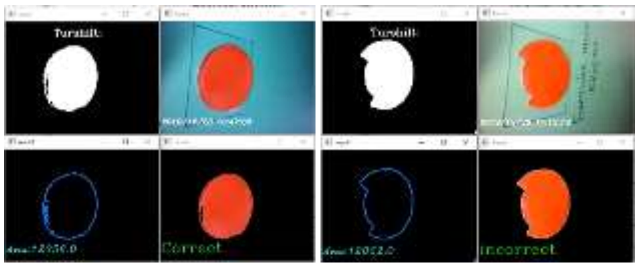

Fig. 9. Normal & abnormal product recognizion in image processing example.

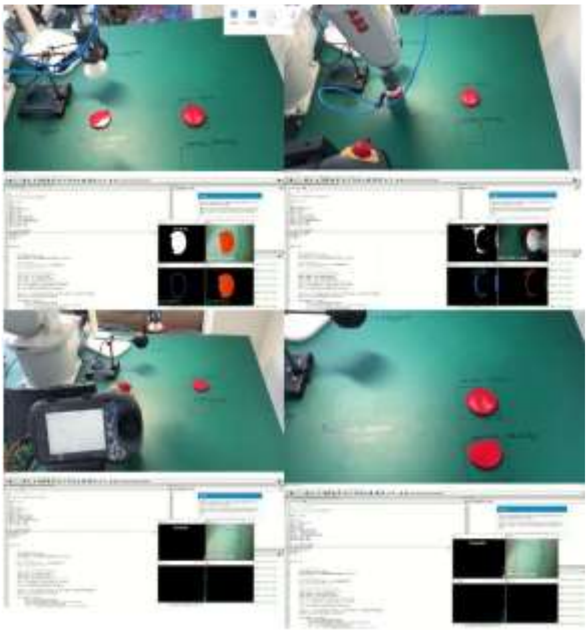

Fig. 10. The experiment of the robot moving objects onto their right places due to image processing results.

Fig. 11. The experiment of drawing text.

V. CONCLUSION

The purpose of the research was to investigate the image processing method, analyze the specific part of the image and developing of the ABB Group's IRB 120 Robot arm. Moreover, we successfully achieved the desired result.

In addition, we have analyzed the images, which are used image processing tools with OpenCV library in Python programming language.

We completed the product distinguishing program performed by Robot arm and sending commands by serial port using image-processing methods for control algorithm.

We have developed a combination of image processing and Robot arm controlling programs, and successfully used in product quality checking and sorting process. In the future, we plan to improve this algorithm for real factory applications and high-precision welding technology.

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REFERENCES

[1] G. Sebestyen, D. Nicoara, M. Rusu, L. Buzdugan, M. Cerghizan, and G. Saplacan, “Supervisory control and quality assurance in food industry,” in *2008 IEEE International Conference on Automation, Quality and Testing, Robotics*, May 2008, vol. 1, pp. 195–199, doi: 10.1109/AQTR.2008.4588733.

[2] G.Ganchimeg, “A method of determining the similarity of the image,” presented at the MMT, 2017.

[3] Baidu, “Artificial-Intelligence Supercomputer Beats Google at Image Recognition,” *MIT Technol. Rev.*, 2015.

[4] Facebook AI Research Publication, “Deep Face: Closing the Gap to Human-Level Performance in Face Verification,” 2014.

[5] G.Urtnasan, “Real-world recognizing technology,” presented at the MMT, 2017.

[6] B. Wang and C. L. P. Chen, “An Effective Background Estimation Method for Shadows Removal of Document Images,” in *2019 IEEE International Conference on Image Processing (ICIP)*, Sep. 2019, pp. 3611–3615, doi: 10.1109/ICIP.2019.8803486.

[7] A. Ishii, T. Mizuta, and S. Todo, “Detection of foreign substances mixed in a plastic bottle of medicinal solution using real-time video image processing,” in *Proceedings. Fourteenth International Conference on Pattern Recognition (Cat. No.98EX170)*, Aug. 1998, vol. 2, pp. 1646–1650 vol.2, doi: 10.1109/ICPR.1998.712034.

[8] R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 2nd edition. Prentice Hall, 2002.

[9] R.Laganiere, *OpenCV 2 Computer Vision Application Programming Cookbook*. 2011.

[10] Y. Zhang, *Image Understanding*. Walter de Gruyter GmbH & Co KG, 2017.

[11] Z. Yepeng, T. Yuezhen, and F. Zhiyong, “Application of Digital Image Process Technology to the Mouth of Beer Bottle Defect Inspection,” in *2007 8th International Conference on Electronic Measurement and Instruments*, Aug. 2007, pp. 2-905-2–908, doi: 10.1109/ICEMI.2007.4350826.

[12] R. C. R. C. Gonzalez and R.E. Woods, *Digital Image Processing*, 3rd edition. Prentice Hall, 2008.

[13] Young, Gerbrands, and van Vliet, *Fundamentals of image processing*. Delft U, 1998.

[14] U. Sanver, E. Yavuz, and C. Eyupoglu, “An image processing application to detect faulty bottle packaging,” in *2017 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus)*, Feb. 2017, pp. 986–989, doi: 10.1109/EIConRus.2017.7910722.

[15] J. Zheng, D. Ma, and X. Hu, “Detection and Location for In-pipe Detector Block Accident Based on Image Edge Processing,” in *2019 Chinese Control And Decision Conference (CCDC)*, Jun. 2019, pp. 2662–2667, doi: 10.1109/CCDC.2019.8832797.

[16] R. Szabó and A. Gontean, “Industrial robotic automation with Raspberry PI using image processing,” in *2016 International Conference on Applied Electronics (AE)*, Sep. 2016, pp. 265–268, doi: 10.1109/AE.2016.7577287.

[17] ABB, “IRB 120 Product Manual.” 2017.

[18] ABB Robotics, “Robotstudio Operating manual.” 2010.

[19] ABB Robotics, “RAPID Instructions, Functions and Data types.” 2018.

[20] Experiment result videos : https://drive.google.com/open?id=1nBV_iMolqgjbP7XKrArHATTltAf9_QwG