VISION-BASED OBJECT'S SHAPE DETERMINATION FOR ROBOT ALIGNMENT

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ABSTRACT

This study provides vision-based system solutions to a peg-in-hole problem facing by a fork lift like robot used to transport copper wire spools from a rack in which the spools are arranged side by side, to a specified place. The copper wire spool is held by 3 round cylindrical shafts; one through the center hole of the spool and another 2 shafts hold at the bottom of the spool. The aim of this development of vision-based system is to make the robot operating autonomously. However, this study scope is limited to copper wire spool detection and confirmation of its alignment compared to camera orientation using a Logitech Webcam C525 which has an autofocus camera and have HD view with lower price. By integrating the Logitech webcam for windows with MATLAB R2016a, all computations, programming and processing of this project are done using the MATLAB. The proposed system uses Circular Hough Transform (CHT) and image processing methods for binarization, morphology and edge detection of the sampled images from real-time video recording. Several simulations have been carried out and from the result obtained, the system is able to detect the copper wire spool with estimated radius in pixel and the alignment of the spool.

Keywords: Vision-based System, Circle Detection, Image Processing, Copper Wire Spool

INTRODUCTION

Robotic manipulator is widely used in manufacturing process since it is a reliable system to maintain productivity and quality. Generally, tasks performed by the manipulators can be categorized to two types; grasping and insertion (peg-in-hole) [1–3]. For the grasping tasks, the robot manipulator is required to grasp object on its outer side. On the other hand, the manipulator should hold an object using its' fingers and insert into another object, such as inserting a few centimetres of a straight plug into an elastic rubber hose and inserting a shaft into O-ring. Almost all the above tasks are performed by 6 to 8 D.O.F robot manipulator equipped with a force or torque sensor to determine grasping forces or touching forces. Some of the grasping tasks utilized a camera, or a camera with a laser range finder to confirm the orientation of the object. After the object is grasped, force or torque sensor will be used to autonomously adjust the grasping force or adjust the position of the peg, in the case of insertion process [4–6]. In this study, task for the forklift like robot is to autonomously pick up a copper wire spool at one time and bring it to other places. The copper wire spools are arranged side by side on a shelf. The robot uses 3 cylindrical shafts to hold the spool; one through the center hole of the spool and another 2 shafts hold at the bottom of the spool. The process of picking up the spool only will be guided by a web camera and no force or torque sensor will be used. Focus in this study is to develop image processing method to determine the correct alignment of the robots' body and shafts to enable the shaft is inserted into the spool's center hole without pushing the spool and cause the spool falling down and damaging the copper wire. To enable the process, the camera will capture the spool and based on edge detection techniques, the spool will be represented by one big circle. The big circle is representing the outer shape and the center hole of the spool. Intuitively, the big circle will overlap when the robot is really facing the face of the spool and the center shaft is on the straight line with the spool's center hole. It means that the robot must move to left and right, turns clock-wise and anti-clock-wise until the big circle overlap having same center point and the outer circle is overlaps reference circle.

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Vision system

Vision-based system by using camera has been used widely especially in recognizing object because it is more reliable compared to other sensors such as temperature sensor, light sensor etc. [7]. Image processing method is one of the cheap algorithm that is widely used for research in vision system [8]. By using image processing techniques, the copper wire spool can be detected. Image processing requires image acquisition, image pre-processing, feature extraction and object decision. Many researchers use Canny edge detection method to obtain the correct results and reduce the noise of the image despite the method has flaw which it may not traverse all weak edge pixels [9]. However, vision system has some problems like the existence of dust, the need for extra lighting, distortion etc. [10].

Circle detection

The copper wire spool has a circular shape thus, the system need to find the alternative to detect the circular shapes. The most popular method used to detect circular objects and locate analytic curves in binary image favoured for its tolerance to noise is Circular Hough Transform (CHT) and its variants [11]. Many researchers proposed a new algorithm based on CHT such as [12–14]. However, some of the methods are not suitable with this system and it uses offline image processing. Nupur J. et al. use Mean Shift technique for image segmentation and Modified Canny Edge Detection Algorithm for circle detection. However, the method was applied by using Google earth images which is it is not a real time images

because this research use real time images. [15]. An innovative implementation of CHT using eigenvalues of covariance matrix for detecting circles is proposed by M. Hossein et al. is robust and against noise [16]. Some of them use Open CV and C++ software because MATLAB cannot perform the system successfully [17]. Most of the current researches are for unknown and familiar objects. There is no literature is discussing on an object that has bigger diameter (copper wire spool) and cannot be grasp using aforementioned gripper designs.

METHODOLOGY

Figure 1 shows the process flow of vision-based object's shape determination system.

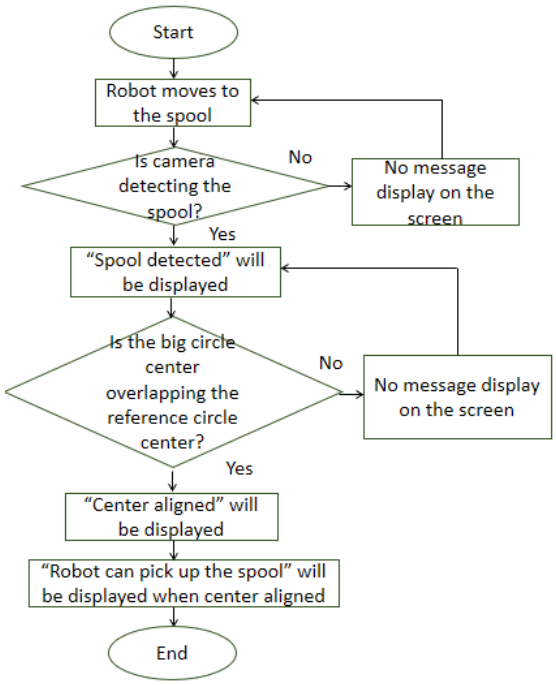


Figure-1. Flowchart of vision-based object's shape determination system

Copper wire spool detection

Images are acquired using Logitech HD Webcam C525 that acts as medium to connect the camera to the system in MATLAB. The resolution video of video used in this system is 640×480 pixels. The real-time video need a proper image segmentation process and technique need to be done to overcome the lighting intensity that affect the original color of the object [18]. Thus, the morphology method was applied in this system which are erosion and dilation method. Next, Canny edge detection method was applied to obtain accurate edges of an input image [9]. The video input of this system is in grayscale color space. Thus, applying edge detection on the grayscale images decrease the computational requirements [17]. CHT was applied after image processing. The copper wire spool considered as detected whenever the system detects a circle within the radius range that has been set in this system.

Figure-2. Logitech HD C525 webcam

After the image has been applied with morphology method, the copper wire spool will be detected by using CHT method with different radius value. As a reference, a reference circle (green color) with radius 124 pixels will be displayed on the screen. The circle that need to be detected is big circle (red color). The radius range for big circle is 100-150 pixels.

Camera and spool orientation

The camera and spool orientation is determined by using image processing technique. The copper wire spool and camera are considering aligned when center of big circle overlap the reference center calculated by using (X,Y) coordinates. Due to slight errors which are radius of reference circle and the other circles might be a little bit different, the distance between the center can be accepted within error range ±3 pixels. The reference center coordinate is (320,240) pixels. The screen will display "Center aligned" when camera and spool are aligned. The mathematical equation to determine the orientation of copper wire spool and camera shown below.

$$Ref.center\ coordinates = (320,240) \quad (1)$$

$$Big\ circle\ coordinates = (X1,Y1) \quad (2)$$

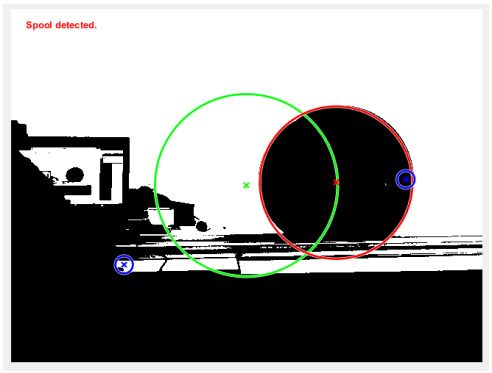
$$Small\ circle\ coordinates = (X2,Y2) \quad (3)$$

$$Dist.center\ 1 = ((320 - X1),(240 - Y1)) \quad (4)$$

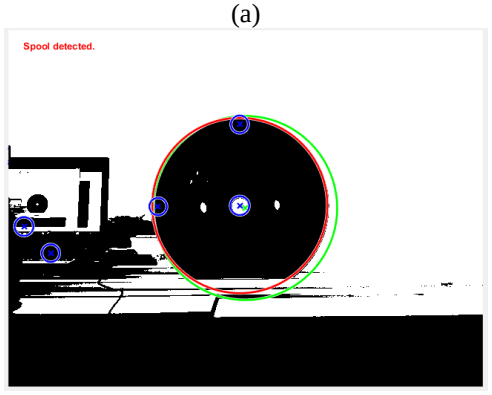
$$Dist.center\ 2 = ((320 - X2),(240 - Y2)) \quad (5)$$

EXPERIMENTAL RESULTS

From the results shown in Figure 3 (a) and (b), the copper wire spool was detected whenever the system detects the big circle within the range of radius as explained in Methodology. The screen display "Spool detected" when the system detects the copper wire spool. The system displayed in binary images so that user can monitor the screen easily than grayscale or RGB images. However, there are some errors due to lighting and noise that hard to be eliminated during image processing. The noise has been reduced by using Canny edge method.



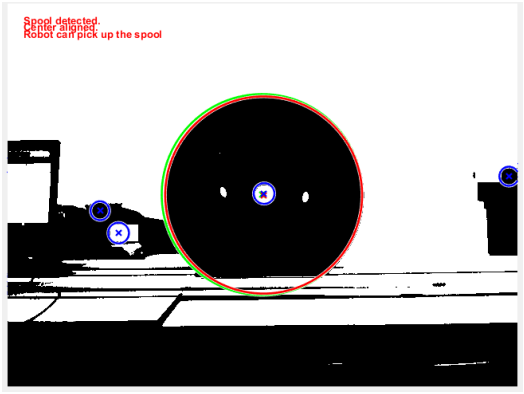
(a)



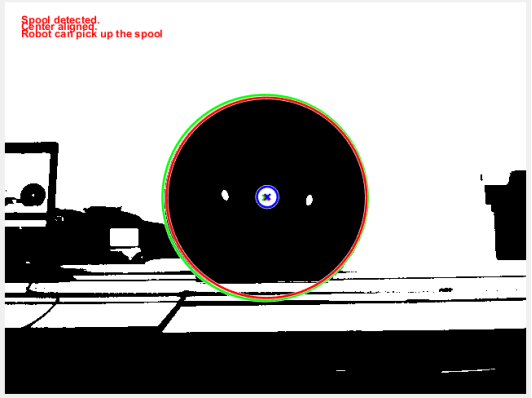
(b)

Figure-3. (a), (b) Spool detected in many situations.

Figure 4 shows that the big circle center overlapping the reference center and the screen displayed "Center aligned" and "Robot can pick up the spool". When the big circle center overlapping the reference center, the camera and the copper wire spool considered to be aligned.



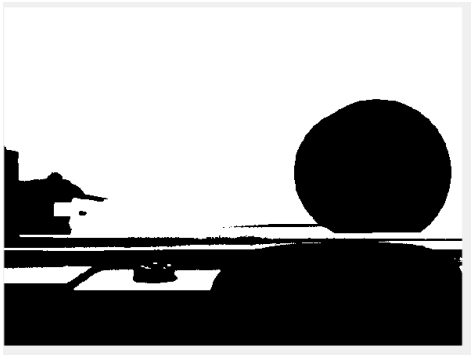
(a)



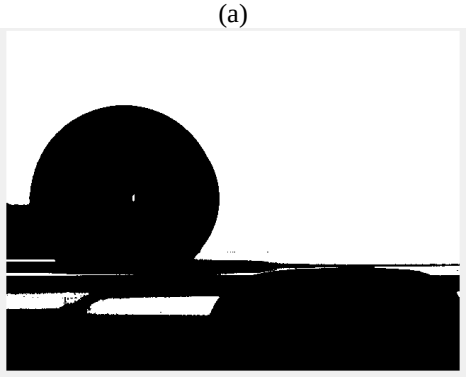
(b)

Figure-4. (a), (b) Center aligned

The image shown in Figure 6 (a) and (b) show that the system cannot detect the copper wire spool and the screen will not display anything.



(a)



(b)

Figure-6. (a), (b) Spool not detected.

DISCUSSION

From the experimental results, it shows that after do the morphology and edge detection method, it will produce some errors on recognizing the small circle. The errors might be due to lighting and image noise problem during the image processing. The real-time video also lagging a few seconds by using MATLAB due to many programming in this system.

CONCLUSIONS

As a conclusion, the system can detect the copper wire spool by using image processing and Circular Hough Transform (CHT). Algorithm results might contain false circles due to noise in images and lighting problems but it does not affect the system at all. The system also able to differentiate and calculate the distance between the center (X,Y) coordinates thus, the alignment of copper wire spool can be determined. Hence, the system can be applied in real environment.

REFERENCES

[1] V. A. Ho, D. V. Dao, S. Sugiyama, and S. Hirai, "Development and analysis of a sliding tactile soft fingertip embedded with a microforce/moment sensor," *IEEE Trans. Robot.*, vol. 27, no. 3, pp. 411–424, 2011.

[2] W. Haipeng, W. Sun, X. Lin, and Z. Wang, "A centralized multi-sensor particle filter algorithm of

formation targets," *2016 6th Int. Conf. Digit. Inf. Commun. Technol. Its Appl. DICTAP 2016*, pp. 50–55, 2016.

[3] N. A. A. Lokman, H. Ahmad, and M. R. Daud, "Design and analysis of FLC and feedback control for three finger gripper system," *J. Teknol.*, vol. 78, no. 10–4, pp. 61–67, 2016.

[4] Y. Suzuki, K. Koyama, A. Ming, and M. Shimojo, "Grasping strategy for moving object using Net-Structure Proximity Sensor and vision sensor," *Robot. Autom. (ICRA), 2015 IEEE Int. Conf.*, pp. 1403–1409, 2015.

[5] E. Arruda, J. Wyatt, and M. Kopicki, "Active vision for dexterous grasping of novel objects," *IEEE Int. Conf. Intell. Robot. Syst.*, vol. 2016–November, pp. 2881–2888, 2016.

[6] M. W. Abdullah, H. Roth, M. Weyrich, and J. Wahrburg, "An approach for peg-in-hole assembling using intuitive search algorithm based on human behavior and carried by sensors guided industrial robot," *IFAC-PapersOnLine*, vol. 28, no. 3, pp. 1476–1481, 2015.

[7] Y. Meng, S. Gong, and C. Liu, "A fast computer vision system for defect detection of rubber keypad," *ICCASM 2010 - 2010 Int. Conf. Comput. Appl. Syst. Model. Proc.*, vol. 2, no. Iccasm, 2010.

[8] N. I. Binti Zaidi, N. A. A. Binti Lokman, M. R. Bin Daud, H. Achmad, and K. A. Chia, "Fire recognition using RGB and YCbCr color space," *ARPN J. Eng. Appl. Sci.*, vol. 10, no. 21, pp. 9786–9790, 2015.

[9] K. Ogawa, Y. Ito, and K. Nakano, "Efficient Canny Edge Detection Using a GPU," *2010 First Int. Conf. Netw. Comput.*, pp. 279–280, 2010.

[10] P. Tsarouchi, S. A. Matthaiakis, G. Michalos, S. Makris, and G. Chryssolouris, "A method for detection of randomly placed objects for robotic handling," *CIRP J. Manuf. Sci. Technol.*, vol. 14, pp. 20–27, 2016.

[11] A. O. Djekoune, K. Messaoudi, and K. Amara, "Incremental circle hough transform: An improved method for circle detection," *Opt. - Int. J. Light Electron Opt.*, vol. 133, pp. 17–31, 2017.

[12] S. Chiu and J. Liaw, "A proposed circle/circular arc detection method using the modified randomized hough transform," *J. Chinese Inst. Eng.*, vol. 29, no. 3, pp. 533–538, 2006.

[13] A. O. Djekoune, K. Messaoudi, and K. Amara, "Incremental circle hough transform: An improved method for circle detection," *Optik (Stuttg).*, vol. 133, pp. 17–31, 2017.

[14] V. K. Yadav, S. Batham, A. K. Acharya, and R. Paul, "Approach to accurate circle detection: Circular Hough Transform and Local Maxima concept," *2014 Int. Conf. Electron. Commun. Syst. ICECS 2014*, pp. 3–7, 2014.

[15] N. J. Gandhi, V. J. Shah, and R. Kshirsagar, "Mean shift technique for image segmentation and Modified Canny Edge Detection Algorithm for circle detection," *Int. Conf. Commun. Signal Process. ICCSP 2014 - Proc.*, no. 1, pp. 246–250, 2014.

[16] M. Hossein, D. Haji, J. R. Mianroodi, N. Norouzi, and A. Khajooeizadeh, "An Innovative Implementation of Circular Hough Transform using Eigenvalues of Covariance Matrix for Detecting Circles," no. September, pp. 14–16, 2011.

[17] J. Ni, Z. Khan, S. Wang, K. Wang, and S. K. Haider, "Automatic detection and counting of circular shaped overlapped objects using circular hough transform and contour detection," *Proc. World Congr. Intell. Control Autom.*, vol. 2016–Septe, no. Kylx15 0496, pp. 2902–2906, 2016.

[18] R. Hussin, M. R. Juhari, N. W. Kang, R. C. Ismail, and A. Kamarudin, "Digital image processing techniques for object detection from complex background image," *Procedia Eng.*, vol. 41, no. Iris, pp. 340–344, 2012.