(g) Conveyor Tracking

For synchronizing the robotic arm and the object, the moving velocity and position of the object and the speed of the robotic arm should be considered as shown in Figure 17, where the black line indicates the conveyor, the blue line indicates the robotic arm, Δt^{synch} is the time for robotic arm to touch the object, and Δt_g^{synch} is the speed for robotic arm to touch the object.

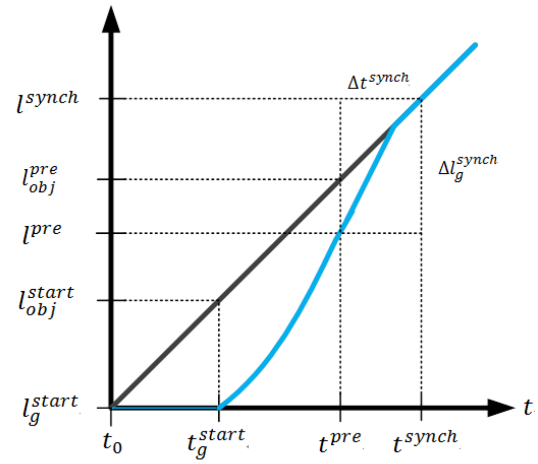
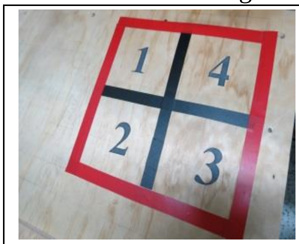


Figure 17: Relationship Diagram of Moving Velocity and Position

4. Experiment Results

First, the research constructs the placement area for the robotic arm and four PET bottles filled with water as shown in Figure 18.



(a)

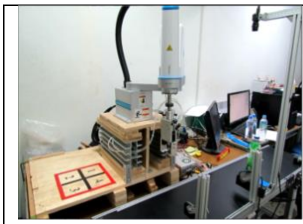
(b)

Placement area and Object for Identification.

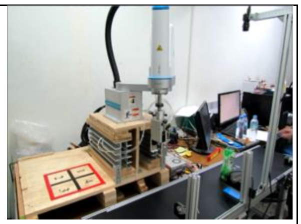
Figure 18: Placement Area of Objects

In the moving path of the robotic arm systems, the research sets four points: the origin point, operating point, temporary point, and the placement point. The robotic arm will operate each process through the four points in sequence. The origin point is the position where the robotic arm is waiting; the operating point is the origin coordinate of object captured by the CCD camera; the temporary point is set for protection, and there are four locations for the placement point where the robotic arm will put objects in a straight movement.

When the procedure starts, the robotic arm returns to the origin and waits for triggers issued by the magnetic sensors. After detecting a magnetic strip, the first magnetic sensor triggers the CCD camera to fetch an image. The image is processed in a series of image processes, and fed back to the computer. At that time, the robotic arm stays in waiting state. When second magnetic sensor detects the magnetic strip, it triggers the operations of robotic arm. According to the coordinate value calculated by the image process, the robotic arm will move to the position and operates object grasping. Then it will put the PET bottles at the four designated placement areas. After completing the process, the robotic arm returns to the origin and waits until the procedure ending. The procedure is illustrated in Figure 19. Moreover, the temporary point is set to avoid the end of robotic arm to crash the seat in the straight movement.

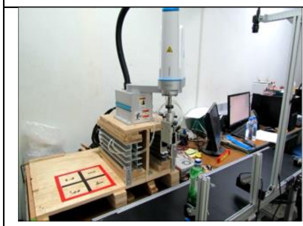


(a)

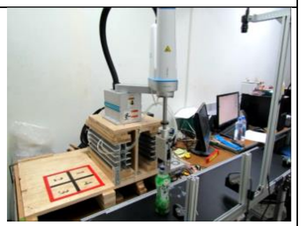


(b)

Procedure Start: Fetching images when the 1st magnetic sensor detects a magnetic strip.

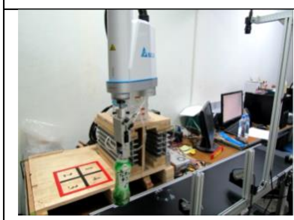


(c)

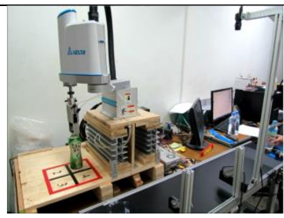


(d)

After detecting the magnetic strip, the robotic arm moves to operating point from the origin.



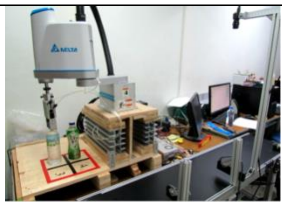
(e)



(f)

The robotic arm moves to the temporary point, and then moves to the designated position to put the PET bottle.


(g)


(h)

The robotic arm returns to the origin. and waits for trigger to put PET bottles in sequence.

Figure 19: Full Test Procedure

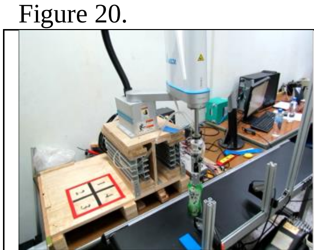
Finally, the research tests the grasping stability of a robotic arm. 10 times of the procedure are practiced for each moving velocity. Each procedure is successful if the robotic arm puts the four PET bottles in the four designated positions. The experiment results are listed as Table 2.

Table 2: Robotic Arm Grasping Test

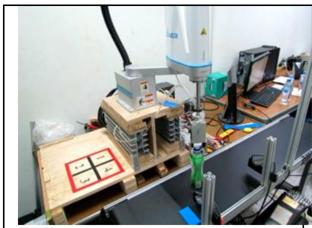
	M/minute			
Success Times	2.9M	4.1M	5.2M	5.8M
	10	10	10	8

The research performs the robotic arm under a various moving velocity. According to Table 2, the robotic arm can put the PET bottles at the designated position stably and precisely if its moving velocity is set between 2.9M and 5.2M. If the moving velocity is set up to 5.8M, there are some unstable results. In the twice of these fail results, the robotic arm cannot grasp the PET bottle exactly. They are caused by the response time of magnetic sensors. Since the response time of magnetic sensors is too short to delay the start time of robotic arm, the robotic arm cannot be synchronized with the conveyor. If an industrial sensor, such as a photoelectric sensor or a proximity sensor, can replace the original magnetic sensor, the robotic arm should provide more stable performance.

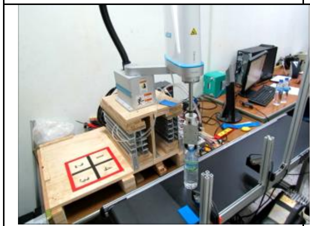
According to the placements of PET bottles and the change of rotation angles based on flat Cartesian coordinate, the end-effector jaw can process the coactive rotation function. The function can enhance the capability of a robotic arm to fetch not only circle objects but also other types of ones, as shown in Figure 20.


Object Rotation 35° CW

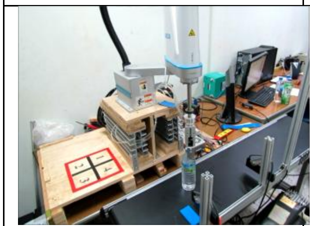

Object Rotation 90° CW


Object Rotation 125° CW


Object Rotation 179° CW


Object Rotation 35° CCW


Object Rotation 90° CCW


Object Rotation 125° CCW

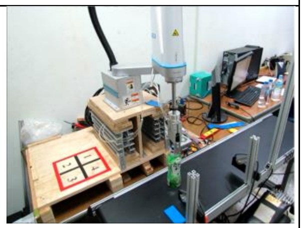

Object Rotation 179° CCW

Figure 20: Rotation Angle Test

5. Conclusions

The research integrates the CCD camera, SCARA robotic arm, and the GS-2744B magnetic sensors to construct a conveyor tracking system. In the system, the object grasping operation of the robotic arm can be stable. Since the robotic arm can complete the object grasping in various moving velocities, it is appropriately applied in product lines to reduce the cost of human resource. In addition, the robotic arm is controlled by programming software. First, the images fetched by the CCD camera should be processed in a series of image processes to enhance the readability and stability. Moreover, the coordinate value of the object origin can be calculated, and fed back to the robotic arm for object grasping precisely. Therefore, the image processing is an essential part in the system. Moreover, the system is easy to output in various operation environment for conveyor tracking.

Restricted by the mechanism of the end-effector jaw, directly introducing the object rotation to the system is inappropriate. In this article, the object rotation is used for test majorly. The movement routes of a robotic arm are controlled in straight lines. It is the most efficient that the end jaw is controlled to face the PET bottles. If the end-effector jaw rotates 90 degree to fetch the object during the movement, it is easy to press the surface of PET bottle cap in the moving process. Therefore, the success rate of operation will be reduced significantly.

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References

[1]. G. S. Huang, C. K. Tung, H. C. Lin, and S. H. Hsiao, “Inverse Kinematics Analysis Trajectory Planning for a Robot Arm”, 2011Proceedings of 8th Asian Control Conference (ASCC), pp. 965 – 970, 2011.

[2]. Xiongzi Li, Biao. Zhang; Fuhlbrigge, T.A.; O. Landsnes, S. Riveland, “Paint deposition simulation for robotics automotive painting line” Proceedings of Cyber Technology in Automation, Control, and Intelligent Systems (CYBER), pp.349-354, 2014.

[3]. K. Namba, and N. Maru,“Positioning control of the arm of the humanoid robot by linear visual servoing”, 2003 Proceedings of IEEE International Conference on Robotics and Automation, ICRA '03.vol. 3, pp. 3036 – 3041, 2003.

[4]. N. Ishibashi, and Y. Maeda, “Learning of inverse-dynamics for SCARA robot”,2011 Proceedings of SICE Annual Conference (SICE 2011), pp. 1300 – 1303, 2011.

[5]. R. Bryngelson, and S. Tosunoglu, “On the Design of a Seven-Axis Modular Robot”, 20th International Conference on Industrial Electronics, Control and Instrumentation, (IECON), vol. 3, pp. 1501–1506, 1994.

[6]. M. Arbulu, G. Ortiz, L. M. Beltran, L. Gonzalez, and C. Garzon, “Cartesian Robot Motion Embedded on Logistics Process Screws Approach”, Proceedings of IEEE International Conference on Robotics and Biomimetics (ROBIO), pp. 2067–2071, 2012.

[7]. R. Kassab, and M. Zohdy, “Feedback Linearizing Versus Integrator Backstepping for Trajectory Tracking of Three-Link Cylindrical-Type Robot”, Proceedings of the American Control Conference (ACC), vol. 4, pp. 2844–2848, 2000.

[8]. R. F. J. Carlos, G. H. Efren, and P. M. Joaquin, “Obstacles Avoidance in a Self Path Planning of a Polar Robot”, Proceedings of the Electronics, Robotics and Automotive Mechanics Conference (CERMA), vol. 2, pp. 157– 162, 2006.

[9]. Y. Qiang, F. Jing, Z. Hou, and P. Jia, “Residual Vibration Suppression Using off-Line Learning Input Shaping Method for a Flexible Joint Robot”, 10th World Congress on Intelligent Control and Automation (WCICA), pp. 3858–3863, 2012.

[10]. G. S. Huang, C. E. Cheng, “3D coordinate identification of object using binocular vision system for mobile robot” Proceedings of Automatic Control Conference (CACS), pp.91-96, 2013.

[11]. G. S. Huang, P. A. Juang, D. W. Gu, “Robotic arm grasping and placing using edge visual detection system”Proceedings of Control Conference (ASCC), pp. 960-964, 2011.

[12]. R. C. Luo, SC Chou; X. Y. Yang, N. Peng, “Hybrid Eye-to-hand and Eye-in-hand visual servo system for parallel robot conveyor object tracking and fetching” Proceedings of Industrial Electronics Society, pp.2558-2563, 2014.

[13]. K. T. Song, C. H. Hsu, “A compliance control design for safe motion of a robotic manipulator”, Proceedings of Intelligent Control and Automation (WCICA), pp.920-925, 2011.

[14]. GUIDE SENSOR GS-2744B, [Online]. Available: http://www.macome.co.jp/PRODUCTS/gs/gs_2744b.htm, pp. 10, 2012.

[15]. TRD-S1000V, [Online]. Available: http://www.koyoele.co.jp/english/product/encoder/01.html.

[16]. MCHB-32, [Online]. Available:http://www.stranskyapetrzik.cz/pneu-en/pneumaticke-valce/valce-upinaci-menu/valce-mchb/valce-mchb-technicke-parametry/.

Guo-Shing Huang (M'02 -SM' 06) was born in Tainan, Taiwan, R. O. C. in 1957. He received the B. S. and the M. S. degree in electrical engineering and automatic control engineering from the Feng Chia University in Jun. 1980 and Jan. 1983, respectively, and earned the Ph.D. in Department of Electrical Engineering, National Cheng Kung University from Sep. 1994 to Dec. 1998. He is currently a Distinguished Professor in the Department of Electronic Engineering of National Chin-Yi University of Technology. His research interests include control application, integrated GPS/INS electronic navigation, fuzzy/robust control, intelligent robotic location navigation and control.

Zhi-Hao Tian is currently a graduate student of Electronic Engineering at National Chin-Yi University of Technology. He engaged in the speech recognition, positioning of mobile robot using magnetic sensors and RFID, and SCARA robotic control and other related research work.