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Research Article

Research on application of industrial robots in automated fueling systems for small individual cars

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ABSTRACT

An automated fueling system for small individual vehicles, such as 4- and 7-passenger cars, is necessary in the modern life. Currently in the car market, in terms of the characteristics of the equipped fuel tanks, it can be divided into two main groups, including the vehicles using the traditional fuel tanks and the vehicles using the cap-less fuel tanks. For the vehicles using the traditional fuel tanks, the vehicle drivers need 4 steps to pump the gasoline. They are opening the outer lid of the body, opening the screw cap on the fuel tank, putting the pump nozzle into the fuel tank and making the fuel pump. For the vehicles using the cap-less fuel tank design, the manufacturers replace the traditional screw cap with the self-opening (close) lid mechanism when there is (without) the pump nozzle. So when operating the gasoline pump, there is no step to open the screw cap on the fuel tank. This new design was pioneered by American car manufacturers such as Ford and General Motor. This paper proposes a solution for the automatic fueling for the vehicles that have the fuel tank without the screw cap. The system is built based on an industrial robot that do the task replacing for the station officer. Firstly, a special tool is designed to help the robot to operate during the automatic fueling. Next, an image processing algorithm is applied to recognize the position of the fuel tank of the vehicles. After that, an automatic fueling algorithm is proposed so that the system can do fueling automatically. The proposed solution is verified by the experiments on the real model. The experimental results show that the proposed system can be used to position the nozzle into the fuel tank with the acceptable error.

Key words: Automatic fueling, image processing, industrial robot, petrol station, vehicle driver

INTRODUCTION

In the modern life, transportation plays an important role in human travel. Among these, the small individual vehicles, such as 4- and 7-passenger cars, are widely used. The demand for the gas pump for those cars is massive. Thus, the gas pumping stations is built extensions to serve this need. In traditional petrol stations, the vehicle operator can pump the petrol by himself or this work can be done by the petrol station officer. However, the manual pump has several disadvantages because of the human involvement.

The first issue is related to the safety of the drivers. There are many robbery cases happening in the petrol stations. Most of these incidents happen when the driver comes out of the car and on the way to make payment at the cashier counter. The unawareness of the driver gives a chance for robber to carry out any immoral action, such as stealing the vehicle or snatch driver's handbag. The second problem is the comfort of the drivers. The drivers clearly do not want to leave the car when the weather is too hot or too cold. In some cases, the driver is not accustomed to the pumping gasoline, often happening when the drivers are women or older people. The third reason comes from the operation of the petrol stations. The traditional gasoline stations are difficult to operate during 24 hours per day, especially on the national highways, where the density of vehicles is not as much as in the cities. In these stations, it is obviously not economic if hiring the officers for operating all day. The use of petrol pump personnel is wasteful. Another problem is the working at night of the employees. Thus, the automatic fueling systems are necessary to overcome these above problems.

The researches on building the automated fueling systems for the vehicles had been mentioned in several papers and patents. Ginsburgh et al. and Butler got the patents from the United States Patent about designing the automatic fueling system for the automobiles [1,2]. Tamilarasu et al. provided the way to eliminate the cost associated with manpower working at fuel filling stations [3]. The principle point of this work was to create a framework which is able to do routinely deducting the money of oil administered from a consumer's card dependent on RFID equipment. Rashid et al. explored a new invention of the fuel dispensing system which providing secure and reliability to

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car users, prevent human contact with potential dangerous fumes, and reduce time usage in fueling up vehicle[4]. Sheth et al. described the methodology and mechatronics design approach of automatic fuel filling station[5]. In the proposed system, the sensors and camera captured the car fuel tank details and sent them to the controller so that the robotic arm can do its alignment with the fuel tank. Andrews et al. explored improvements over existing systems mainly by cost reduction through design simplification[6]. These simplifications were mainly achieved by re-design of the vehicle positioning and fuel dispensing systems. Becchi et al. presented the architecture of a robotic arm for refueling[7]. Special attention was allocated to the safety characteristics of the automatic refueling station, assuring the highest protection of people and their safeguard against accidents. However, these above researches just concentrated on the theory of how to build the automatic fueling system, and did not mention about the real system to verify the proposed ideas.

Currently in the car market, in terms of the characteristics of the equipped fuel tanks, it can be divided into two main groups, including the vehicles using the traditional fuel tanks and the vehicles using the cap-less fuel tanks. For the vehicles using the traditional fuel tanks, the vehicle drivers need 4 steps to pump the gasoline. They are opening the outer lid of the body, opening the screw cap on the fuel tank, putting the pump nozzle into the fuel tank and making the fuel pump. For the vehicles using the cap-less fuel tank design, the manufacturers replace the traditional screw cap with the self-opening (close) lid mechanism when there is (without) the pump nozzle. So when operating the gasoline pump, there is no step to open the screw cap on the fuel tank. This new design was pioneered by American car manufacturers such as Ford and General Motor. Up to the present time, it is gradually becoming a trend in the design of fuel tanks and is being equipped with other foreign car companies such as Honda, and Audi.

Dutch firm Rotec-Engineering and Danish company Autofuel designed an automatic gas pump system using an industrial robot, called Tankspistop, for the traditional vehicles[8]. However, the cost was high and the research results were not published. In this design, vehicle drivers must use the special screw cap of the company so it is not suitable for different vehicles. The vehicle must enter the correct position to recognize the fuel tank cap. An RFID card must be used to determine the vehicle size, the configuration, and the fuel tank cap location.

These above researches mentioned about the automatic fueling system for the traditional fuel tank vehicles with the screw cap. There is little research about the automatic fueling system for the new design of the vehicles using the cap-less fuel tank. Fuelmatics AB, a Swedish robotics company, has designed an automatic fuel injection system for this type of vehicles using a lifting mechanism[9]. In this research, a specialized and uncommon type of pump nozzle must be used. However, the orientation of the pump nozzle cannot be adjusted because a three degree-of-freedom Cartesian arm is used. The vehicle driver must drive the car to the correct position and orientation, comparing the fuel system so that the system can detect the fuel tank cap and make pump. If the car is deflected from the vertical plane of the fueling system, it is difficult to pump gasoline. In the case of large deflection, the system cannot put the nozzle into the fuel tank.

To overcome the above problem, in this study, an automated fueling system using the industrial robot is proposed to pump fuel for the new cars without a screw cap in the fuel tank. Using a six degree-of-freedom robot, it is possible to position and orient the pump nozzle into the fuel tank even though there is the deflection between the car and the fueling system. In addition, this system uses the camera to accurately locate the fuel tank without knowing the car's parameters in advance. Besides, an algorithm is proposed to detect the deflection angle of the car if the car is deflected. The second contribution of this paper is that a traditional fueling system, including of the fuel tank and the nozzle can be used to develop the automated fueling system. Thus, the cost can be reduced comparing making the new one.

In this paper, an automatic fueling system is built for making automatic fueling for 4- and 7-passenger cars. Section ***System hardware configuration*** shows the hardware configuration of the automatic fueling system. Section ***Designing mechanical tool*** describes about the tool of the robot so that how the system can make automatic fueling. An image processing algorithm is shown in section ***Algorithm to calculate the position of the outer lid in the robot coordinate system*** to look for the position of the outer lid of the fuel tank. Section ***Experimental setup and results*** mentions about the experimental results of the real system. Section ***Conclusion*** concludes the content of the paper and proposes the future work.

MATERIALS AND METHODS

System hardware configuration

The scenario of the proposed solution can be explained as follows. Firstly, the vehicle driver drives the car to park in front of the pump station. Next, the driver chooses the type of fuel and how much does the car need to be pumped. After that, the system needs to detect the position of the outer lid of the fuel tank. Next, the robot moves and grasps the nozzle to reach to the position of the outer lid. The robot uses the special tool to open the outer lid. After that, the robot moves the nozzle into the fuel tank and presses the pump button to make pump. Finally, the robot retracts the tool and returns to the rest position. The overview of the hardware configuration of the system can be shown in Figure 1.

To design the automatic fueling system, it needs to solve three main following problems. Firstly, a special tool is designed to replace the working of the person's hand. The tool should have ability to do 3 tasks including opening the outer lid of the fuel tank, grasping the nozzle, and pressing the pump button. Secondly, an algorithm is proposed to look for the position and orientation of the outer lid of the fuel tank using the camera. Thirdly, the graphical user interface is designed to control the system.

The industrial robot supported in this research is a YASKAWA MH12 Robot with DX200 Controller. MH12 is a 6-axis robot with the light weight, high travel speed, good accuracy and extreme flexibility. The robot can operate with a maximum load of 12 kg. It has the maximum horizontal reach range of 1440 mm, and the maximum vertical reach of 2511 mm. The repeatability precision reaches 0,08 mm. These parameters are used to design the operating mechanism and install the system.

Designing mechanical tool

This section mentions how to design an end-effector for the robot to support the automatic fueling task. There are 3 main tasks that the mechanical tool need to implement. They are opening the outer lid of the fuel tank, grasping and holding the nozzle, and squeezing and releasing the nozzle to pump fuel. Basing on these above 3 tasks, the pneumatic drive system is chosen for designing the end-effector. The reason is that the pneumatic drive system has a compact weight and area. It is also suitable for the simple movements that having not much working state.

The first task is opening the outer lid of the fuel tank. The ordinary outer lid of the fuel tank is relatively flat and only has one side in contact with the environment. Its shape can be square, round, pentagon, and have no too complicated shapes. The hinge joints are used to open and close the outer lid. The tilt angle between the outer lid and the vertical plane varies depending on the design of the vehicle. In this design, the vacuum suction cup system is used to open the outer lid of the fuel tank. When the position of the outer lid is known, the vacuum suction cup sticks and hold the lid of the fuel tank. The flexible suction cup can change according to the profile. Several necessary parameters of the first part of the tool have been calculated. The suction cup and the coupling are about 70 millimeters in length. The suction cup has the diameter of 20 millimeters at the maximum position. The weight of the whole set is about 150 grams. In the design, 2 such sets are used to open the fuel tank cap depending on the position of the fuel tank cap, on the left or on the right.

In the second task, the tool need to grasp and hold the nozzle. The translational movement of the tool consists of 2 states, including holding and releasing the fuel pump. There is no middle state. The mass of the fuel pump is about 2 kilograms. The tool can hold and move the pump in many different orientations. Thus, a clamp cylinder is chosen for the actuator of the tool. The clamp cylinder is available in translational motion, including 2 opening and closing states, and it is simple control. The design of the gripper can be changed depending on the nozzle shape. The clamping force is large enough with compact size. To grasp the fuel pump and hold it, the gripper should be adjusted in the structure. The preliminary design of the extension clamps on the cylinders with the basic dimensions can be seen in Figure 2. This structure enhances the ability of grasping and holding the fuel pump with different shapes.

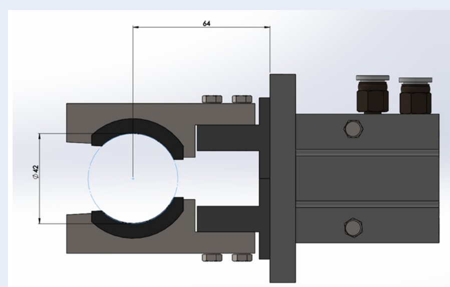

Figure 2: The design of the extension clamp

The third task of the tool is squeezing and releasing the trigger of the fuel pump to implement the fueling. This task also needs the translational movement and includes 2 states of squeezing and releasing the trigger. There is no middle state. The squeezing force is large enough, about 20 newton, to hold the pump trigger. A push cylinder is chosen for this task. The model type is CJ2 of SMC. The cylinder has the diameter of 16

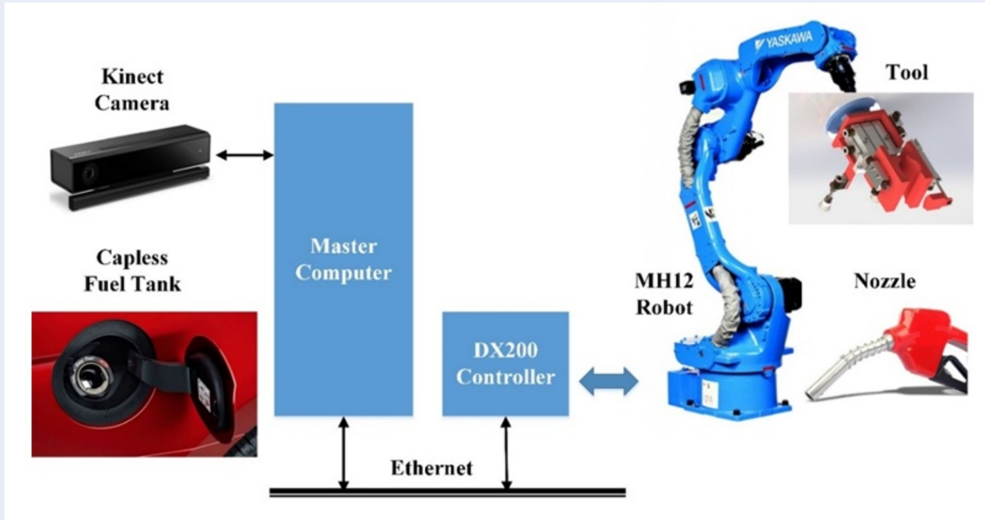

Figure 1: System hardware configuration

millimeters. The stroke of the cylinder is 30mm. The complete design of the tool is shown in Figure 3.

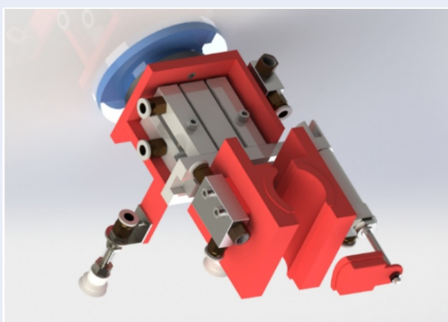

Figure 3: The preliminary design of the tool

Controller of the system

The robot controller DX200 is YASKAWA's new generation controller that comes with the teach pendant that controls the robot, and helps the robot to communicate with the external peripherals. The DX200 and teach pendant come with the large memory, support for a variety of communication, and have friendly programming languages (INFORM III and Ladder).

The devices in the system that need to be controlled are pneumatic valves, indicators and push buttons. The pneumatic valves are turned on and off while the robot is pumping gasoline, while the indicators and push buttons are intended to show the operating status of the whole system. The pneumatic valves are controlled by the robot controller. The indicator lights and the push buttons are controlled by the Programmable Logic Controller (PLC) because the PLC is able to manage the system's operating status through communications.

The communication between the robot controller and the PLC is Common Industrial Protocol (CIP). CIP is an industrial protocol standard, applied in the fields of automation, supported by many manufacturers. CIP is the core technology for ControlNet, DeviceNet, CompoNet and Ethernet communications.

The communication between the host computer and the PLC is Socket communication. The OMRON NX1P2 PLC supports the user to program the Socket communication by executing instruction blocks in the program. Since the location data from the gas pump station is so important, the Transmission Control Protocol (TCP) is chosen for its data security. The communication order between the host computer and the PLC via TCP protocol will take place as follows, the host computer is the client and the PLC acts as the server.

Proposed model of the automated fueling system

The purpose of this algorithm is determining the position of the outer lid of the fuel tank in the robot coordinate system. This part is usually located at the end of the car body, and has the same or different color as the car body. It has 3 main shapes including quadrilateral (rectangular or square), pentagon (irregular) and circle. The outer lid usually has few complex motifs around.

Because the shape and the color of the outer lid are diverse, it cannot be relied on these features to identify the position of this part. The outer lid is a moving mechanism, so there is always a gap with the body. This gap is small, so it will turn out the black color. This color is different from the glossy black due to the paint thickness on the body. Thus, it can rely on this profile to determine the location of the outer lid. The camera must be a large resolution color camera to accurately identify the narrow contour, thereby providing a good source of images for the image processing algorithm.

In addition, the position of the outer lid of the fuel tank must be located in the space. In terms of the orientation angles, the outer lid has 2 angles that affect the fuel pump. The first angle is the inclination compared to the ground alignment. This angle is due to the design of the car body. The second angle is the inclination compared to the standard vertical plane of the system. This angle is due to the vehicle driver parks in the work area in many directions. This angle needs to be measured. Based on the above analysis, a high resolution color image camera is needed, and there is a solution to measure the depth of space in a wide area. After researching the types of cameras, the appropriate camera Kinect V2 is chosen.

The whole system can be shown in the Figure 4. In this figure, a car model is put in front of the camera and the robot. Firstly, the camera takes the picture and process to find the position of the outer lid in the camera frame. Next, this position is transformed to the robot frame. After that, the position of the outer lid can be determined in the tool frame. Finally, the robot is controlled to manage the nozzle to do fuel pumping.

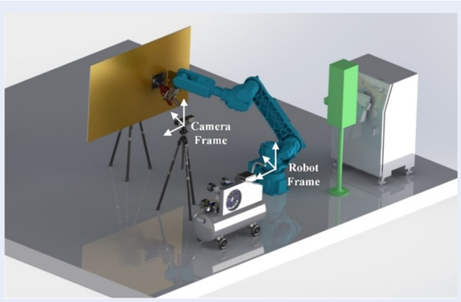

Figure 4: Camera coordinate system and robot coordinate system

Algorithm to detect the shape and position of the outer lid in the photo frame

This section will give an algorithm to determine the position of the outer lid of the fuel tank in the photo frame using camera Kinect V2. The color camera and the infrared camera supporting the depth reading are set apart in the device and have the different resolutions and the viewing angles. Thus, it is necessary to synchronize the viewing angle of these two cameras. This research chooses to switch the view of the depth camera to the color camera to take advantage of the high resolution. After synchronizing, a virtual view can be gotten with both the color and the depth data. This view is located in the color camera, with a horizontal angle of 70^0 and a vertical angle of 53^0.

The complete algorithm is shown in Figure 5. The photo should firstly have the background removed to avoid being disturbed by other shapes of the environment. Because of the black nature of the outer lid, the algorithm suggests to convert the color image to the black and white image and using the Dilation algorithm to reconnect the contours. This black and white image gradation varies depending on the color of the vehicle. For each found boundary, the algorithm approximates to the polygon by using the ApproxPolyDP algorithm. The number of edges must be greater than 3, and the angle between the two consecutive edges must be in the range 80 to 100 degrees. To avoid confusion with other vignettes, the algorithm adds a constraint on the area, which is drawn from the experiment, and varies depending on the distance to the camera.

The results of each step in the above detecting the outer lid algorithm can be shown in Figure 6. The results show that the proposed algorithm can be used to detect the shape and the position of the outer lid in the photo frame, shown as Figure 6 (e). For the different condition of the light and the shape of the outer lid, the proposed algorithm still can detect accurately the shape and the position of the outer lid in the photo frame. The results can be shown in Figure 7. Cases of unrecognized most fall into the car with a sticker on the outer lid and the car body with a matte black color, shown in Figure 7 (e). Some other cases are due to the large deflected angle of the car body that causes distortion.

Algorithm to calculate the position of the outer lid in the robot coordinate system

The above part had identified the outer lid of the fuel tank in the photo frame. In order for the system to operate, it is necessary to determine the actual position of the outer lid relative to the camera coordinate

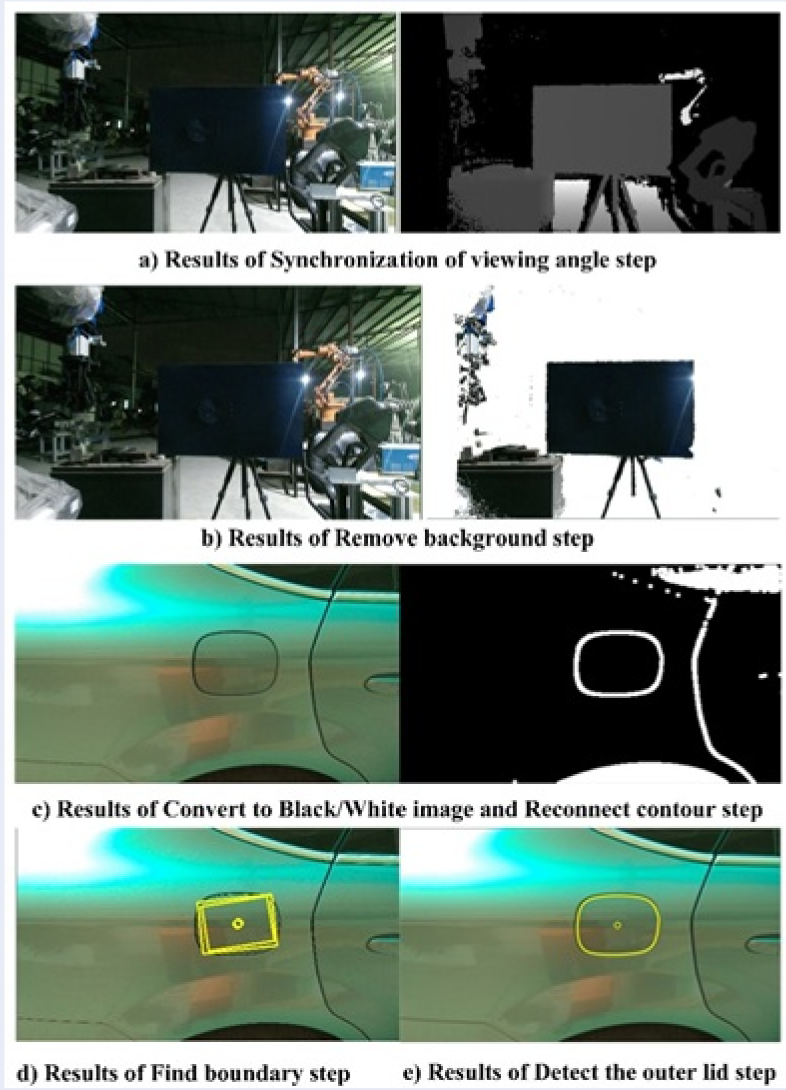

Figure 6: The results of each step of detecting the outer lid algorithm

system. Firstly, it is necessary to determine the point that the robot will operate. Here the center point of the outer lid can be chosen because of the safety. The center point of the outer lid can be found by calculating the moment of the shape profile. Next, the internal parameters of the camera are used to find out the actual position of the outer lid compared to the camera coordinate system. These parameters can be seen in Table 1 including the focal length and the principal point[10].

With the above results, the set of positional parameters of the outer lid of the fuel tank has been determined in the camera coordinate system. In order for the robot to operate, it is necessary to have the position of the center of the outer lid in the robot coordinate system. To do this, the external parameter matrix showing the relationship between the camera coordinate system and the robot coordinate system need to be found, shown as Figure 4.

The general external parameter matrix often has the rotating element and the translating element. For simplicity of calculation and control, the robot coordinate system is set to the same orientation as the camera coordinate system, only with different positions. Thus, the rotating element of the external parameter matrix is the unit matrix. Since the camera coordinate system and robot coordinate system do not differ in orientation, but only in position, the transformation matrix

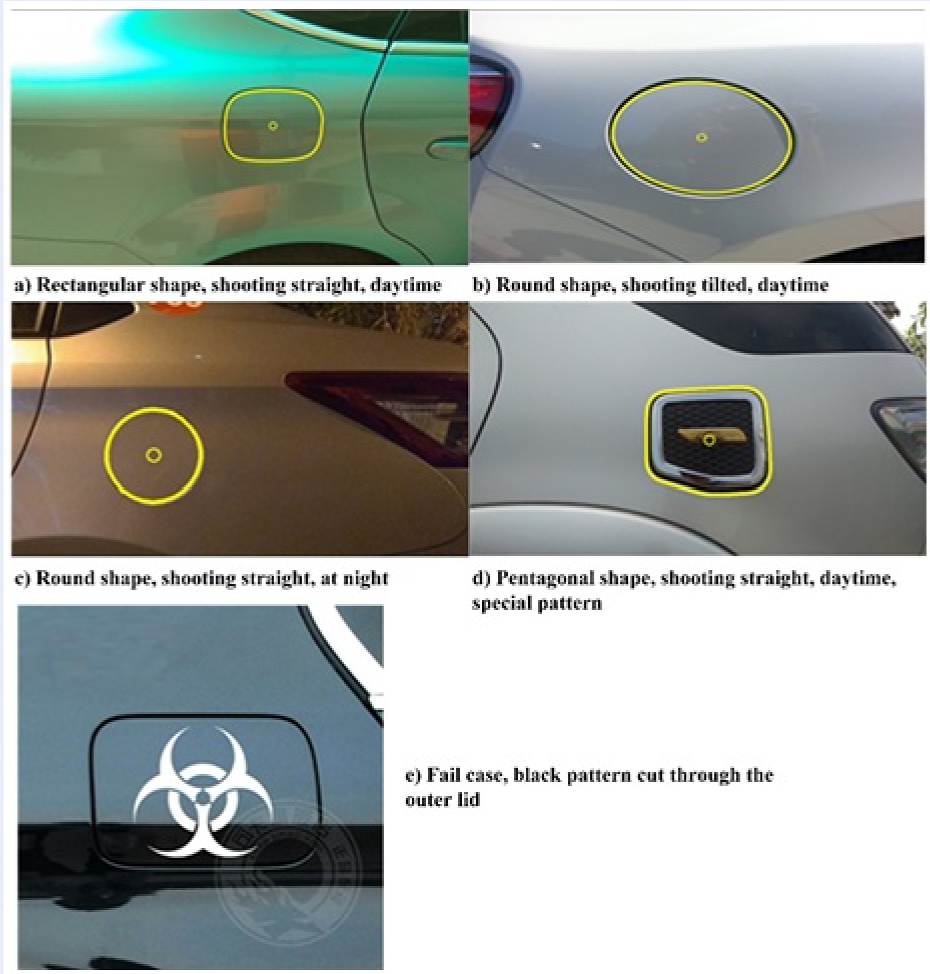

Figure 7: Results of detecting several different shapes of the outer lid

Table 1: Internal parameters of the Camera Kinect V2

Parameters	Color camera	Depth camera
Focal length	[1053.622; 1047.508] ± [4.6884; 4.5323]	[1053.622; 1047.508] ± [4.6884; 4.5323]
Principal point	[950.3941; 527.3442]	[265.5583; 206.6131]

${}^{R}T_c$ between them is shown in equation (1).

$$ {}^{R}T_C = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1) $$

The position of the outer lid in the robot coordinate system can be calculated from the position of the outer lid in the camera coordinate system by using equation (2).

$$ P_{robot} = {}^{R}T_C P_{camera} \quad (2) $$

Where $P_{robot} = \begin{bmatrix} x_r & y_r & z_r \end{bmatrix}$ is the position of the outer lid in the robot coordinate system and $P_{camera} = \begin{bmatrix} x_c & y_c & z_c \end{bmatrix}$ is the position in the camera coordinate system.

The three coefficients d_x, d_y, and d_z can be determined by putting the operating head of the robot in the camera's field of view, and measuring the position of one known point on the operating head in the camera coordinate system $\mathbf{P}_{camera}$. This point can also be determined in the robot coordinate system $\mathbf{P}_{robot}$. From equations (1) and (2), the coefficients of the external

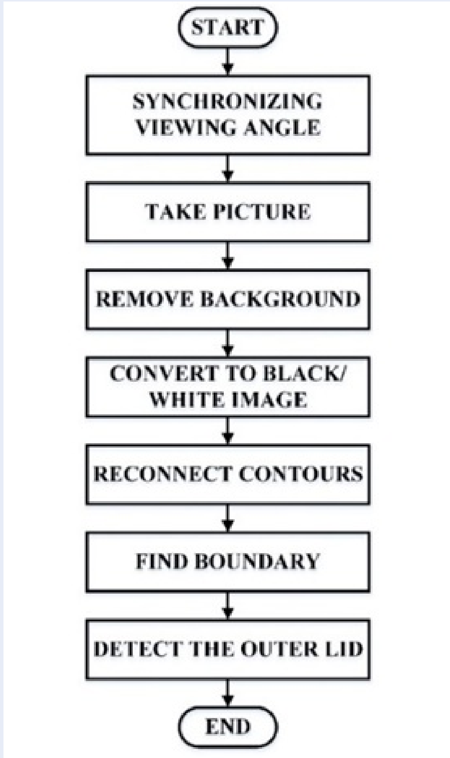

Figure 5: A flowchart of detecting the outer lid algorithm in the photo frame

parameter matrix can be determined.

From the dimension of the links of the robot, the dimension of the nozzle, and the value of at the joints of the robot, the transformation of the base coordinate system to the tool coordinate system can be determined. The tool coordinate system is attached at the robot's end-effector. Thus, it is possible to detect the distance from the robot's end-effector to the outer lid.

However, there exists a deflection angle when the driver parks the car next to the automatic fueling system. This angle is the inclination compared to the standard vertical plane of the system and can be measured by the method shown in Figure 8.

The system measures the distance between the camera and the car at 2 points. Assuming that the distance values are a and b. The distance between these 2 points is c, measured along the horizontal line. Thus, the inclination angle can be calculated as in equation (3).

$$\alpha = \tan^{-1}\left(\frac{b-a}{c}\right) \tag{3}$$

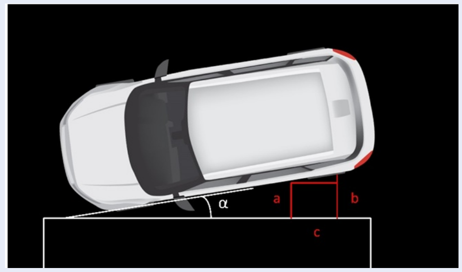

Figure 8: Method of measuring the inclination angle

Finally, the external parameter matrix needs to be adjusted as in equation (4).

$$^{R}T_{C} = \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 & d_x \\ \sin\alpha & \cos\alpha & 0 & d_y \\ 0 & 1 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4}$$

RESULTS AND DISCUSSION

Experimental setup and results

To test the performance and stability of the proposed system, an experiment is developed based on the YASKAWA MH12 type robot, shown as Figure 9. The system includes the robot, the mechanical tool, the nozzle, the camera, and the fuel tank model. After arranging the system, the translational parameters of the robot coordinate system to the camera coordinate system need to be calculated. According to the position of the robot and the camera, these three parameters are determined (d_x = 1087 mm, d_y = 153 mm, and d_z = 1136 mm). Figure 10 shows the sequence of task during the fueling petrol. Figure 10 (a) shows the opening the outer lid task. Figure 10 (b) shows the grasping the nozzle task. Figure 10 (c) shows the squeezing the trigger of the pump task. The system completes one fueling period in less than one minute and thirty seconds, excluding the pump waiting time. In this experiment, the distance between the camera and the fuel tank model is 1,2m. There has the error between the real position of the fuel tank model and the position of the robot. The position error is less than 1cm and the error of the angle is less than 5 degrees in case the fuel tank wall is put parallel to the camera. This error comes from the image processing algorithm to detect the center point of the outer lid of the fuel tank. Besides, the calculation of internal matrix and the external matrix also affect to this error. However, due to the flexible properties of the suction cup, the errors are compensated resulting in distortion of the suction cup, shown as Figure 11.

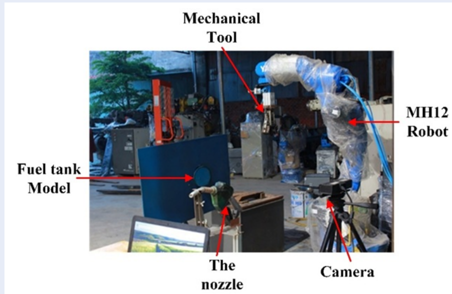

Figure 9: The automatic fueling system model

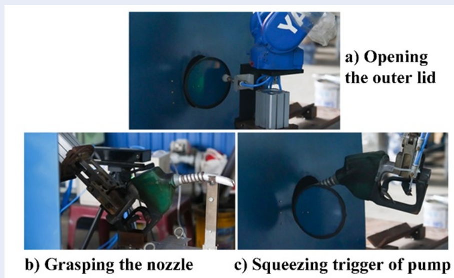

Figure 10: The steps of pumping gasoline

Discussion

The first factor affecting to the operating of the system is the distance between the camera and the fuel tank model. The farther the fuel tank model is, the greater the error. At a distance of 2.5m, the position error is 15cm and the angular error is 8^0. The reason is that the quality of the image of the fuel tank will reduce at the far distance. Thus, the position error of the center point of the outer lid will increase. The second component is the inclination angle between the vertical plane of the fuel tank model and the vertical plane of the camera. In the case of inclined 30^0 and under some experimental lighting conditions, the fuel tank cannot be recognized by the camera. The reason is that the angle of inclination causes loss of detail and the camera cannot detect the gap between the outer lid and the body of the model.

Although, there is an error about the position and angle between the real model position and the calculated position, the system still can complete the fueling task. The fuel tank model should be put in the good working range of the camera. In this experiment, the fuel tank model should be in the position of 1,2m from the camera Kinect V2.

A graphical user interface (GUI) is aimed at the user who is the vehicle driver, shown in Figure 12. This interface incorporates the camera image, and the data transfer steps are processed automatically. The GUI has a large picture frame collected from the camera in real time to help users observe the robot's operation and check that the robot has received the correct fuel tank or not. The driver can input the information by the amount of money or the amount of the petrol that he wants his car be fuel. In this user interface, the operator cannot interfere to the robot controller for safety.

Figure 11: The deformation of the suction cup

Figure 12: The graphical user interface for the vehicle drivers

CONCLUSION

The paper proposes an automated fueling system for the small individual cars. In this research, a mechanical tool attached to the industrial robot has been designed so that the robot can complete the fueling task. The paper also developed an image processing algorithm to find the position of the outer lid of the vehicle's fuel tank in space. Finally, the proposed system has been tested by the real experiments and give the good results. Although there is an error, the system still can complete the fueling task. In the future, an improved algorithm need to be considered to reduce the error in the experimental model.

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LIST OF ABBREVIATIONS

PLC: Programmable Logic Controller
CIP: Common Industrial Protocol
TCP: Transmission Control Protocol
GUI: Graphical User Interface

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHORS' CONTRIBUTION

Chi Tam Lam has proposed the image processing algorithm and made the experiments under the instruction of Tri Cong Phung. Tri Cong Phung has also written and edited the manuscript.

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Bài nghiên cứu

Nghiên cứu ứng dụng robot công nghiệp trong hệ thống bơm xăng tự động cho xe ô tô cá nhân loại nhỏ

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TÓM TẮT

Một hệ thống bơm xăng tự động cho các xe ô tô cá nhân loại nhỏ, chẳng hạn như ô tô 4 và 7 chỗ, là cần thiết trong cuộc sống hiện đại. Hiện tại trên thị trường xe hơi, nói về đặc tính của bình xăng, chúng ta có thể chia ô tô thành 2 nhóm chính, bao gồm các xe sử dụng bình xăng dạng truyền thống và các xe sử dụng loại bình xăng không có nắp vặn. Đối với các loại xe sử dụng loại bình xăng truyền thống, người lái xe cần 4 bước để thực hiện việc bơm xăng. Đó là các bước mở nắp che bình xăng bên ngoài, mở nắp vặn của bình xăng, đưa vòi bơm xăng vào bình xăng và thực hiện việc bơm xăng. Đối với các xe sử dụng loại bình xăng không có nắp vặn, nhà sản xuất thay thế nắp vặn dạng truyền thống bởi cơ cấu tự đóng mở khi có hoặc không có vòi bơm xăng. Vì thế khi thực hiện việc bơm xăng, người lái xe không cần phải thực hiện bước mở nắp vặn bình xăng. Thiết kế loại mới này được thực hiện bởi các hãng sản xuất xe hơi của Mỹ như Ford và General Motor. Bài báo này đề xuất giải pháp bơm xăng tự động cho các xe loại bình xăng không có nắp vặn. Hệ thống được xây dựng dựa trên một robot công nghiệp làm nhiệm vụ thay thế cho nhân viên trạm xăng. Trước tiên, một đầu công tác đặc biệt được thiết kế để giúp robot hoạt động trong quá trình tiếp nhiên liệu tự động. Tiếp theo, một thuật toán xử lý hình ảnh được áp dụng để nhận biết vị trí bình xăng của các xe ô tô. Sau đó, một thuật toán bơm xăng tự động được đề xuất để hệ thống có thể tự động nạp nhiên liệu. Giải pháp đề xuất được kiểm chứng bằng thực nghiệm trên mô hình thực. Kết quả thực nghiệm cho thấy hệ thống đề xuất có thể được sử dụng để định vị vòi phun vào bình xăng với sai số chấp nhận được.

Từ khoá: Bơm xăng tự động, xử lý ảnh, robot công nghiệp, trạm xăng, tài xế lái xe

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