Research on Position Tracking Algorithm with Vision Sensor for the Auto Liquid Filling Machine

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Abstract

The liquid filling machine is used in packaging fields such as food, chemistry, and oil industries. In particular, the machines are used to package products in drums after manufacturing products in hazardous chemical factories. Existing filling machine allows the operator to directly inject the product and set the injection capacity only to the standard drum. In this paper, we propose position tracking algorithm with a vision sensor that can track the inlet location of various types of drums. Hough transform detection method is used to search for objects in images from the vision sensor. The proposed algorithm can calculate the position of the injection hole after extracting the feature points so that it is possible to inject the product by automatically moving the injection nozzle. Therefore, it expected that the developed algorithm for the automatic liquid filling machine will give more production and save a lot of manpower for packaging industry.

Keywords

Automatic liquid filling machine, Manufacturing products, Vision sensor, Position tracking algorithm, Hough transform

Introduction

Data With the interest of smart factories, automatic production systems are continuously developing technology to improve productivity and safe. In particular, the liquid filling machine is used to package products in drums after manufacturing products in hazardous
chemical factories. There has been numerous research regarding the liquid filling machine to automate in package industry (Lee et al., 2020; Solanki et al., 2015; Baoyun & Daniel, 2016). Lee et al. proposed the smart liquid filling machine which can raise the nozzle according to the water level to remove bubbles and inject the accurate amount of fluid (Lee et al., 2020). The objective of the present study is to propose position tracking algorithm with a vision sensor that can automatically track the inlet location of various types of drums. In order to reduce manpower through factory automation, a lot of research using vision cameras is being conducted. It takes an image through a vision camera and detects an object through this image. In particular, it detects an object from an image and extracts the outline line of the object to find the object's characteristics. Based on this feature, it is possible to estimate the exact location of an object and move unmanned equipment. In order to estimate the location in this way, most of the images are taken and analyzed using two or more cameras. When two or more cameras are used in this way, the amount of data to be analyzed increases, and analysis time is consumed a lot (Luis et al., 2017; Yang et al., 2020; Hongda et al., 2020; Christoph et al., 2018). In this paper, we propose an algorithm to track the position of an object using a single camera. Using the proposed algorithm, it is possible to perform fast calculations with less data collection.

Related Works

The Hough transform is a concept widely used in digital image processing and computer vision. In Windsor's study, a laser scanner was used to photograph a buried object, and the Huffman transform was used to distinguish the overlapping object. The generalized Hough transform (GHT) is extended to store data pairs in associative storage so that Huffman operations can be performed. As a result of applying the actual laser scan data using this method, it was possible to detect the buried pipe (Colin et al., 2014).

As mentioned above, the generalized Hough transform is widely used to find the position of an object or an object. However, GHT requires a lot of storage depending on the data, which consumes a lot of computation time. In Yang's research, a polygon-invariant GHT algorithm was proposed to quickly calculate the position of an object based on vision (Yang et al., 2020, Hua et al., 2016; Daming et al., 2020).

Hough Circle Transform

Basically, the standard circle equation to express a circle is as Equation 1.
\[(x - a)^2 + (y - b)^2 = r^2 \tag{1}\]

In Equation 1, \(r\) means the radius, and \((a, b)\) means the center of the circle. To represent the circle in this equation, we need three parameters \((a, b, r)\). Since two parameters \((\rho, \theta)\) are used in the Hough line transformation, a line can be detected through a two-dimensional cumulative array. However, since the Hough circle transform to find a circle requires three parameters, a three-dimensional stacked array is required. Due to this arrangement, a large amount of memory is required and the operation speed becomes slow. If we know the length of the radius in the image, we can turn the stacked array back into a two-dimensional plane. The reason is that only \((a, b)\), which is the center of the circle, needs to be found. If the formula is modified based on this content, it becomes as Equation 2.

\[
x = a + r \times \cos(\theta) \\
y = b + r \times \sin(\theta) \tag{2}\]

The trajectory of the point \((a, b)\) in the parameter space belongs to a circle of radius \(r\) centered at \((x, y)\). It is explained through Figure 1.

**Figure 1. Hough transform detection**

In Figure 1, the graph on the left is a graph in geometric space, and the graph on the right is a graph in parameter space. Each point contained in the real circle on the left creates a new circle in the parameter space on the right. By accumulating and drawing circles in the parameter space, it can be seen that the most accumulated value (red dot) is the actual center.
value of the circle. Multiple circles with the same radius can be found in the same way. The center point of the real circle on the left is represented by a red dot in the parameter space graph in the figure on the right. If multiple circles overlap, fake center points such as blue dots can also be found. In this case, the fake circles on the right can be removed compared to the original image.

**Hough Circle Transform**

A circle can be detected by applying the Hough transform described above. However, when the equation of a circle is expressed on the parameter coordinate plane like a straight-line detection, it becomes a three-dimensional accumulation plane, so the calculation speed takes too long. To solve this problem and make it faster, we use the Hough gradient method (Weichen et al., 2021; Hong et al., 2020; Hao et al., 2019). In this method, information on the circumferential point of the edge detected in the circle is used. Figure 2 shows circle detection using Hough gradient method.

Compute the gradient from the circle edge pixels. After that, the values are accumulated while drawing a straight line in the gradient direction. The gradient magnitude points towards the center of the circle, so the straight lines converge at the center of the circle. Find the center of the circle using this method. Find the center of the circle and find the radius. From the center of the circle, increase the radius gradually to see if it meets the circumference. The disadvantage of this method is that it cannot detect multiple concentric circles and only detects the smallest circle.

![Figure 2. Circle Detection using Hough Gradient Method](http://www.webology.org)
Proposed Methods

Figure 3 shows the schematic of liquid filling machine system. The system consists of conveyor, traverse, injection nozzle and vision sensor. In this study, the 300,000-pixel vision sensor (FZ-SC/S, Omron) was used to measure the location of injection holes in three different types of drums (IBC Tank, 200L and 60L drums) on the conveyor system. The injection nozzle and traverse system can raise and lower the nozzle and inject the accurate amount of liquid in the drums. In the proposed tracking algorithm, a single vision sensor is fixed to the wall of the traverse system so that its position can be adjusted up and down. By adjusting the vertical position, the image of the drum to be tracked can be acquired in units of one pallet. As shown on the left of Figure 3, if there are 9 drums of 60L, it is possible to determine the location of all drums by shooting at once. In addition, there are 4 drums of 200L on the left pallet, and all injection holes can be identified through one image shooting. Through the position information of the identified inlet, the liquid filling machine can be moved to automatically fill the liquid.

![Figure 3. Schematic of liquid filling machine system with a vision sensor](image)

Result and Discussion

Usually, the Hough Transform algorithm is used to detect linear shapes in an image (Colin et al., 2014; Hua et al., 2016). This algorithm is a method used to detect all figures that can be mathematically modeled in an image. Since the circular shape can also be modeled mathematically, the Hough Transform can be applied. However, when modeling a circle, it requires three parameters consisting of the circle's midpoint \((x, y)\) and radius \(r\) and requires three-dimensional memory. However, using a three-dimensional model has the problem of...
slowing down the computational speed. To solve this problem, we applied the Hough Transform using the gradient of the edge (Hua et al., 2016; Daming et al., 2020).

Figure 4 shows an algorithm for finding the position of the injection hole of the drum barrel. The algorithm is divided into four steps. In order to find the injection hole located at the top of the drum, we need to acquire the original image. To acquire the image of the drum, Omron’s fz-sc camera was used, and the specifications are as follows. As shown in the picture on the right, a camera was attached to the wall to take pictures of drums of various sizes. In the second step, the image acquired in step 1 is converted to gray scale. This is because it is difficult to find the center point of a circle when a color image is used when searching for a circle using the Hugh transformation. For this reason, the color image is converted to grayscale and applied to the algorithm. In the third step, we apply Gaussian blur to the grayscale-converted image. When applying the Huffman transformation, the result varies a lot depending on the noise of the image, so Gaussian blur is applied to remove the noise. In step 4, we use the Huffman transform to detect circles inside the image. For accurate circle detection, various experiments were performed in advance to set parameter values. In addition, it was confirmed that errors may occur depending on the experimental environment. The reflected part of the bottom left is a case in which it is judged to be a circle, that is, an injection hole. This problem could be solved by removing the injection hole on the outside of the drum.

```plaintext
src : read original image
if src then
  gray : convert src to gray image
  blur : add Gaussian Blur to gray image
  while finding circles do
    setting some variable values for the algorithm
    circles : finding circles in an blur image using Hough Transformation
  end
  if circles then
    draw a circles on the original src image
    save the src image
  end
end
```

**Figure 4. Algorithm for detecting an inlet in the image**

Figure 5 shows the result of finding the inlet in the figure. The actual implementation is described using the figures. To apply the algorithm, load the original image as shown in Figure 5(a). In order to detect the circle in the original image, it is converted to grayscale as shown in Figure 5(b). Since Hough Transform is sensitive to noise, noise is removed
using Gaussian blur as shown in Figure 5(c). Apply the Hough Transform using Figure 5(c) from which the noise has been removed and detect the circle. Using the information of the circle detected in Figure 5(c), it is possible to find the location of the inlet of the drum. Figure 5(d) shows the location of the searched inlet in the original image.

![Images](a) Original image  (b) Gray image
(b) Gray image  (c) Blur image  (d) Finding circles

**Figure 5. Results of detecting an inlet**

**Conclusion**

The objective of this work is to develop a position tracking algorithm with a vision sensor that can detect the inlet location of various types of drums. Thus, it is expected that the developed algorithm for auto liquid filling machine will give more production and save a lot of manpower for packaging industry. In the future, we plan to increase the efficiency of automatic control by increasing image processing speed and accuracy. In addition, deep learning will be used to analyze various types of drum images. Through this, it will be possible to increase the search probability of the inlet and apply it in various environments.
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References


