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# Application of Computer Image Technology in Automated Liquid Filling Machine

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In order to better study working demands of automated filling machine, this paper bases on computer vision technology, puts forward the positioning method for detecting center coordinate at the mouth of material bucket by using computer vision technology, and designs an automated software system to realize pipelined automated filling. Through analysis of filling requirements, Simulink is used to establish a simulation model for control system of automated filling machine, simulate the control system through relevant simulation rests, and finally designs the control system of filling machine. Experimental results show that filling quantity has small deviation and control system can be operated stably. It can be known from this that computer image technology has many advantages in automated liquid filling process, which can not only improve automation degree of filling machine, but also reduce the occurrence of accidents and save the labor costs.

## 1. Introduction

Automatic filling technology is widely used in the petroleum, chemical engineering, military science, and medical treatment and other production fields. (Akhtar and Falk, 2017) Automated filling equipment has become an important symbol of industrial modernization level (Cho et al., 2010). At present, most filling machines used in the production line of chemical enterprises in China are semi-automatic, i.e. positioning the bucket mouth and filling manually. But, it affects production efficiency seriously. For acetic acid and TDI and raw materials of other chemical products with high toxicity, strong corrosivity, inflammability and explosiveness, the filling process is very dangerous and it causes great harm on personal safety of long-term operators. (Crimi et al., 2016) In addition, main workers of manual filling and semi-automated filling system are operators. (Feng et al., 2015) So, the working efficiency of such filling system is achieved under the premise of fastest speed of the operators. (Gao et al., 2016) In addition, operators wear protective clothes, protective masks, have physical fatigue, low working efficiency and low working enthusiasm due to long-time single work. So, accidents may happen easily (Konstantinidis et al., 2017).
With the background of computer vision technology developed rapidly in the recent time, automated filling system is developed to solve this problem (Liu, 2015). Based on the working demands of automated filling machine, this paper puts forward the method for detecting position of positioning bucket mouth by computer vision technology, and uses automatic software system to realize pipeline filling process and unmanned production, which can greatly improve the production efficiency and automation degree, and reduce occurrence of safety accidents and consumption of raw materials, energy consumption and labor cost (Liu et al., 2015).

## 2. Design of image capture and detection system

The design of image capture and detection system is the emphasis and difficult steps of this paper, which is finally aimed at determining the position of feed pipe and material bucket mouth and its distance. (Liu et al., 2016) Through calculation, walking steps of X/Y stepper motor can be obtained to achieve the filling objectives (Lopes et al., 2016). The software system is composed of material bucket image extraction, image denoising, image enhancement (McLoughlin et al., 2015), image edge detection and extracting center coordinates of bucket mouth through Hough transformation, which is shown in Figure 1.

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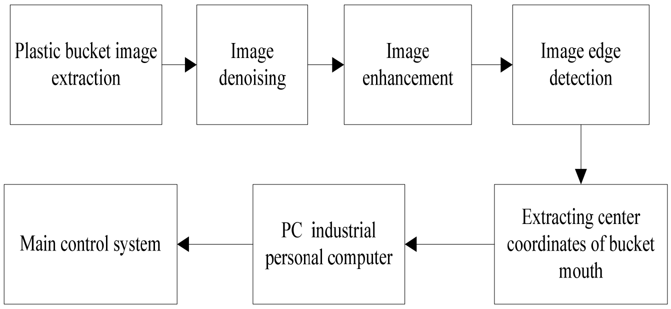



*Figure 1: Process Chart of Image Acquisition and Detection System*

### 2.1 Hough transformed detection line

As shown in Figure 2, it's assumed that one line of the rectangular coordinate system is l, distance from original point to the line is λ, and the included angle of the line and x axis is θ, the parameter equation of the line should be:

$$\lambda = x\cos\theta + y\sin\theta \quad (1)$$

Polar coordinate of the line refers to one point (θ, λ). It can be seen that any line in the rectangular coordinate system can be provided with one-to-one correspondence in the polar coordinate system. Such conversion from line to point is the core principle for transformation of Hough.

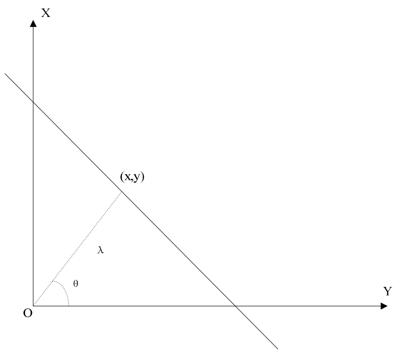



*Figure 2: Polar coordinates of a line*

Hough transformation can be used to transform the line to polar coordinate space. Then, polar coordinate space is used for simple accumulation and detecting the straight line. Hough transformation is characterized in strong anti-interference capacity and accurate positioning. If there are noisy points or non-obvious effect drawing, it doesn't affect the accuracy.

### 2.2 Algorithm experiment results

General equation of the circle (x-a)2+(y-b)2=r2 can be expressed by polar equation as follows:

$$x = a + r\cos\theta, y = b + r\sin\theta \quad (2)$$

Then, parameter equation of the circle is:

$$a = x - r\cos\theta, b = y - r\sin\theta \quad (3)$$

In the equation (2) -(3), θ refers to gradient angle at peripheral point ($x^i$, $y^j$) of the circle. Second laplacian edge detection algorithm is used in the image edge detection module to determine gradient θat peripheral point ($x^i$, $y^j$). The equation is used to determine the specific values in 3D parameter space (a, b, r). Algorithm process is similar with Hough transformation before improvement. The improved Hough transformation gives full play to image edge information, eliminates unnecessary edge information and noises (Menzel et al., 2015). Compared with traditional Hough transformation, the improved one greatly reduces the quadratic sum and extraction of a root to achieve small calculated amounts and fast operation etc (Park, 2016).

Improved Hough transformation algorithm is used in the system to determine the bucket mouth and its center coordinates (Shojaeilangari et al., 2015), through image capture, image enhancement, image edge detection and bucket mouth detection. In this system, the bucket mouth has a fixed range, and grey value in this area is small. It’s necessary to improve during system detection (Sironi et al., 2016).

## 3. Realization of control system of automated filling machine

Object controlled by control system of automated filling machine should be the decisive factor for determining the hardware selection of control system of automated filling machine. Generally speaking, during hardware design and selection of control system of automated filling machine, sensor for data acquisition has simple design and control system and actuating elements have complicated design (Wang et al., 2017). Each element and whole performance affect the performance of control system of the whole automated filling machine. It can be known from above composition, modelling and simulation of automated filling machine, control system is used to not only control measuring cylinder and stirring system of servo drive, but also accurately control movement of pneumatic system, so as to ensure accurate and orderly implementation of whole filling movement and raise a stricter requirement for hardware configuration and selection of whole system (Wu et al., 2017).

### 3.1 Control system of programmable controller

Hardware structure of control system of automated filling machine designed herein is shown in Figure 3, which includes control center PLC, man machine operation interface HMI, sensor and actuating elements.

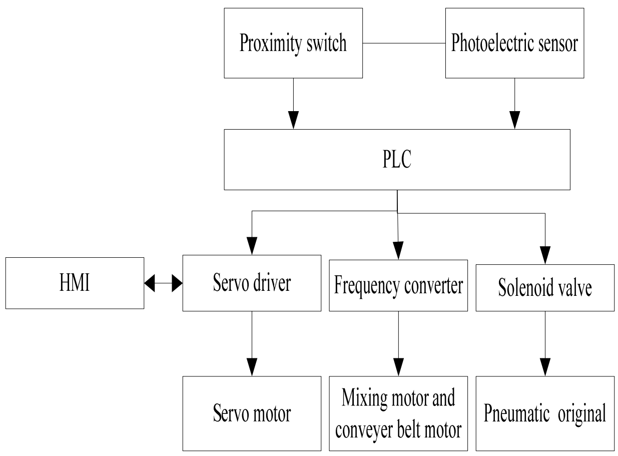



*Figure 3: Hardware Structure Diagram of Control System*

### 3.2 PLC control program of a filling machine

Function realization of PLC should be implemented by compiling relevant control procedures by the user, which are then downloaded to the control system (Wu et al., 2017). During design of control system of automated filling machine, PLC control system mentioned above should be able to achieve the control functions, analyze moving principle of measuring cylinder system, pneumatic system and stirring system of servo drive, prepare corresponding control program (Yuan, 2017), store the compiled control program and parameter settings of control objects of automated filling machine into CPU of PLC. Then, motion control command of actuating element of filling machine can be transmitted by PLC to the corresponding operation equipment. In this paper, the selected PLC programming software is Delta WPLSoft (Version 2.38) based on Windows and made by China Taiwan Delta Company (Zeng et al, 2016). This programming software is developed by Delta company to adapt to whole series of DVP-PLC and can be used for establishment of the program, read-in and read-out programmable controller, effective monitoring software or ladder diagram, commissioning the compiled program in a real-time way, PLC diagnosis, and encryption of PLC program. WPLSoft has strong help function, which means that in case of strange commands and unabling to operate, it can be found in the help. For specific compilation of PLC program, WPLSoft programming environment is mainly provided with three compiling and display ways: ladder diagram, step ladder instruction and sequential function chart, which can be mutually transformed. The ladder diagram is characterized in simple and easy understanding. So, ladder diagram language is used for software development of the system designed herein.

### 3.3 Motor selection

Through above modelling and simulation, it has a higher requirement for control system designed herein, especially hardware configuration of control system, which is due to that the system designed herein should satisfy the efficient and accurate sequential actions. For hardware configuration, motor is the core component. Motor control of automated filling machine designed herein mainly includes servo motor of driving metering cylinder and motor of stirring system.

Servo motor: drive motor of metering cylinder is the core part of whole automated filling machine, which has great influence on basic performance of filling machine. Through comparison of various motors, it can be known that servo motor, an electro-mechanical transformation equipment, is a product with integrated with mechanical and electronics. It is characterized in small volume, light weight, high efficiency, small inertia and high control accuracy and widely used in various fields. Delta ECMA-C21010RS servo motor is used in this system to drive metering cylinder of servo drive with parameters shown in Table 1:

*Table 1: Motor Parameters*

| ECMA type | C21010 |
|---|---|
| Rated power (KW) | 1.0 |
| Rated torque (N.M) | 3.18 |
| Maximum torque (N.M) | 9.54 |
| Rated speed (r/min) | 3000 |
| Maximum speed (r/min) | 5000 |

Stirring motor: it should be selected by considering the followings: 1) Motor selection. it is determined by load characteristics of the machine and its production technology, and corresponding requirements for motor braking, reversal, start-up and speed regulation etc. 2) Power and ventilation pattern of the motor. It is determined by maximum bearing temperature, starting torque and overload capacity of the motor, speed variation interval of motor, starting times and load torque etc. 3) Protection type and structure form of the motor. It's determined by environmental index in the application site of the motor, such as humidity, dust, rainwater, gas, temperature, content of corrosive and flammable and explosive gases. 4) Type and voltage grade of the motor. It's determined by the grid voltage load limit and power factor and other comprehensive performance index of the user. 5) Rated speed of the motor. It's determined by the maximum speed of the equipment, central process of electric drive speed-regulating system and complexity degree of mechanical deceleration parts. 6) Safe operation and energy-saving of the motor. It's determined by operation reliability of the motor, universality of spare parts, installation and maintenance complexity, product price, operation fees, and maintenance fees and another comprehensive economic index.

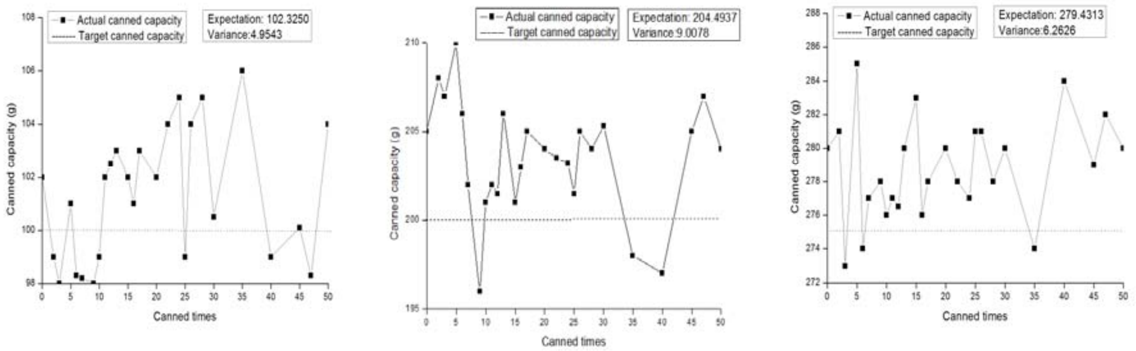
Y2 series Y2-71M2-4 motors are used in this plan. This motor can be connected in two forms, i.e. Y shape and △ shape, which are respectively used in the 380V and 220V three-phase supplies. In consideration of power conditions in the laboratory, △ shape connection is used and its corresponding parameters are shown in Table 2.

*Table 2: Y2 Series Motor Specific Parameters*

| Type | Rated power | Rated current | Revolution speed | Efficiency | Power factor | Noise | Vibration velocity | Weight |
|---|---|---|---|---|---|---|---|---|
| | KW | A | r/min | % | P.F | dB(A) | mm/s | kg |
| Y2-71M2-4 | 0.37 | 0.12 | 1400 | 67.0 | 0.75 | 55 | 1.8 | 9.5 |

### 3.4 Fixing experiment simulation

Theoretically, touch screen of experimental prototype can be used to set any filling volume in the filling range. At present, in order to investigate system performance, it's necessary to set 100g, 200g and 275g three different filling volumes for test. The filling test is conducted for three different kinds of targeted filling volumes. Each target filling volume should be filled for 300 sets, 6 bottles for each group, totalling 1800 bottles. Among them, 48 bottles are randomly drawn for weighing and the weighing accuracy is 0.1g. The analysis diagram of each kind of experiment is shown in 4(a)-(c)




(a) 100 g filling accuracy (b) 200 g filling accuracy (c) 275 g filling accuracy

*Figure 4: The accuracy of three filling volumes*

Through analysis and calculation of experimental data by Matlab, the obtained filling accuracy should be 1008, 2008 and 275 g, as shown in the figure. Among them, the expectance and variance of a sample with targeted filling volume 1008 should be 102.3250 and 4.9543 respectively; the expectance and variance of a sample with targeted filling volume 2008 should be 204.4937 and 9.0078 respectively; the expectance and variance of a sample with targeted filling volume 275g should be 279.4313 and 6.2626 respectively.
It can be seen from the diagram that actual filling volume of three experiments fluctuates up and down near the targeted filling volume. Through calculation of mathematical expectation and variance of actual filling volume, it can be known that the expectation of actual filling volume obtained through experiment is slightly larger than the targeted filling amount, which is reasonable and satisfies the design requirements of filling machine system; through analysis of variance, the variance of actual filling volume in three experiments is small, which means that the filling machine has a stable performance and there is no large filling variance.

## 4. Conclusions

This paper mainly studies the control technology for automated filling machine of high-concentration fried pepper source, analyzes the filling requirements for filling materials, establishes a simulation model for control system of automated filling machine, simulates the control system through related simulation experiment, and finally completes design of control system of filling machine.
Firstly, this paper summarizes the research progress and development status of automated filling machine in the home and abroad, introduces the composition of mechanical driven system and control system of automated filling machine, and analyzes the mathematic model for main components of automated filling machine by studying the principle for controlling the automated filling machine.
Secondly, it gives the common used coordinate transformation theory and pulse width modulation theory used for controlling the motor and verifies its emulation; provides system modelling and control simulation for induction motor of the stirrer, to simulate actual operation of stirring system and give explanation on simulation curve; it implements simulation comparison and analysis of measuring cylinder system in step drive and servo drive, further states difference of open-loop and closed-loop drive in the system application according to the simulation results, and verifies the advantages of servo drive.

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