

The Implementation of DC Motor Speed Control Using Image Processing and OPC Interface in the S7-1200

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Abstract

In this study, it is aimed to control or get synchronized the AC motor speed by taking the motor speed of DC as a reference. Speed control is usually done using the encoder or tachogenerator. In this study, motor speed is controlled by using camera instead of these. A mechanism is used to determine the DC motor speed on the motor shaft. The speed of the DC motor is obtained by using a USB camera. Received images with camera are transferred in MATLAB. The speed of the DC motor is calculated by using image processing methods in MATLAB. Calculated speed data is sent to Programmable Logic Controller (PLC). Thus, PLC controls AC motor according to speed data. AC motor has been synchronized with the DC motor. Speed data is sent to PLC from MATLAB by using OPC (OLE for Process Control). AC motor is controlled by PLC by using MICROMASTER VECTOR driver. This driver works with 380 Volt constant voltages. Received data is in the range of the 0-10V from the PLC. AC motor driver controls the speed by changing the frequency of 380V constant voltage.

Key words: Image Processing, DC Motor Speed Control, OPC Interface

1. Introduction

Image processing is the process of replacing features and characteristics of the images that are derived from real life [1]. The basic logic of the human visual system is vital to be able to fully explain the image processing. Namely, the basic logic of the human visual system is that the eye replaced with a camera and the visual portion of the brain functions as a complex image processing system [2]. Nowadays, image processing technology is applied indispensably in many industrial applications. This technology is used in motorways to count the number of vehicles passing, to recognize the vehicles' license plate, to distinguish the objects with different shapes, to recognize the items according to the colors and in many other fields such as clarifying a tomographic image.

Programmable Logic Controllers (PLCs) are the microprocessor-based on devices that are used instead of relay automation, timers and counters in circuits. In this device, timing, counting, sorting, and all kinds of combinational and sequential logic operations are performed with the software. Therefore, it is possible to solve complex automation problems quickly and safely [3-7].

PLCs make possible to both low-cost solution for controlling the complex systems, and quick and easy adaptation to other systems, as well as resistance to electrical noise, vibration and hit [8]. OPC is a technological correspondence standard that helps to solve adaptation problems in the industrialized automation field. Control systems using different correspondence protocols and different brands can communicate by using OPC [9-11]. As shown in Fig. 1, for

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corresponding and OPC server, SIMATIC NET software, as OPC requester, MATLAB software and for programming the PLC, TIA portal V11 software is used.

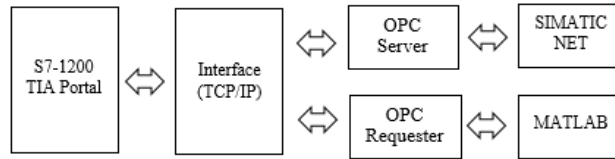


Fig. 1: OPC position in the data exchange

2. Test Setup

Speed control is carried out using the devices shown in Fig. 2. As seen in test setup, USB camera constantly stands facing to the DC motor. There is a wheel with halfway line on it at the end of the dc motor. The angle determined by computer image processing method is scanned taking samples from wheel. And it is transformed to speed information.



Fig. 2: Test Setup

The speed information is determined by sending from computer to PLC as seen in the Fig. 2. OPC is used for sending the speed information to PLC. AC motors are driven according to the incoming velocity information after the necessary parameter settings are done.

To be able to control the speed by image processing, the camera and DC motor used in the system and it is required to compensate necessary qualifications. USB camera taking image rate was measured as 11-12 ms. To access information using the camera, speed of the camera must be faster than the motor's one full tour. Considering this, a DC motor with 400 ms rev/time, 150 rpm and 24V is used. AC motor with 1680 rpm asynchronous is used. AC motor control and drive in the system is realized by using MICROMASTER VECTOR S7-1200 PLC.

3. Image Processing

Image processing is basically correction and modification of a recorded digital image. In other words, it helps to change, edit or improve the existing images and graphics [12]. In test setup, USB camera is used for image processing. USB camera is constant and is faced to the wheel inserted to the tip of DC motor. Angles are calculated separately with the algorithms mentioned the part of determination of DC motor speed. At least two samples are obtained in a complete tour. The angle covered is calculated by difference of two angle values. The time elapsed is calculated at the same time. Angular velocity comes by dividing the angle to the time. The image processing algorithm is illustrated in Fig. 3.



Fig. 3: Image Processing Algorithm

3.1.Determination of the DC Motor Speed

12 cm diameter wheel is inserted into angular type of the DC motor to determine the motor speed. Black line is drawn in the thickness of about 2 cm from the center point to the outward on the wheel to access information of speed. The reason for using the black line the image processing methods can be used more easily. Two samples were taken with the camera in 400 ms. In the samples, angle of the black is measured by positive side of x-axis. Two different angles are measured in complete tour duration (400 ms) and in two different times. The angle of the black line was determined by subtracting angle taken in sample 2 from sample 1. At the same time, duration between two samples is calculated by 'tic toc' function in MATLAB. The angular speed of DC motor is obtained by dividing the angle with the elapsed time. It must be at least two samples of 400 ms to calculate the angle covered by wheel. Unless the numbers of images are more than one, revolution information is missed. This prevents the acquisition of the speed information.

Motor speed is determined by considering the angle that the angle line has gone on the wheel. For faster and easier measuring, the possible area was determined in advance. When determining the area, the center of the wheel is considered X_I , Y_I . Area has been identified as suitable square at the wheel's size of X_I , Y_I being on the center. The pixel values of the

possible area is analyzed in MATLAB to determine the optimum color and threshold values for getting the most possibly clear black line. Appropriate color channel is taken to an empty area and the operations are carried out with this image. All the images are not passed through this threshold. Because the study area is squarely determined. Thresholding is done for areas according to the determined thresholds. The algorithm determines the values more than the threshold are '255' (white), and the others are '0' (black), black line is emerged. Fig. 4 shows examples of wheel that is obtained as a result of thresholding.



Fig. 4: Taken wheel sample

MATLAB considers the imported images as matrixes. The pixel values of the images are assigned into rows and columns. Image processing methods in MATLAB using the pixel values is reached when applying the required row and column number. When developing algorithms applied to images, it should be taken into consideration the image that is made up from rows and columns. The geometrical method of gradient of a line between two certain points is applied to determine the angle. The algorithm that is calculating the angle is formed interpreting the row and column coordinates according to that method.

Between points A and B, gradient is shown as ' α ' in Fig. 5 in the coordinate system. This slope between two points is equal to the tangent of ' α '.

$$\tan \alpha = \frac{Y_2 - Y_1}{X_2 - X_1} \quad (3.1)$$

In order to get the angle α in 3.1, $\arctan \alpha$ value is needed.

$$\alpha = \arctan \frac{Y_2 - Y_1}{X_2 - X_1} \quad (3.2)$$

Sample is shown to the determination of θ in Fig. 6.

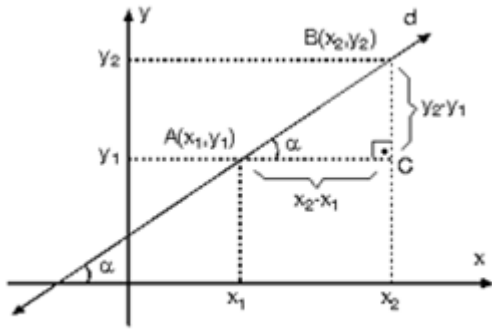


Fig. 5: The coordinate system illustration of a line with two certain point

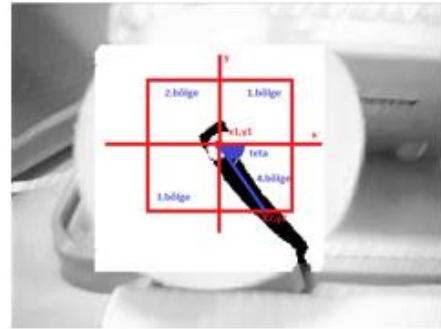


Fig. 6: Algorithm applied on the image

The coordinate system is adapted to image in Fig. 5. Images are perceived reversely on the MATLAB compared to the real coordinate system. The rows represent the y coordinate, the columns represent the x coordinate. A central point is determined experimentally in order to utilize from Eq. 3.2. Wheel center point used to determine the black line X_1, Y_1 was used as the central point in angle measurement. Angle can exactly be measured because the point is constant in two situations. X_1, Y_1 point must be determined for implementation of Eq. 3.2. Wheel X_2, Y_2 point is constantly changing due to the continuous rotation. To determine the variable X_2, Y_2 point a square frame is formed, X_1, Y_1 point being on the center on the taken image. Frame coordinates are regarded as symbolic X_2, Y_2 points. The framework is shown in red at Fig. 6. In the image, if the red line is interrupted by the black pixels of the lines, the intersection point is stored as X_2, Y_2 point. X_2 value is stored of x -coordinate, Y_2 value is stored of y -coordinate. At the same time, the quantity of intersection points is counted. Therefore, x and y coordinates come out as much amount as intersection points. X_2 is found with x coordinates divided into the number of intersection points and so does Y_2 . The angle obtained from Eq. 3.2 is the angle with x axis. The angle between two points is at most 180 degrees wherever the points are. So the angle between two points can't be more than 180 degrees. Positive side of x axis is determined as start point for wheel line (assumed as 0^0). To measure the angle value with Eq. 3.2; the side location of the X_2, Y_2 with reference to X_1, Y_1 is determined. Rows and columns start from the left upper corner on the MATLAB images. Region is determined in order to 360 degree angle calculation. Region separation of X_2, Y_2 coordinates is made according to conditions in Table 3.1.

Table 3.1: Area separate of Coordinate of X_2, Y_2

| Condition | Area |
|-----------------------------|----------------------|
| $X_1 < X_2$ and $Y_1 > Y_2$ | 1 st Area |
| $X_1 > X_2$ and $Y_1 > Y_2$ | 2 nd Area |
| $X_1 > X_2$ and $Y_1 < Y_2$ | 3 th Area |
| $X_1 < X_2$ and $Y_1 < Y_2$ | 4 th Area |

Considering the angle with x axes comes out of the Eq. 3.2, necessary angle subtracting and adding are done. For example, in Fig. 5, example of the illustrated wheel is in the fourth area. The angle that comes from Eq. 3.2 with x axis. Actually wheel is in 4th area and it more than 270 degree. For accurate calculation, the position of the line of wheel is evaluated regarding to the x axis. The positive values of angle with the X axis subtract from 360 degrees and right angle calculation is made for 4th area. Table 3.2 is shown adding and subtracting the angles by the area.

Table 3.2: Angle calculation by area

| Area | Angle |
|----------------------|--------------------------------------|
| 1 st Area | The angle made with x axis |
| 2 nd Area | 180- The angle made by the axis of X |
| 3 th Area | 180+ The angle made by the axis of X |
| 4 th Area | 360- The angle made by the axis of X |

Note: The angle made with the x -axis equals to the absolute value of the angle comes out of Eq. 3.2.

For accurate measurement, firstly a sample image is taken and X_I, Y_I center point is marked. This process is very important for the system working. Otherwise, a randomly positioned camera causes a shifting of center point and inaccurate results. This means obtaining the wrong speed information. After speed data is obtained, required proportioning are performed for the data that goes to PLC, considering the nominal speed data of AC engine and DC engine. 150 rpm engine completes 360-degree tour in 0.4 second. Angular velocity of the DC motor is the angle ratio of the passing time.

$$w = \frac{360^\circ}{0.4} = 900 \text{ (degree/sec)} \quad (3.3)$$

150 rpm speed of motor in second is calculated 2.5 rev/s. Full set angle ratio of full tour time were obtained $w = 900$ angular velocity value for DC motors. Angular velocity value is also illustrated as 2.5 rev/s. The measured angle ratio of time shows that the speed is approximately w . Angle values in Table 3.3 was demonstrated.

Table 3.3: To obtain information of speed

| Calculated Angle | Elapsed Time | Angular Velocity |
|--------------------|--------------|------------------|
| 55.76 ⁰ | 0.07sn | 796,5 |
| 61.78 ⁰ | 0.069sn | 895.36 |

Table 3.3 also includes calculated angle between the two samples, elapsed times and information of speed. The common variables used in both MATLAB and PLC defined in OPC SCOUT software. While defining the variables, access of variables come into existence. Information of speed is sent to the PLC by this access path.

Using the computer's IP, PLC and computer get connected. Access paths are formed for the variables that are defined in OPC SCOUT. Information of speed obtained is written to the PLC memory every 400 ms. The speed of the AC motor is controlled according to received information of speed.

4. PLC and MICROMASTER VECTOR

The calculated speed information is sent PLC via OPC. Necessary adjustments of MICROMASTER VECTOR used for driving the AC engine are carried out using manual prepared by SIEMENS [13]. After the initial parameter settings, the AC motor has been drove manually using the buttons on the MICROMASTER VECTOR. Required connections and required parameter settings are performed so that AC motor can be controlled analogously

with the PLC. Calculated speed information is sent to PLC in type of voltage. The speed information is converted to type of voltage as follows.

AC motors nominal speed of rotation frequency is 60 Hz. In this study, the maximum rotation frequency is set to 10 Hz. Motor rotation speed at 10 Hz;

$$60 \text{ Hz} \quad 28 \text{ d/sn}$$

$$10 \text{ Hz} \quad x$$

$$x = \frac{28 * 10}{60} = \frac{14}{3} \text{ d/sn} \quad (4.1)$$

PLC analog output gives range of 0-10V output. AC motor rotates in the speed of 14/3 rev/s when output voltage is 10V. The speed data received from MATLAB is shown in equation 4.2 as voltage in PLC.

$$10 \text{ V} \quad \frac{14}{3} \text{ d/sn}$$

$$x \quad w \text{ (the speed data received from MATLAB)}$$

$$x = \frac{w * 10}{\frac{14}{3}} = \frac{15}{7} w \quad (4.2)$$

The speed data coming to the PLC is between 0-10V. The value in number of this is 0-27648 is sent to the driver from PLC. As the start command comes to the system, samples are being collected in specific time periods. Speed data is acquired by these samples. Image processing algorithms are shown in Fig. 3. The motor rotates with the speed data sent to the PLC. This occurs periodically. The way the system works is shown in Fig. 7.

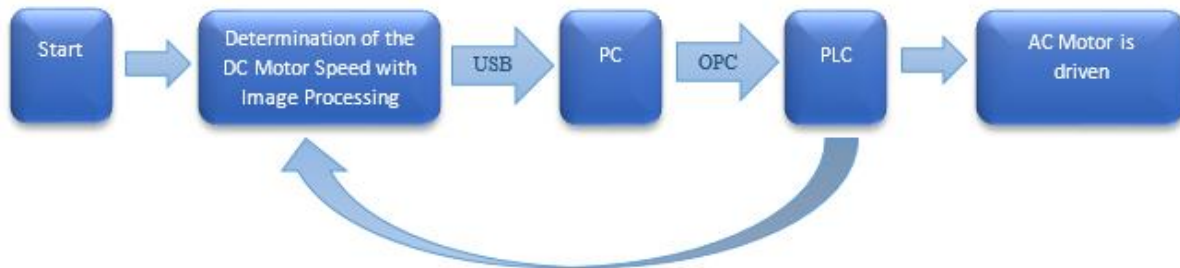


Fig. 7: Speed Control Algorithm

5. Conclusions

In this application, motor speed is determined with image processing methods using fixed positioned camera. PLC-computer communication is done using OPC-server because different types of devices are used. The speed information is obtained by sending from computer to PLC by OPC in certain periods so that the other engine is under control of speed with the help of driver. In this application, camera is aimed to use as an encoder which is used instead generally. One of disturbance of this study is the problem of changing light intensity as in most cases. Insufficient light intensity causes unclear or no line on the wheel. Thus,

angle difference calculation might be incorrect; moreover, speed calculation can be incorrect as well. To resolve this disturbance, study needs to be carried out under constant light intensity. At the same time, the camera must be positioned by the calibration. Without calibration, speed data might be incorrect. It is concluded that study would be exactly carried out under constant light and adequate calibration.

More than the devices used in this study has caused the delay is. In order to reduce these delays, more than different methods can be used. In order to prevent this delay, quality camera with high resolution, and more accurate speed information is needed. Next studies with these devices the study will be more feasible and less processing time.

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