Design of determining performance indices of positioning drive using computer vision laboratory bench

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Abstract. The right choice of an electric machine directly affects the quality indicators of the technological process. Positioning accuracy and movement repeatability are key parameters for the robot. A servo drive with position feedback is most suitable for these requirements. A robot based on DC servo drive was built for educational purposes. In order to determine the quality indicators of the drive control, an experimental setup was built, and software was developed for the experiment using computer vision. As a result of the obtained data analysis, significant shortcomings of this drive type were detected.

1. Introduction
The automation of technological processes and production has an increasing impact on different branches of industry, which influence on the important factors such as an efficiency of production, quality of products and its prime cost. There is a tendency to introduce multi-axis robot manipulators into the process of production, which are capable of performing a wide range of tasks, depending on the specifics of the working element. The five-axis robot manipulator drives, which are made of organic glass to implement educational purposes, are considered in this paper [1]. The 3D model is shown in the figure 1. The robot is based on the MG995 servomotors. The servomotor is an electric drive system in a single-engine housing, which includes a control card, a gearbox, a potentiometer and a DC motor. The control system is based on the Arduino microcontroller.

Figure 1 – Five-axis robot manipulator.
2. Methods and Equipment
The set of experiments for quality factors evaluation such as a positioning accuracy and a response rate has been conducted [2]. The indirect servo motor temperature measurements have been implemented by means of the motor housing temperature measurements. Figure 2 shows the experimental installation, which includes:

1. Drive with fixed lever on a motor shaft;
2. Control board (Arduino Mega);
3. Temperature sensor;
4. Illuminated screen;
5. Image capture device (Webcam);
6. Electrical power source

![Figure 2 - Schematic of the experimental installation.](image)

The experimental installation connected to the personal computer with a running control program, which is written by the Python 3 programming language. A reference signal is transmitted to the control card via a serial port to set the motor shaft reference angular positions, and then the load is applied to the servo drive shaft for the period of time required for positioning. Images received from the camera at the time of retention are stored on a computer and are supplemented by recording the phase of movement, measurement number and time stamp. After processing the image from the camera, a binary image was obtained. Binary images are often used in image processing as masks or as the result of certain operations such as segmentation, thresholding, and dithering [3-6]. We can find the center of the figure using moments in OpenCV [7]. Image Moment is a particular weighted average of image pixel intensities, with the help of which we can find some specific properties of an image. Binary images can be interpreted as subsets of the two-dimensional integer lattice. For each monochrome image obtained the barycenter is calculated - the arithmetic average of all points in the form. A digital image has a finite number of points, which are calculated by the equation (1) because it is raster, thus consists of pixels:

\[ c = \frac{1}{n} \sum_{i=1}^{n} x_i, \]  

After processing three hundred frames in a graphical editor, the distribution map was obtained, which is shown in Figure 3 (c), where 0F and 0S are the position areas of the monitored point without load, 2.56F and 2.56S load with moment 2.56 kgf·cm, and 8.3F and 8.3S, according to the position under servo motor loaded with the rated torque.
3. Results and Discussion

Geometric constructions are made based on the positions allocation map in order to verify automated calculations. The map is obtained by overlapping of all processed images in image editor. Angle values are obtained with the built-in tools of image editor.

The calculated values agree with the values obtained graphically. It proves that the performed analysis is made correctly.

![Figure 3](image)

Figure 3. Image processing steps: a – raw captured image, b – monochrome image, c - map of position distribution, d - geometric interpretation.

The angular positions of the servo motor shaft vs. time for the first 100 measurements have been shown in the Figure 4 [8]. The starting point is the average position value at a zero reference signal with no-load. Data, which was obtained during the analysis, allows noting that averaged difference of angular positions is 4.3 degree without load. The accidental angular positions are 0.4 degree. The displacement of angular positions by 2 degree and increasing of the accidental angular positions by 1.4 has been set with the 2.56 kg*cm torque load. The one and the other points have displaced more than 5 degree. Difference of angular positions is 2.7 degree at the start of the experiment. It was also noted that the servo motors intensely heated during experiment. The working ability of servo motors reduced due to risk of overheating. Servo motors worked for less than 4 minutes, in such loading pattern and then motors were overheated causing full stop. Experimental data is given in details in the Table 1.

| Table 1. The results of the experiment |
|---------------------------------------|
| Load, kgf*cm                        |
|                                       |
| 0                  | 2.56          | 8.3          |
| Reference signal     |
| 0                  | 5             | 0            | 0            | 5            |
| Actual angular positions, ° | 0       | 4.28         | -2.16        | 2.46         | -5.66        | -3.10        |
| Angular difference, ° | 4.28     | 4.62         | 2.56         |
| Positioning error, °   |
| 0                  | 0.72          | 2.14         | 2.54         | 5.66         | 8.12         |
| Static error, °        |
| 0.37                | 0.37          | 1.39         | 0.37         | 1.55         | 3.52         |
4. Conclusion
The desired positioning accuracy has not been obtained during experiments. With one third of the rated load the positioning error is higher than 2 degree and the steady-state error is 1.4 degree.

Such quality indicators do not satisfy requirements for the mechanism and also can not be improved because the behavior of starting process is not logical. It was also noted that the servo motors intensely heated in the holding mode.

Thus, significant disadvantages were found in this version of the robot manipulator during the experiment and operations. First of all, the design of organic glass does not provide necessary rigidity, due to the wide number of flexible joints. Secondly, the DC servo drive does not allow users to achieve high accuracy of the working element positioning. Thirdly, the robot manipulator can not be used for a long time due to the features of servo motors, behavior of the manipulator and the design features of the servo drive since the DC motor overheats too quickly. According to all mentioned disadvantages, one has decided to refuse of using DC motor based servo drives, as well as to change the approach to the implementation of the kinematic scheme.

References
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