

Servo Control Education Tool for Industrial Applications

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Introduction

Machining tools that are frequently used in industrial manufacturing sector are generally dependent on position and speed basis. Position and speed controls are generally carried out using electrical motors. Although, those motors' structures vary, all of those transform electrical energy to mechanical energy [1, 2]. For position and speed control every electrical motor might not be suitable. In such a case, when choosing an electrical motor the magnitude of force to be controlled must be considered. In the applications in which position should be controlled accurately, stepper motors or servo motors are usually employed. Stepper motors are mostly preferred in system controls with low power demand and low moment requirement. On the other hand, servo motors are generally implemented in systems requiring fast reaction, high power and strong moment [3]. Servo motors can be grouped into two subcategories: AC-servo motors and DC-servo motors. These motors can make positioning and speed adjustment precisely and quickly, thanks to their own structures and drivers.

The students who are studying in fundamental fields like electrical-electronics and mechanical engineering need to complete their education regarding industrial manufacturing machines. When considering Turkey's education institutions that are active in this field, most of the graduates are employed in private sector. Capability of those to solve problems that might be encountered in their career is only possible with educating them about the systems that they might encounter in their real life. Straightforward, versatile and advanced training tools are needed to teach students easily about available manufacturing machines. Therefore, various commercial and scientific educational tools have been produced. In this education tools either AC or DC motors have been used and only uni-directional position and speed have been controlled. In addition, these education tools are based on development of hardware and operating software. They are

controlled via a touch panel or a computer uni-directionally. But in this study, both using AC and DC servo motors a control mechanism which enables control of speed at one, two, three or four axis depending on user demand is formed. User controls of the axes are maintained via computer or operating panel software. Moreover, to allow students to acquire theoretical knowledge effectively and to allow them to see important simulations beforehand, the education tool is supported by local network based software.

Servo Motor Control

Quick advancement in technology forces manufacturing tools to equip with more sensitive and faster actuating units. Recently, thanks to servo and stepper motors' programmability and sensitive movement control properties, they are supplanting conventional actuating systems [4]. In this study, to control the servo motors, four-axis control supplier, Panasonic FPX series PLC (Programmable Logic Controller), is used. Technical properties of the PLC are given in Table 1. PLCs are important control units which provide adequate input-output units for the controlling of hardware that are installed for industrial automation systems. They allow execution of a previously written program on demand and automatically [5]. In this training set; three AC-servo motors and a DC servo motor are used. Technical details are given in table 2.

Table 1. Technical Properties of Panasonic FP-X series PLC

Processor speed 0.32 η s	Program edit during process
32K program memory	FP-X 24 V sensor power supply
Insertable cards	16 station master / master network
50 microsecond process speed	USB input
I-PD control	Automatically configured PID
100 KHz speed of movement	Floating point unit
Modbus Master & Slave	8 channel speed counter

Table 2. Technical features of AC and DC servomotors

Axis	Voltage	Current	Power	Torque	Speed
X	220 AC	1,8	400	1,27	3000
Y	220 AC	1,8	400	1,27	3000
C	220 AC	1,8	400	1,27	3000
Z	12 DC	6,5	80		3000

For AC servo motors Delta ASDA series and Yaskawa SGDh-04AE series drivers are chosen which are presented in Table 1. Photograph of driver circuit for DC servo motor and open circuit diagram for this driving circuit are given in Fig. 1 and Fig. 2, respectively. 6A fuses are used to protect drivers from over-current. In order to determine activation order of PLC and servo drivers and to protect the system relay is used. In this case firstly servo

drivers and secondly PLC initiated. The reason for that is to protect hardware against errors that may occur during control. Drivers and PLCs are supplied from 24V power supply.

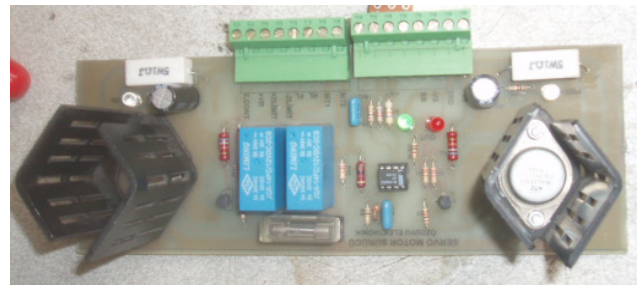


Fig. 1. DC servo motor driver circuit

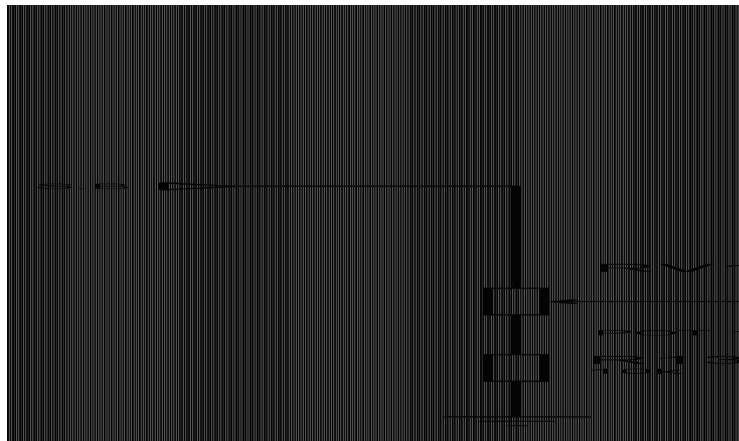


Fig. 2. Open circuit diagram of DC servo motor

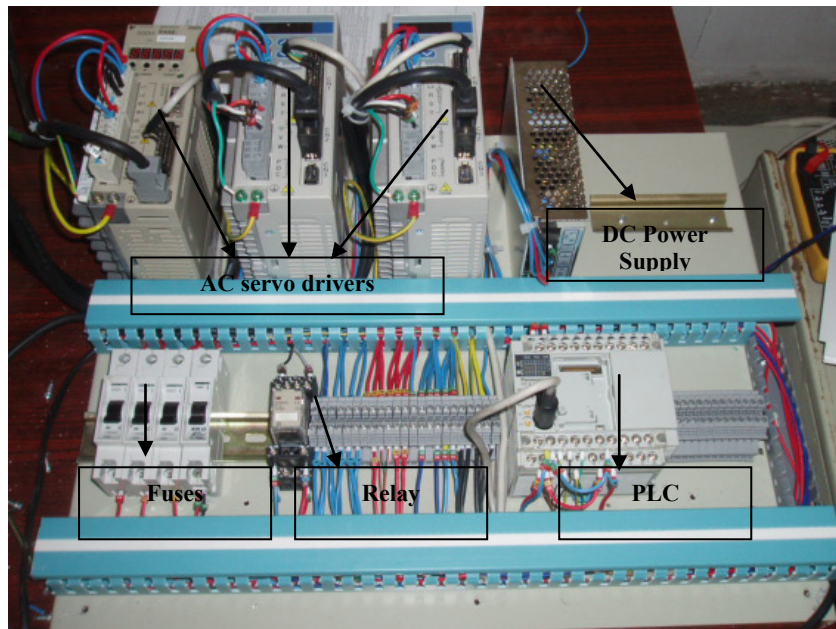


Fig. 3. Photograph of driver circuit

Position and speed information which is entered through touch panel or computer is sent to servo drivers in real time via PLC. Servo drivers, move to the desired position at the desired speed in accordance with position and speed information. As it can be seen in Fig. 4, servo motors move slowly to their destinations. In addition, a

servo motor starts its motion with increasing speed until reaching its maximum and it decreases its speed when getting closer to its destination. Servo motors move slowly to avoid sudden stops and starts that may cause errors or defects in the workpiece.

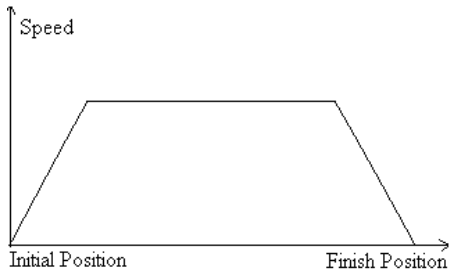


Fig. 4. Change of speed according to the actual position

Servo drivers send pulse signal to servo motors in order to move to desired position. This signal determines working condition of driver comparing real time data acquired from servo motors. The general working system of servo motors is illustrated in a block diagram which is given in Fig. 5 [1, 2].

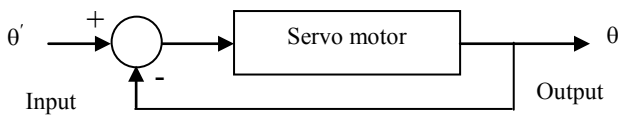


Fig. 5. Block diagram of Servo motor working principle

At the stage of position control; if the position angle and the aimed position angle are considered as θ and θ' respectively, then the magnitude of signal generated by driver circuit, becomes as the following

$$\Delta\theta = \theta' - \theta . \quad (1)$$

Interface Programme

Driver circuit is designed in such a way that it has required infrastructure for miscellaneous applications. In order to send user-entered data to driver circuit, touch panel and computer, that are compatible with PLC, are used.

Touch Panel Software

General block diagram of operating panel software is given in Fig. 6. According to the diagram, user can follow two different algorithms during the process, which is similar to the industrial applications. These algorithms are position and speed processes. Optionally, position and speed operations can be carried out simultaneously. Moreover, training set is user friendly by means of its tools. For example; login-logoff identities can be controlled by means of its system setting tool or by means of its user setting tool user operations can be dealt with and daily reports of all data can be taken thanks to the report tool.

Operating panel is a touch-screen panel, through which user controls the system and it is widely used in industrial applications. It can be thought as a kind of mini computer. In order to maintain user control of this developed training set, Easy View branded MT506S colored model operating panel is used (Fig. 7).

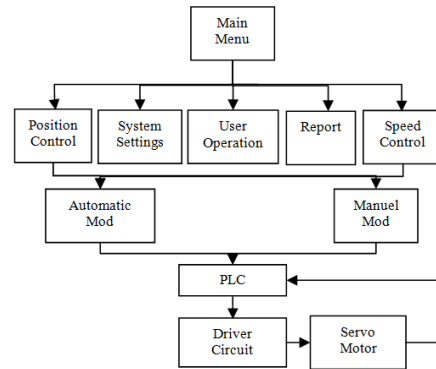
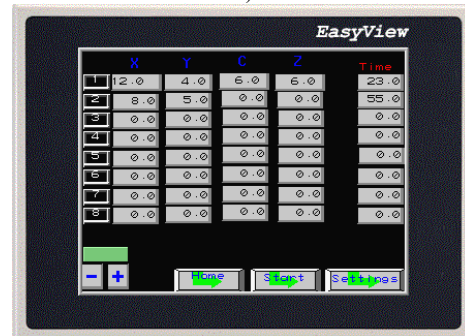


Fig. 6. General block diagram of touch panel software algorithm



a)



b)

Fig. 7. Touch panel: a – start up screen; b – automatic mode

As illustrated in Fig. 7(a), user can choose any operation in the start-up screen. In this screen with manual choice, position and speed data of each axis are entered one by one. However, in automatic mode, position values for movement should be entered for the four axis by means of the screen shown on Fig. 7-b in accordance with the example position information entered by user. “Time” field shows the duration of standing in a given position. A process ends after all terms of a row are being zero. In “JOG” mode, speed settings of servo motors are entered. All axes are moved to their datum positions in “Home” mode. In “Clock” mode time and date can be set, in “Event log” the information of logging users can be reached, in “Help” mode some information about the use of program can be found and in “Password” mode some settings related to password can be changed.

Computer Software

Conventional learning of digital system design is normally carried out by the help of a lecturer, laboratory

design studies and projects. Development of interactive computer software allows students to activate their theoretical design knowledge and lets them to design new circuits [7]. Students studying engineering subjects prefer simulation programs due to their positive effects on their education. These students stated that simulative learning is straightforward and attractive [8].

For the developed computer software, an object oriented language, Visual Basic and a database called MSSQL, which allows faster and comfortable processing of software data on local network, are used. MSSQL is installed to the server and tables of database are created on that server. The architecture of designed hardware system is illustrated in Fig. 8 [9]. Following the development of hardware architecture, MSSQL, which is a fast and reliable database, is used to store student-lecturer transactions, animations and example applications. In addition to being a strong API, providing database management control and locking capability, and also being a free software, makes it one of the most widely used and popular CGI script developers [10–12].

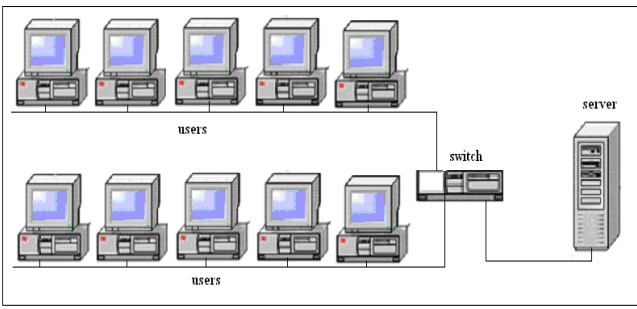


Fig. 8. Network topology of the system

The general block diagram that belongs to developed computer software algorithm is illustrated in Fig. 9.

As it can be seen in Fig. 10, a user that logs into the system as an instructor, can give the lecture on the network to his/her students using theoretical lecture notes that are previously added to the database. Furthermore, the lecturer can contribute the development of education by using animation and simulation techniques (Fig. 10(b)). After the lecture, the effectiveness and success of the theoretical knowledge can be assessed by making a quiz. Since all quiz grades of each student are recorded to the database, success of each can be graphed out at the end of each semester or any time desired.

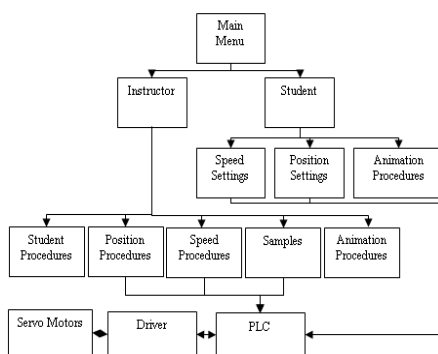
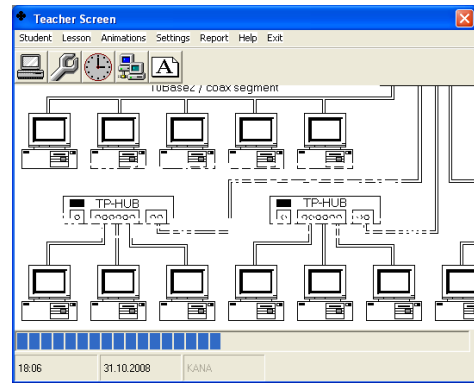
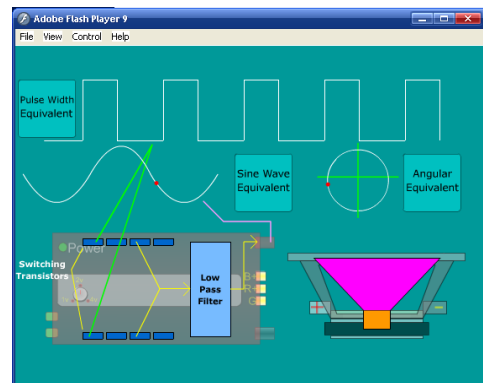


Fig. 9. General block diagram of computer software algorithm



a)



b)

Fig. 10. Instructor log in screen (a) and an example of animations (b)

The block diagram of training set, which consists of hardware and software, is shown in Fig. 11.

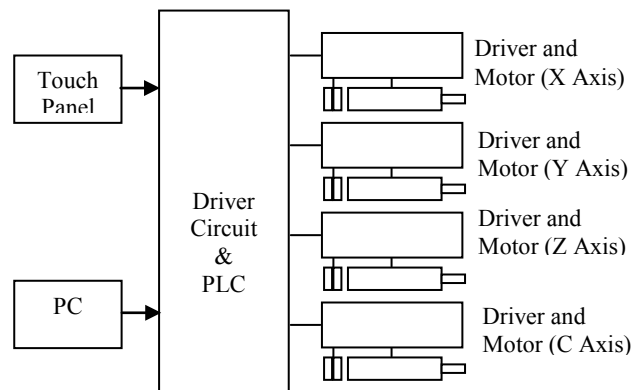


Fig. 11. Block diagram of training set

In Fig. 12 a product of a sample application can be seen. In the application, traces of the sample show that machining tool was operated on various positions during the process.

According to Fig. 11, touch panel or computer primarily communicate with PLC which lies on the driver circuit. User commands to the PLC addresses are transmitted in the form of electrical signals, makes servo motors to move at a desired destination with a desired speed. A photograph of developed servo-controlled training set is given in Fig. 13.

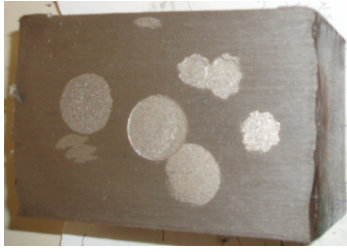


Fig. 12. One of the products obtained at the end of application

Advantages of the Training Set

Advantages of the above described training set can be listed as follows:

- It can be controlled bi-directionally; therefore many industrial applications can be taught. Thus, an economical laboratory is established
- A special driving circuit is designed for training set which is controlled either via computer or a touch panel.
- Training set can be controlled on the network.
- Enables lecturer to give theoretical information on the network
- Enables lecturer to test students on the network
- With the help of animation and simulation techniques learning is intensified
- Software of training set is capable of being updated without changing any hardware
- Computer software is prepared in installation format and can easily be loaded to any computer.

Assessment and Evaluation

Students who were enrolled to the course in the same period were divided into two randomly selected groups in order to examine the effect of training set on learning skills of students and accordingly assessment and evaluation were made based on interest in the lesson, performance and the changes in handcrafts. A training programme was prepared for each group and same subjects were explained in these programmers. Training set was used for the first group, for the second group the lesson was taught

theoretically on the blackboard. 56-hour training programme was applied to two groups each formed of 25 students.

Table 3. The student's attendance condition on group basis

Term	Number of enrolled students	The mean of attendance during training
1.Group	25	24
2. Group	25	20

As it will be seen in Table 2, 96% of the 1st group students attended class and the mean of attendance for 2nd group students became 80%. The interest of 1.group students in the lesson was 16% more than 2nd group students.

Performances of student groups who were asked the same questions during the education process and within the period and in the end of the period are shown in Table 4. Students who received 60 points out of 100 were regarded successful. The group using training set in Table 4 was 20% more successful within the period and 28% more successful in the end of the period than the group who is not using training set.

Table 4. Performance within the period and in the end of the period

Term	Number of students entering exam within the period	Number of students entering exam in the end of the period	Success rate within the period	Success rate in the end of the period
1.Group	25	25	%84	%88
2. Group	25	25	%64	%60

The number of experiments performed by the 1. group students with training set, no experiment was conducted by the 2. group. Thus, 1.group students gained the ability to conduct their experiments on their own and to use the training set

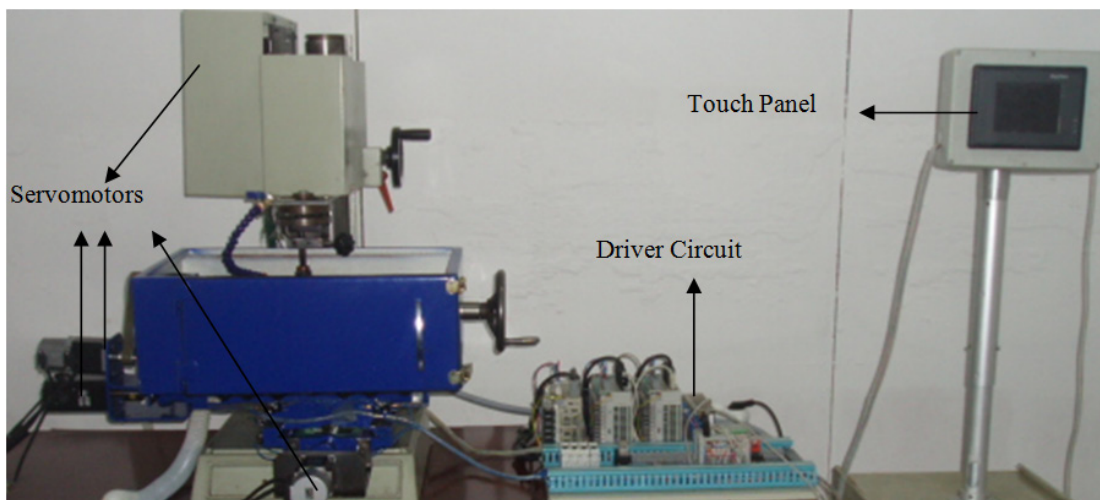


Fig. 123. Developed servo motor controlled education tool

Conclusions

It is admitted that learning of students of technical education can be improved with the assistance of training set. However, some mistakes that are made by students can seriously harm training sets, so that in some cases these tools become incapable of serving at all. For that reason, applications of these tools must be succeeded by making simulations just after giving the theoretical knowledge. This process is also important to see the results of students' actions on the system. Improvement of skills of students to control and to use industrial machines is dependent on development of their manual dexterity throughout their university education. Therefore, observation of controlling of the prototype will surely help them to reduce errors that may occur during learning and controlling applications. Generally the machines with automatic positioning capability in enterprises are very expensive to buy and it is necessary to allocate a certain budget for maintenance and repair costs. It is observed that the knowledge and skills acquired in this study provides machine maintenance and repair to be economical and to be quick as well as be beneficial to position control processes. This education tool provides economical and multi-purpose laboratory for education institutions.

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M. F. Işık, İ. Coşkun. Servo Control Education Tool for Industrial Applications // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 10(106). – P. 159–164.

In this study, a training set consisting of servo motors is designed to assist development of the students, especially who are in electrical, electronics and mechanical engineering, in industrial field. For this training set; three AC servo motors and one DC servo motor are used and four-axis control mechanism is generated. In order to control servo motors a special driving circuit is developed through which position and speed is controlled. These controls can be managed either via operating panel (touch panel) or via computer depending on user's purpose. In addition, a local network based training software is developed, which involves theoretical information regarding servo motors and allows testing opportunity and observing animations. Thus, a practical, functional and also economical training set allowing students both to learn and to perform many applications that they might be introduced with industrial field is developed. Ill. 13, bibl. 12, tabl. 4 (in English; abstracts in English and Lithuanian).

M. F. Işık, İ. Coşkun. Vykdyimo kontrolės mokymo rinkinio vaidmuo pramonėje // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 10(106). – P. 159–164.

Elektros, elektronikos ir mechanikos inžinerijos studentų įgūdžiams formuoti suprojektuotas ir sudarytas mokymo rinkinys iš pramoninių vykdomųjų variklių. Rinkinį sudaro trys AC ir vienas DC vykdomasis variklis su keturių ašių valdymo mechanizmu. Variklių padėčiai ir greičiui valdyti specialiai sukurtos valdymo grandinės. Variklių minėti parametrai gali būti kontroliuojami valdymo pultu ar kompiuteriu. Taip pat galima stebėti ir gauti informaciją per vietinį kompiuterių tinklą. Tokia mokymo sistema leis studentams įgauti praktinių žinių. Il. 13, bibl. 12, lent. 4 (anglų kalba; santraukos anglų ir lietuvių k.).