Original Article

DIDACTIC AUTOMATED STATION OF COMPLEX KINEMATICS

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ABSTRACT

The paper presents the design, control system and software that controls the automated station of complex kinematics. Control interface and software has been developed and manufactured in the West Pomeranian University of Technology in Szczecin in the Department of Automated Manufacturing Systems Engineering and Quality. Conducting classes designed to teach programming and design of structures and systems for monitoring the robot kinematic components with non-standard structures was the reason for installation of the control system and software.

Keywords: the automated station, industrial computer, Ethernet PowerLink, servo drive

INTRODUCTION

Certain experiments are too dangerous, difficult, or expensive to conduct in a classroom. However, the emergence of innovative technological tools yields some possibilities [4]. Educational theorists believe that robotics has tremendous potential to improve classroom teaching. Educators have started to generate ideas and develop activities to incorporate robotics into teaching various subjects, including math, science, and engineering. However, without research evidence to support their direct impact on students' academic performance, robotics activities may be just a "fad" [5].

The control system of the didactic automated station of complex kinematics has been designed and constructed in the Department of Automated Manufacturing Systems Engineering and Quality of West Pomeranian University of Technology in Szczecin, with student participation.

Developing construction of automated station has been ordered in Norwegian company IMS by Szczecin company SONION manufacturing medical instruments for people with hearing impairment [1]. Due to many faults in the control system, the company has donated the robot to university, where the construction was supposed to serve didactic or scientific purposes, thus the concept of adapting the construction to new control system on Bernecker&Rainer components.

Currently, automated station may serve as independent unit for didactic and/or scientific purpose, especially learning to program non-standard automated structures.

STATION CONSTRUCTION

The automated station is characterised by non-standard mechanical solution, presented in Figure 1. A station with two degrees of freedom allows manipulative operations in the space of 379×67 mm.

Station's construction is based on two arms: horizontal and vertical. There is a slider mounted on the horizontal arm, along which the body (actuator) moves; the vertical arm is fixed inside the body. Both arms are controlled with M1 and M2 motors, which, by means of axis gears, drive one cogbelt transmitting the drive and moving end "arm" of the machine, as presented in Figure 2.

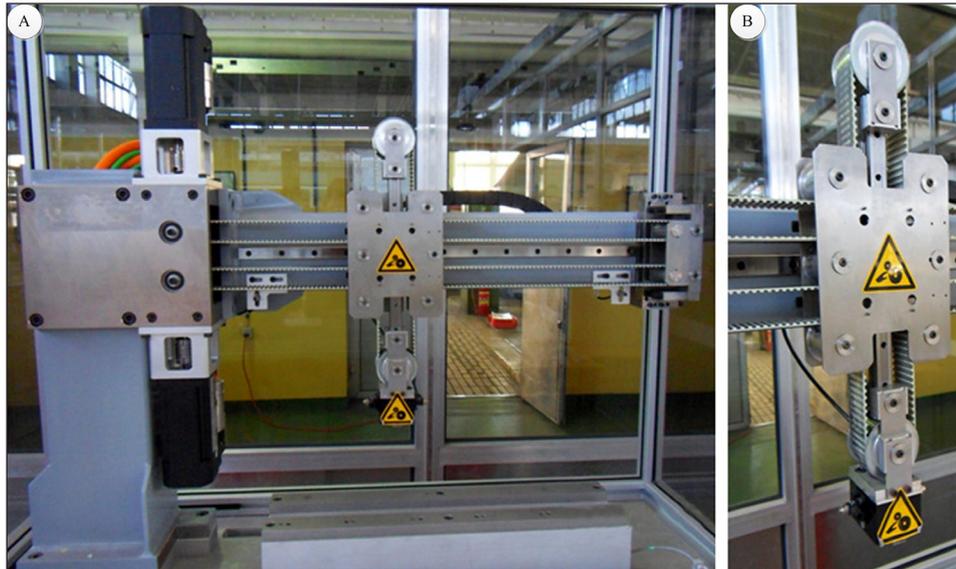The layout of cogbelts and pulleys provides proper „winding" ensuring proper movement of

Fig. 1. The automated station with complex kinematics; A) external appearance B) actuator
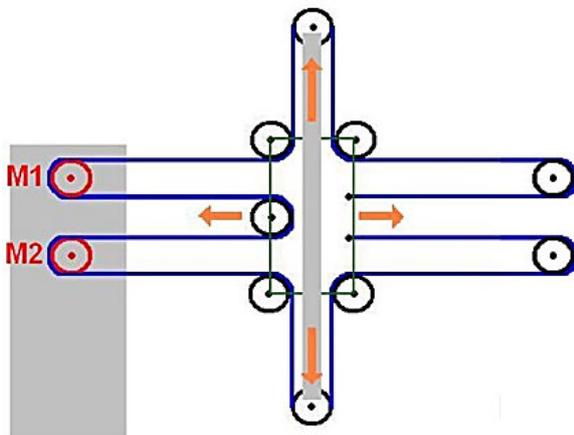

Fig. 2. Layout of the machine work

the arm. Both ends of belt driver are fastened in two points, as presented in Figure 2. Arm movement depends on movement and rotational speed of the motors. For the basic vertical and horizontal movements the engines must operate in the following manner:

- M1 right, M2 right – upward movement,
- M1 left, M2 left – downward movement,
- M1 right, M2 left – leftward movement,
- M1 left, M2 right – rightward movement.

The movement of actuator is thus a combination of the movements of M1 and/or M2 motors.

On the basis of abovementioned analyses, formulas have been developed for all directions, describing change of actuator's in the lower part of vertical "arm", based on changes in motor shaft position:

$$\Delta X = \frac{1}{2} N_{M1} - \frac{1}{2} N_{M2} \qquad (1)$$

where: N_{M1} and N_{M2} defines shaft position.

These equations proved significant for the whole project, as they allowed to develop translocation and movement at random angle.

The whole structure is encased in glass box and rests on a stable bench with control system installed beneath the bench.

CONTROL SYSTEM

For the developed structure of automated station, a new control system has been designed, controlling and supervising robot's work. The concept of control has been presented in Figure 3.

The control system contains: visualisation panel (industrial computer), servodrives, digital input/output modules and two synchronous motors of alternating current. The control system is connected to an industrial computer, where control software is installed. The program sends and reads control signals to and from servodrives and other modules with Ethernet PowerLink.

The system controls the work of synchronous motors of alternating current and cooperation with other devices, e.g. peripheral, robot.

The whole control system is based on a proper number of drivers (control modules) coupled parallelly. Basic version requires two servodrives and two digital input/output modules. All elements except visualisation panel are placed in control cabinet, as shown in Figure 4.
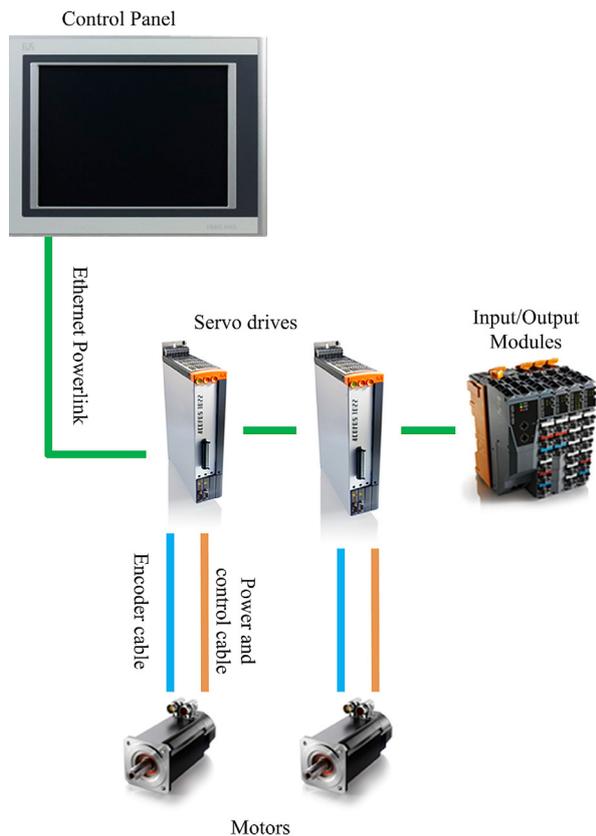
Control Panel

Fig. 3. Block diagram of control system

Fig. 4. The control cabinet

Fig. 5. Computer appearance; 1) slot for communication terminal, 2,3,4) sequentially – buttons for connecting, reset and diagnostics of computer 5) power jack, 6) USB, 7), Ethernet jack, 8) serial link RS232, 9) diode signaling the work of computer, 10-11) configuration switches, 12) card slot for a saved program, 13) battery socket backup memory.

The main foundation of control system is open module structure and free extension and modification of the control system. Control of automated station is unrestrained, depending on scientific or research aim and task, thus customized to the user's needs.

Industrial computer

Industrial computer is a driver integrated with PP420 panel manufactured by Bernecker&Rainer, presented in Figure 5. The driver has 15" colour touchscreen, with 32-bit Geode LX processor. TFT Green with 1024×768 resolution enables graphic display and the processor allows fast arithmetic-logic calculations with 400 µs time interval. To ensure fast transmission between servodrives and modules, additional interface Ethernet PowerLink has been used [2].

Servodrives ACOPOS

Servodrives ACOPOS 1016 series have been selected to control automated station due to their unusual flexibility in terms of programming. The outer appearance of servodrive is presented in
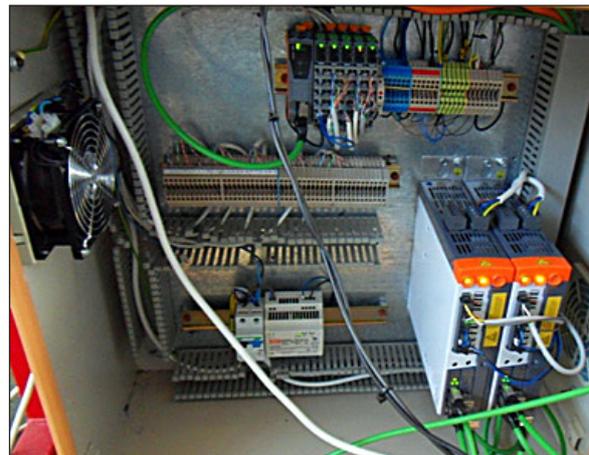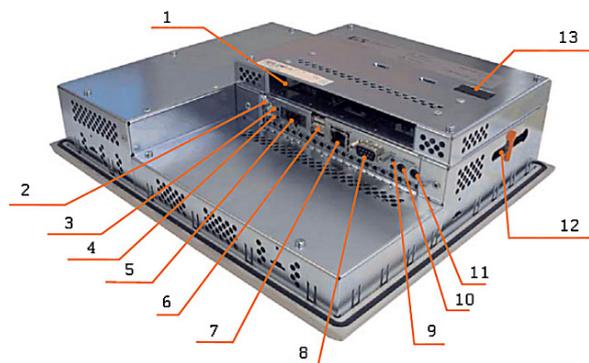
Figure 6.

Servodrive is powered by alternating current 230V and proper lead cap plate enables control, signal exchange with other servodrives and fast communication with industrial computer. Servodrives cooperate with all kinds of synchronous motors as well as the asynchronous ones with built-in encoders. The most significant advantages are:

Fig. 6. ACOPOS 1016 servodrive

- functional blocks, enabling realization of system of limit switches resulting in faster and more reliable work, independent of control program,
- movement system on *CAMAutomat* cams,
- possibility to implement virtual axes and drives synchronization,
- possibility to change key drive parameters directly from control program, using service channel,
- tools for testing and analyzing the work of the drive.

Digital input/output modules

All modules have similar external construction, which facilitates installation and simplifies replacement. The appearance of individual control modules has been show in Figure 7.

The whole module comprises of Ethernet PowerLink gate (Figure 7a) and digital input and output (Figure 7b).

The modules are connected to Ethernet PowerLink gate and communicate by its means, sending/receiving control signals to/from the industrial computer. The reaction speed of these modules is below 100 μs.
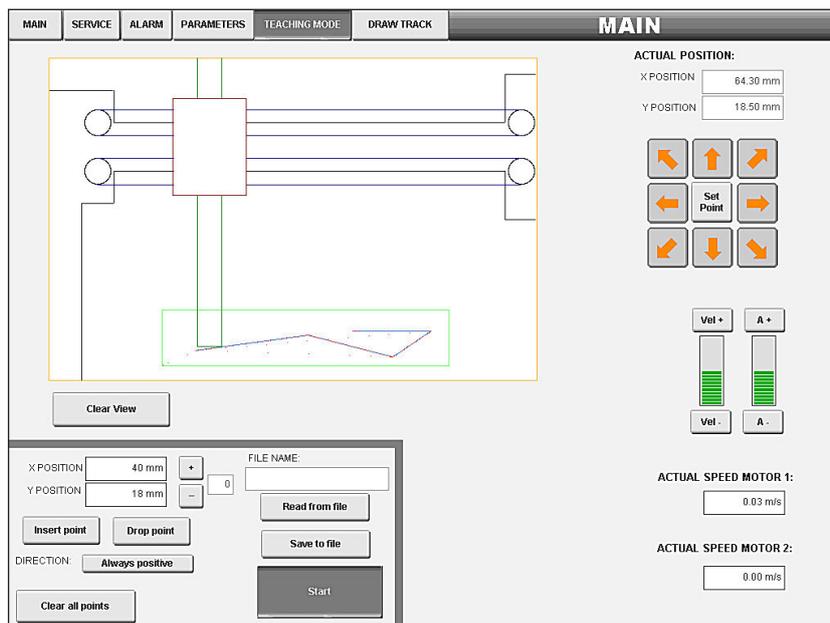
Each module has 12 clamps, where additional control signals can be connected.

Synchronous motors of alternating current

The actuator is a synchronous motor of alternating current, type 8LSA25, as shown in Figure 8. The motor has good dynamic parameters and built-in encoder.

Fig. 7. Modules; a) the PowerLink gate, b) digital input module

Fig. 8. AC drive

Fig. 9. The main screen of the control program

SOFTWARE

Program controlling automated station designed in Automation Studio 3.0 has been implemented into the developed control system. The operator communicates with the program using main touch panel. Complete control program contains six tabs, presented in Figutre 9.

The tabs are as follows: service screen, page displaying alarms on the station displayed automatically when error appears, screen showing changes in movement parameters and teaching and visualization of the robot.

Every tab is divided into three sections in order to establish communication with the automated station, placing it in base position, operating robot's positions database and writing program for the robot to execute.

The most advanced is the tab used for teaching movement path of robot arm. There are two methods of movement realisation. The first is based on sequential saving arm positions with cursors in the screen. The second option is teaching by drawing it on the screen. This method allows fast generating of complex trajectories.

Implemented program in visualization panel ensures easy and intuitive use. When using visualization panel, not only may the operator generate certain movements, but also change their

parameters, e.g. speed, acceleration, etc. Before activation of the robot, it is possible to verify previously loaded movement using virtual window. Additionally, the program uses interpreter of record/readout of the trajectory to/from the file, by means of so-called G-codes taken from CNC systems [3]. Exemplary G-code generated by control system has been published in Listing 1.

Listing 1. The sample trajectory in a form of the G-code generated by the control system

```
G01 X 0  , Y 0
G01 X 116 , Y 45
G01 X 46.9, Y 23.4
G01 X 155 , Y 23.4
G01 X 119 , Y 41.4
G01 X 91.0, Y 41.4
M30
```

Each program containing G code and X and Y position ends with M30 command, finishing movement of the robot. Additionally, in every line after X and Y positions it is possible to introduce parameter M0÷9 informing the system about interactions of control system with peripherals.

The concept of control system is based on main control algorithm, presented in Figure 10.

After activating industrial computer, main control algorithm runs reference positioning procedure and awaits operator's command. There
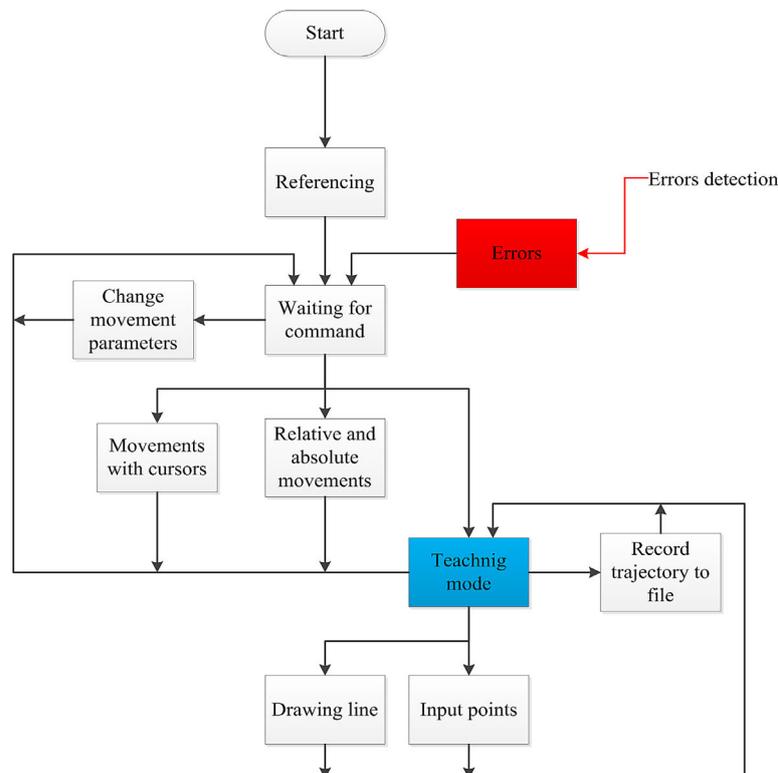
Fig. 10. The main algorithm of the station

are two modes of work available. Basic mode means sequential input of steps using control buttons on computer screen. The extended mode includes drawing paths with option of creating own trajectories.

Regardless of generating mode, each path can be saved/read on memory stick connected to USB1, as text file or G-codes. It is also possible to change parameters of movement, speed and acceleration. The program has a built-in alarm system informing about possible mistakes in the servodrive.

SUMMARY

Automated station designed and constructed in cooperation with student may serve as a learning tool for controlling and programming robots, but also enable realization of simple production processes for research application, including co-operation with real machines. It is possible due to the following features:
- Precision in robot's positioning allows precise manipulative functions.
- Control system with drivers based on PLC technology allows programming automated station using operator's panel or PC computer.
- Presented concept of robot construction and control system create opportunities for engaging students in development and, more importantly, experience-based verification of software, customized to user's needs.
- Control of automated station is unrestrained, depending on didactic aim and task, that is customized to the user's needs

The station enables conducting classes, mainly for Engineer and Master's Papers, related to programming, control and design of robots.

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