Web Controlled Pneumatic Press

Zvonimir Dabčević, Juraj Benić, Željko Šitum

Abstract:
The article describes a web controlled pneumatic press as an example of a system designed to demonstrate the control of pneumatic devices via the Global Area Network (GAN). System implementation is divided into several phases: (1) establishment of Internet protocol-based communication, (2) web application development, (3) reaction to events, analysis, and data display on the user's web page, (4) implementation of PID algorithm for force and position control of pneumatic press, (5) design and implementation of the human voice control system using artificial neural networks.

Keywords:
pneumatic press, force and position control, web-controlled system, voice-controlled mechatronic system

1 Introduction

The viral epidemic caused the interruption of regular contact classes in many schools and higher education institutions. Consequently, teaching at faculties took place exclusively at a distance through various web tools. This form of teaching at technical faculties has mostly influenced the performance of the practical part of teaching where laboratory exercises are in most cases replaced by video materials recorded by professors or assistants. The Internet no longer includes just computers. Today, many devices we use daily can be connected to the Internet including vehicles, machines, household appliances, and even parts of the human body. This system of interconnection of different devices is known as the Internet of Things (IoT). Illustratively, the Internet of Things can be explained as a giant network that includes many devices that collect and exchange information with each other. Such devices have a new level of digital intelligence that allows them to communicate and exchange data in real time without human involvement in that communication. The full potential of this technology will be visible with the introduction of the fifth-generation mobile network (5G). A scenario in which a patient from one country undergoes a very sensitive operation by a surgical team located in another country several thousand kilometers away from the site of surgery is still unthinkable, however with a significant increase in data rates with minimal latencies brought by the 5G network artificial intelligence algorithms have the potential to significantly change our lives.

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How a classic mechatronic device becomes a member of the IoT and what advantages such a system has are the topics elaborated in this article.

2 System components

Figure 1 shows a photo of the pneumatic press used for the experimental verification of the proposed study [1]. A pneumatic double acting cylinder (1) with 100 mm stroke and 50 mm bore is used as actuator to convert compressed air into mechanical power. A proportional pressure-control valve (2), SMC ITV3050, is used to control the pressing force. It has current type input signal in the range 4-20 mA for the pressure output range of 0-9 bar and gives an analog output signal in the range of 1-5 V proportional to the pressure output. The force acting on the spring (4) is directly measured by a disc load cell (5), type TAS606. Rated load of the load cell is 200 kg, while the maximum output is 7.5 mV when the sensor is connected to 5V power supply from Arduino Ethernet shield (9).

The Arduino Ethernet shield allows the Arduino microcontroller to connect to the Internet using a standard RJ-45 connection. It is based on the Wiznet W5100 Ethernet chip which supports up to 4 simultaneous socket connections (both TCP and UDP protocol) [2]. The board has a micro-SD card slot that can be used to store and send data over the network and has a reset button. The signal converter or load cell amplifier (3), type HX711, with analog to digital converter is used to amplify the load cell output signal. The position sensor (8) has a measuring range of 4 to 30 cm, which is suitable for this pneumatic press due to the height of the press and the deflection of the spring. The sensor works on a simple principle so that the infrared signal sent from the sensor hits the obstacle, and the

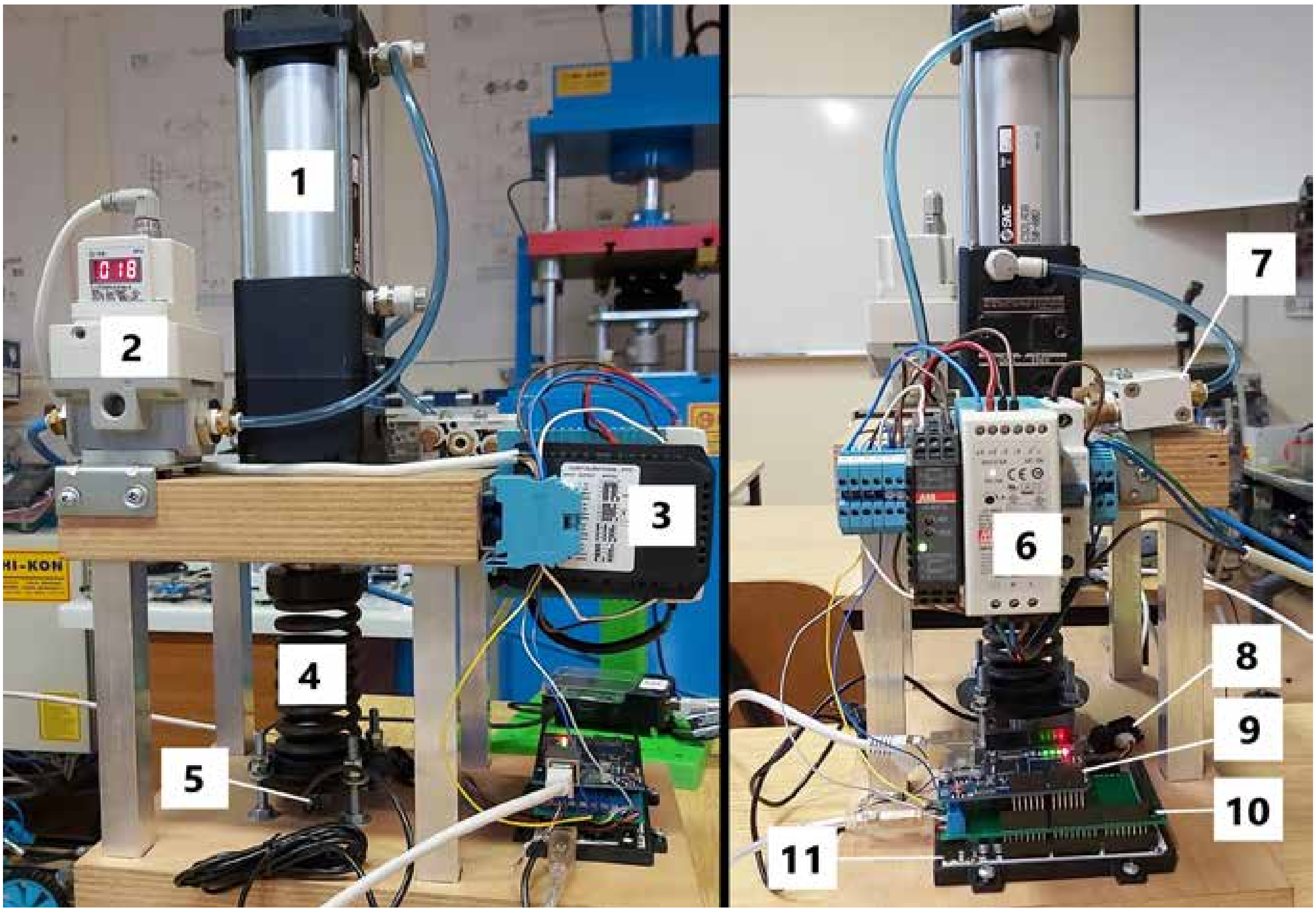

Figure 1 : *Pneumatic press: 1-Pneumatic cylinder, 2- Proportional pressure-control valve, 3-Signal converter, 4-Spring, 5- Load cell, 6-Power supply, 7-Monostable valve, 8-Position sensor, 9-Arduino Ethernet shield, 10-Printed circuit board, 11-Arduino MEGA microcontroller*

return analog voltage signal defines the distance of the obstacle (the closer the obstacle, the higher the voltage). The Arduino Mega 2560 microcontroller (11) is used for data acquisition and USB connection to a microcomputer Raspberry PI. A printed circuit board (10) is placed between the Arduino microcontroller and the Arduno Ethernet board for the purpose of their communication. The Raspberry PI microcomputer was used to implement live video streaming and to monitor the pneumatic press system during operation. The signal converter (3) is also used to convert Arduino 0-5V voltage output to 4-20 mA current input signal for the proportional pressure-control valve. Both the signal converter and the proportional pressure-control valve are powered by 24V power supply (6). The control software is encoded in C ++ and Python programming languages [2].

A Logitech C170 USB camera connected to a microcomputer was used for real-time video streaming. The TP-link router AC 750 is used as a network device to transmit data packets to the local computer network and this process is performed on the network layer of the OSI model. The TP-link router used in this setup is shown in *Figure 2*.

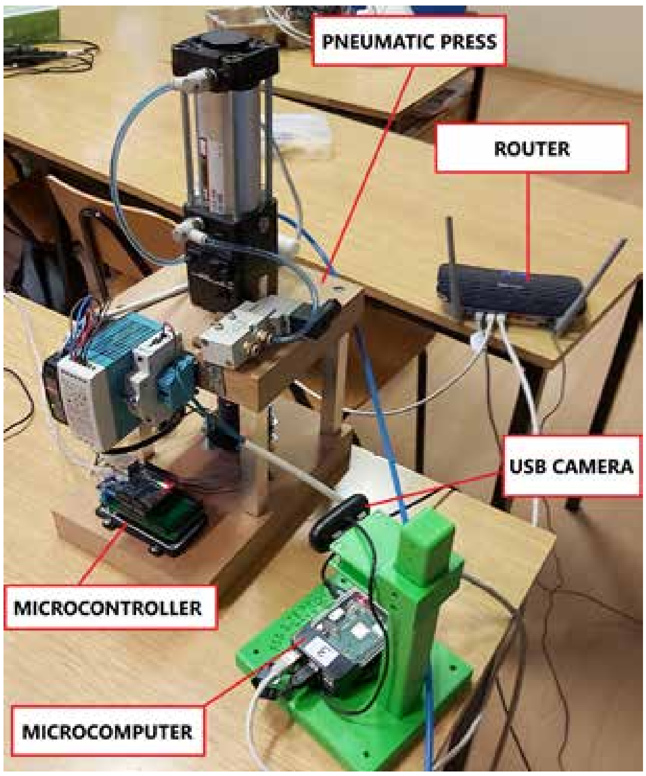

Figure 2 : *Devices connected to the local area network (LAN)*

3 Operational principle

The created web application contains two interfaces: for administrator and for users. The administrator determines the period of access to the web portal interface. To avoid a collision during control, only one user can control one pneumatic press in the period specified by the administrator. The options offered to the user during control are switching the pneumatic press on and off, selecting the type of control (force control or position control) and setting the force or position reference value. The user can define this option manually using the keyboard or mouse as well as using voice messages with the implemented neural network. User-defined data are sent to a web server located at the University Computing Centre (SRCE) which forwards the same data using socket communication (UDP protocol) to the external static IP address of the server located at the Faculty. From the static IP address, the data are delivered using a network cable to the router, which transmits the obtained data to the local network on the microcontroller. The microcontroller then unpacks and interprets the data, reads the type of control and the reference value defined by the user. Force and position sensors are connected to the microcontroller, which continuously measures the control values of the pneumatic press. Since the microcontroller has now information on the reference values, type of control and sensor values, then the voltage PWM signal is calculated using the implemented PID control algorithm. The calculated PWM control signal is converted by a signal converter into an input current signal for the electro-pneumatic proportional pressure valve which sets the pressure in the pneumatic cylinder. After receiving the data, the microcontroller responds to the received message, and the collected data from the position, force and pressure sensors is continuously sent in the opposite direction to

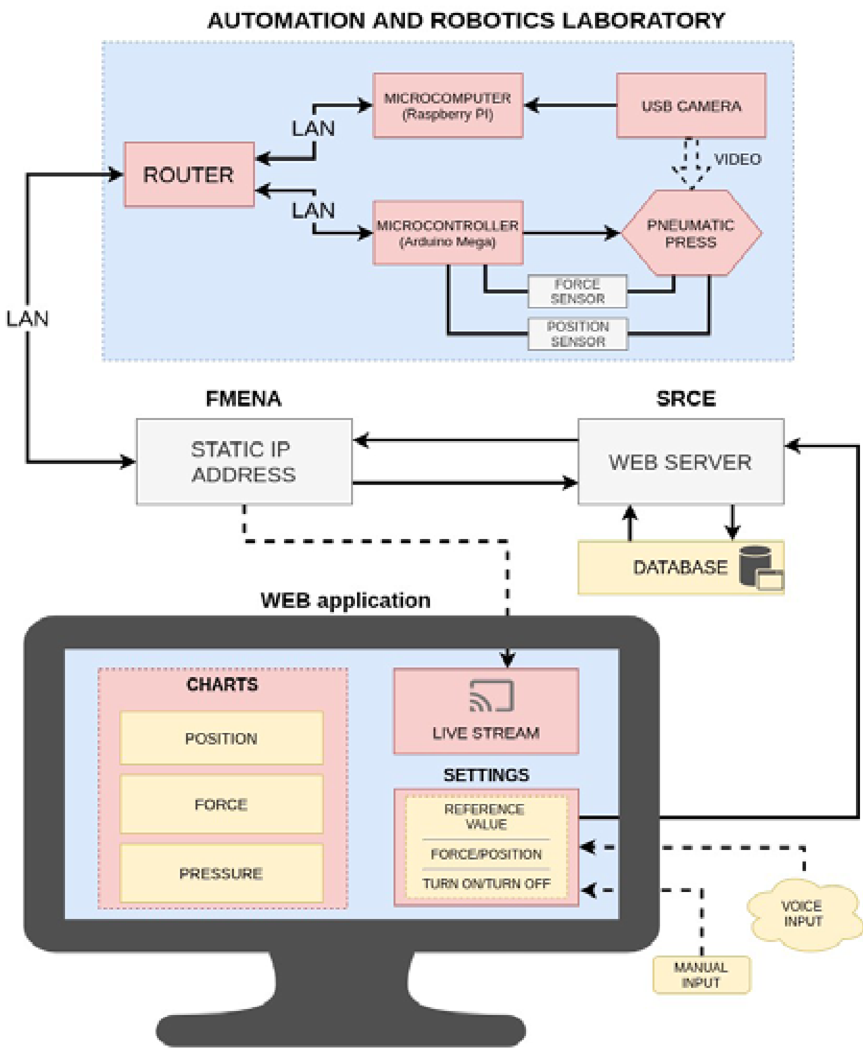

Figure 3 : *Block diagram of the web-controlled system*

the web server, where the data are stored in the database. Stored data from the database are constantly displayed on the web portal in the form of graphs, giving the user feedback on values from the sensors. Also, the user can continuously monitor the control process of the pneumatic press throughout the selected period with the help of a USB camera connected to the microcomputer. The microcomputer sends a video signal to the router, which forwards the received signal to the faculty server, and finally the live signal is displayed in the user's browser. The block diagram of the system is shown in *Figure 3*.

The microcontroller stops sending data after the user selects the option to turn off the press on the web portal or by exiting the web browser.

4 Voice controlled automation system

Sound classification is currently a very popular research area with numerous real-world applications. Considering recent research in the classification of images using convolutional neural networks, the same approach will be applied in this paper to the problem of speech recognition. [3].

The task of the neural network will be to recognize certain words. In this example, 7 words are defined that will be classified: 'down', 'up', 'position, 'force', 'stop', 'turn off' and 'turn on'. Since it was not pos-

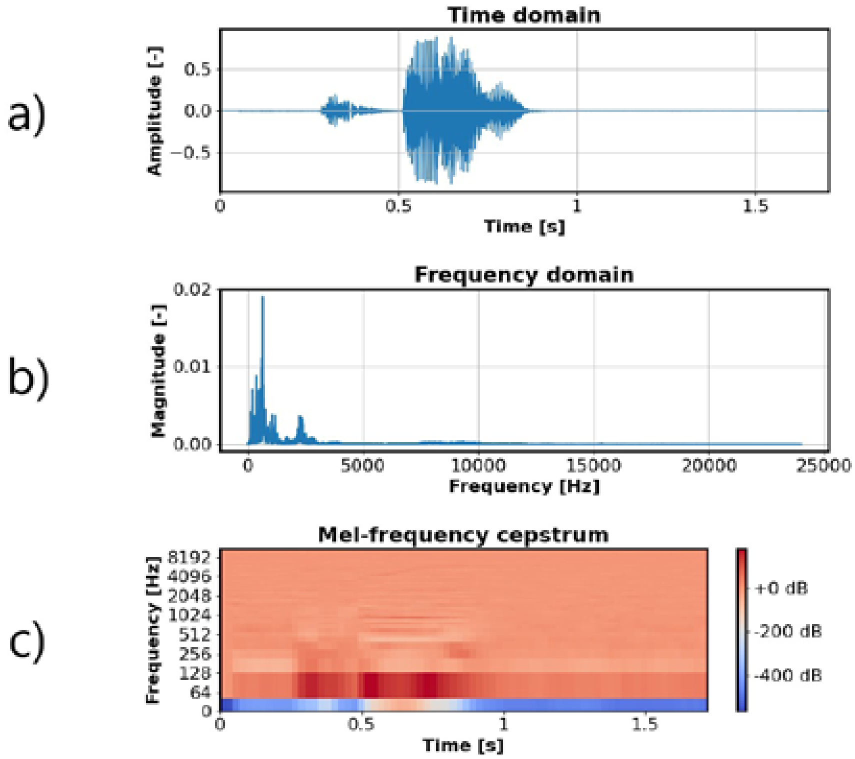

Figure 4 : *Speech sequence in a) time domain, b) frequency domain, c) mel-frequency representation*

sible to download a set of audio files of the listed words, the data was collected individually. For each word, 2000 sound samples were collected, which represent the input to the neural network. Patterns of the same words should have as much similarity as possible but should be as different as possible from other words to ensure the uniqueness of the commands.

The audio signal is first displayed in the time domain as shown in *Figure 4a*). Visualization of signals in the time domain is a good initial step for further analysis and improved representation of signals, however the amplitude-time relationship does not provide much information since we only read the amplitude of the sound signal from this graph.

Accordingly, signals from the time domain using a discrete Fourier transform are displayed in the frequency domain. Since the sound signals in this case represent human speech, it is normal to expect that these frequencies are in the range between 0 and 1 kHz, which dominate in human speech, as shown in *Figure 4b*).

However, time information is lost by displaying the signal in the frequency range. The time domain is important because it gives information of the order of the syllables, i.e., letters in a particular

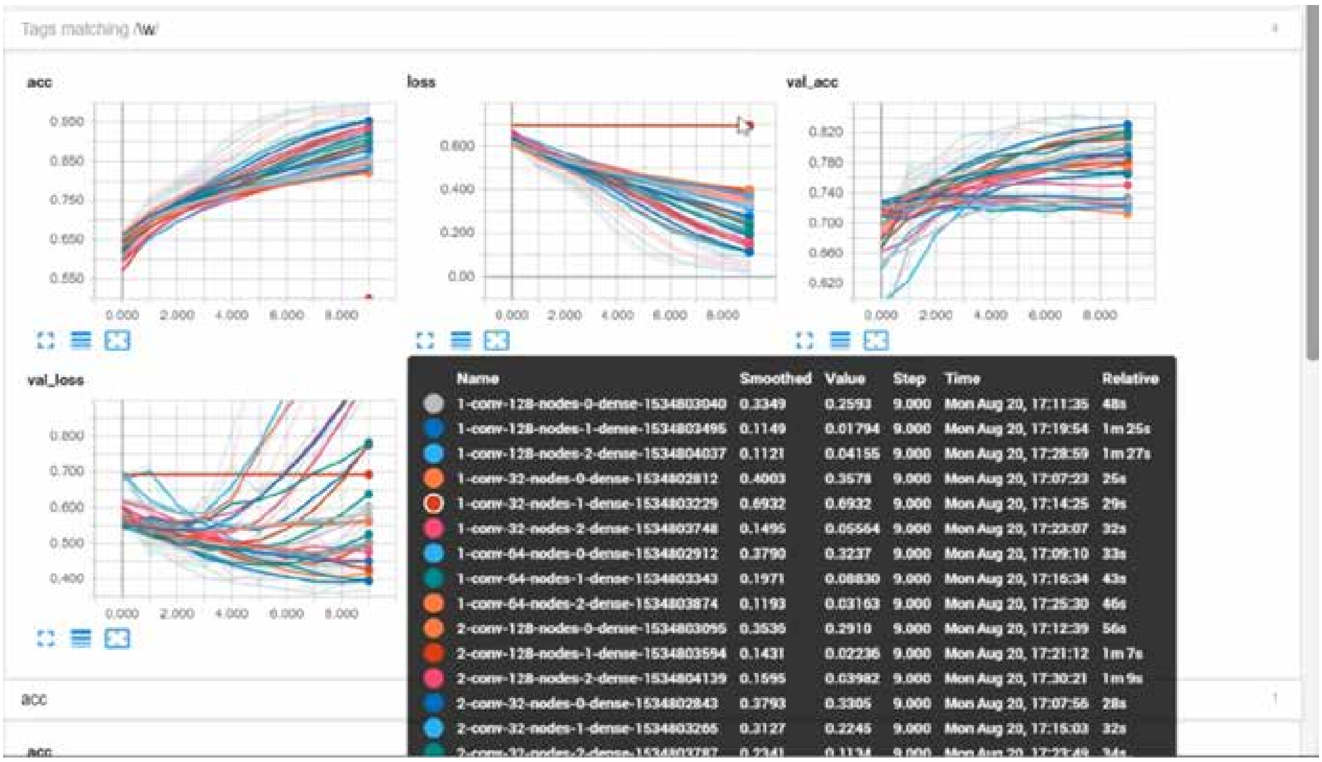

Figure 5 : *Comparison of neural network structures*

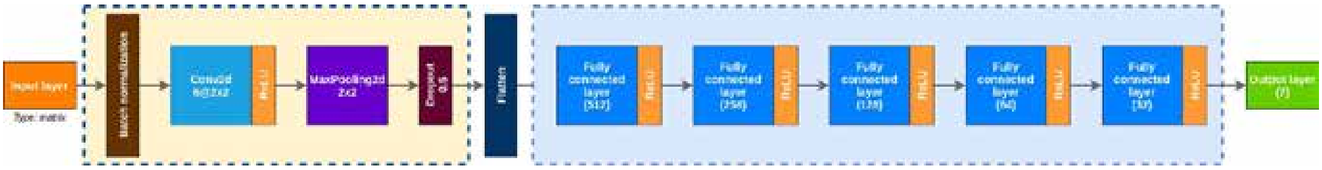

Figure 6 : *Neural network final architecture*

word. Therefore, signals need to be displayed not only in the frequency but also in the time domain.

The visual representation of the signal frequency as a function of time is called a spectrogram. The spectrographic representation of speech signals uses a linear frequency scale. However, in the analysis of speech signals, the term mel-frequency is often mentioned [4]. The mel-frequency uses a quasi-logarithmic scale to describe human speech more accurately. Signals in mel-frequency are given in *Figure 4c*), where the amplitudes of the recorded frequencies are shown in different colors. Thus, the problem of speech recognition data is translated into the classical problem of image classification, where sound data in the form of mel-frequencies are written in matrix form and represent the input to the neural network.

The neural network training process was performed for several different structures and the following parameters were changed: layer type, number of layers, number of nodes, activation functions and dropout values [5-6]. The structures of different neural networks were compared and the architecture with the best accuracy was selected. The comparison is shown in *Figure 5*. The chosen architecture consists of a single input layer, batch normalization layer, one convolutional layer with six convolutional filters of size 2 x 2, one max-pooling layer of size 2 x 2, single dropout regularization layer, five fully connected layers with 512, 256, 128, 64 and 32 neurons, and the single output layer (see *Figure 6*). The corresponding NN architecture is implemented in Python programming language (version 3.6.0), by using the Keras module [7] with Tensorflow [8] as backend. The stride property (i.e., the number of rows and columns traversed per slide) of the considered convolutional and max-pooling layers is set to 1. To allow more effective training of the network by mapping negative values to zero, non-linear activation function (ReLU) is used. For the purpose of training the developed neural network, Adam optimization algorithm is used with its parameters set to default values [9]. This neural network achieved the classification accuracy of 92.41% on the training set and 85.75% on the test set.

Figure 7 : *Control interface*

5 Web application development

In order to control the pneumatic press over the Internet, it is necessary to create a web application, in which the individual user (student) will define the desired parameters and start communication with the microcontroller. Also, it is necessary to disable the control of a single pneumatic press by multiple users, i.e., only one user can control one system in a defined period. A web calendar has also been designed to extend the application to several control systems in the laboratory, but to ensure that one user controls only one system in a defined period. Python programming language with web2py framework and SQLite database were used to create web application on the back end, while Bootstrap library (HTML + CSS) and jQuery were used on the front-end with three standard web technologies (HTML, CSS, JavaScript).

5.1 Control interface

The user can watch the live streaming video of the pneumatic press on the video window (1) in real time. The type of control is set by clicking on the desired button (3): force control or position control. Depending on the type of control, one reference value (2) is set. The maximum displacement reference value is 2.1 cm, while the maximum force reference value is 1000 N. By clicking on the button (5) it is possible to turn the pneumatic press on and off. Also, all these options can be started by voice, by pressing on the button (4) and saying one of the following words: 'turn on', 'turn off', 'force', 'position', 'up', 'down', 'stop'. The control interface is shown in *Figure 7*.

5.2 System login

To access the user interface, an individual visitor should first log in to the application. There are two types of login: as an administrator and as a regular user. Depending on the authority, one of the graphical interfaces is launched. The application system is shown in *Figure 8*.

5.3 Administrator and user interface

The web calendar of events is realized so that the administrator (professor) sets the dates, and students can choose one of the available time frames. The administrator can generate time frames to control the pneumatic press, an overview of the current system situation, and a list of students whose time frame has passed. The simple principle of generating time frames is enabled through several options located in the title bar. The offered options are: creating a time frame (single or set), deleting the assigned period (single or set), defining the number of users in the time period, defining the limit (the number of starts of the control process and the total time in which the press will be active), overview of all users in a certain period, possibility of their additional registration, defining IP addresses (from microcontrollers and microcomputers), press status (on/off), cleaning databases, video monito-

***Figure 8 :** Login system*

***Figure 9 :** Administrator interface*

ring of all active systems and automatic sending of messages to users via electronic mail if there is no possibility of performing the exercise in a certain period of time. The layout of the cover page of the administrator interface is shown in *Figure 9*.

The user has the option to select one of the offered time frames defined by the administrator. After logging in, a web calendar is displayed with all available time frames that are not filled or expired. The user can access the control interface only at the reserved time. If the reserved period has expired, the user does not have access to the control interface, but if the user has booked some future free period, the time to possible access to the interface is displayed.

6 Conclusion

The coming IoT technology will cause many changes in the existing way of producing material goods, as well as changes in the social, safety, medical, environmental, and other levels of human life. IoT offers quite large opportunities for the future, and companies are increasingly using this technology in their business that allows them to integrate large amounts of devices that have built-in sensors that communicate with each other and with various applications, and applications then communicate with people. Connecting physical devices, machines, mobile objects, and other laboratory devices, which collect, share and exchange data using Internet technologies provides completely new opportunities in the process of education at colleges where interaction (communication) is achieved in the implementation of online distance learning. In this direction, the demonstration of controlling the force and position of a pneumatic press using human speech, using advanced web technologies has been presented in this paper. A web application has been developed that includes communication between users with one typical mechatronic device, implementation of PID control algorithm, storage, and display of received data and implementation of control system using neural networks for recognition of user voice commands.

From such an example, a broad set of ideas can emerge that are even more complex and intertwined from different perspectives, with no inherent limitations to Internet applications and services, that will greatly change current paradigms in the college education process.

5 Literature

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Internetno krmiljena pnevmatična stiskalnica

Razširjeni povzetek

V prispevku je opisan postopek regulacije sile in položaja batnice pnevmatičnega valja stiskalnice, ki se krmili z internetom. Pnevmatična stiskalnica je povezana v internetno omrežje z mikrokrmilnikom. Tlačno zaznavalo in merilnik pomika sta povezana z mikrokrmilnikom. Tlak v komori pnevmatičnega valja stiskalnice se krmili s proporcionalnim tlačnim ventilom. Pnevmatična stiskalnica stiska kovinsko vzmet, ki služi kot sila bremena. Razvita je bila internetna aplikacija, ki omogoča več dejavnosti: a) internetno povezavo, b) izdelavo spletnega programa, c) odziv na rezultat analize delovanja stiskalnice in prikaz izmerjenih vrednosti, č) kontrolo algoritma PID-regulacije sile in/ali položaja batnice pnevmatičnega valja stiskalnice, d) realizacijo krmiljenja stiskalnice z nevronskimi mrežami s prepoznavanjem glasu upravitelja. Algoritmi regulacije in nadzora procesa se izvršujejo v realnem času. Razvita programska oprema pri tem skrbi za zajem podatkov z zaznavala tlaka in pomika, zbiranje podatkov s spletne strani, izračun krmilnih veličin in pošiljanje izmerjenih vrednosti v pretvornik signala ter pošiljanje povratnih informacij nazaj uporabniku spletne strani. V tem prispevku predstavljena pnevmatična stiskalnica se lahko uporablja za izobraževanje študentov na področju naprednih krmilnih algoritmov.

Ključne besede:

pnevmatična stiskalnica, regulacija sile in položaja, sistem, krmiljen preko interneta, glasovno-krmilni mehatronski sistem