The human-cobot collaboration in mounting and assembly operations in instrument making

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Abstract. The issues of collaboration between humans and cobots during assembly operations in instrument making from the point of view of metrological support are considered. The possibility of using specialized cobots in instrument making is shown. A study is described, which purpose is to develop a system that recognizes the actions of a human operator in order to increase the efficiency of collaboration between a human and a cobot when performing standard mounting and assembly operations. The system is based on an accelerometer attached to the operator's hand. The signals from the accelerometer for different operator movements are given. The principle of constructing a training sample for recognizing operator movements using an artificial neural network is shown.

1. Introduction. Human-robot cooperation approaches
Collaboration of a human and a cobot (collaborative robot) allows to maximize the positive synergistic effect of such a production system, realizing the advantages of both system elements and minimizing their disadvantages [1-6].

Approaches to human-robot cooperation in manufacturing operations include approaches to tracking human actions during production activities and the corresponding cobot’s response to them (figure 1). To track the actions of an employee, it is possible to use such technical systems as: video camera, accelerometers in combination with signal processing software. A video camera, in contrast to an accelerometer, is a more complex and expensive device that requires more complex signal processing algorithms [7-9].

The collaborative robot market is currently in active development. Major robot manufacturers produce models of cobot with a fairly large number of degrees of freedom. These cobots are universal and can be used both in manufacturing operations and for social interaction with people. The versatility of such robots can be considered as a disadvantage, since not all production operations require a large number of degrees of freedom from the cobot. For a number of instrumentation operations, it makes sense to design specialized cobots with fewer degrees of freedom and less cost. Such specialized cobots can already «out of the box» understand the actions performed by the operator, predict the consequences of these actions. Due to this, it is possible to reduce the production operations duration performed by the human-cobot system. Understanding human actions by a cobot is realized by recognizing human actions. For this purpose, a study was carried out, the results of which are given below.
Figure 1. Human-Cobot Collaboration in instrument making.

For the study, a laboratory setup was created (figure 2). The laboratory setup is a «Highscreen FEST XL» smartphone mounted on the experimenter's hand with the «Physics Toolbox Apps» preinstalled, which takes readings of the accelerometer and gyroscope chips in the smartphone.

Figure 2. Lab installation used in this study.

«Physics Toolbox Apps» uses mobile device sensors to collect, record, and export data to a CSV file. Data can be displayed as a graph with time dependence or displayed numerically. Users can use the application function to export the received information for further analysis in the form of a spreadsheet or graph. The application menu contains several physical parameters that the user can measure. An example of the CSV file structure with measurements generated by «Physics Toolbox Apps» is shown in figure 3.

Figure 3. An example of a CSV file structure.

2. The study description
The aim of the study is to measure the acceleration of a PCB assembler's hand using a smartphone accelerometer and software during various typical hand movements when performing production actions, such as: gripping an electronic component with tweezers, tightening-unscrewing a screw with a screwdriver, and soldering a component (figure 4).
Figure 4. PCB assembler movements to be tracked by the cobot.

Recording time is a few seconds. The program saves the performed measurements to a file in the smartphone’s memory. Then files with measurements are copied to a personal computer, data from the files are extracted and visualized using a script written in MATLAB (figure 5).

```matlab
d=csvread('paikaslow1.csv') subplot(3,1,1) plot(d(:,1),d(:,2)) grid subplot(3,1,2) plot(d(:,1),d(:,3)) grid subplot(3,1,3) plot(d(:,1),d(:,4)) grid```

Figure 5. MATLAB script that extracts data from a CSV file and visualizes them.

3. Visual analysis of experimental data
Figures 6-9 show the signals from the accelerometer installed on the operator’s hand during production operations. Accepted coordinate system: upper graph – X coordinate, middle graph – Y coordinate, bottom graph – Z coordinate. Abscissa – time in seconds, ordinate – acceleration in m/s².

Figure 6. Gripping a component with tweezers.
A visual analysis of the graphs shown in figures 6-9 allows us to come to the following conclusions:

- different operator actions are distinguished by different signals from the accelerometer,
• tremor of human hands is noticeable and can be a source of error in signal recognition.

4. PCB assembler’s action recognition system based on artificial neural network
Intelligent recognition of a PCB assembler’s movements can be realized using an electronic system based on artificial neural networks. In general, the recognition system can be implemented in the form shown in figure 10.

![PCB assembler’s actions recognition system based on artificial neural network.](image)

**Figure 10.** PCB assembler’s actions recognition system based on artificial neural network.

To train the artificial neural network shown in the figure 10 a training sample is needed, which formation principle is shown in figure 11.

![The principle of forming a training sample for the system shown in figure 10.](image)

**Figure 11.** The principle of forming a training sample for the system shown in figure 10.

5. Conclusion
To ensure the human-cobot collaboration, it is necessary to use an acceleration sensor and a microcontroller on a PCB assembler’s hand, which collects and recognizes information about the operator’s movements.

For the operator's actions recognition system to function, it is necessary to use all three coordinates of the accelerometer: X, Y and Z. A two-stage signal conversion is required: first, the signals from the accelerometer are read, then the received signal is analyzed using an electronic circuit (microcontroller) that recognizes these typical operator movements and controls the collaborative robot.

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