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Design Methods of Teaching the Development of Internet of Things Components with Considering Predictive Maintenance on the Basis of Mechatronic Devices

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Abstract

The paper describes educational approach to teaching through practice of robotics and mechatronics. The approach is based on regular annual competition organization, motivating students to take part in technical creativity projects with restrictions of real-life resource and team management. Within the framework of the research, the concept of a universal intelligent communication platform for integrated embedded robotics solutions is proposed, which allows connecting the decision module and heterogeneous sensor elements of the robotics navigation and positioning system into a single whole. The main attention was paid to the application features of basic universal designs that provide flexibility and reconfigurability of intelligent embedded electronic control systems and an opportunity of operational maintenance and predictive repair within the concept of "Internet of things". Typical results of practical appliance of this approach to teaching are presented in a few student projects related to such studies. The project's results may be easily implemented within the European Zero Energy Building, which opens wide prospects for exporting solutions.

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Keywords: Educational robotics, Project-based education, Interdisciplinary training, Mechatronics, Career guidance.

INTRODUCTION

The issues of operational control and predictive repair of intelligent embedded systems with the ability to process data in a single SCADA system are becoming increasingly important for monitoring the main parameters of engineering systems with timely notification of emergency and critical situations. The current state of education in the world confronts teachers, scientists and industrialists with an urgent task to find effective ways of knowledge transfer to future generations taking into account the real constraints of our time. The obtained solution could solve them all, but the question of whether this solution can be found just within the boundaries of only one direction remains open.

The authors present supplementary education approach and emphasize the possibility of pairing knowledge obtained in ordinary today's schools with a practice of actual real-world device design. As a testing ground for the implementation of methods for predictive repair in intelligent control systems, the Eurobot international robotic contest was chosen.

This work adds to the islands of existing student knowledge and skills forming a backbone of complex knowledge, useful for further studies and deliberate choice of a university and future profession. Simply put, the final destination for a student in the described competitive supplementary education approach is better self-orientation in the vast number of professional work areas and sufficient practical experience to find his/her place in any project team of interest.

The main objective of this paper is to show an alternative way of effective education process organization and student motivation. Main goals of this approach can be formulated as follows:

(1) the ability of the scholar to build a working complex mechanism, involving mechanics, electronics and programming in the building process;
(2) the ability of the scholar to work in a team, lead and manage a small team;
(3) the ability of the scholar to better orienteer in a broad spectrum of professions, understanding better what to expect from a university education.

Having years of robotic competition organization experience, the authors find it very appropriate and natural to motivate the young through participation in a team preparing a mobile robot to compete in a friendly and sporting spirit.

REVIEW OF LITERATURE

The practice of using robots in education is enormous. The most successful in terms of building a training program at the moment is the competition of mobile robots called Eurobot [1-4]. Competition rules suggest that the competitive cycle is repeated each calendar year. The cycle consists of the preparatory phase (7-8 months) and competitive phase along with some rest. Each cycle participants face 4-5 tasks of varying difficulty. The competition considers schoolchildren and university students; putting same tasks for both but allowing human control of the robot for younger ones (the robot should be autonomous otherwise). This way a scholar can take courses for several years being motivated to do better each year. The annual competition is gathering 7-8 months long students' work results. While main competences and ability to build a reliable solution to several tasks are revealed through gaining points in matches additional focus is formed around technical creativity [5].

While working on their robots scholars experiment a lot with mechanics. Modeling is performed with real materials or within a 3D computer environment. Depending on the technical level some work includes design and usage of electronics which most of the time leads to the need of programming [6].

At some point, digital fabrication environment becomes very important for further progress – a number of rooms connected with each other and forming common integrated space for students to work together at different competition tasks they choose. The typical machinery of such environment would include: laser cutter, 3D-printer, precise milling machine and freely accessible computer class [7-9]. Final grading of student results is performed in the form of a competition with team standings distinguishing better solutions. Intermediate competitions are possible within teams of the same class or different classes of different schools to grade students' knowledge [10-13].

The main value of this approach is a hand-on experience of scholars with better equipment allowing learning more complex techniques. In fact, some of the teaching classes given did not have any digital fabrication machinery at all, but at the same time the results were of a very basic, introductory level.

METHODOLOGY

The development and debugging of robotic solutions for participation in annual robotic competitions imposes a number of requirements on the constructive and software solutions used. The most urgent issues are the application of basic universal designs, flexibility and reconfigurability of the management system used and the possibility of prompt maintenance and predictive repair of objects of robotic systems within the concept of "Internet of Things". To achieve this goal, multi-agent technologies are needed. Each participant from the real world (i.e., each person and each device) is put in correspondence with a software agent – an object with some degree of intelligence.

Modern systems providing this set of functions do not exist, yet there are some similarities. Widely known automation systems based on KNX and HDL wired buses or Zwave and ZigBee wireless standards are often not equipped with required options and at the same time do not have priority important functions.

The software and hardware complex should interact with the following subsystems – power supply, universal chassis, navigation module. The software and hardware set should perform:

- monitoring of engineering systems (collection of information with the construction of graphs and temporary reports on current data);
- processing of the received information (calculation of maintenance, predictive repair and replacement of elements),
- timely notification and assistance in decision-making,
- remote control of engineering systems if such functionality is available,
- self-diagnostics of the main nodes; monitoring results should be transferred to a single cloud storage.

Within the framework of the work, the concept of a universal intelligent communication platform for integrated embedded solutions (including robotics) is proposed, which allows connecting the decision module and heterogeneous sensor elements of the navigation and positioning system into a single unit (Fig. 1).

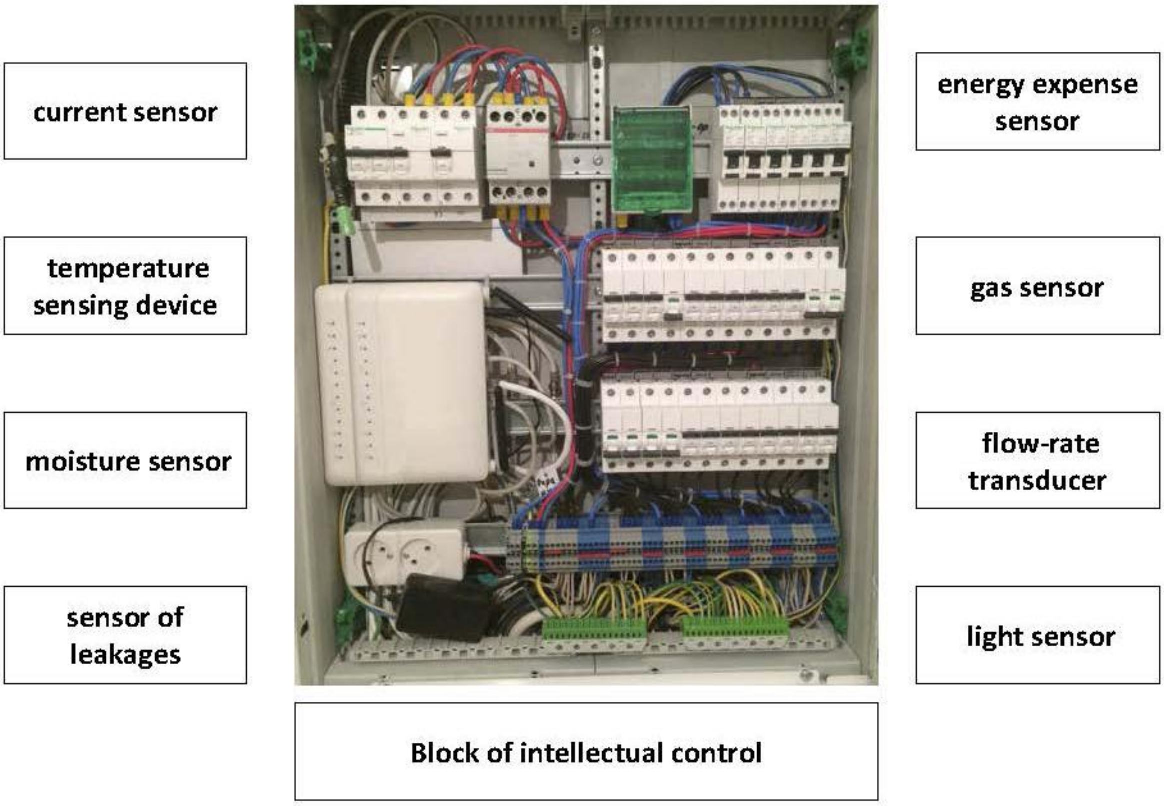

Figure 1: Universal communication module for embedded intelligent systems

In the “Internet of Things” paradigm, a subsystem is added to the hardware subsystems, which allows transferring computational tasks directly to the devices and the actuators, and transmitting the processed data to the data collection and storage station. This task can be solved with the help of universal controllers. Such controllers have sufficient computing power to perform tasks not only of processing data received from field devices, but also those requiring the implementation of complex calculation algorithms. Universal controllers can function as a buffer memory device: all measured and calculated values are recorded to the controller memory and stored for the required period. Thus, even if communication with the data collection station is lost, they will be buffered, and then transferred to the server when communication is resumed.

When solving practical problems, special attention should be paid to ensuring that the created software and engineering solutions are scalable and expandable to localize solutions for specific parameters. One can identify the following tasks, which should be addressed at the hardware level (controller level):

1. transfer of signals from field level devices (sensors) to engineering units and transfer of information to a data collection station;
2. implementation of algorithms for calculating physical quantities to take into account the obtained data;
3. control of technical systems, both taking into account the embedded algorithms, and at the direction of the head station;
4. generation and transmission of warning and alarm signals.

The tasks of the data collection station (processing module) can be described in more detail as follows: structuring and formalization of measurement information, accumulation of the dynamics of changes; processing and analysis of incoming data; analysis of the results of processing to identify non-typical behavior and search based on the results of an analysis of the list of possible causes and factors that may lead to the development of contingencies.

In general, the information obtained may contain noise and be heterogeneous which requires applying mathematical methods to the data obtained, such as estimating the average value of the observed random variable, estimating the probability of a random event by frequency, estimating the necessary number of experiments to estimate the probability of a particular event, analyzing and clustering parameters, and others. The deviation analysis can be performed using both the simplest threshold values and the analysis of the data set [2], when each parameter is separately within the allowable interval with a given uncertainty [14, 15], and the set of values indicates the development of an abnormal situation.

The most effective recursive algorithm for predicting processing is the Kalman filter [2]. The system recognizes specific situations occurring at the test site, and reacts to them according to a previously modeled scenario of actions. One system is able to control the behavior of others according to a predetermined algorithm. The Kalman filter (FC) is an effective recursive filter that estimates the state vector of a dynamic system using a series of incomplete and noisy measurements [16, 17] (Fig. 2).

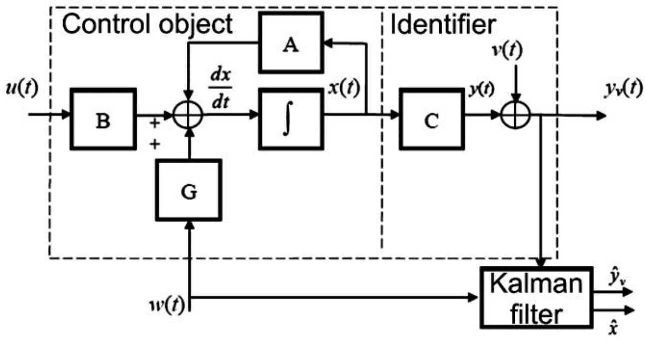

Figure 2: Kalman filter scheme for design of data processing systems for robotics

Through this functional, the collected information will be processed to analyze the forecast of predictive repair of engineering systems equipment and their components.

RESULTS AND DISCUSSION

The approbation of the proposed model for development and operation of embedded intelligent systems in conditions of flexibility and reconfigurability of the control system used with an opportunity of operational maintenance and predictive repair was carried out based on the development of intelligent robotic systems for Eurobot annual international competitions.

The work of the authors is associated both with pupils (schoolchildren) and with university students. Search for an effective training program led the team to the competition approach, as a very powerful driver of knowledge and skills transfer to the younger generation. Solving same tasks differently leads to interest and intercommunication and in the end – a sort of a natural self-education.

Training courses are built around competitive tasks in this case, and a teacher is involved in the development process along with the students, without having a specially prepared solution for any of the tasks.

The choice of a mobile robot as an object of study and in fact as a result of training is due to its educational versatility. Competitive approach adds teamwork on a real project with real deadlines, which leads to the study of subjects such as project management and resource management. Below there will be presented some of the results obtained by those who took the proposed “competitional” training for 4-5 years while learning in secondary school. The age of the projects' authors presented is between 15-17 years.

A mobile robot

A very natural result of each educational year is a mobile robot used to win a competition. Below two robots are presented: one is common for juniors, who control robot actions with self-made control panel, and the other is performing tasks autonomously.

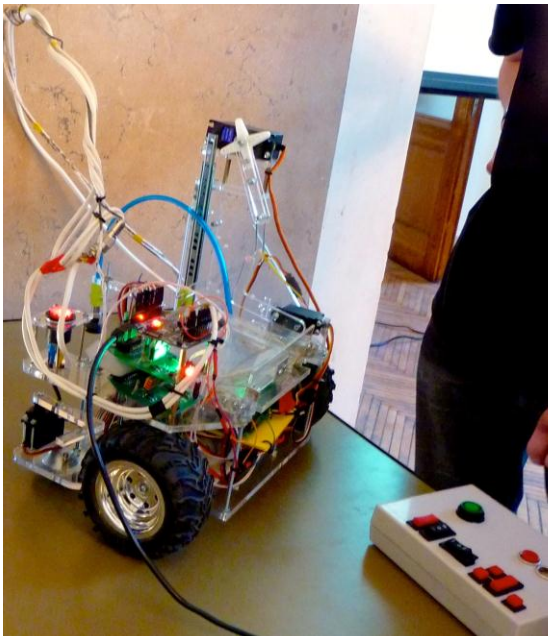

Figure 3: Human-controlled robot design for the competition

Figure 4: Autonomous robot designed for the competition

Both robots in Fig. 3 and Fig. 4 were prepared for Eurobot 2014 competitions. Robot in Fig. 3 is autonomous and was built by a secondary school team. The robot won the 3rd place among university student teams on an International Final in Dresden, Germany (6-8 June 2014) being the youngest (in terms of team member age) to participate in this difficulty level.

Precise milling machine

Working with machinery is an important part of any modern hands-on experience. Normally scholars taking the proposed training course use several types of such machines in their everyday work. While working on machines, students learn how they operate and sometimes discover and propose improvements. One of the most noticeable facts about the competition phase is that most robots look and operate differently. The ability of scholars to choose solutions themselves leads to unique mechanisms. This diversity is presented in Fig. 5-6.

Figure 5: Professional Roland precise milling machine (prototype)

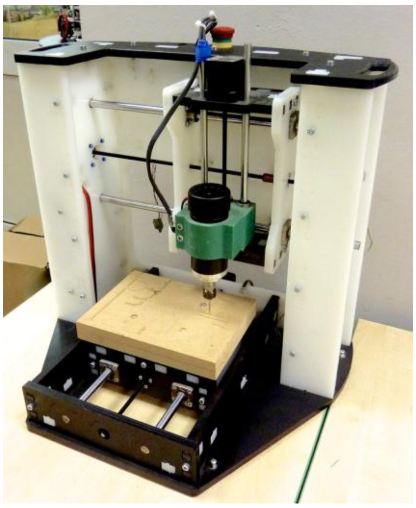

Figure 6: Custom precise milling machine design

3D-printer

Age of personal digital fabrication started with open hardware approach presenting the first affordable self-made 3D-printer (Fig. 7). It is possible to reproduce one once you have the needed fabrication machines and the digital file with technical drawings.

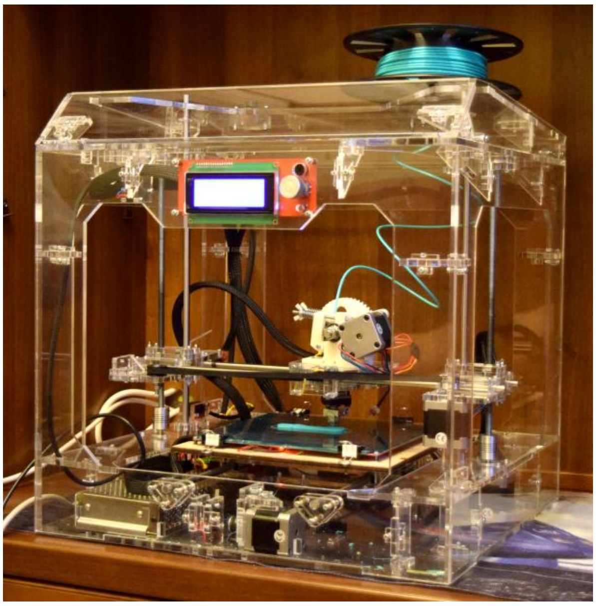

Figure 7: Custom 3D-printer design

Being an object for learning best engineering practices itself the 3D-printer presented in Fig. 7 also served its author, a student graduating from secondary school, as the source of custom robot parts for robotic competitions he participated to for several years.

Convertiplane

Convertiplane has a number of key characteristics, giving it an advantage over other types of UAVs: airplanes and multi-copters (multi-engine helicopters). The author, who had previous several-year experience in wheeled mobile robotic competitions, was asked to take part in a project in a completely unfamiliar design area – design of an aircraft.

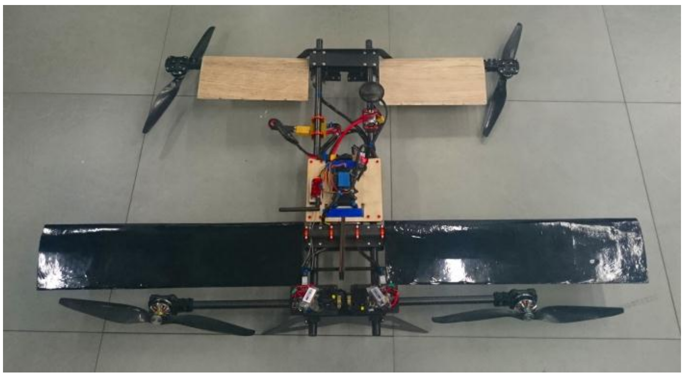

Figure 8: Convertiplane project

Robotics being a vast field of practical and theoretical knowledge forms a very good basic potential for young engineers in new projects not directly connected to robots. Convertiplane project presented in the picture above could be one of such sophisticated projects extending 2D plane movement to 3D navigation. Successful project participation shows potential schoolchildren gain in competition robotic education approach.

The results of the project can easily be applied within the framework of the European standard Zero Energy Building, which opens wide prospects for the export of solutions. One cannot but note the social significance of the project results, since the reduction of the received data into a single SCADA system will allow monitoring of the main parameters of engineering systems with timely notification of the emergency and critical situations. Thus, the result of the project forms a new look of the system for the synthesis of flexible robotic solutions.

CONCLUSION

The proposed integrated software, engineering and design solutions for the creation of a single universal robotic platform allow the collection of information from various sensors, monitoring, remote automated or independent control of engineering modules, as well as working with regular events for their servicing and estimating the need for predictive repair in order to determine the time of replacement or service maintenance of objects (elements) of the system's robot systems (including in competition conditions).

Practice shows that 3-5 cycles of participation for schoolchildren in the competition of Eurobot Junior, regardless of the participant's age, allows them to jump into the university student competition and perform no worse than many teams of university students of older age having no such experience. This actually leads to learning the basics of university programs even before entering the institution itself providing universities with interested and motivated students with vast practical experience. This way the role of a university becomes clear for its applicant – it can fill the missing systematic theoretic knowledge for better problem solving and broaden the horizon of specialties to better orient in collaborating teams. The project results may easily be implemented within European standard Zero Energy Building, which opens wide prospects for exporting them.

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