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Discovering mechatronics with children

Introduction

Universities of Children are a new form of developing the interests of children by regular meetings at universities and other institutions of culture (e.g. at the Pedagogical University of Cracow or in Wadowice Culture Center). During this meetings, 5–11 years old children have the opportunity (sometime the first one) to get in contact with technology, science and humanities. Their live interest is a good reason for organizing such university meetings, which can be seen as an experience opposite to the virtual education in cyberspace – learning without direct contact with physical reality. Themes and methodology of the classes are matched to the age of young students.

In the present work the technical classes, called "Discovering mechatronics with children" are presented. It allowed children for a contact with modern, programmable mechanical devices. The participants of the experiments had an opportunity to observe operation of various robots, and computerized numerical controlled machine tools. The classes was lead by scientists and technicians, who guided participants how to operate and control the devices, and presented the theoretical basis of machine's operation. The sections of the paper describe an independent exercises devoted to different devices.

Lego Mindstorms mechatronic toys

A popular Lego bricks as the basis component for building a simple mechatronic toys and learning a simple programming. They are equipped with sensors, engines and central processing unit. Sensors provide the contact between the toy and environment, the signals from sensors are processed in central unit and a result of computation are an electrical signal sent to executive elements, which are stepper motors.

The available sensors are:
- ultrasound distance sensor with 1cm-precision,
- touch sensor detecting even a gentle touch,

- grayscale sensor – recognizes colors in grayscale, operates in the predefined range of lightness (lower and upper threshold),
- RGB sensor; recognizes colors, operates in the predefined range of lightness for each of 3 colors (lower and upper thresholds),
- digital sound sensor; operates after crossing the predefined threshold.

Executive elements are:

- 3 stepper motors, user can choose a direction, angle of movement, number of turns or time of turning,
- speaker – allows generating simple sounds and playing a recorded and programmed small sound files,
- display – allows displaying simple graphics or a few lines of text.

During the laboratory classes students learn simple maintenance, principles of functioning, simple programming and building working toys. The principle of programming is easy. It relies on dragging the function blocks using mouse (for example, blocks associated with the operation of the sensor or associated with the movement of the engine) in the workspace Lego bricks software. In addition to the function blocks that support the sensors and actuators also available are:

- loops (finite and infinite),
- cases/switches.

The aim of the exercises is to assemble and program a robot using Lego bricks. Basing on them we can build several sets, involving robots responding to the appropriate incentives: touch and change of distance, mobile robots, dancing robots, etc. During the classes with children, the stage of construction and programming is skipped because of their age. The programmed sets are presented to children and their principle of operation is explained. Using an available bricks one can build:

- vehicle controlled via Bluetooth (Fig. 1). The vehicle has the possibility of moving forward, backward, and it is able to turn. It uses two engines. The vehicle can be on wheel or a caterpillar track, depending on the idea. The central unit has a built-in Bluetooth receiver. To exploit its full functionality, it is necessary to have a Lego software installed on the Android-based phone.
- autonomous vehicle. This vehicle is not controlled by the user but it moves autonomously, avoiding detected obstacles.

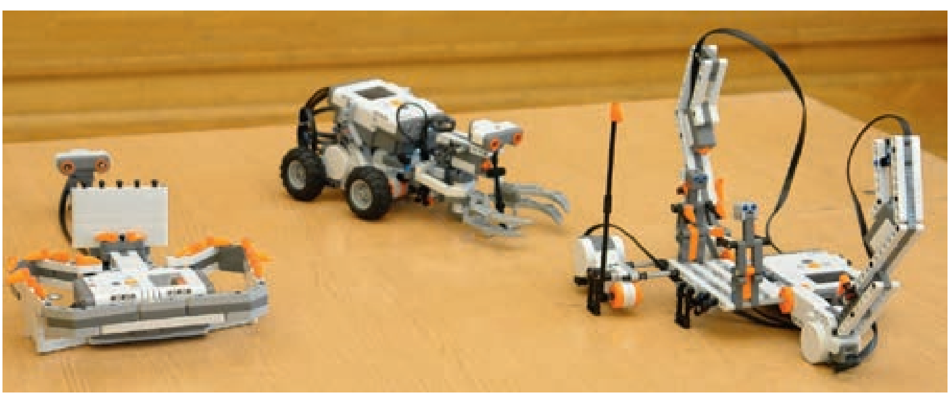

Fig. 1. Various mechatronic toys composed of Lego bricks (from left to right: guitar, a vehicle controlled by Bluetooth, arcade game)

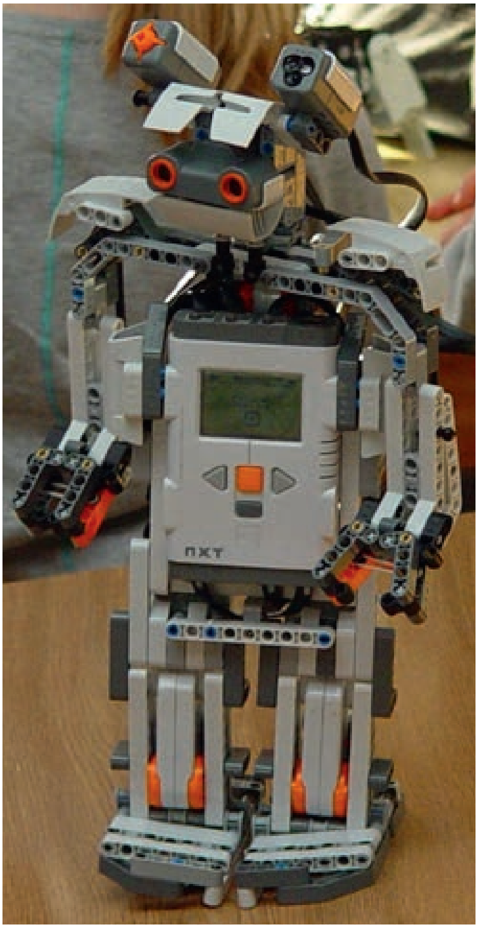

Fig. 2. Humanoid robot made of Lego bricks

- Arcade game for two people (Fig. 1),
- electric guitar without strings (Fig. 1). Instead of strings a sensor is used, and on the basis of the measured distance, CPU generates a programmed sound,
- humanoid robot (Fig. 2).

Bioloids

More advanced mechatronic systems are built up the from the sets produced by Bioloid company. Available parts consists of 18 servo drives, equipped with engine shaft position control, programmable central unit and a powerful set of sensors (e.g., sound sensor, color sensors, distance sensor and others). This set has great capability for programming, for example a particular response can be matched to the certain number of hand claps. Additionally, these systems can be modified or reprogrammed to create a new one. Only imagination is the limit. Programming environment allows for:

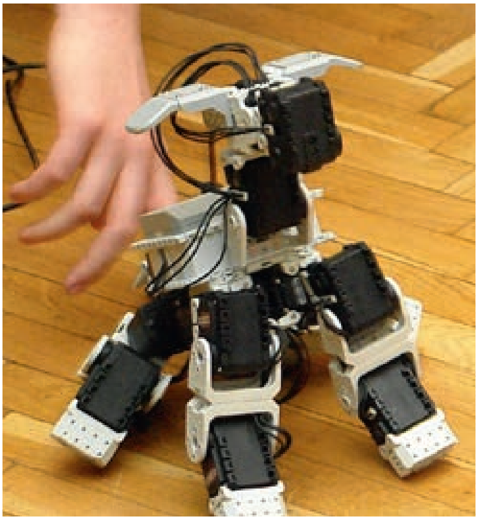

Fig. 3. Robot-dog made of Bioloid elements

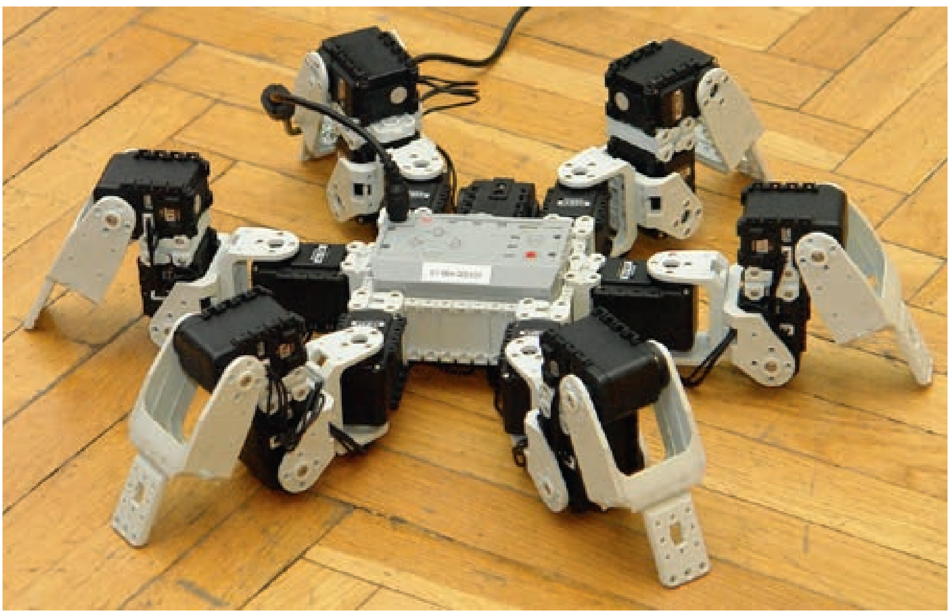

Fig. 4. Robot-spider built-up from elements of the company Bioloid

- programming the movement sequences (requires to build robot exactly according to the specifications in the instruction manual), suitable for beginners and for those who are starting their adventure with Bioloid robots. Thanks to the use of robot movement sequence the results are easier to obtain.
- ladder programming intended for medium-advanced programmers. The robot can be built freely, you do not need to use the propositions from the operating instructions. This type of programming can be used to modify the factory functions and movements.

- command line programming is intended for advanced programmers. The developer has full and conscious control of the signals and processes inside the central unit.

For the purposes of classes the two predefined units have been built: a robot-dog (Fig. 3), and a robot-spider (Fig. 4). Depending on the type of input signals in both cases devices are programmed with different reactions.

The input signals are:

- hand claps (up to a maximum of 4 claps),
- signals from the buttons on the main unit.

Because of the complexity of the robots and software implementation, the order of the input signals is crucial. That is, for example one clap proceeded by two claps calls different reaction than the reverse sequence of claps.

Wide programming capabilities allow for organizing a Bioloid robot contest. For example, the World Football RoboCup was held in in Istanbul, Turkey. The team was made up of RoboCup-Bioloids. The aim was to get as many goals as possible in a given time.

Gyroeggs

Gyroeggs is an advanced mechatronic toy (Fig. 5).

Gyroeggs provide an example of a toy using accelerometer and sensor of position relative to the Earth's surface. The principle of operation of this toy is the same as for Segways, a two-wheel urban electric vehicle of the future. Accumulators providing power are placed inside. On-board computer controls the vehicle so as to prevent it from toppling. Gyroegg retains vertical position regardless of the inclination of the ground. It is controlled with the included wireless radio remote control. University of Children classes are conducted using two such devices:

Fig. 5. Gyroeggs

– obstacle course. There was a track with the marked path. The track was characterized by variability and had a banked floor. The goal for the user was to travel through the obstacle course in the shortest time possible.
– soccer on a miniature football field. Two competitors participated, each controlled one Gyroegg. The aim of the game was punching the ball into the opponent's goal. The person who achieved more goals than their opponent won the match.

Kawasaki robot arm

Modern industrial plants need an automated production lines operated by robots in order to increase their efficiency and quality of production. These lines were constructed and are programmed in such a way as to eliminate the physical work of man. Man oversees these devices, programs them and provides maintenance. The Institute of Technology of the Pedagogical University of Cracow owns one of the links of such a production line, the Kawasaki robot arm. Laboratory classes are taught to handle and program the arm. The gained skills can be used for programming the industrial robot for any company, because the principle of programming is the same. The only difference is software and a programming language. During laboratory classes students will get acquainted with the possibilities of mobility and safety conditions of the mechatronic devices of this type. Typical tasks performed by students are lifting and moving objects using the electromagnetic gripper, and writing simple program to perform industrial tasks. All Kawasaki robots arms consist of three basic parts:
– arm with 6-degree of freedom with working tip attached to the last axis (Fig. 6a),
– control cabinet which is "heart" of the entire system (Fig. 6b),
– hand-held programmer (teachpendant) (Fig. 6v).

The programming rules are very simple. The user indicates the points which the robot should reach, and the state of analogue and digital outputs. During the operation the robot repeats the steps of the program. The program itself runs in an

Fig. 6. The Robot Kawasaki RS006L type installed at the Institute of Technology of the Pedagogical University of Cracow (a- robot arm; b-CPU; c-Teachpendant)

endless loop. The program can be written in several different ways, depending on the application, the destination program and the convenience of the user, and these are:

- programming using Teachpendant. Is it a manual setting the robot in the chosen positions and storing this settings as the steps of the program. The program recreates the recorded steps and moves the robot arm to the relevant coordinates.
- programming using a PC and AS programming language. The program is written in a script file as a sequence of commands, then sent to the robot and run.

For the sake of user safety, the following steps needs to be undertaken on the way from the idea to the physical launch of the program:

- writing the program using any method,
- checking the program using Teachpendant,
- the introduction corrections to the scheme and rechecking the program (this step is often repeated multiple times),
- running the program in the work mode when the developer is satisfied with the effect of simulation.

When programming, you must specify:

- the position of the consecutive points in the program,
- trajectory of robot arm movements (as defined by the driver, linear or circular),
- the accuracy which has to be met by arm reaching the destination point,
- the maximum speed achieved by the tip of the arm during movement between the points,
- the time to wait for the arm after reaching a destination,
- values of the output signals set by the driver,
- values of the input signals which are to be awaited by the driver.

In addition, the developer can use:

- loops,
- conditional statements,
- complex mathematical engine to calculate the coordinates of the points.

A developer should keep in mind that this robot has 3 coordinate systems:

- jucntion (uses angles of rotation of each of the engines),
- cartesian (uses the location of the arm tip using the X, Y, Z coordinates, and angles of rotation around the axes, O, A, T) anchored in the base of the robot,
- local cartesian (uses the location of the arm tip using the X, Y, Z coordinates, and angles of rotation around the axes, O, A, T) anchored in the last used axis or at the tip of the arm.

Young students learn about the basic principles of industrial safety of the arms of robots and manually perform the work that is to performed by the robot. For example, the objective is to move an item from point A to B. To do this you must:

- open the jaws of the electromagnetic clamshell (i.e. set a signal to the level 'high' on one of the outputs),
- move the robot from the neutral position (safe to the people and the production process) so that it could hold the item,
- close the clamshell jaw,
- move the robot in the place where you put item,
- open the jaws of electromagnetic clamshell,
- move the robot to the neutral position.

Laser Cutter

Cutting using a laser is a technology widely used for producing a variety of items made of Plexiglas or thin wood (such as key pendants, chassis, doorplates, information inscriptions, parts of models and many others) by cutting the desired shape from the larger slab, as well as for engraving inscriptions, logos or any arbitrary shapes on metal, stone, glass, plastic and other materials. The aim of the classes prepared for the students of the University of Children was to demonstrate the operation of the Laser500 cutter, by producing a key pendant with the logo of Pedagogical University. To introduce the attendees to the world of light, the difference between the white light and the laser red light was explained by showing the phenomena of dispersion using a flashlight and laser pointer. The second phenomena, which was reminded was a thermal effect of sun light focused in the single spot – this lead the students to the conclusion, that a focused beam of light can create a very high temperature. The same effect is used in the Laser500 cutter (Fig. 7a).

The two main operation modes are

a) cutting: the power of the laser is set to high value, and the speed of head motion is slow,
b) engraving: the power of laser is set to low value, and the speed of head motion is fast.

The head on the cutter operated in the OX and OY positions. In the engraving mode the head produces a desired shape by engraving it line by line. The shapes

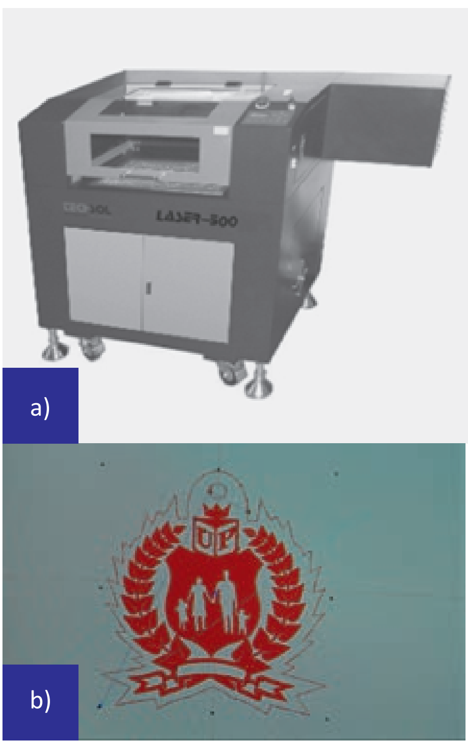

Fig. 7. a) Laser–500 cutter; b) Screen from the LaserCut software

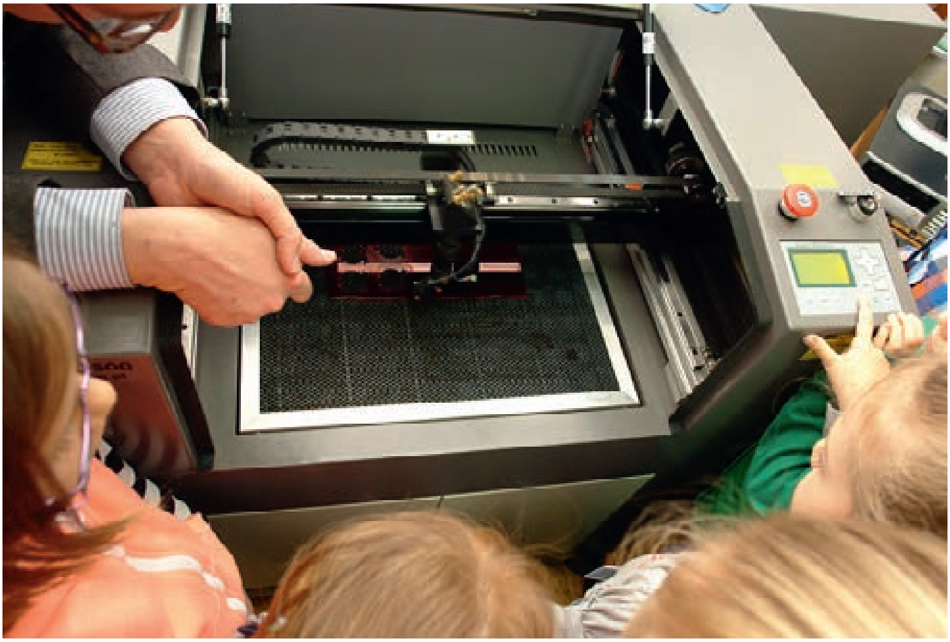

Fig. 8. Adjustment of the head position in Laser–500 cutter (photo by M. Pasternak)

which are to be engraved are prepared using an arbitrary vector graphics program, and then imported to the LaserCut software, where the settings of the processing can be adjusted (Fig. 7b).

The project of the key pendant was prepared beforehand, and during the classes the children operated only on the laser cutter itself, by moving the head with the laser to the appropriate position and beginning the cutting/engraving process (Fig. 8). After the end of processing, each of the attendees was presented with the key pendant, prepared before the classes.

3D printer

3D printing is a novelty in the world of technology. It allows producing items from a variety of materials, mostly plastic or similar. There exists also a variety of 3D printing methods. Institute of Technology at the Pedagogical University owns a PIRX 3D printer (Fig. 9). 3D printing in this device relies on melting a plastic wire and imposing layers of molten material on the base. The head can move in plane in OX and OY axes while deposing the layer. The stand of the printer moves in OZ axis, allowing for the deposition of another layer of the material, after the previous layer is congealed. The print process is maintenance-free. If you need to print a pendant items, the included software will complement the solid with support which should be removed after printing using a knife.

The Institute owns also 3D scanner capable of scanning objects in the distance between 2–3m with an accuracy of a few millimeters. During the classes with children, the subject of scanning is one of the children, then the process of printing is

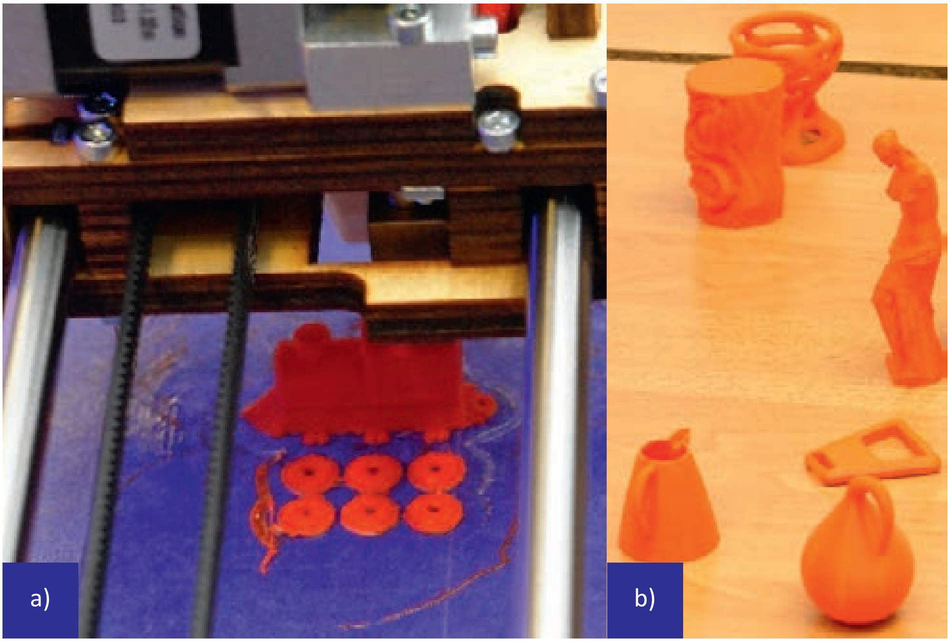

Fig. 9. a) head of 3D printer and the printed element; b) prints

prepared (processing of the STL spatial model, demonstration of the program used to cut the STL model to layers, in order to generate G-code controlling the printer for each layer of the printed model) and the scanned object is printed in the 3D printer. Due to the long time (a dozen or so minutes) up to two or three objects are printed.

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Abstract

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Key words: mechatronics, children, robot

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