MoKraRoSA: A Constructionist Platform for All Ages and Talents

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Abstract

In the summer 2019, we organized three summer camps: a two weeks long summer camp of IT Akademia national project at Krahule in Slovakia, and two weeklong daycamps in FabLab Bratislava. For this purpose, we have designed an original versatile modular educational robotic platform MoKraRoSa. Children have built 80 such robots in the camps, participated in the developments of software, parts, attached various electronics components, designed their own choreographies, and later used the robot in other projects. We introduce the platform, share our goals, results and experiences from the summer camps.

Figure 1. Participants of summer camp of IT Akademia at Krahule building their robots

MoKraRoSA consists of 3D printed modules that could be connected in different ways to form various robot morphologies. It is controlled by a simple Arduino, communicates wirelessly over BlueTooth connection, and it is accessible to learners with any skill levels. The robots built by participants can walk, roll, and dance. In addition to robot building and programming, the participants learned about 3D modelling, Linux, and film making. The platform is completely open-source and available at Github.

Keywords

educational robotics, robotics platform, Arduino, legged robot, summer camp

Introduction

According to the register at fablabs.io, the renowned network of Fablabs currently consists of almost 5000 labs around the world. One of them, FabLab Bratislava, is open for general public daily. It has been providing its equipment, space, and expertise to pupils, students, groups, and others for more than 5 years. Thousands of projects of various proportions have been realized. Three informatics-related faculties located in its vicinity have been offering creative digital technology courses to their students in cooperation with Fablab for at least the past two years. An organic group of volunteers and supporters have formed around this space. Fablab regularly organizes excursions and workshops for elementary and secondary schools. Some students from a local technical high school carry out their obligatory practice there. A regular robotics seminar invites experts to give talks and presentations in Fablab every month.

IT Akademia is an (almost) nation-wide primarily EU-sponsored 20 million Eur project initiated by the Pavol Jozef Šafárik University in Košice shaping educational models to meet the demands of knowledge society and thus fostering the interest in informatics and ICT. In addition to providing methodologies, school subjects content definition and augmentation, it has also been providing courses, workshops, seminars, competitions, and summer camps. Due to its large scale and impact, informatics teachers have during the past three years of the project become familiar with the project calls. As a result, they now provide a very valuable and active communication channel allowing the organizers to reach the target audience of the project events.

LSTME is a traditional electronics summer camp whose origins can be traced back to early 1980s. Tens of children aged 12-18 years spend 14 days in the summer in the middle of nature with about 15 experienced adults to learn about technology in a series of workshops, talks and other activities. LSTME, due to its successful record, has been included into IT Akademia project. However, the cooperation only lasted for a single year. The project requirement not to support the same child in the same activity more than once was in a strong conflict with the importance of community building and participation recurrence for LSTME. A new empty space in the project had to be filled and the authors of this paper were called to action. This paper explains how we have approached this challenge and presents the constructionist platform that we have developed for the purpose of the IT Akademia summer camp in 2019. We believe the platform has a wider potential and therefore chose to share it with the constructionist community. We also report on the evaluation of the camp, and a couple of follow-up events.

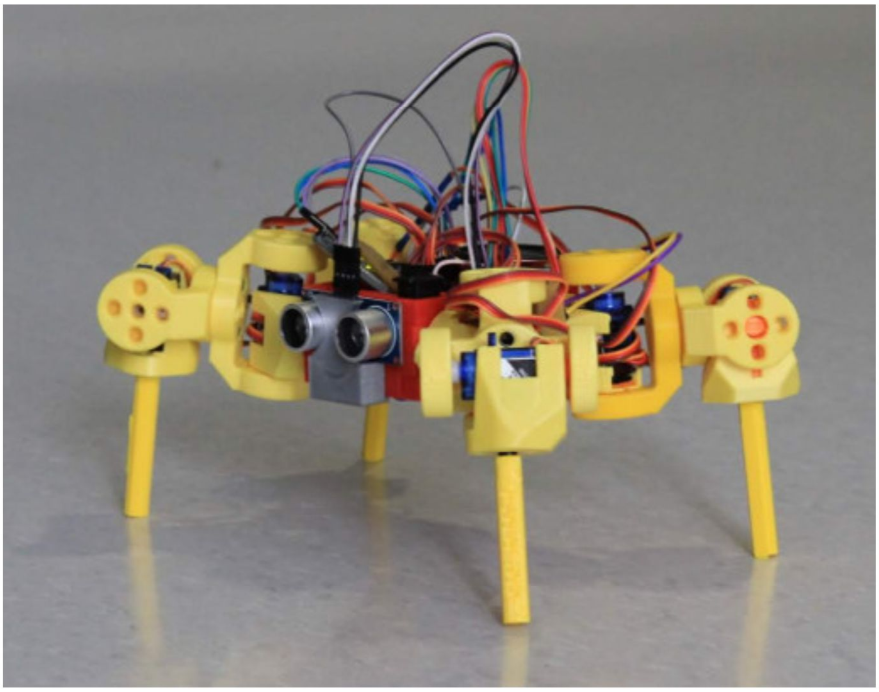

Figure 2. Robot MoKraRoSA: Modular Robot with Arduino built at Krahule in 2019

Previous Work

LSTME

The first week of the summer camp for talented youth in electronics consists of a standard set of workshops. Every child: 1) completely designs and builds a PCB-mounted flashing device, 2) gets an introduction to programming (of a chosen platform of the year, for instance JavaScript, C#, Python, PHP, Arduino, and Micro:bit, have been used previously), 3) learns basics of 3D modelling, and 4) learns basics of film editing and clip making. 3D modelling was added only after FabLab started to get involved. Our vision was to provide a common theme for several workshops, and even though it has not been shared with all the organizers, in two consecutive years, children have built a tiny mobile wheel-robot with line-following, obstacle-avoidance, remote-control, and sound capabilities, all at the cost of less than 20 Eur. The chassis was a parametric design in OpenSCAD and the participants have customized their own robot before they got it 3D-printed. Seeing various designs, they could compare their physics properties and their influence on the robot behavior and performance. We have repeated the Multimouse project also at LSTME 2017, but we ran into a couple of difficulties: 1) there were many other activities in the camp, and thus we have not dedicated sufficient time for this project and 2) the electronics based on Arduino Nano with a single 5V signal and only two GND signals required soldering wires for all the connected devices, a time-consuming task and an organizational challenge.

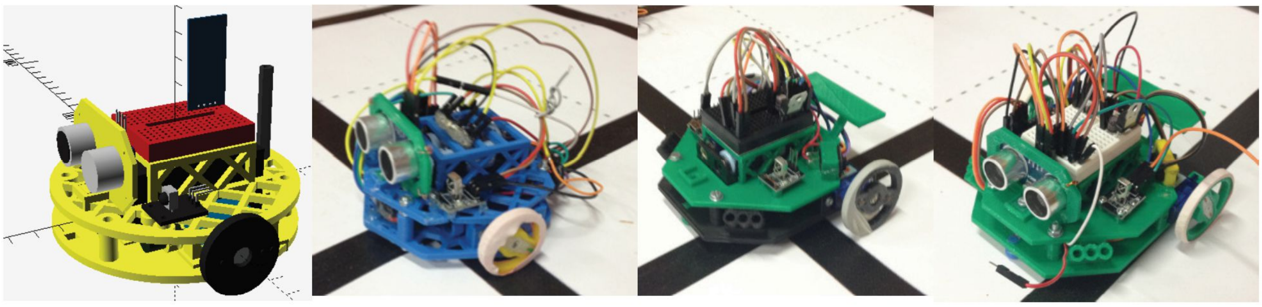

Figure 3. Multimouse – a mobile robot built at LSTME 2016, OpenSCAD model (left) and various modifications made by camp participants [1]

Figure 4. From a final presentation and playing with Otto robots in Fablab day camp 2018

$(DT)^2$ 2018

Inspired by the outcome of the LSTME Multimouse project, we decided to organize a series of day camps in FabLab Bratislava and harness the previous experience for an even better outcome. This event was more focused, children coming only for the workshops and staying at home overnight. The camp accommodated only two simultaneous workshops – 3D modelling, and Arduino programming with robot building, children alternating after 4 hours of continuous work in each. In this case, children have built a modification of the famous robot Otto [2] – either a 3D printed version or a laser-cut plywood.

Again, children could take the robot that they have built home with them and continue the learning process at home further on. We have documented our work in [3]. One of the advantages of the Otto robot as compared to Multimouse was the Arduino Nano Expansion Board that contains multiple VCC and GND pins for the connected devices.

Related Work

Modularity

Before we proceed with the details on the 2019 camps, let us stop here at the concept of modularity that we consider having a much higher importance than is recognized. An ample example of modularity can be seen in solutions of the over-performing teams in FLL competitions. Their robots started from the base enter the field and solve a couple of missions before they return to the base again so that a new attachment could be installed. The children typically simply lift the previous attachment up and place a new one on top of the robot. The newly placed attachment automatically aligns with the robot-core and the gears „click-in". No further action is needed, and the robot can immediately smoothly approach the new set of missions, see Figure 5.

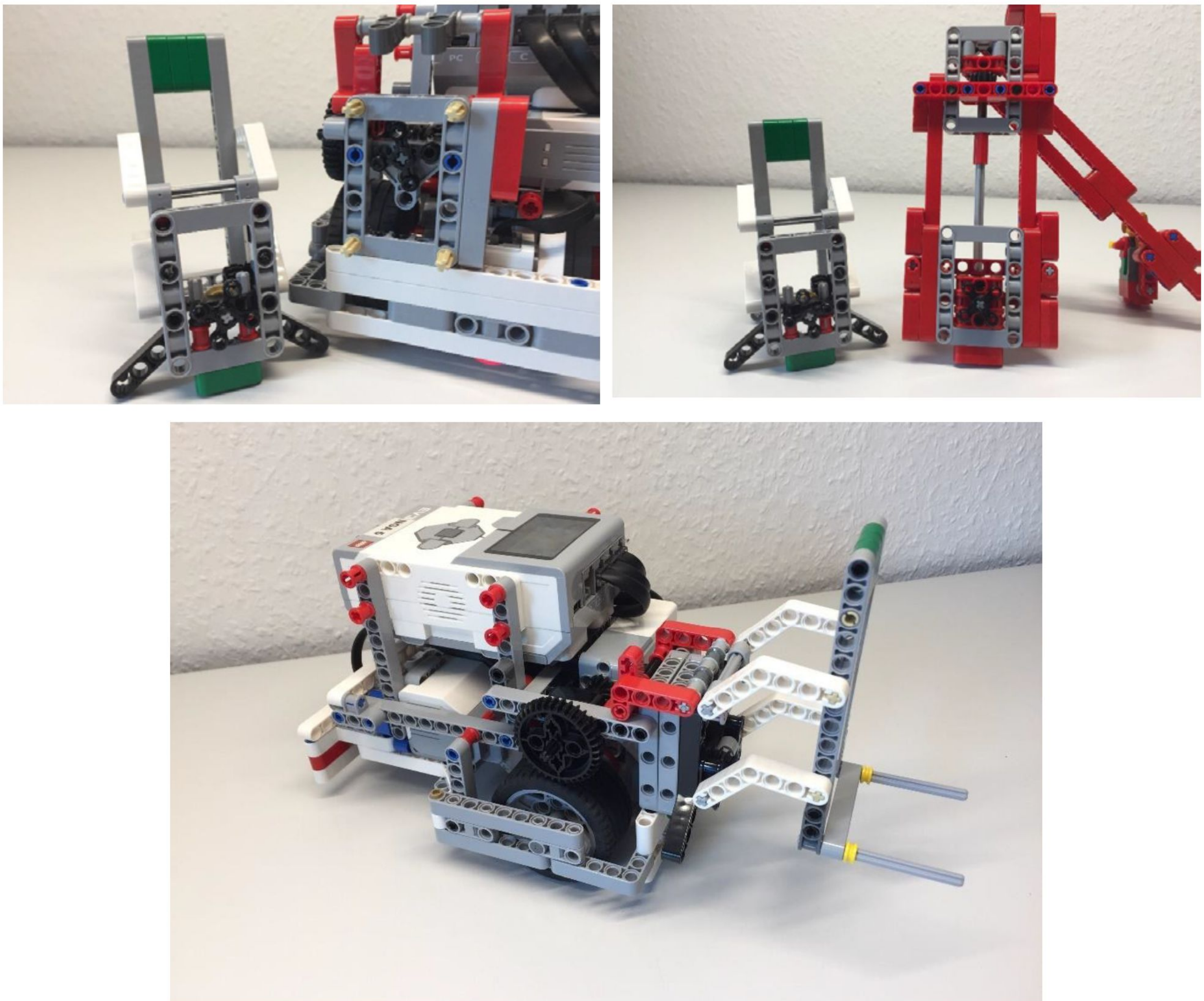

Figure 5. Modular robot attachments for FLL competition, from the Robot Design Hardware handbook provided by NanoGiants Academy e.V. [4]

In general, we consider a system to have a modular design, if it is configurable, consists of independent parts that can be developed separately and that can easily be added or removed from the system without any need for further modifications of other parts of the system, seamlessly adding or removing the respective functionality or feature. Designing a system in a modular way takes extra efforts, resources and time. The benefits are often invisible, especially in a single purpose system. Yet, the elegance of the modular design emerges as soon as the system needs to scale up to larger developer or user base, experiences multiple deployments with varying purposes, and when a repair is attempted. We believe that more efforts in the learning process are needed in order to allow the transition of our society to a real modularity, saving considerable resources, eliminating waste, improving product longevity as well as providing new employment opportunities.

Modular Robotics

Robots as devices that operate in real environments are especially prone to frequent repairs, the field is in a rapid development resulting in continuous partial upgrades, and obtaining the individual parts is (time or money) costly and thus their reuse is desirable. In addition, for certain tasks, specific robot morphologies are more fit than those with universal configurations. Modular robotics allows building complex robot systems from easily replaceable components. Truly modular robots are often called reconfigurable robots, while some of them can change their morphology autonomously, the self-reconfigurable robots. See [5] for an overview of such experimental systems. A direct inspiration for our work was the work of [6] on modular reconfigurable robots that the authors use in a student course to teach chaos and complex systems. Various morphologies can be constructed from the basic elements, see Figure 6. However, our goals were to build a fully autonomous robot without the many cables leading to control and power source. We needed to incorporate some control units. One idea we explored was to use a simple control unit in every component, incorporating them into a network of interconnected parts. This would allow a complete versatility and flexibility the modules would have both mechanical and electrical connections to convey power and information. A result could be similar to a wonderful modular robotics educational system Cubeletes [7]. We see some limitations though. The building blocks are somewhat bulky, the resulting constructions are inflexible and difficult to move around, designs are of a monotonous square-shape, and it is a commercial closed solution so also the cost is relatively high. In this occasion we aimed at designing something low cost, yet interesting, flexible, and moving in some interesting ways in its environment. We have therefore abandoned the idea of distributed control and accepted a solution with a single control unit.

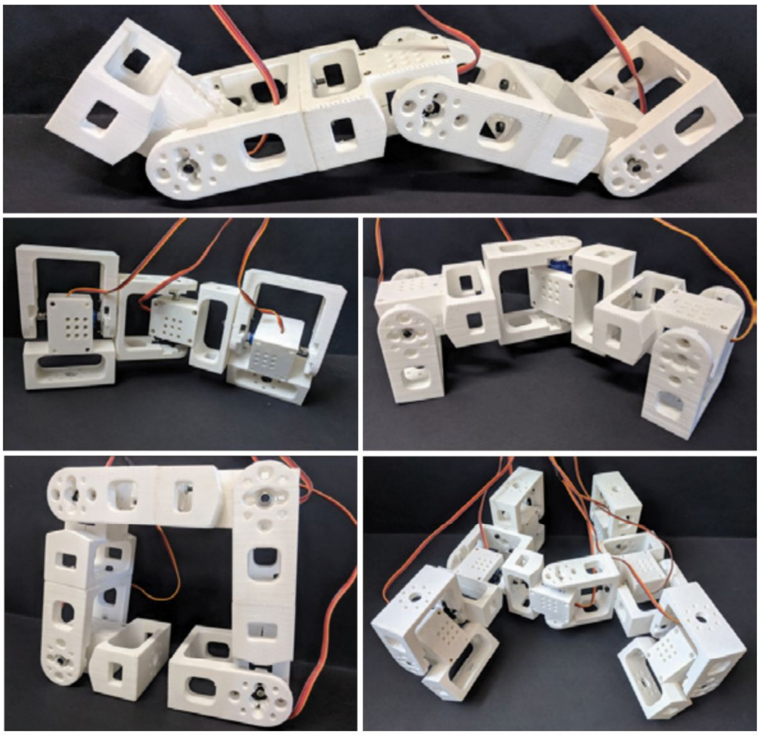

Figure 6. Modular EDMO robots used at Maastricht University in DKE Swarmlab, Laboratory for Cognitive Robotics and Complex Self-Organizing Systems [6]

MoKraRoSA platform

After the successful day-camp in Fablab in 2018, we immediately began thinking about the next season for the summer of 2019 and started to search for a new platform. Even though there still was a lot of potential to work with robot Otto, we had several reasons to change: some participants from 2018 were expected to visit the 2019 camp as well, then we wanted to get experience and study the suitability of different platforms, and our desire for creativity and the long term wish to learn about modular robotics also contributed. Inspired by EDMO described above and having experienced many LEGO robotics projects, we have soon arrived at an idea of creating a LEGO connector peg compatible mechanical parts that could hold motors, control units and any other parts. The first attempts were ours, but soon Martin Slimák, a student taking a practical semester project course and member of FabLab Bratislava has volunteered to create a complete design in a student version of Fusion 360 modelling software. Parts of the result after several iterations are shown in Figure 7.

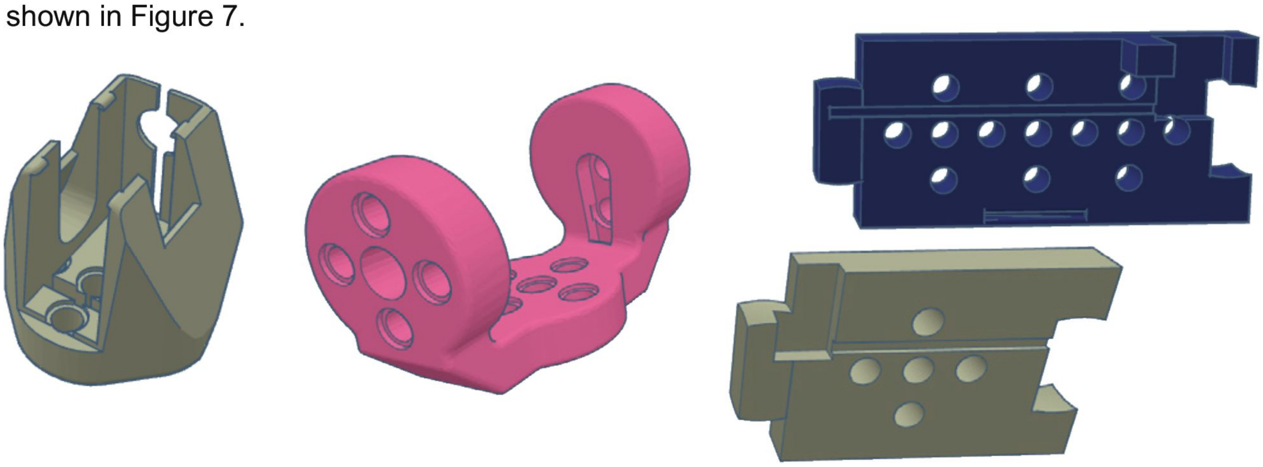

Figure 7. Some of the mechanical parts that formed the base of the modular robot morphology, version 1

The first robots that we have built were simple worms with four degrees of freedom, see figure 8. We have tried adding some components for building a robot arm, such as gripper, stand and length extensions, and a small humanoid, we have later focused on a 4-legged creature (version 1 shown in Figure 7) in order to provide a well-tuned starting point for experimentation.

Goals

Our goals were to prepare a modular 3D printed platform that is easy to assemble and disassemble and holds stable together without any screws, or other fixing except for LEGO connector pegs. Only the servo motors should be secured with the tiny screws they are accompanied with for better stability. We wanted to create a platform that could be both programmed and remotely controlled, with a software allowing easy design of choreographies without the need of programming (coding in a programming language). The resulting set should be easily adopted by the large number of schools that have recently purchased a 3D printer and are looking for its interesting educational applications.

Evolution of the Morphology

To save time and material, most pieces were printed with a very low infill percentage. The consecutive updates intended to accommodate more robustness. We started with the square-shaped designs similar to EDMO but improved on the ergonomics in the later stages. This has been a constructionist experience on its own. Student was learning about the Fusion 360 capabilities, interacting with us in an iterative manner, and discovering the principles of a stable construction throughout the course of several weeks. The four walls of the control unit box have carefully designed hubs curved in two directions that allow the parts to fit and hold together. The Arduino control unit is inserted into grooves in the walls. It is mounted together with the power supply, battery holder and switch as one unit. We have prepared these units beforehand so that the children did not have to deal with the soldering, and wire cutting (about 12 connections per piece). This was the most time-consuming preparational manual work that cost us about two days of work before each camp.

Electronics

Based on our previous positive experience with Arduino Nano in the Multimouse and Otto projects, we planned to remain with the same platform. The disadvantage of the plain Arduino Nano, the lack of the GND and VCC connections, was solved in the Otto project with the Nano Expansion Board. This time, we have found an even better solution: Arduino Nano Strong, a combination of the Expansion Board with Nano in single, smaller-factor board. Powering 8 motors that can move simultaneously is quite demanding. The 4-pack of AA-size batteries as used in Otto has two main disadvantages: it provides unstable voltage since the difference between fresh and almost used-up batteries is more than 1V, and it takes a lot of space and weight. In case of MoKraRoSA, we have used a pair of 14500 Li-ion batteries with the benefit of 66% reduction in weight and 50% reduction in space. Two such batteries provide the voltage between 7 and 8.4 V, which is further transformed to a stable 5V with a tiny power supply with up to 97% efficiency providing 4A output, which is sufficient to power the electronics and servomotors. A new challenge is that these batteries should never be fully discharged and thus require a voltage divider (we used 220K and 22K resistors) to scale the voltage down for the 1.1V ADC reference value. The most unreliable part was the MPU6050 gyroscope/accelerometer. It is a very useful part that can integrate all 6DOF directly in the sensor allowing a specialized firmware to be uploaded in its control chip, but both MPU6050 and HC-05 Bluetooth module are originally designed for 3.3V electronics. Fortunately, both work with 5V Arduino even without level shifter, but the sensitivity of the fragile I^2C bus protocol is high and sometimes leads to communication loss. Full list of parts is available at the platform website [12]. The overall cost of MoKraRoSA robot (from the cheapest suppliers) including the PLA material for 3D printing sums to about 35 Eur including the batteries and the charger.

Control Software

We started with a small program to test the motors and sensors and as the hardware capabilities were developing, we have been improving it incrementally. Soon we found that creating and storing choreographies would be useful, however, in a little bit different way than in Otto. Instead of specifying the choreography as a sequence of single motor moves at specified moments, here, it is a sequence of positions of all 8 motors. The software allows to manually control each degree of freedom and to observe the result and store the reached configuration as the next point of the choreography. Replaying the dance means interpolating all motors in the interval formed by the consecutive positions in 100 steps – in a specified speed. This allows the choreography designer to replay and observe the choreography step-by-step in a debugging mode, and adjust each individual position if needed, insert or delete the points in the choreography. It can easily be transferred to a PC or back, and it can be saved to the EEPROM memory. The robot can be configured to start playing the choreography automatically after it is powered. Alternately, it enters the control mode over the USB cable or Bluetooth connection, it lists the help for all commands when requested and contains a set of predefined moves – such as walking in all directions in a normal or upside-down orientation. Since the robot is almost symmetrical, it can walk and operate in both orientations. After the children have built their robots, we have provided them only with an early version that allowed creating the choreographies so that they have something to start with at all skill levels. At that time, we were only hoping that these creatures will be capable of stable walking one day. What followed, surprised us very much. While we were serving and helping all out of the 40 children in the camp to get started, some of them – the more experienced one asked for more parts, such as the Bluetooth module and Gyroscope, and for the details how to operate them, and soon we could observe pairs of the “spiders” walking and fighting in the corridors while controlled from their mobile phones. Several independent versions of walking emerged, and soon the children have copied and uploaded the best program and worked on improving it and integrating their ideas in it. We merged their and our program together. The software is open-source, it is being still improved and currently its version 9 is available at Github [8].

Figure 8. Worm with 4-degrees of freedom, the first robot we have built from the modular components

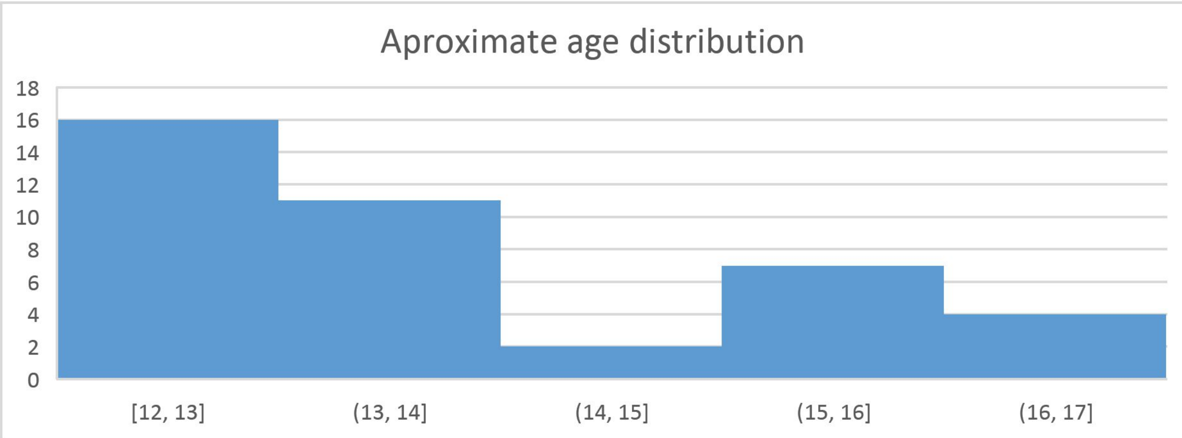

Figure 9. The age distribution in the IT Akademia camp

Summer Camp of IT Akademia

Selecting the Participants

IT Akademia as an EU sponsored project has strict rules and requires formally specified criteria with point system in advance. Points were assigned mostly for participation in various scientific, technological and robotics competitions. We received about 120 applications, and the system generated 40 best students to be invited. However, since the gender-equality values were included in the IT Akademia principles, we could use the option to raise a quote for female participants. After a discussion we have agreed on 50% girls participation. We remained somewhat frightened as we have never experienced a technical camp with such a composition. In the previous, we have both participated in multiple girls-only workshops organized by the organization *Aj Ty v IT* whose purpose is to promote girls' interest in informatics and technology. In our experience, girls are often very active and well-performing when in girls-only activity, while in mixed groups the prejudices originating from social and cultural stereotypes sometimes result in girls taking a passive role and lacking a healthy self-confidence. To our surprise none of these effects could be observed, and the group cooperated in a very productive atmosphere of joyful learning where everybody was equally actively involved. We were thus very happy about the choice of the 50% composition. It created a very nice and motivational social environment with successful outcomes. The age requirement was set to 12-17 years, Figure 9 shows the detailed age distribution.

Activities

The 40 participants of the camp were divided into 4 equal-sized groups at random. A typical day consisted of two about 4 -hour workshops and some more activities in the evening. In addition to sport, games, and social time together, the workgroups alternated between the following workshops.

Film Making

The goal of this workshop was to learn about film making and editing. The participants learned about making animated clips, and every group has produced one. The leader of the workshop was a graduate of the Film and TV Faculty at Academy of Performing Arts and she shared her expert knowledge in the field. All groups have produced several interesting artistic clips and they were filming workshops of other groups and documenting the camp.

Figure 10. From the film making workshop

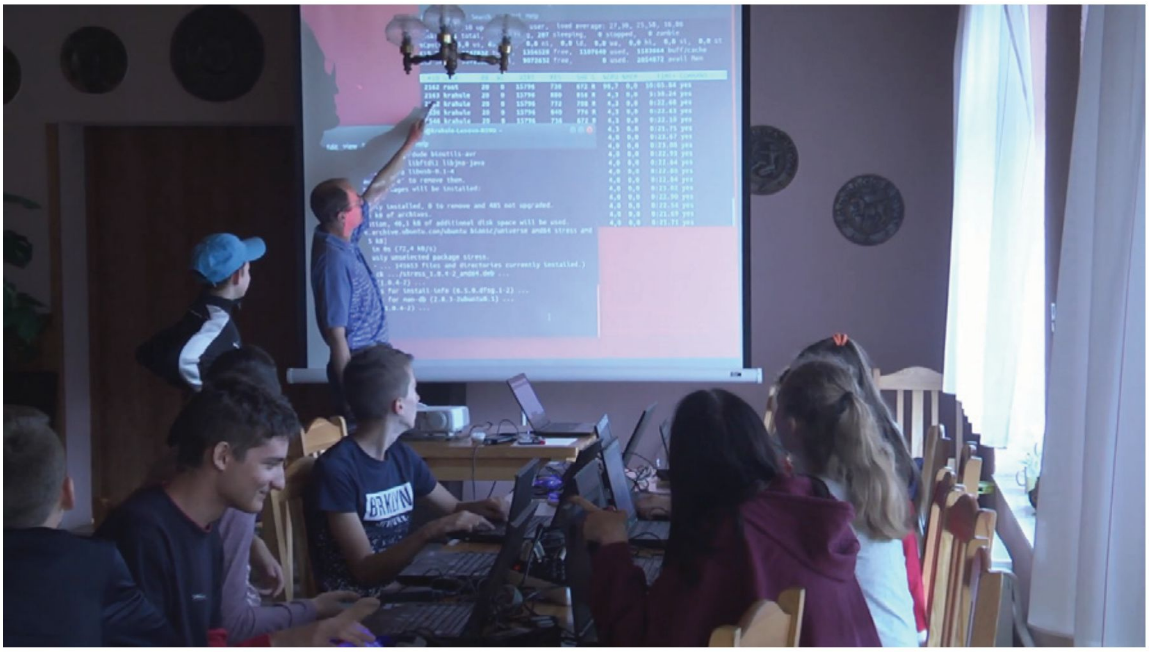

Figure 11. From the Linux workshop

Linux

In the various educational opportunities where we meet young people, we have observed that the awareness of Linux operating system, and the Linux user and programming skills are usually quite poor in Slovakia. Yet, we believe Linux has a very large potential, not only as a most typical server OS, but also as a base platform for educational applications, and a reasonable Desktop system. Especially after the release of Windows 10 that rides roughshod over the computer resources and changed many powerful PCs into a useless brick. This workshop was targeted on learning basic usage, scripting, and automation. Every participant learned how to install and setup Linux, and thanks to a generous sponsor contribution received a fast 32GB external drive where they have installed Linux and took home for further learning, using and exploring. They have also learned about the Raspberry Pi platform. One of the leaders was a practitioner from an IT company designing computer networks, and the other one was a university teacher with experience in teaching Linux system programming course among others.

Arduino Programming

Since the MoKraRoSA is based on Arduino platform, the choice for the programming language and environment to learn was C-programming and Arduino. The workshop was a project-based work. The participants learned about all the basic I/O, serial communication, introduction to C-programming. For this purpose, we used the Acrob mobile robots [9] in a playful way, and various sensors and other parts connected to a breadboard, such as potentiometer, microphone, ultrasonic sensor, gyroscope, passive buzzer, IR distance sensor, LEDs, etc.

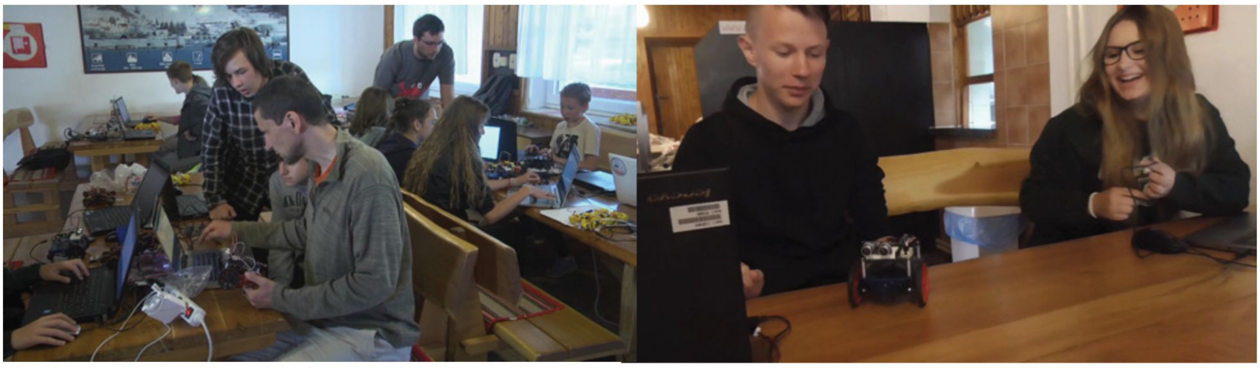

Figure 12. From the Arduino workshop

Figure 13. From the 3D modeling workshop

3D modelling

In 3D modelling workshop, the participants have learned basics of the solid geometry modeling using the TinkerCAD system. They have received the designs of the MoKraRoSA robot and all of them have designed their own legs for the robot. A graduate student who has a bachelor's degree in the field related to 3D printing and who is also a Fablab volunteer was servicing almost ten 3D printers that were in a permanent operation during the camp. After the first week, we have merged the Arduino and 3D modeling workshops into a single workshop focused on building and programming MoKraRoSA, which had a double frequency. Learning design enables constructionism at new level. With design, the subject gains the skills that open possibilities for personal and group discovery in an iterative experimentation, observation and hands-on learning.

Building the Robot

Actual robot assembly took about 2 hours, however a special care had to be taken when inserting the servomotors to have them properly pre-calibrated and mounted at a proper position. All the electronic parts were mounted around the robot at various places either using a separate 3D printed parts (such as the ultrasonic sensor, mp3 player, passive buzzer) or simply attached using a thick double-sided tape. The wires of the servo-motors were folded and the folds inserted in separate envelopes formed in the servomotor holders. Based on the reports from the participants, this building part was one of the most interesting activity for them. 30 out of 40 participants chose to take the robot with them home, we have provided it for the raw cost of the parts.

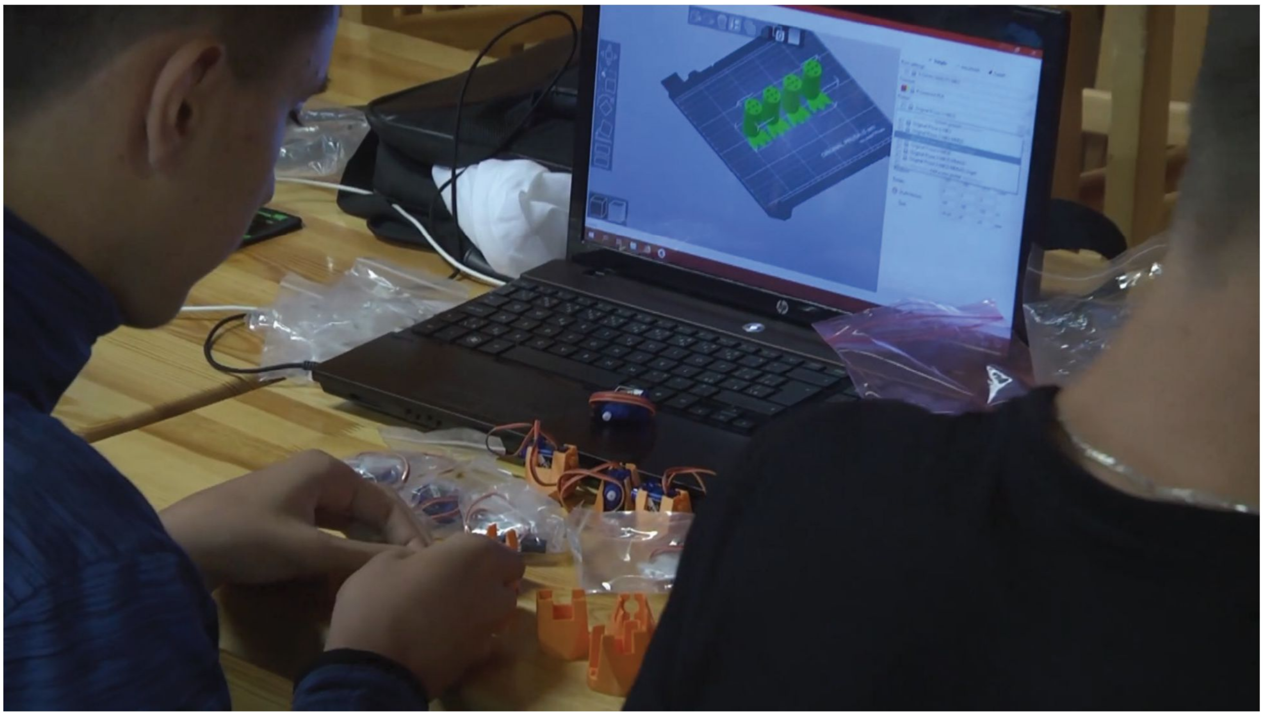

Figure 14. From the robot building workshop. The legs designed by the participant are on the screen

Figure 15. From the robot fighting tournament

What has happened

After the participants had built their robots, we expected them to work on their own a choreography so that we could see some ideas for creative movements, and many of them did. However, some of them have asked for parts that we hoped to start using later in the program and worked evenings on their own. We have planned to focus on walking gaits only after everyone would be comfortable preparing the choreographies. However, these talented students soon came up with an efficient solution for walking and programmed remote control using the Bluetooth module and their mobile phones, implemented various gestures and arranged fighting tournaments, and they have shared the best programs among themselves on their own initiative. This has been an unexpected development, but it has shown that MoKraRoSA is a functioning constructionist platform that motivated learning and sharing in a natural way.

Other Activities

As in our other camps, we have used some of the activities from The Systems Thinking Playbook [10] to help open minds of the participants. Every morning started with a sport warm-up activity, for the evenings, we have prepared quiz, the participants prepared dances, and songs, we have played various social and sport games, and the final half-day consisted of a rallye, where the participants used the learned knowledge. Almost all the time schedule was covered by organized activities.

DT^2 camp

After a break one week long, we have continued with two day-camps directly in the space of Fablab Bratislava. About 30% of the participants joined us already for the second year. We have used the experience on MoKraRoSA platform that we collected in the two-week camp so that the building and programming would be smoother. This camp was targeted at the age of 11-15 years. 20 participants in each camp were split into two groups based on their skill level. The groups alternated between two 4-hour workshops. In the first workshop, the participants enjoyed the usual Fablab activities – such as making T-shirt and textile bag decorations, producing small 3D printed and laser-cut jewelry and items and learning about 2D and 3D modelling, while in the second workshop they first learned about Arduino programming in hands-on projects and then built their robots and worked on their choreographies. All 40 children have taken their robot home. At the end of all three camps, the participants have demonstrated the results of their work to their peers in a constructionist spirit.

Example choreographies

When connected over the USB cable or Bluetooth connection, the robot can be controlled directly in control mode or switched to edit mode for defining a choreography. Pressing a certain key in edit mode (16 keys altogether) moves one of the 8 DOF in one or the other direction instantly. As soon as the user is satisfied with the next position, he or she hits the ENTER key and the position is stored as the next point in a choreography. The user provides the speed of movement for each such transition. At any time, the user can replay the current sequence once, or in a repetitive loop. After entering the debug mode, the user can perform the steps one at a time, insert, delete or modify the respective steps at any position. Preparing a choreography is a kind of a programming activity, but it is available to anyone without any programming experience.

Greeting

The simplest of the three example choreographies is the greeting. The robot first moves 3 of its legs in a position where they provide a stable tripod. The fourth remaining leg is free and lifted and in a vertical or horizontal movement greets the observer.

Swimming

This is the easiest choreography that allows the robot to travel. We call it swimming as it resembles the movements of a swimmer. It can be performed in as few as four steps. The robot first lays down by lifting all its legs simultaneously. Then it moves all the legs forward, while laying on its belly. After putting down and standing on its legs again, it moves the body forward simply by moving the legs backward.

Acrobat

The robot is designed to be almost symmetrical and it can flip upside-down on its own. Among the popular choreographies designed by several participants were various forms of roll overs. All three choreographies can be seen in a gallery on the platform website [12].

Feedback and evaluation

It was difficult to leave the first camp for most of us as the two weeks period is long enough to form friendships and bonds. We have sent a questionnaire to all the participants to receive a feedback on all the activities in the camp. 80% of them responded, and Figure 16 contains the results. We also asked for verbal comments, which were very encouraging and indulging the authors appetite for a perfectly cooperative group. Overall, not only the goals of the camp were fulfilled, but we are confident that the platform we have prepared serves as a useful constructionist case study.

After the camp

We tried to stay in contact with the participants sending news, and updates, met several of them in person to help them correct any issues that they have experienced after returning home. Two girls from a secondary technical school participated in Amavet Science Festival, where they have prepared and presented a popularization project for the MoKraRoSA platform. After advancing from the regional round, they have been awarded one of the prizes at the national level.

We have continued the software development after the camp for a while to improve on some of the features. However, we have also developed a new version of the robot body – so that all of the electronic parts are seated in their little containers, and the box for the control unit is covered from both sides – thus storing and hiding all of the wires except of those leading to servo motors. A comparison of the two versions in shown at figure 18.

On November 15th, the first Mini Maker Faire festival took place in Bratislava. Fablab has prepared a workshop where 10 registered visitors have built their own MoKraRoSA robot. Ten other visitors have built a Makey version of robot Otto. This turned out to be more challenging in a noisy and busy place as compared to a camp with much controlled conditions and more time, but the enthusiastic visitors have managed to overcome all the obstacles. We have also demonstrated the platform to public in a similar event 3D Expo in Bratislava in November (Figure 18), where one of the authors held a talk about this robot story for public.

Some of the participants have already spent efforts to upgrade their robots to a new version. We have prepared a public website about the robot with example choreographies, links to the open source code, all STL files for the 3D printed parts, and more.

Conclusions and Further Plans

We have described our experiences with the modular mobile robot platform MoKraRoSA. It has served as a constructionist platform for all ages: participants in the camps aged from 11 to 17 have been building it, programming it and designing choreographies. A student of Applied Informatics in his 2nd year of study has worked on designing the robot body, and the two authors of the article were designing and implementing its control software, and managing the overall design process, and the system philosophy, and tinkered about the applications, and the way of introducing the platform to the participants. In total, four generations of constructionists worked in a concert towards a common goal, they all learned together in groups, shared and presented their knowledge and experience to each other. All parts of the system are open-source and published on Github [8].

Open Challenges

Our aim is to increase the user base of the platform, primarily in the community of primary and secondary schools in Slovakia. We have already negotiated with a private company that delivers 3D printers to schools and we have agreed on a cooperation. The idea is to prepare sets of parts, documentation, manuals, and tutorials, and the schools will print and build and further develop their robots. We plan building new complete systems from our modular platform in addition to the 4-legged creature. Inspired by another similar activity Robot League [11] we are considering an online contest – instead of regular problems published every two weeks, we provide several open challenges that will start after the participants will try to solve them.

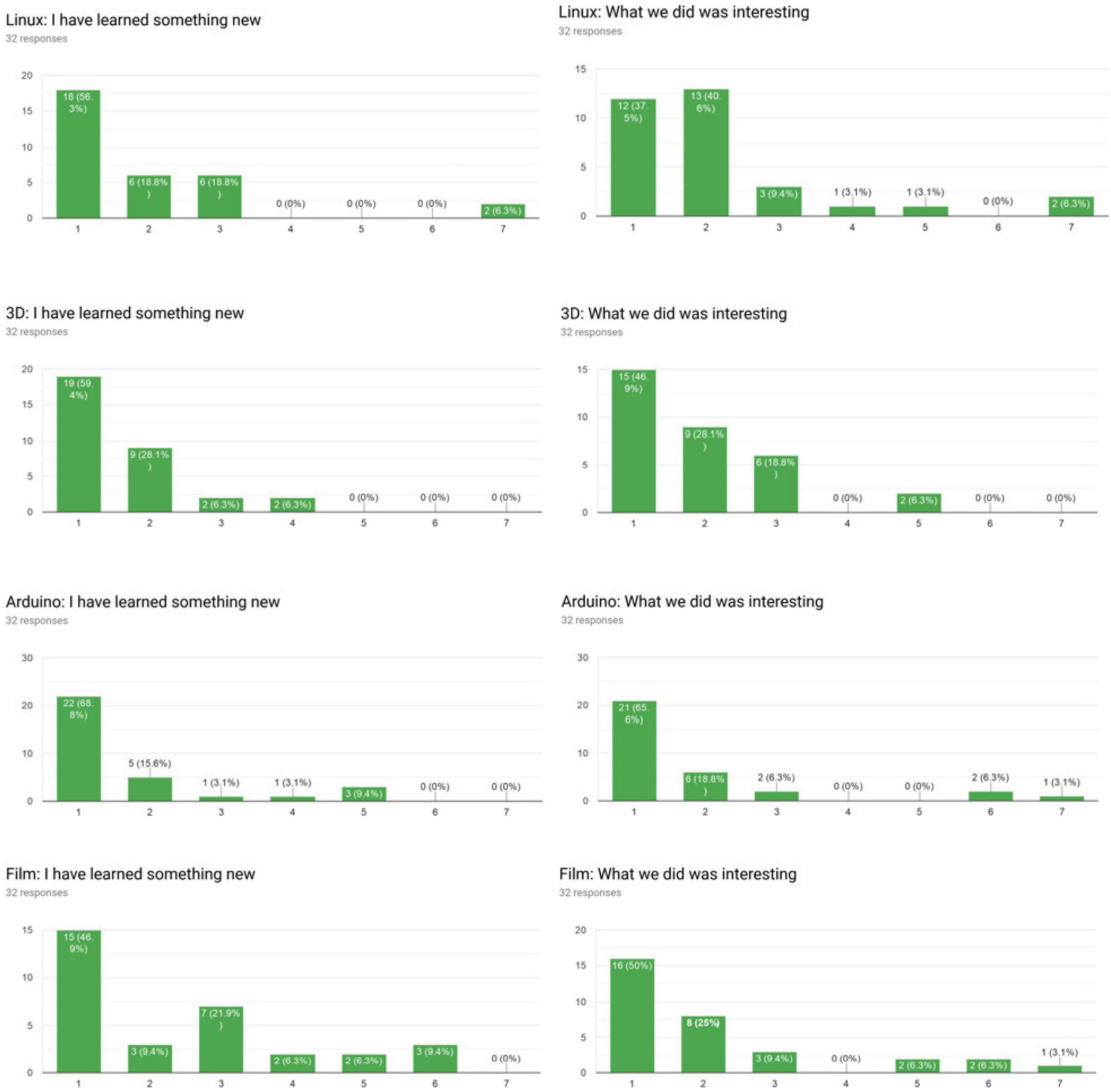

Figure 16. Evaluation of workshops (1 means more excellent, 7 means less excellent)

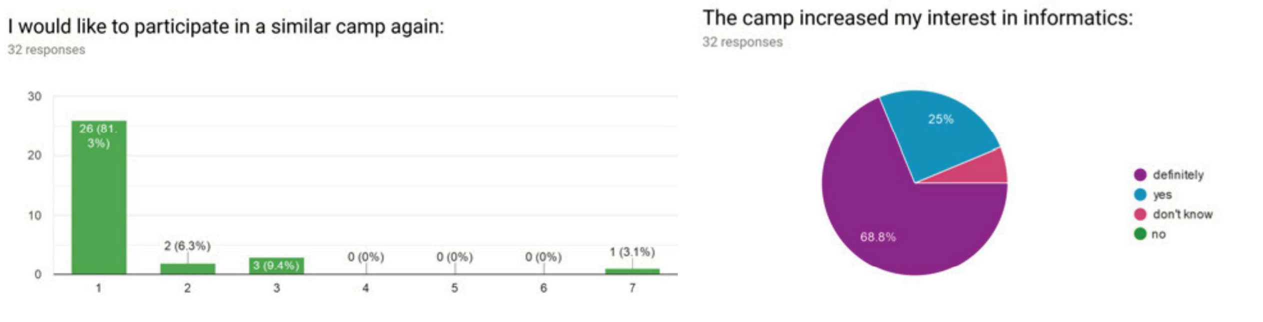

Figure 17. Evaluation: general questions (1 means more excellent, 7 means less excellent)

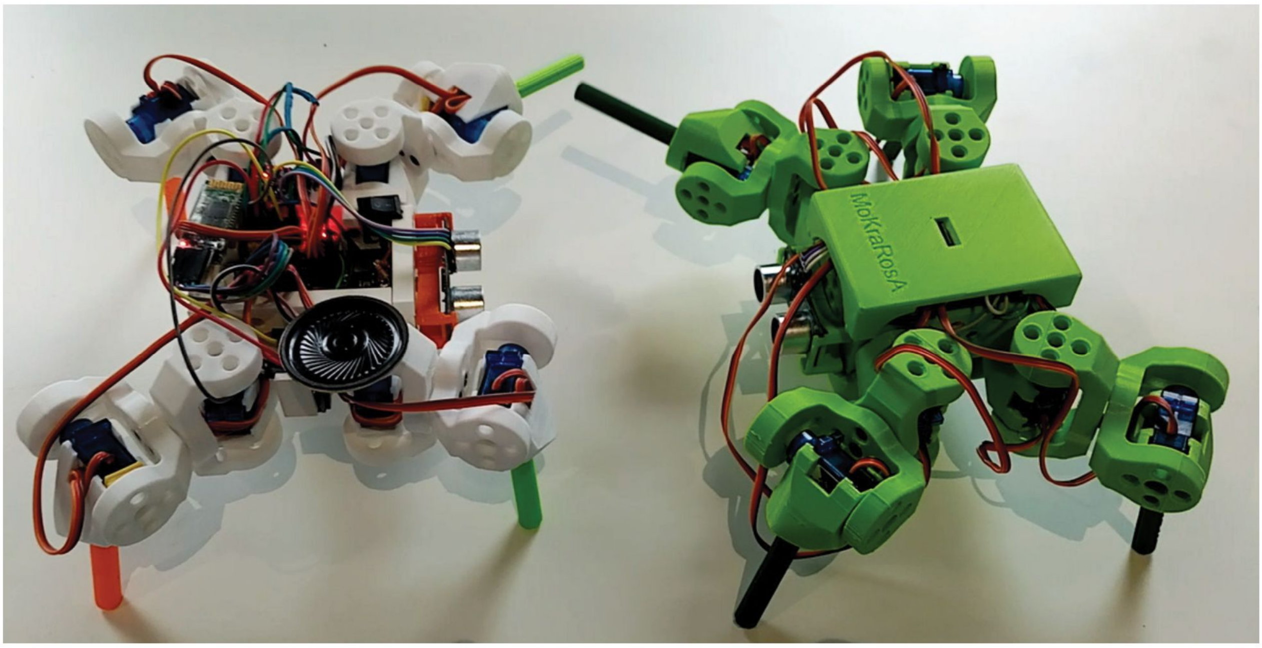

Figure 18. Comparison of the version of the robot used in camps and a new version developed in autumn

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