O3

How to Design and Use an Intelligent Object for Interaction Aims

- 2020 -

Contents

1. Introduction

The Internet of Things is a reality which is spreading in all activities of our day to day life, with a great potential of improving the human life. According to (Burgess, 2018) experts predict more than half of new businesses will run on the IoT by 2020. Since IoT field is expected to grow significantly in the next years, it is a must to prepare young generations for these changes, by teaching them related aspects connected to IoT, providing them with the skills that would help them understand those changes and face them with joy and enthusiasm (Suduc, Bîzoi, & Gorghiu, 2018).

Since the whole idea of the "IoT in education – We are the makers" project was also to rise students motivation on Sciences, in the first part of this manual there is presented a motivation about approaching real life problems in Science education, which proved to increase students interest for Science subjects.

The main objective of this manual is to "put together" the 3D printing competences gained with the help of the first manual from this website - http://www.wemakers.eu/ (O1 – Educational 3D Printing Manual) and the competences of coding and working with programable devices and electronics, gained from the second manual (O2 – Educational IoT Manual – Online editor) in order to create *interactive things*. The manual has three main parts: first part include a framework for the teachers, the second part is a theoretical part which explain several useful concepts and technologies related to IoT and the last part, dedicated to practical activities includes a set of tutorials. The tutorials part aim to help the teachers to teach students different aspects of IoT by providing them step by step directions on how to create different interactive devices, IoT devices or close to the idea of IoT.

2. A Bunch of Arguments for Education through Science

A Bunch of Arguments for Education through Science

Author: Gabriel Gorghiu, Universitatea Valahia din Targoviste, Romania

The importance of *Science* for the development of society is an indisputable axiom. Becoming a relevant social factor, *Science* has acquired a particular status in the current socio-cultural context, and the degree of advancement of the level of scientific knowledge has become a conclusive indicator of the societal evolution.

The major role played by *Science* nowadays is reflected by the support given by many governments or international agencies in order to conduct research in the field of science and innovation, to spread the favorable image of the scientific activity, as well as for promoting science for youngers, but also for general public.

However, multitude of studies highlighted a major decline in young people's interest for key science studies and mathematics. Despite numerous projects and actions that are being implemented to reverse this trend, the signs of improvement are still modest. This means that the longer-term capacity to innovate and the quality of related research will also be in a massive decline. Furthermore, among the population in general, the acquisition of skills that are becoming essential in all walks of life, in a society increasingly dependent on the use of knowledge, is also under increasing threat (Rocard, et al., 2007).

Anyway, it is obvious that the actual societal changes claim new requirements for education, and in strong direct respect, for *Science* education. The importance of knowledge and traditional skills is decreasing because their life span is getting shorter. The society wants schools to equip young people with creativity, curiosity, change management and life-long learning. Those are strongly linked to a crucial raise of students' motivation to get interested in science. And this requires changes in science education, by revising related scientific contents dedicated to school students and applying appropriate and modern teaching/learning methods (Trna, Trnova, & Sibor, 2012) and approaching real life problems.

But why the basic competences and skills in *Science* are so important?

The competences in Science refer to the ability and availability to use knowledge and methodologies in order to explain the natural world, to identify related problems and questions, and to draw evidence-based conclusions. Here, there can be also mentioned the competences in *Technology*, which regard the application of knowledge and methodologies in strong response to the human needs or desires. The competences in Science and Technology imply the understanding of the changes caused by human activity and of the responsibilities of the citizen concerning the use of science and technology in order to improve our lives, by enriching and involving essential scientific knowledge, skills and attitudes in the citizens' acts and behaviors. The necessary knowledge in science and technology includes the basic principles of the natural world and basic scientific concepts and principles, main results and products of the actual technological processes, and the understanding of the impact that science and technology have on the natural world. Those skills should enable the individual to understand the advances, limitations and risks of scientific theories, applications and technologies throughout society (regarding decision making, values, moral questions, culture etc.). More, the skills include the ability to use tools and technological equipment and machines, as well as scientific data, in order to reach the goals or to draw decision/conclusion based on evidences. Individuals must be able to recognize the essential features of scientific research and be able to communicate the conclusions and reason that led them regarding the technological and scientific progress, but also in report to their own feelings, family, community and global problems.

The students' interest and curiosity about the world around us is introduced and cultivated by *Science* education, which has also as one of the main aims to enhance the scientific thinking. Accepting the obvious assumption that science education is a part of education, the issue arises concerning the role of science education within the education provision.

Today, as *Science* plays an important role in society, and students but also the large public are welcome to play an active role for understanding how science address significant issues of modern times, but near that, how they are solved, with an essential emphasize on responsibility, respect and ethics. In fact, **Science with and for Society me**ans "*to build effective cooperation between science and society, to recruit new talent for science, and to pair scientific excellence with social awareness and responsibility*" (European Commission). In this respect, te*aching Science in school has to be sustained on several directions for development, from the economic one, going to the democratic one, reaching the skills one and ending with the cultural one* (Tytler, 2007) (Turner, 2008) (Holbrook, 2011):

- supporting Economic development - school science represents one end of a vital (if leaky) pipeline which channels science-oriented students from schools through to post-secondary institutions. The pipeline ultimately supplies highly trained scientific and engineering personnel to the economy. Those persons are vital for the economic well-being of the country and the national competitiveness.
- enhancing Democratic development - the main responsibility of school science should be to prepare students to be informed citizens and enlightened consumers who can intelligently

negotiate the techno-scientific challenges of modern life, politics, and society. An introduction to basic science principles and content would not be absent, but focus would shift toward contemporary technological and real-world applications of these principles and their intersections with students' lives. Science education, the democratic argument insists, should be education about science as well as in science.

- promoting Skills development - a third important rationale for school science hinges on the claim that certain kinds of science study inculcate desirable transferable skills that include the ability to formulate and conduct experiments, evaluate empirical evidence, appreciate quantitative arguments, carry out inductive generalization, and engage in critical thinking. Proponents of the skills argument urge a curriculum and accompanying pedagogy that encourage hands-on work, that call on students to collectively negotiate the significance and meaning of data, and even to plan and conduct open-ended investigations in the alleged style of adult scientists.
- covering the need for Cultural development - science plays a roll today somewhat like the great mythologies of the civilizations of the past: it provides the great narrative of truth, meaning, and essence that we live by. The proper goal of school science, according to the cultural argument, is to bring students to understand that great story and the enterprise behind it, so that they might not remain ignorant and alienated strangers to modern, scientific culture. Proponents of the cultural argument sometimes urge a strong role for the history of science and the philosophy of science in the school curriculum. Advocacy of both has been an important reform current in science teaching for the last thirty years.

Today, "science education for all" has become more and more popular. Practically, it is strongly connected to scientific literacy and public understanding of science, having the objective to prepare future citizens to function more effectively in an increasingly science-driven future. It is obvious that all young people need to be prepared to think deeply and critically, so that they have real chances to become innovators, educators, researchers or leaders, who can solve the most pressing challenges facing their own nation and the world, today and tomorrow.

3. IoT in education

IoT in education

Authors: Ana-Maria Suduc, Mihai Bizoi, Universitatea Valahia din Targoviste, Romania

Internet of Things is "the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data" (Oxford Dictionary). The things that are connected in IoT are either (McClelland , 2019):

1. Things that collect information and then send it – sensors (e.g. temperature sensors, motion sensors, moisture sensors, air quality sensors, light sensors, etc.)
2. Things that receive information and then act on it - executing machines
3. Things that do both.

All three of these are very important on elaborating "smart" objects/systems.

3.1. Sensors

Sensors are useful and very important for the devices in order to collect data from the environment. A sensor is an electronic device that is constantly measuring a physic variable. Depending on how this variable is measured, there are digital sensors and analogue sensors. **Analog sensor** senses the external parameters (e.g. wind speed, solar radiation, light intensity etc.) and gives analog voltage as an output. **Digital sensor** produces discrete values (0 and 1's).

The most used sensors in the IoT devices (Macharla, 2018) are:

- Temperature Sensor
- Pressure Sensor
- Proximity Sensor
- Accelerometer and Gyroscope Sensor
- IR Sensor
- Optical Sensor
- Gas Sensor
- Smoke Sensor

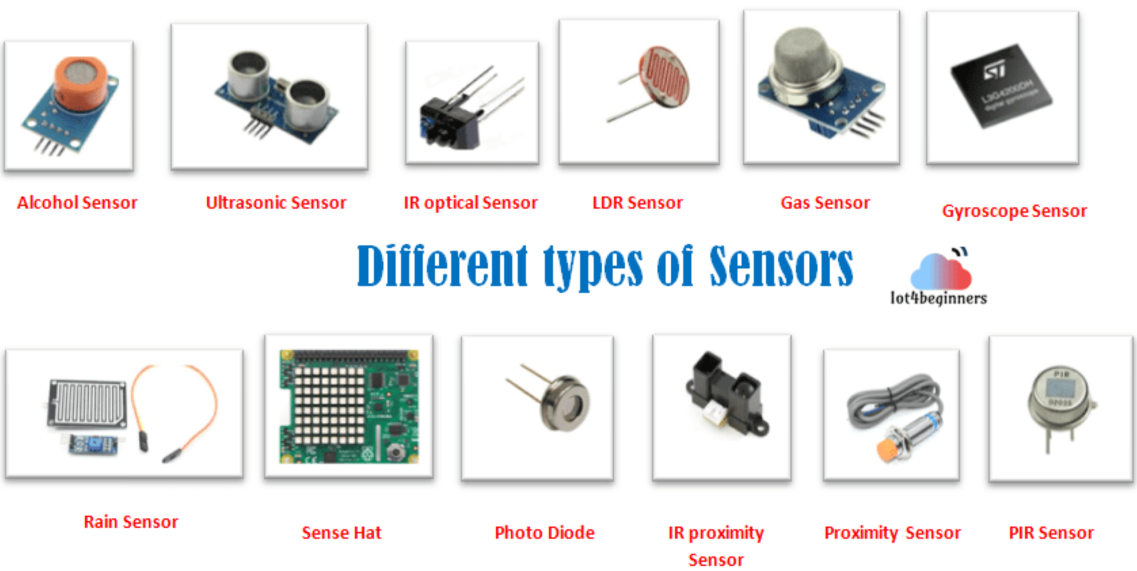


Fig. 1 Different types of Sensors (Image credit: Iot4beginners)

More information, about sensors and how the most commonly used sensors work, may be found on O2 – Educational IoT Manual – Online editor.

3.2. Communication technologies

Communication technologies plays an important role in any IoT system. The most used communication technologies/protocols IoT are presented in the following subsections.

3.2.1. Bluetooth

Bluetooth is a communication standard (IEEE 802.15.1 standard) for low cost, short range which has been designed to offer significantly reduced power consumption (especially new Bluetooth Low-Energy (BLE) – or Bluetooth Smart). This reduced power consumption makes Bluetooth communication of great value for IoT since many of the devices in IoT have limited power resources (Aqeel-ur-Rehman, Kashif, & Ahmed, 2013). The most important disadvantage of Bluetooth communication is that it cannot provide direct connectivity to the Internet. This will involve the use of an intermediate device such as a Bluetooth hub, a smartphone or a PC. According to (DataFlair, 2018), Bluetooth is expected to be key, in particular, for wearable products.

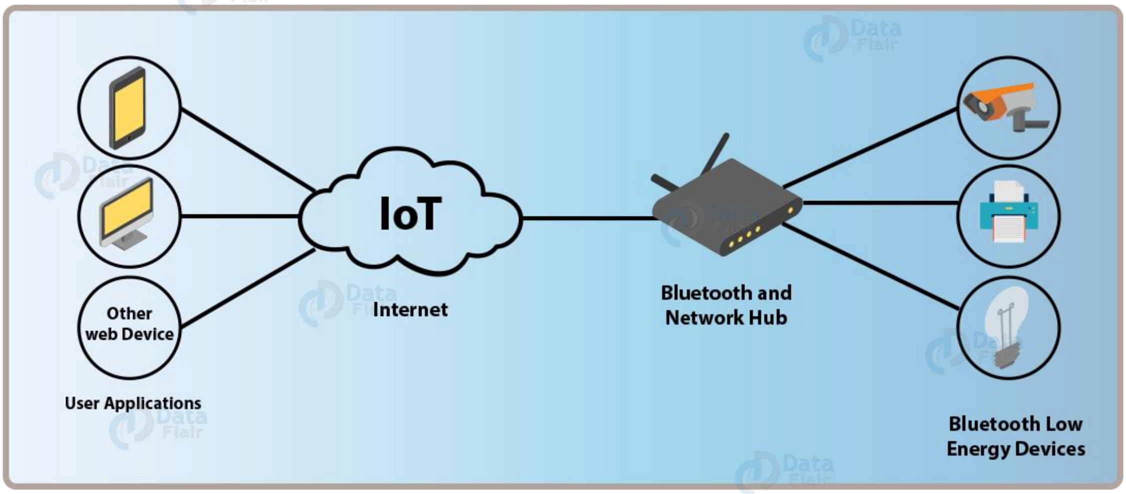


Fig. 2 Bluetooth communication in IoT (Image credit: Data Flair)

An useful guide on Bluetooth may be downloaded from here.

3.2.2. ZigBee

ZigBee is an IEEE 802.15.4 standard, similar to Bluetooth, designed for limited range network monitoring and controlling due to its low data rate and short range. ZigBee is widely considered an alternative to Wi-Fi and Bluetooth for some applications including low-powered devices that don't require a lot of bandwidth - like smart home sensors (Tillman & Hall, 2019). Some of the big ZigBee users are: Amazon (e.g. Amazon Echo Plus), Honeywell, Huawei, Philips, SmartThings, Texas Instruments, Nokia, Osram, Bosch, Indesit and Samsung.

Zigbee creates a mesh, where each interoperable device becomes a sort of outpost, able to communicate with the next device. A ZigBee network may connect 65,000 devices at any given time.

Regarding the security of the current version, ZigBee 3.0, the 128-bit symmetric encryption makes the data in the network secure to a high degree.

Since Zigbee works at 2.4GHz, the transfer data rate in the network is around 250kbps, which is more than enough for simple signals common in most applications which use ZigBee (Stables, 2019). The disadvantage of working at 2.4GHZ is that it may interfere with other devices working at the same frequency (e.g. WiFi devices).

In December 2019, Apple, Google and Amazon announced, alongside the Zigbee Alliance, the creation of the *Connected Home over IP project:* an initiative to simplify development for manufacturers and increase compatibility for consumers in the smart home world. The project has been set up to make it simpler for brands and manufacturers to build devices that are compatible with likes Alexa, Siri, Google Assistant (Stables, 2019).

3.2.3. Z-Wave

The Z-Wave protocol is an interoperable, wireless, RF-based communications technology designed specifically for control, monitoring and status reading applications in residential and light commercial environments (Z-Wave Alliance, 2020). Like ZigBee, Z-wave technology creates a wireless mesh network. The devices "mesh" together by sending signals over low-energy radio waves on a dedicated frequency. Z-wave operates on frequencies which varies by country. Every Z-wave device has a tiny built-in signal repeater that sends and receives network information (Ferron, 2019). Related to the number of nodes, Zigbee can handle as many as 65,000 nodes, while Z-Wave can handle 232 nodes (Alfrey, 2019).

In (Ferron, 2019) there is presented the Z-Wave protocol in compare with other popular protocols/technologies. According to (Ferron, 2019) the biggest improvement that Z-wave makes over Bluetooth is signal strength. Unlike Bluetooth, where all the Bluetooth devices compete with one another for bandwidth because send and receive information on the same 2.4GHz band, in the Z-Wave, the signal strengthen with each new device added in the network (since they work as repeaters). Regarding WiFi, the Z-Wave has the same advantage as comparing to Bluetooth, but in applications which requires big amount of data, WiFi is better.

The Z-Wave and ZigBee technologies works on the same mesh idea, but Zigbee is open-source software, while Z-wave is proprietary software supported and certified by the Z-Wave Alliance. Right after Apple, Google, Amazon, and Zigbee announced that they were going to work together on a common smart home standard, Silicon Labs, the owner of Z-Wave, announced that it plans to open the Z-Wave standard to third party manufacturers and development in 2020 (Kastrenakes, 2019). These two important actions make Z-Wave and ZigBee two very important technologies for future IoT.

3.2.4. WiFi

WiFi connectivity is one of the most popular IoT communication protocol, due to the wide existing infrastructure which offers fast data transfer and the ability to handle high quantities of data (DataFlair, 2018). Currently, the most common WiFi standard used in homes and many businesses is 802.11n, which offers a big rate of data transfer, but with too much power consumption for many IoT applications. Wi-Fi uses radio frequencies to provide network connectivity and operates on either a 2.4 GHz frequency or a 5 GHz frequency. Wi-Fi uses a router which creates a local network for smart home devices. Each device on the local area connection can communicate with one another because they are on the same network.

Useful comparisons between Z-Wave, ZigBee and WiFi are presented in (Pretty, 2018) and (Alfrey, 2019). The following table presents pro and cons of each of the three technologies.

Table 1. Pro and cons of three communication technologies used in IoT - WiFi, ZigBee and Z-Wave (Pretty, 2018)

	WiFi	**ZigBee**	**Z-Wave**
Pro	- *Ubiquitous* – most people already have a Wi-Fi network setup - *No need for a hub* - the devices communicate directly with the router - *Low cost*	- *Mesh network* - up to 65,000 nodes - *Scalability* - the scalability is unparalleled - *Lowest power consumption* - uses even less power than Z-wave	- *Mesh network* – up to 232 nodes - *Frequency* – operates on a different frequency than WiFi - *Low power consumption*
Cons	- *Router quality matters* - *High power* consumption - *Crowded frequency* – many devices lead to slow connection	- *Range* - the range of Zigbee (10m) is only a third of Z-wave (35m) - *Security* - Zigbee is also not as secure as a Z-wave or Wi-Fi-based systems - *Zigbee Alliance* - All devices to be certified by the Zigbee Alliance (a standardization body)	- *Hub requirement* - prices ranges from €50 to €150 - *Compatibility* - *Dependence* - the future of Z-wave is still controlled by Sigma Designs

3.3. Microcontrollers and microcomputers

In education and not only, the most popular platforms that IoTs are based on are Arduino and Raspberry Pi. For education activities very often BBC Microbit is also used.

Raspberry Pi is a **microcomputer** (it has an operation systems and interface that is accessed by plugging it into a monitor) and Arduino and Microbit are **microcontrollers** (have the capacity to store and run only one program at a time, but can be reprogrammed as many times as possible). A useful comparison between the three platforms can be found in (Noor, et al., 2018), article which can be found here.

3.3.1. Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software available. Arduino was built at the beginning (in 2005) as an easy tool for fast prototyping, aimed at students without a background in electronics and programming, then it was adapted for IoT applications, wearable devices, 3D printing, and embedded environments. All Arduino boards and software are completely open-source and has a loyal and supportive community behind it. More about Arduino can be found at https://www.arduino.cc/.

3.3.2. Microbit

The Micro Bit is an open source hardware designed by the BBC for use in computer education in the UK. It was first announced on the launch of BBC's Make It Digital campaign on 12 March 2015 with the intent of delivering 1 million devices to pupils in the UK. BBC micro:bit has been developed as a platform for teaching children the principles of computer science and engineering by engaging them in creative play. According to (Knowles, Beck, Finney, Devine, & Lindley, 2019), "*in contrast to other programmable IoT devices (e.g. Arduino and Raspberry Pi) that have seen some adoption in the classroom, the micro:bit ecosystem does not presume a level of proficiency that includes knowledge of electronics and circuitry and the ability to program, configure networks, or configure and install software*". This makes Micro:bit great for beginners.

More about Micro:bit can be found at http://microbit.org.

Inspired by Micro:bit, a similar platform was developed in Germany to be used in primary education: Calliope Mini. This tiny controller include, as Micro:bit, a 5x5 LED matrix, a compass sensor, an accelerometer, a light sensor, two buttons and radio and Bluetooth, but in addition it has also an RGB led, a built-in speaker and microphone, and a built in DC motor controller for 2 DC motors (Codomo, 2017).

3.3.3. Raspberry Pi

Raspberry Pi is a series of microcomputers developed in the United Kingdom by the Raspberry Pi Foundation to promote teaching of basic computer science in schools and in developing countries. It has its own OS which is known as Debian OS and it has all the components of a computer such as processor, memory, and a GPU for video input processing and the HDMI output. Although Raspberry Pi does not offer internal storage, SD cards can be used as the flash memory for the entire system. The first Raspberry Pi was released in 2012 and the current version is Raspberry Pi 4 Model B.

More about Raspberry Pi can be found at https://www.raspberrypi.org/

3.4. Interactive things

By interactive things/objects we mean that type of devices that include a microcomputer or microcontroller, sensors and actuators and react to different stimulus.

If we think to IoT we may go closer to the idea of smart devices which generally are connected to other devices or networks and can operate to some extent interactively and autonomously.

On the market there are many types of interactive things/IoTs such as:

- Smartphones
- Smartwatches
- Fitness trackers
- Wristbands with different functions (e.g. Adapting to the coronavirus situation, a startup called Slightly Robot redesigned their wristband created for the people with trichotillomania, a disorder that compels people to pull out their hair, to vibrates if the owner touch his face, in order to prevent Covid-19 infection (Constine, 2020))
- Connected cars
- Smart clothing with built-in technology

- Augmented reality headsets
- …

In education, often the interactive things designed in classroom are called robots.

3.5. 3D printing in education

In the last 10 years we experienced a tremendous growth in the production and use of desktop 3D printers. This growth has been driven by the decreasing costs of 3d printers and by its increasing availability. Growth is also spread widely due to the increasing number of 3D designs shared by people on Internet, designs which can be manufactured and reengineered by anyone interested.

The use of 3D printing technologies in industry is growing as new applications are found that take advantage of their functionalities. In this context, education started a while ago to integrate 3D printing in schools.

Additive manufacturing and 3D printing technologies can facilitate learning, develop skills, and increase student engagement (Berry, et al., 2010); inspire creativity, improve attitudes towards STEM subjects and careers, while also increasing teachers' interest and engagement (Horowitz & Schultz, 2014). According to Ford and Minshall (2019) after reviewing 44 articles, 3D printing in schools is used in physical prototyping mostly for improving the understanding of science and mathematics. Several examples of use of 3D printing in schools identified in literature and listed by Ford and Minshall are as follows:

- to introduce atomic structure in Grade 10 chemistry classes (Chery, Mburu, Ward, & Fontecchio, 2015)
- to learn about audio frequency through creating 3D printed police whistles (Makino, et al., 2018)
- to the construction of 3D printers (Dumond, et al., 2014)
- for computational thinking through a combination of Minecraft and 3D printing (Roscoe, Fearn, & Posey, 2014)
- for design thinking through a 3D printed city planning game, Kidville (Mahil, 2016)
- to create prosthetic hands, in elementary schools (Cook, Bush, & Cox, 2015) and high schools (Jacobs, et al., 2016)
- etc.

The many benefits of 3D printing go beyond math and science comprehension. An important aspect to be mention is that 3D printing also supports inclusion efforts for students of various learning styles and improves collaboration and speaking skills.

Ford and Minshall (2019) also list different 3D printed artefacts created during design projects in schools (e.g. biomedical devices, bridges, desk lamps, home appliances, orthotics, robots, etc.) and subjects in which the use of 3D printing has improved student understanding of a topic:

- Biology
- Chemistry
- Design
- Engineering
- Mathematics
- Pharmacology

For other very interesting information about 3D printing in education, as it is viewed in scientific literature, read the Ford and Minshall article here.

(MakerBot, n.d.) presents 5 major benefits of 3D printing in education:

- creates excitement - 3D printing offers students the opportunity to experience the whole process from designing to bringing to physical world.
- complements the curriculum – the students become active and engaged participants through the conception, design, and execution of their projects and interacting with the 3D printer and the teacher.
- gives access to knowledge previously unavailable – since the 3d printing process is an iterative process which involves also failure, the students "begin to understand that failure is part of the process, they become less afraid to attempt and execute new and different ideas in life. This builds students' confidence and teachers enjoy the results of having self-motivated, self-confident students."
- opens new possibilities for learning – the 3D printers give students the opportunity to visualize their ideas. 3D printers open up new opportunities for presenting information to young students in an economical and efficient manner.
- promotes problem-solving skills **–** students need to learn how different 3D printers work and how to operate them, and how to troubleshoot and solve problems. By learning how to troubleshoot and solve 3D printer problems, students learn to practice persistence and endurance in overcoming difficulties.

A nice list of 3D printed robots or with 3D printed parts can be found on All3DP website at: https://all3dp.com/2/3d-printed-robot-print-robots/. Many of these robotic projects can be tried at home.

4. Pedagogical framework & Learning methodologies for the implementation of the WEMAKERS/IOT learning scenarios

Pedagogical framework & Learning methodologies for the implementation of the WEMAKERS/IOT learning scenarios

Authors: Rene Alimisi, Anna Vasala, Dimitris Alimisis, EDUMOTIVA, Greece

4.1. Pedagogical background

The proposed learning methodologies have their roots in Maker Movement (Blikstein, 2013) and Papert' s constructionism (Papert & Harel, 1991) and can offer a vision for IOT education that will enable learners to make their own IoT artifacts using the 21st century technologies. The incorporation of the Maker Movement culture in IoT education implies a paradigm shift in IoTs curricula from step-by-step guided tasks and predefined robots towards open projects and making practices where learners become "makers" of their own transparent IoT artefacts (Alimisis, 2013).

The Constructivist "learning by making" methodology is strongly related to the "Do-It-Yourself" (DIY) philosophy (Schon, Ebner, & Kumar, 2014) and is the driving force behind the WEMAKERS pedagogy. Hence, the WEMAKERS project suggests that the 21st century learning ecosystems should be designed in a way that can actively engage students with learning tasks, hands-on activities and learning experiences that promote young people's creativity, critical thinking, teamwork, and problem solving.

To exemplify this learning paradigm in concrete terms, we present in the next sections the WEMAKERS learning methodology.

4.2. The WEMAKERS learning methodology

Embedded in a constructionist pedagogical model, the learning methodology is aimed to encourage teachers and students to work together and explore the fun and challenges of the making process. The methodology proposes stages highly interlinked: ideation, planning, creation, programming and sharing. The main pillars of the pedagogical model are presented shortly in the following lines.

4.3. Project-based learning

The WEMAKERS learning methodology focuses on the project-based learning, a model for classroom activities, that shifts away from the traditional classroom practices of short, isolated, teacher-centered lessons. The methodology encourages learners' engagement in a real-life scenario that requires taking an action for making or using a robot in a creative way, planning and designing their own IoT projects, making and programming their own IoT artifacts, testing and reflecting on their solutions and finally sharing their experiences with the community. Students are encouraged and supported to devise their own heuristic approach to a solution which offers much more space for creativity and involvement in creative design for learners compared to closed problem-solving.

4.4. Teamwork

Following the pedagogical ideas underpinning the WEMAKERS methodology, the team work is highly encouraged. The students early from the beginning are invited to form groups of 3-4. As the sessions are going by, the students can move to support other groups as well, to exchange tips and to allocate roles. In some groups the students may be equally involved in the project tasks but in most cases, there is a role rotation. For example, some students may be more involved into programming, others more into electrical circuit making while some others are taking care of the handcrafting tasks or 3D modelling. The reasons for this role allocation is usually related to time constraints and personal interests.

During the first session focus is placed on familiarizing the students with the WEMAKERS tools, technologies, and resources. Some groups need more time for familiarization than others but the whole familiarization process is integrated into the making process and occurred through the practical engagement in projects for computer-supported artefact constructions. It is worth mentioning, that as the workshops are progressing the students are expected to become more confident in using the available tools and more eager in trying out different ideas.

4.5. Ice-breaking and setting the rules in the class

The 1st session starts with ice-breaking activities, the setting of the ground rules and the elaboration of the process which the students will go through. These activities are selected in advance by the teachers with the aim to activate the necessary mechanisms for the "group-development process" and the establishment of a positive and warm atmosphere.

In the context of the ice-breaking activities, the students are encouraged to form a circle and introduce themselves, to talk about their hobbies and interests; through playful techniques were also invited to have short one-to-one conversations. These discussions are also seen as important steps towards team bonding and good relationship establishment.

During the 1st session, focus is also placed (at group level) on creating a set of rules that will reflect the accepted behaviors in the group and in the lab, for both teachers and students. The discussion about lab safety rules is revisited as the sessions are progressing. The ice-breaking activities and the setting of the rules is followed by the exploration of the lab equipment at group level.

4.6. Implementing the WEMAKERS methodology.

The **ideation** stage is considered a challenging process. The students are asked about any possible idea that they would like to implement soon. Noteworthy, through their diaries, they are also encouraged to periodically document their ideas for new projects. Their responses on this matter are not very enlightening in the beginning. However, as they become more familiar with tools and the technologies, they start expressing interest in working on specific or thematic projects.

The teachers discreetly observe and support this process; by providing useful explanations (i.e. in making circuitry more transparent, increasing students' understanding of electronics) to help students move forward. The teachers are encouraging the group members to bring their ideas in the plenary session for the benefit of the whole group. Sharing existing ideas, plans for implementation, problem solving practices and thoughts in group and in the plenary session are seen as a process that can significantly boost the generation of ideas for new constructions.

There is also encouragement towards analyzing ideas, breaking down complex activities into sub tasks, keeping notes about Science-Technology-Engineering-Arts-Math (STEAM) concepts related to their project (i.e. electrical circuit making), listing the materials that will be needed, sketching the structure of the construction, visualizing the key processes. This is the stage of **planning** that in many cases is embedded in the ideation process, re-visited and creatively re-approached by the groups during the creation of the artefacts and the programming phase. In a way, these practices show how interlinked the stages of the WEMAKERS methodology are.

4.7. Role allocation in teamwork

The role allocation may happen at group level and is not enforced by the teachers. The group members are involved in all the parts of the development of the IoT artefact supporting one another. The teachers only intervene in cases where one member of the group is inactive. They should be mainly trying to understand the reasons behind the inactivity and to create a situation where through the interaction with the other group members, a role for him/her would emerge.

4.8. Sharing

The sharing of the learning processes and of the projects with others is considered of great significance. The teachers encourage all the groups to share the current status of their work in the end of each session, to talk about the processes that they went through and their future plans.

In addition, the groups are encouraged to showcase their work in the school community and the wider public. In this light, the students may present their projects in Festivals and interact with people of all ages and from varying scientific backgrounds as well as with other groups of students that participate in the festival either as exhibitors or visitors.

The students and the teachers are also encouraged to record their work using their smartphones or cameras. At a later stage, some of this material may be uploaded by them in their social media accounts.

4.9. The role of the teachers

The description above revealed already many interesting aspects of the role of the teachers. The teachers are invited to act as supporters of the learning process, co-makers, boosters of the collaborative work, the discussion, and the sharing at team level and beyond.

The teachers support the generation of ideas prompting for relevant group discussions and existing project ideas extension. In addition, they boost a lot the 'Can-do' attitude, sharing their enthusiasm with the students and creating an atmosphere conducive to learning.

The teachers in the WEMAKERS projects should be ready to step out of their comfort zone. Regardless their backgrounds and level of experience, they are invited to apply new practices, to explore new tools and technologies (i.e. DIY electronics, sensors, new programming tools and more).

The WEMAKERS projects invite failures and exploits them from a learning perspective. The teachers should approach failures as opportunities for creating deeper and richer learning experiences.

It is important to encourage the students to work on projects that are meaningful to them. However, big ideas may not easily emerge. Even when the project scenarios are proposed by the teachers, it is important to offer students opportunities to extend the scenario of the project based on their personal interests and preferences. When the students work on something they really like, it is more likely to dedicate themselves in the making process, to engage in explorations and to come up with new and more advanced ideas.

Teachers are not the sages on the stage, and they are not supposed to have all the answers to the questions that may emerge. They rather help and encourage the students to explore and construct their own knowledge, to organize their thoughts and ideas, to work effectively in teams. They encourage teamwork, experimentation, hands-on activity, challenge seeking and the sharing of knowledge.

It is important to provide students with opportunities to share their ideas, accomplishments, experiences and struggles with each other. It is important to show them that they can build upon the experiences and results of others and others can learn from their own experiences and outcomes. Sharing can happen in the class, in teams, in online platforms, in public festivals, school events and more.

The making process is not linear. It involves several stages that are interlinked and often take place in parallel. As a result, the teachers are moved to take several roles (the roles of the mentor, trainer, facilitator of the learning process, self-esteem booster, co-maker, co-learner, evaluator and more) and adapt their support and guidance based on the needs along the way.

The WEMAKERS projects call for synergies and partnerships among teachers of different disciplines (Science, Technology, Engineering, Arts, Math). In this way, interdisciplinary projects and innovative ideas can be better supported. In addition, within a partnership of teachers, it is more likely to deal with organizational and administrative issues emerging often in the formal education settings.

5. Tutorials

5.1. Tutorial 1. Directional indicator system for bicyclists

Author: Ana-Maria Suduc, Universitatea Valahia din Targoviste, Romania

A. Scenario

Alex is an 11 years old child. He loves to ride his bike and he prefers to go to school and come back home by bike. Alex is in 5th grade and he has afternoon classes. During winter, when he finishes the classes and returns home from school it is already dark outside. Not always the drivers notice his arms pointing in the direction he needs to go. Let's help Alex by creating a wearable device for him which displays a lighting flashing arrow which points the direction!

B. Description

A wearable device which may help Alex can be created with a micro:bit placed on the back of his helmet. When he would bend his head to the right, the micro:bit would display a right flashing arrow. A similar behavior would have when he bends his head to the left (but a left arrow would be displayed). For creating this wearable device, you need only a micro:bit and batteries for it. In this case the program for the micro:bit would be the one presented for micro:bit H in Step 2 section, of this tutorial (removing the radio related blocks).

An issue of such a system would be the following: how Alex can be sure the micro:bit showed the arrow corresponding to his intention. Did he bend his head enough for the micro:bit to detect his movement? That's why, we propose in this tutorial a system made of two micro:bits: one placed on the bicyclist helmet (we will name it *micro:bit H*) and a second micro:bit placed on the handlebar (we will name it *micro:bit B*). The second micro:bit is used to show exactly what the micro:bit on the helmet is displaying.

Fig. 3 The positions of the two micro:bit microcontrollers

In this way, Alex will know for sure if the appropriate arrow is displayed to the other traffic participants.

When Alex bends his head to the left/right, the micro:bit H will detect the movement and display a flashing left/right arrow, and it also send a radio signal to the micro:bit from the handlebar, to do the same. The micro:bit B is for checking if the micro:bit H detected well the bicyclist head movement and displays the correct arrow.

C. Required materials:

- 2x micro:bit + batteries holder
- 1x USB cable
- 1x micro:bit printed case for micro:bit H
- 1x micro:bit printed case for micro:bit B
- Velcro, duct tape or other tape/ribbon to attach the micro:bit case on the helmet

D. Steps

Step 1. Open MakeCode for microbit editor at https://makecode.microbit.org/
Step 2. Using the knowledge gained in O2 about MakeCode for Microbit, write the code for micro:bit H. Example of possible code:

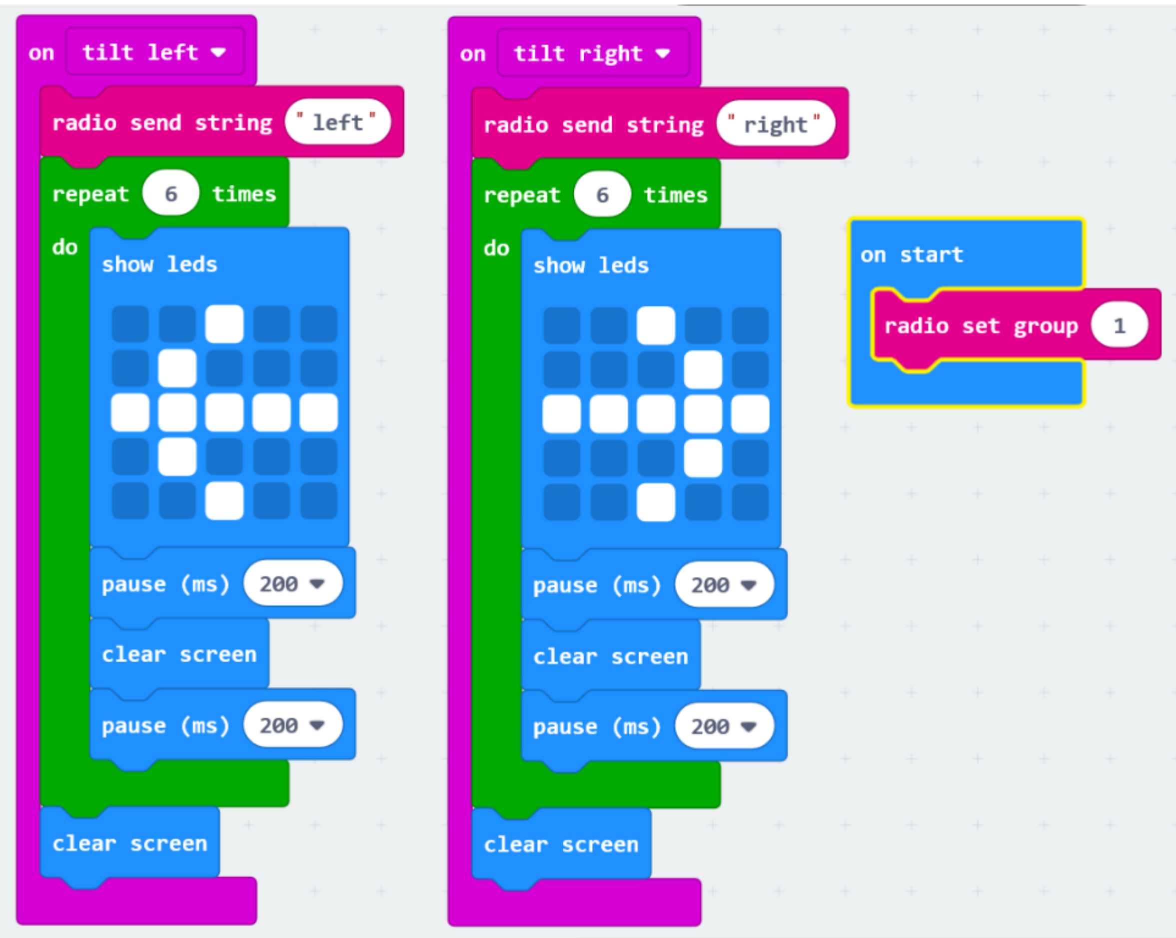


Fig. 4. Code for micro:bit H (placed on the helmet)

Step 3. Connect the micro:bit H to the computer using the USB cable. Upload the hex file with the code on micro:bit. Test it by tilting the micro:bit left. A flashing left arrow should be displayed. Similar when the micro:bit is tilted right, a flashing right arrow should be displayed. If it is not working well, check the code and upload again the corrected code. When the micro:bit H works as expected disconnect it from the computer and you may attach the batteries connector and test it again.

Step 4. Write the code for micro:bit B. Example of possible code:

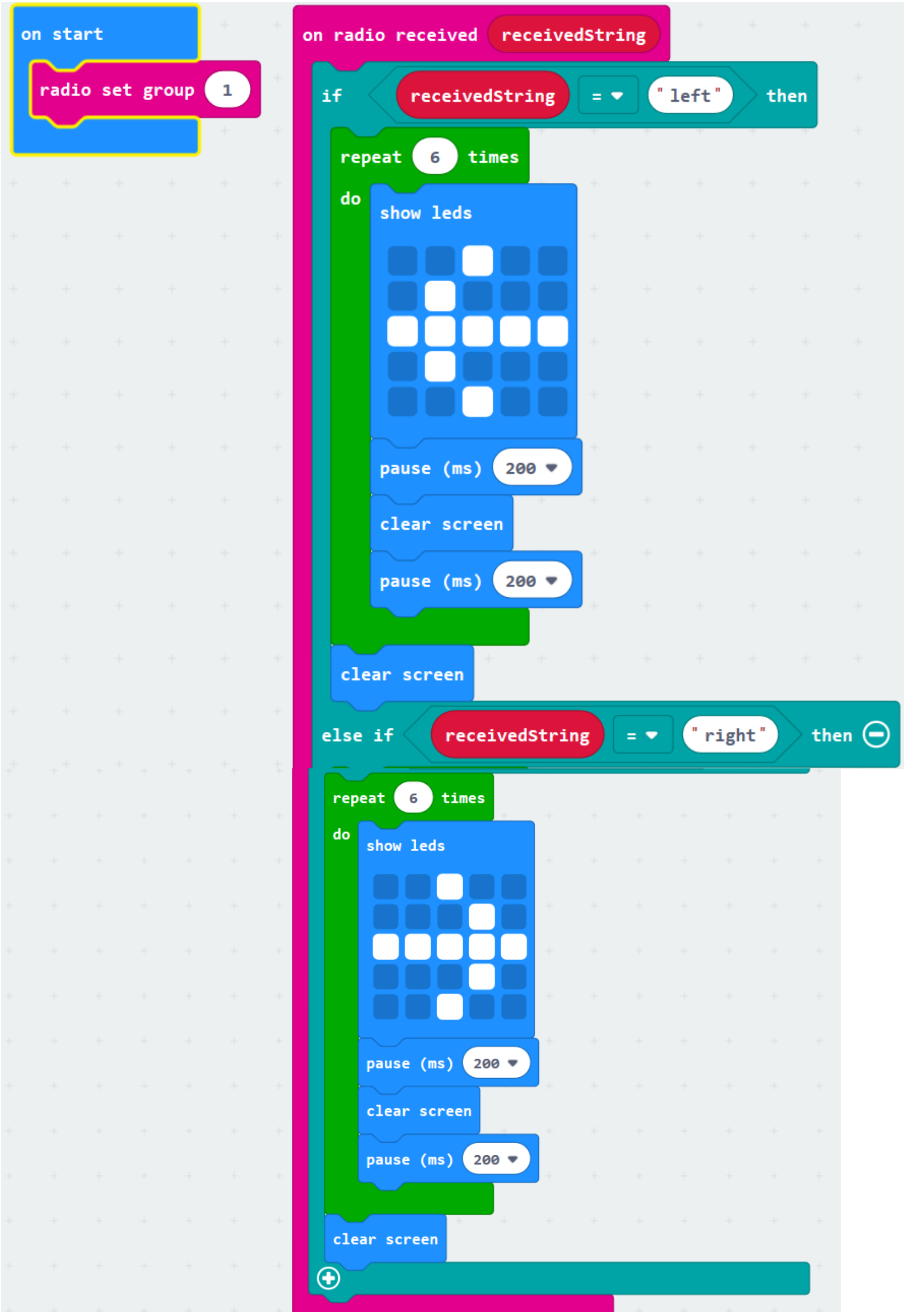


Fig. 5. Code for Micro:bit B (placed on the handlebar)

Step 5. Upload the .hex file on micro:bit B. Test it by tilting he micro:bit H left and right. Both micro:bit chips should display appropriate flashing arrows. If it is not working as expected, check the code and repeat this step. Then disconnect it from the computer and connect the batteries. Test the system again. If it is working as expected, go to the next step.

Step 6. Using the knowledge gained in O1 about 3D modeling and printing, design your own cases for the micro:bit microcontrollers, or download the .stl files for already made 3D models for micro:bit cases from here.

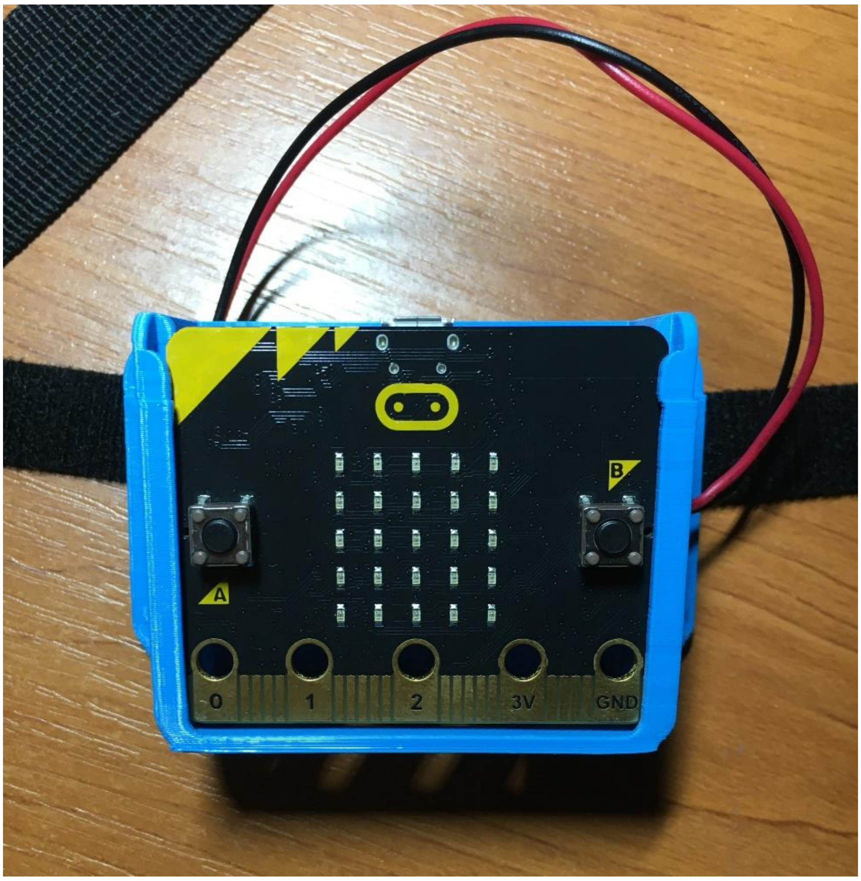


Fig. 6 Case for Micro:bit H - helmet (stl file source: https://www.myminifactory.com/object/3d-print-micro-bit-multi-mount-21845)

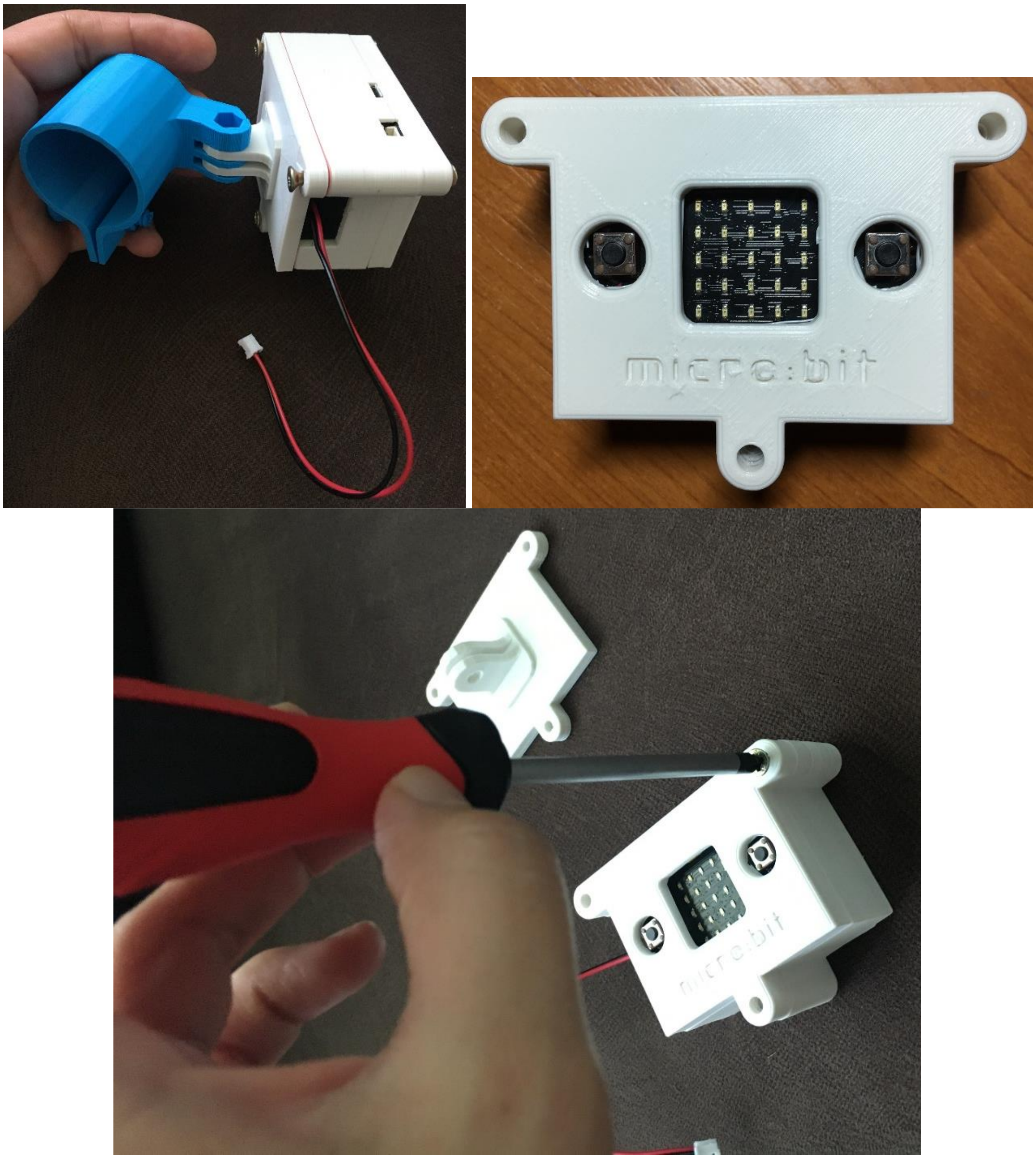


Fig. 7 Case for Micro:bit B – handlebar – Variant 1 (adapted after https://www.thingiverse.com/thing:2676331)

Fig. 8 Case for Micro:bit 2 – handlebar – Variant 2 (Adapted after https://www.myminifactory.com/object/3d-print-micro-bit-post-box-21891)

Fig. 9 The right arrow displayed on both micro:bit chips when the helmet is bended to the right

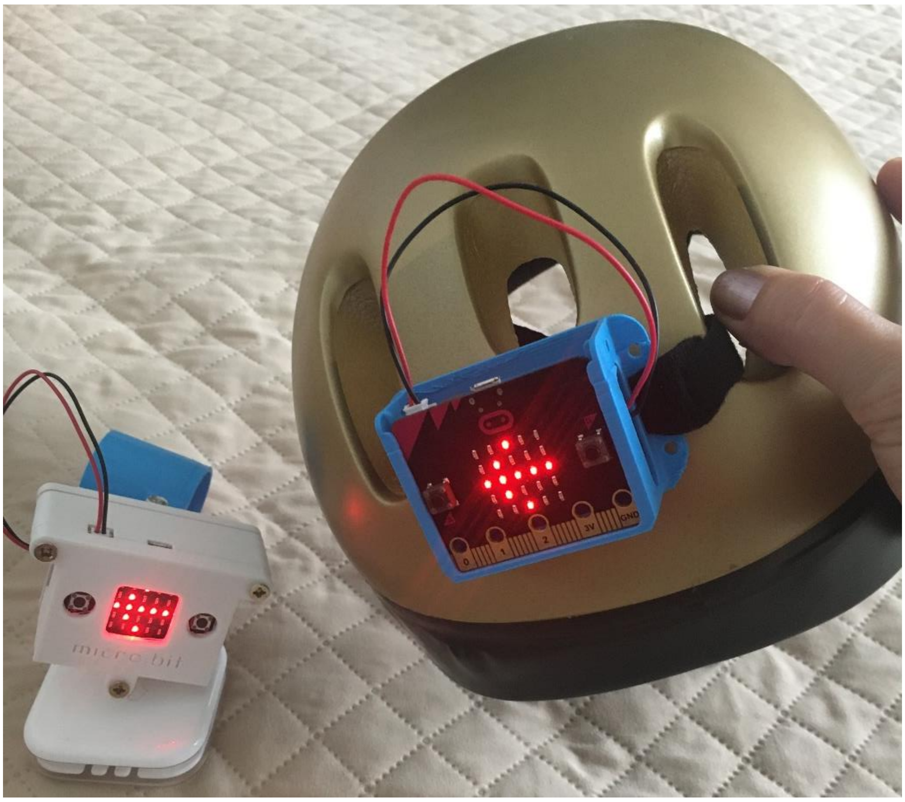


Fig. 10 The left arrow displayed on both micro:bit microcontrollers when the helmet is bended to the left

Tutorials on how to develop other similar devices may be found at:

- https://make.techwillsaveus.com/microbit/activities/mod-a-helmet
- https://www.instructables.com/id/A-Microbit-Direction-Indicator-for-Biking-Helmets/
- https://www.kitronik.co.uk/blog/zip-tile-microbit-bike-light-isaac-gorsani/

5.2. Tutorial 2. Web-based weather station

Author: Mihai Bizoi, Universitatea Valahia din Targoviste, Romania

Monitoring environmental parameters in a particular place or room is a very important topic. A project in this sense can be approached as a children's hobby or can be developed from a professional perspective.

A. Scenario

Dan's parents have a country house where they also have a greenhouse where many plants grow. Given that a WiFi Internet connection is available, Dan thought he could create a simple device to monitor the environmental parameters in the greenhouse.

He conducted a study on the Internet and concluded that in order to create this device as easily as possible, he needs a programming platform to which sensors can be easily connected to monitor environmental parameters. That platform should also have a built-in WiFi interface and an operating system on which a web server can be installed and configured. Also, an accessible programming language.

After the study, Dan chose Raspberry PI as his development platform because it allows the installation of a web server and allows programming in the Python language. Another reason is that on the Raspberry PI it can connect an electronic board that includes all the sensors needed for his project (Sense HAT).

B. Description

Raspberry PI is a small computer that can run a Linux-based operating system - Raspbian. Due to the fact that it runs an operating system, it can be programmed using a variety of programming languages and tools. From a hardware perspective, the Raspberry PI has 40 GPIO (General-Purpose Input / Output), which can be used to connect various sensors or components.

Raspberry PI is a good platform for interfacing various sensors with the web because it allows the installation and configuration of a web server, as well as the development of web applications directly on it.

The Sense HAT is an add-on board for Raspberry Pi. The Sense HAT can be programmed in Python language and includes numerous sensors on the same board: temperature, humidity, barometric pressure, magnetometer, accelerometer, gyroscope, etc. Using Sense HAT offers the advantage of having a multitude of sensors available without the need for electronic knowledge to connect these sensors to the Raspberry PI board.

This tutorial shows how to create a device that displays temperature, humidity, and barometric pressure in a web interface. If it is connected to the Internet with a public IP address, the web interface can be accessed from anywhere in the world, from any device that can access the Web.

In addition to the hardware and configuration of the operating system and the tools on it, such a device is implemented through a script made in the Python language. The script will access, through a library, the temperature, humidity, pressure sensors and will store the values read in local variables. Another role of the script in Python is to create the interface with the web. In this sense, an HTML and

CSS template (languages that are interpreted by web browsers) is used to display the collected values in an attractive format.

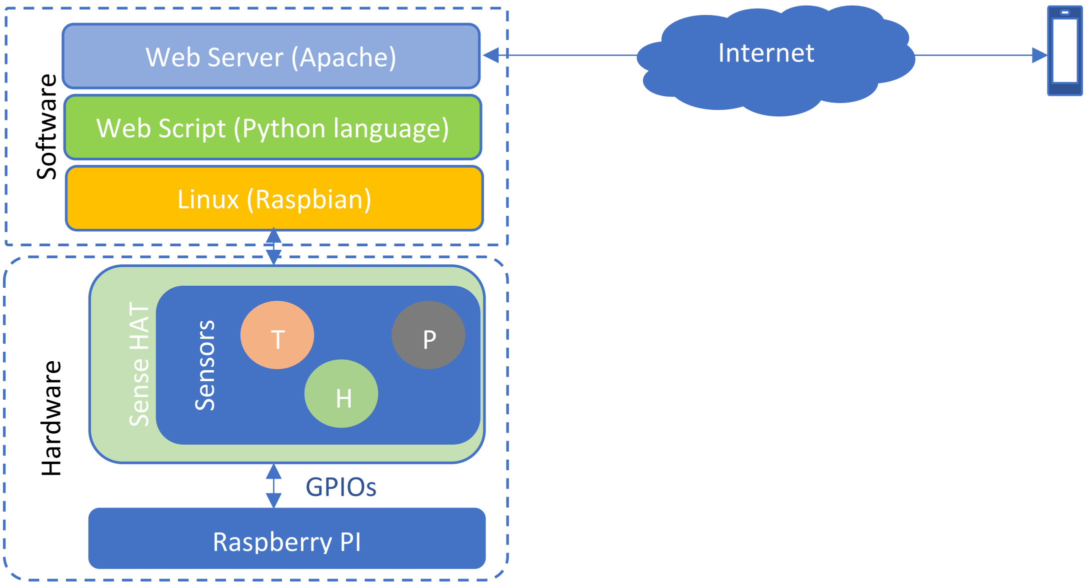


Fig. 11 Proposed system architecture

C. Required materials:

- 1x Raspberry PI 3
- 1x Micro SD Card with Raspbian OS
- 1x Power Supply (5V/3A)
- 1x Sense HAT
- 1x WiFi or Ethernet connectivity
- 1x HDMI cable
- 1x Monitor or TV
- 1x 3D printed case

D. Steps

Step 1. Place the Sense HAT over GPIO pins on the Raspberry PI as is presented in the following image.

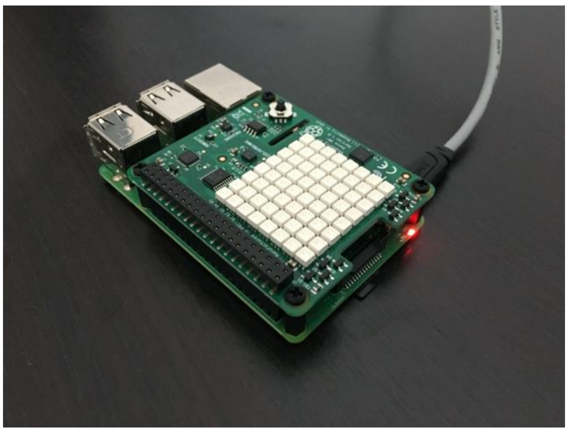


Fig. 12 Raspberry PI with Sense HAT

Step 2. Insert the SD card, the HDMI cable to Monitor and connect the power supply to start the system.

Step 3. Assuming the Raspbian operating system is installed on the SD card, wait for the operating system to boot and configure the Internet connection (using WiFi or an Ethernet cable).

Step 4. We need to be sure that Raspberry is running the last version of software. To do that, open a Terminal and run the following commands:

```
sudo apt-get update
sudo apt-get upgrade
```

Step 5. We should install the Sense HAT Software Package. This will provide all the libraries that will allow us to interact with Sense HAT. After that, reboot the Raspbian OS.

```
sudo apt-get install sense-hat
sudo apt-get install python-gpiozero
sudo reboot
```

Step 6. Our intention is to obtain the weather information over the Web. So, the next step is to install the Apache Web Server and activate mod *cgid*. Open a *Terminal* and write the commands:

```
sudo apt-get install apache2
sudo a2enmod cgid
```

Step 7. Modify the configuration file of the default website.

- Open the file with *nano* editor:

```
sudo nano /etc/apache2/sites-available/000-default.conf
```

- Uncomment the following line, by removing the # character in front:

```
#Include conf-available/serve-cgi-bin.conf
```

- Add the following line under the line with "`DocumentRoot ….`"

```
DirectoryIndex /cgi-bin/webstation.py
```

- Save the file with CTRL+O and exit from the file with CTRL+X.

Step 8. Change the user used by Apache Web server (change user *www-data* with *pi*).

- Open the file with *nano* editor:

```
sudo nano /etc/apache2/envvars
```

- Change the line:

```
export APACHE_RUN_USER=www-data
```

with

```
export APACHE_RUN_USER=pi
```

- Save the file with CTRL+O and exit from the file with CTRL+X.

- Restart the web server.

```
sudo service apache2 restart
```

Step 9. Create a small web script with the name webstation.py. The script will collect the data from Sense HAT sensors and will present them through a web interface.

- Open the file with *nano* editor:

```
nano webstation.py
```

- Write the program in the file:

```
#!/usr/bin/env python
from sense_hat import SenseHat
from datetime import datetime
from gpiozero import CPUTemperature
import cgitb

print("Content-Type: text/html \n\n")

cgitb.enable()
sense = SenseHat()
sense.clear()

temp_nc = sense.get_temperature()
cpu = CPUTemperature()
temp = temp_nc - (cpu.temperature - temp_nc)
temp = round(temp,1)

humidity = sense.get_humidity()
humidity = round(humidity,1)

pressure = sense.get_pressure()
pressure = round(pressure,1)

now = datetime.now()
datetime = now.strftime("%d/%m/%Y %H:%M:%S")

html_code = """
<html>
 <head>
  <link rel="stylesheet"
href="https://stackpath.bootstrapcdn.com/bootstrap/4.4.1/css/bootstrap.min.
css" integrity="sha384-
Vkoo8x4CGsO3+Hhxv8T/Q5PaXtkKtu6ug5TOeNV6gBiFeWPGFN9MuhOf23Q9Ifjh"
crossorigin="anonymous">
  <meta name="viewport" content="width=device-width, initial-scale=1,
shrink-to-fit=no">
  <meta http-equiv="refresh" content="5">
  <Title>Weather station</Title>
 </head>
<body>
 <div class="container" style="padding-top: 20px;">
  <h2>Weather station</h2>
  <p>Current time: {datetime}</p>
```

```
  <table class="table table-striped" style="width:30%;">
  <tr><td>Temperature:</td><td>{temp} C</td></tr>
  <tr><td>Humidity:</td><td>{humidity} %</td></tr>
  <tr><td>Pressure:</td><td>{pressure} Millibars</td></tr>
  </table>
 </div>
</body>
</html> """

print(html_code.format(**locals()))
```

- Save the file with CTRL+O and exit from the file with CTRL+X.

Step 10. Move the file *webstation.py* in the directory */usr/lib/cgi-bin* and add the execution permission:

```
sudo mv webstation.py /usr/lib/cgi-bin/.
Sudo chmod +x /usr/lib/cgi-bin/webstation.py
```

Step 11. Open the Web Browser and test if application is working. In the address field, please enter the name *localhost*.

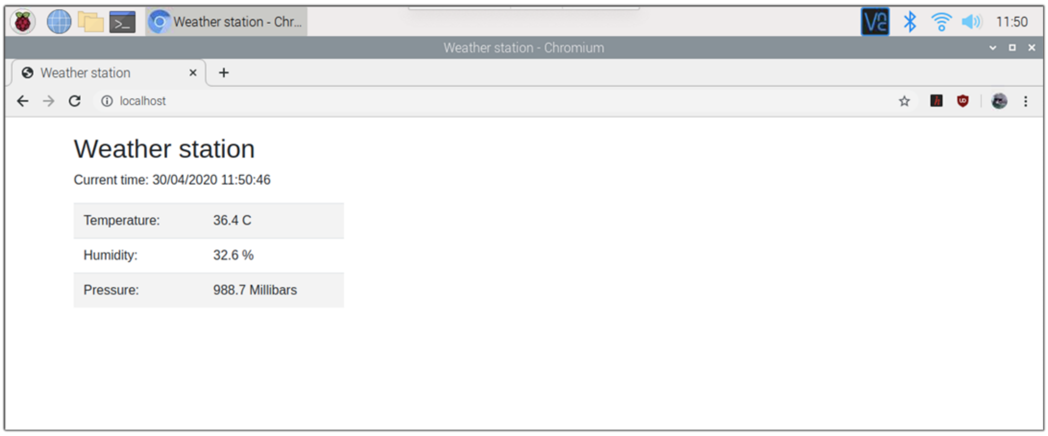


Fig. 13 The web interface of the weather station

Step 12. Discover what is the IP Address of the Raspberry PI. In the Terminal, run the command:

```
sudo ifconfig
```

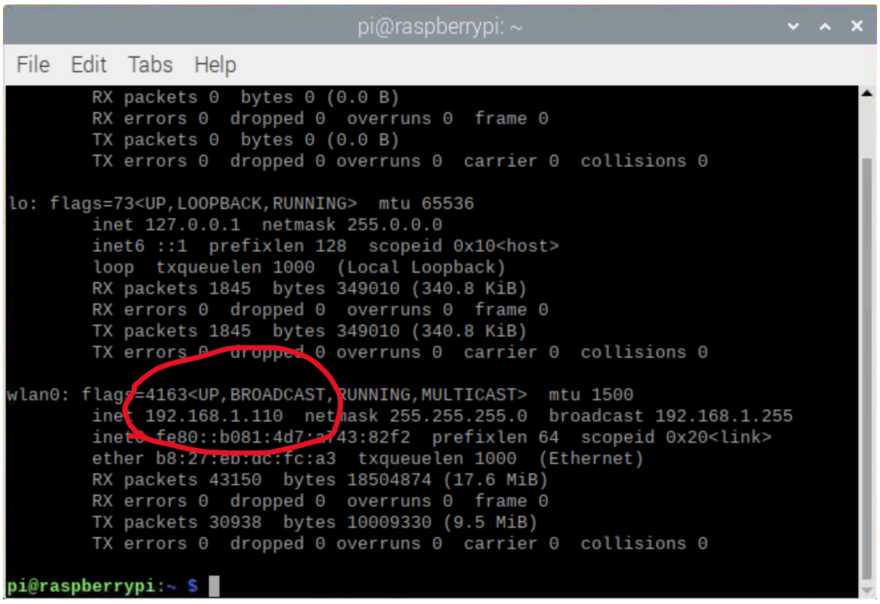


Fig. 14 How to identify the IP address of the device

Step 13. Verify the web interface over the network, using a mobile phone. Open the web browser on the phone and type the IP Address found before. The phone must be connected in the same network with Raspberry PI.

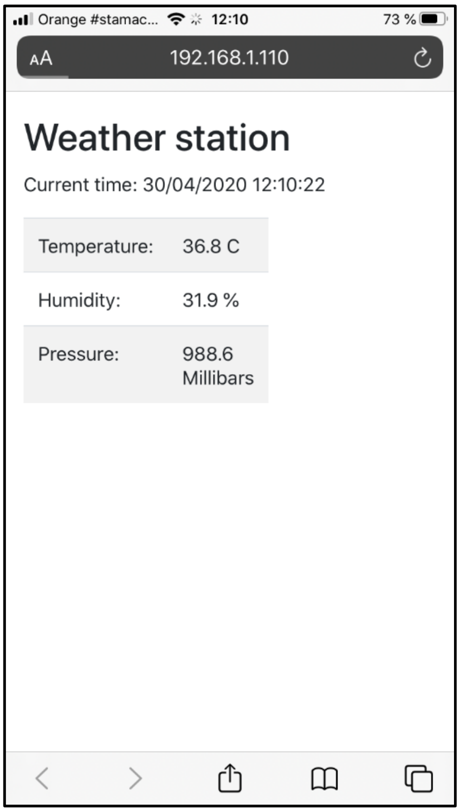


Fig. 15 Weather station web interface accessed on a smart phone

The Raspberry Pi and Sense HAT can be placed in a 3D printed case. In the following there are presented three examples of cases which can be 3D printed and used in this application:

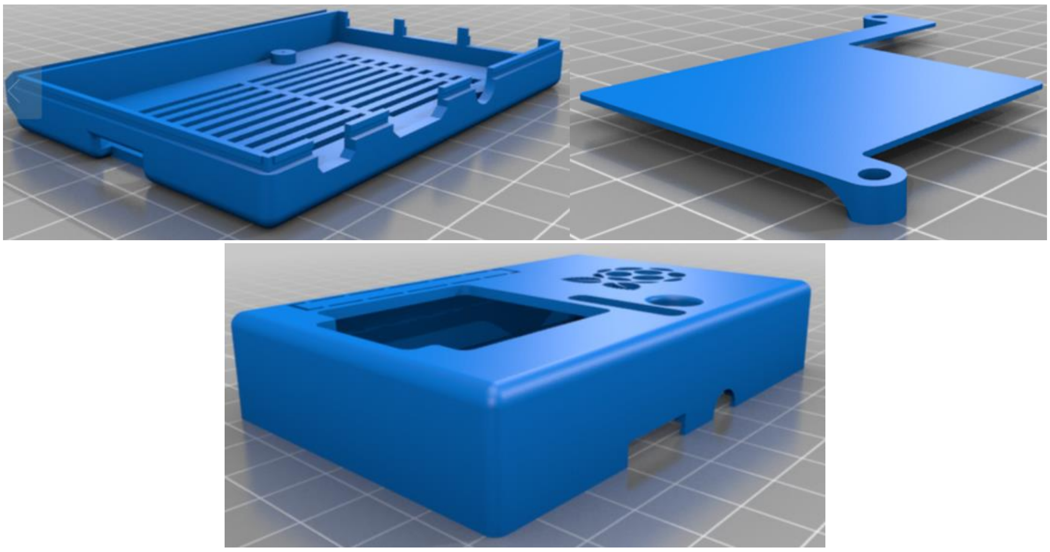


Fig. 16 Example 1. The stl files can be download from: https://www.thingiverse.com/thing:4012845

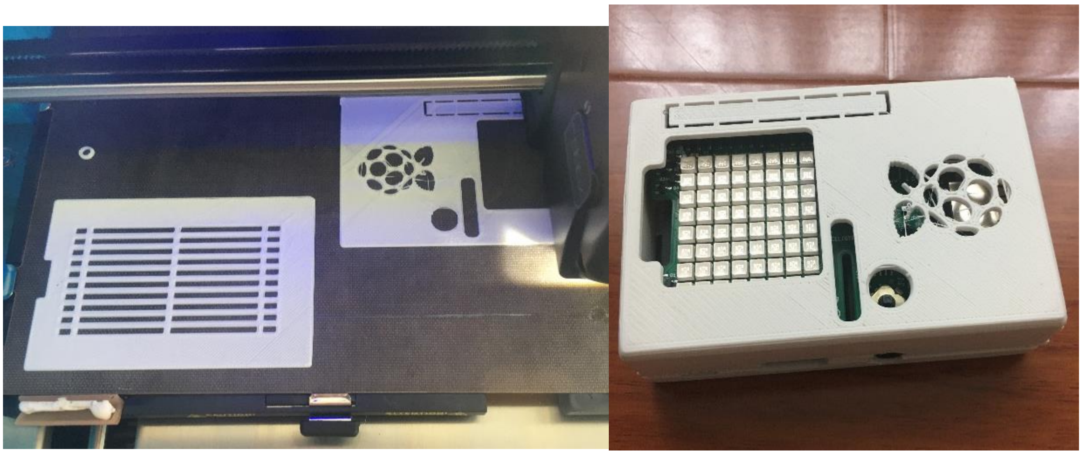


Fig. 17 Example 1 3D printed

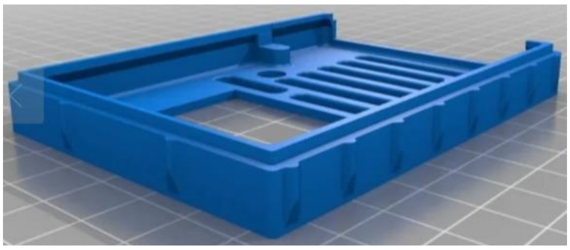
a)  b) 

Fig. 18 Example 2. a) The .stl file for the bottom part can be download from: https://www.thingiverse.com/thing:1572173 ; b) The .stl file for the top part can be download from: https://www.thingiverse.com/thing:2757144

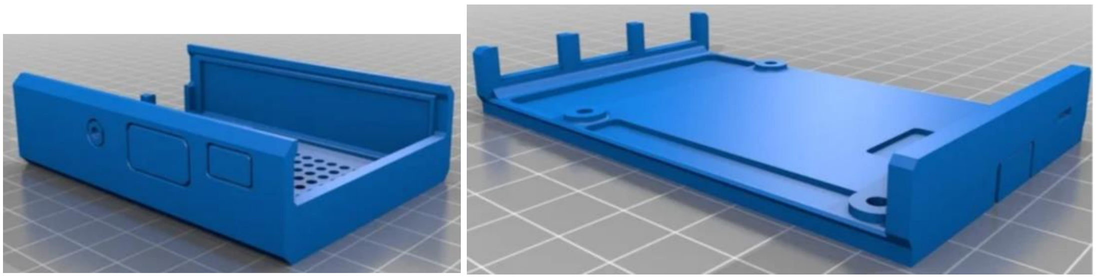


Fig. 19 Example 3. The .stl files can be download from: https://www.thingiverse.com/thing:3454787

One more example may be found at https://www.stlfinder.com/model/raspberry-pi-23-case-compatible-with-pi-hats-9cK2tg7f/7742181/

5.3. Tutorial 3. Prosthesis controlled by electromyographic sensor

Author: Davide Canepa, Emanuele Micheli, Michela Bogliol, Scuola di Robotica, Italy

A. Scenario

Diego is a 5-year-old boy, he was born with Poland syndrome, a disease for which usually people have a congenital aplasia and syndactyly. Normally they have the absence of a part of a phalanges, hand or arm. Diego has the hand and the wrist, but he doesn't have a part of the fingers.

Diego loves to help his grandfather with manual work, use tools, hammer nails, but unfortunately, he has a lot of trouble.

We try to help Diego use the tools to work with his grandfather.

B. Description

People are developing prostheses individually, and large communities have been established. Most of the development of 3D printed prostheses began after the establishment of the global community e-NABLE. This community has grown into a worldwide movement of tinkerers, engineers, 3D-printing enthusiasts, occupational therapists, university professors, designers, parents, families, artists, students, teachers and people who have developed 3D-printed prostheses.

One of these prostheses already developed in the E-nable community can be used to satisfy Diego's need.

In addition to this 3D prosthesis to make everything smarter could be added sensors and programmable boards to create an augmented prosthesis.

For creating these prosthesis you need a programmable shield and a muscular sensor to detect the activity of a muscle to which it is connected; Electormiography is the method of detecting this muscle activity.

Electromyography (EMG) is based on the recording of muscle electrical activity; normally to detect this activity it uses two type of electrodes: needle electrodes, invasive; surface electrodes, non-invasive.

The electrodes used in this tutorial are surface electrodes and are placed on the skin at specific points as presented in next section in the Step 4

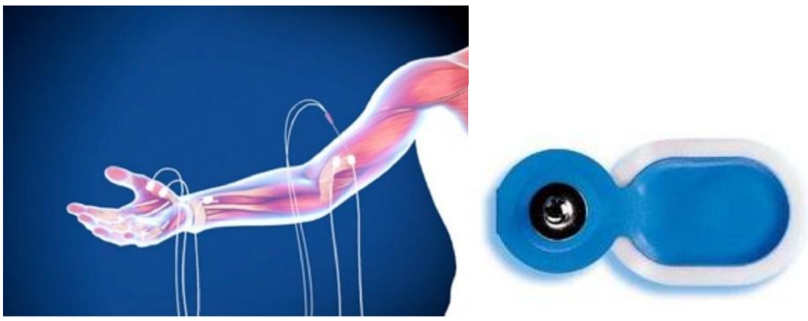


Fig. 20 Electrodes

The contraction of sarcomere creates a field electromagnetic activity whose intensity reflects the muscular activity.

The signal propagates by volume conduction through the tissues, making possible his registration both inside the muscle and on the skin.

In this tutorial we therefore use this electronic component that can be applied to a 3D prosthesis made by the E-nable community and customized at our pleasure.

C. Required materials:

- 1x Arduino or other shields
- 1x USB cable
- 1x Muscle sensor

It is recommended to use one that has the third reference electrode and that already eliminates the common mode noise and therefore provides the measurement of the filtered and rectified electrical activity of a muscle.

An example of a sensor that works well and it provides a good measurement without noise is the **Sparkfun's MyoWare** muscle sensor.

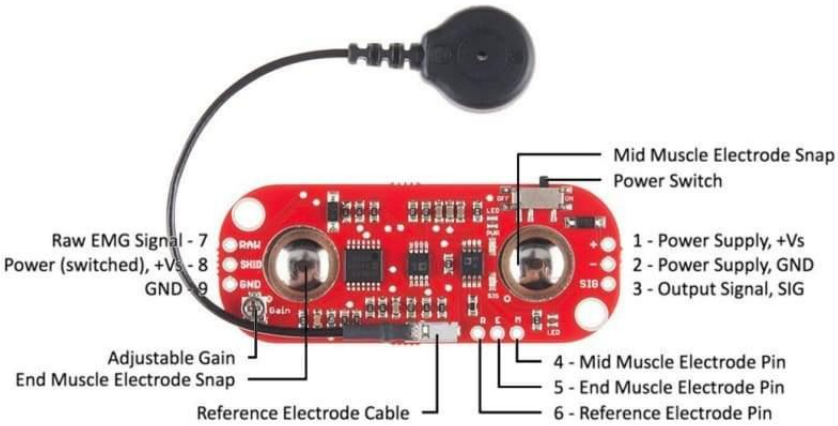


Fig. 21 Sparkfun's MyoWare muscle sensor

- Pediatric Electrodes with clips and gel, single use
- 1x 9v battery
- 1x Servo motor:

It is necessary to use one that has a 180° rotation, the important thing is that it has a quite high torque (2/3Kg), so that it can pull all the fingers to close them without effort.

Example of features:

1. Bearings 1
2. Torque Kg*cm 3.5Kg (6Vdc)
3. Speed sec/60° 0.13 (6Vdc)

4. Weight 24.2 gr
5. Type Nylon Gears
6. Dimensions 27.9 x 11.4 x 29.2 mm

D. Steps

Step 1. Using 3D CAD software (i.e Tinkercad, knowledge gained in O1) design and customize all part of the prosthesis

Fig. 22 3D models of Phoenix hand parts

Step 2. Using the knowledge gained in O1 assemble the prosthesis

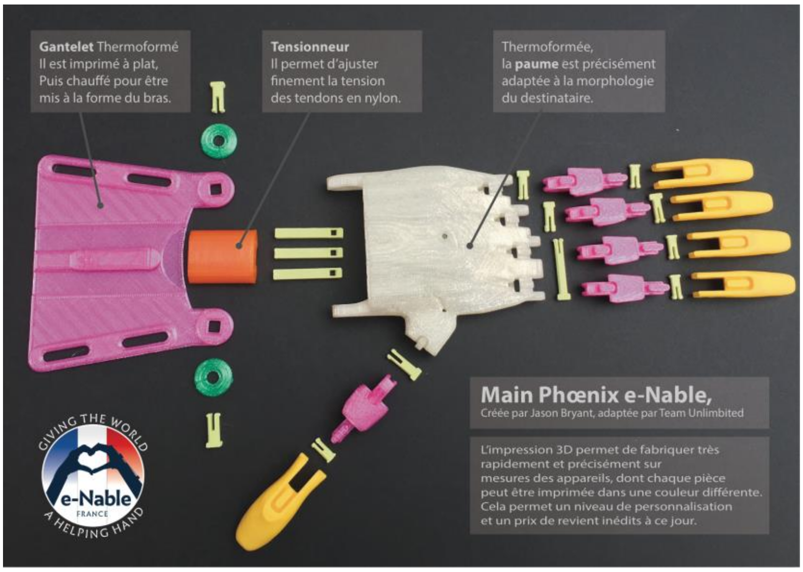


Fig. 23 Phoenix hand assembling

Follow the video at the link: https://www.youtube.com/watch?v=Der_DD2_zps&feature=youtu.be

Step 3. Get all the necessary electronic equipment.

Step 4. Connect the electrodes to the muscular sensor with the clips. Place the electrodes on the skin at these points:

- 2 electrodes on the biceps muscle (2 cm distance between each electrode)
- 1 reference electrode on the elbow or pisiform bone of the hand (where there is no muscle activity)

Step 5. Connect the Arduino to:

- the computer with USB cable
- the muscular sensor
- the Servo motor

The connections to be made are shown below:

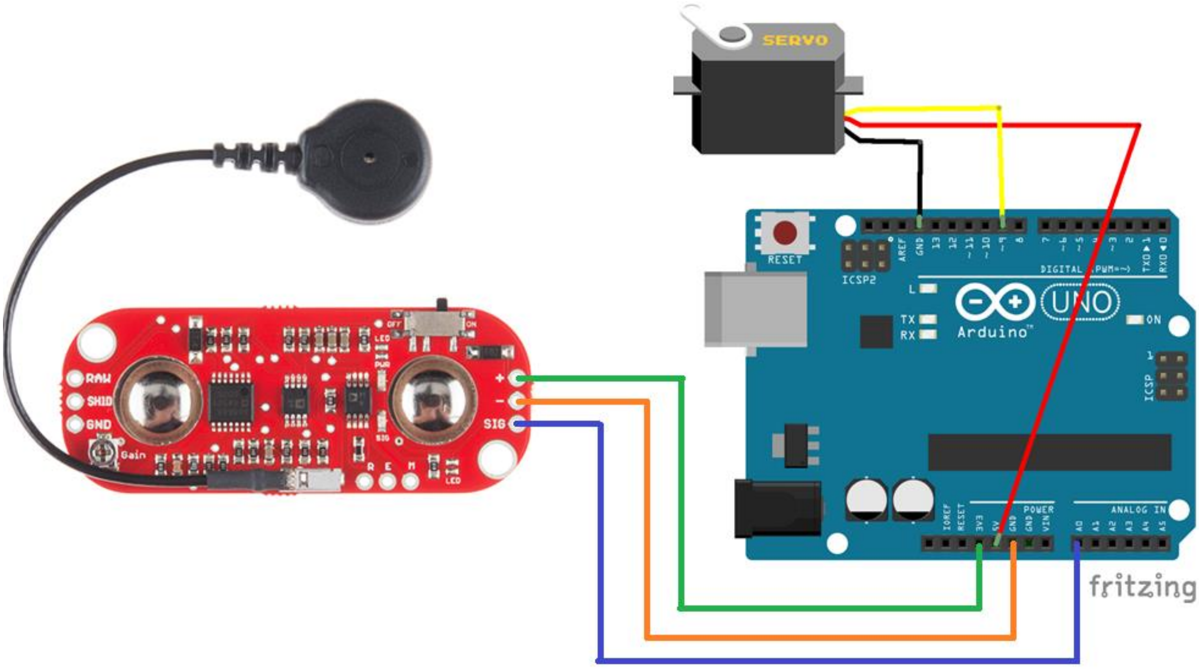


Fig. 24 Connections to be made

Step.6 Connect the Servo motor to all fingers of the prosthesis.

The 5 finger tensioning wires therefore instead of being attached to the box on the wrist, they will be attached to the Servo motor, in particular to the plastic propeller connections. The servo motor will then be placed on the wrist of the prosthesis, which must be blocked in the movement of flexion and extension of the wrist, as now the opening and closing movement of the hand is no longer driven by the movement of the wrist but by the rotation of the Servo motor.

When the muscle contracts, the electrical signal emitted is used to move the Servo motor and consequently the prosthesis, according to the muscle signal measured.

Step 7. Start with the programming of the Arduino bord.

The muscle sensor library must be included in the Arduino IDE.

An example of code to read the muscle signal and activate the servo is shown below.

```
#include <Servo.h>
Servo myservo;

int valori[15];
int sensorPin = A3;  //sensore muscolare collegato ad A3
//int ledPin = 13;
int sensorValue = 0;

int somma=0;
float media=0;

int pos = 0;

void setup()
{
  myservo.attach(9);  //servo collegato al pin 9
  //pinMode(led Pin, OUTPUT);
  Serial.begin(9600);
}


void loop()
{
    for(int i=0; i<15; i++)
    {
    valori[i] = analogRead(sensorPin); // leggo i valori rilevati dal sensore
```

```
    Serial.print("//");
    Serial.print(valori[i]); //stampo 20 valori rilevati dal sensore
    }

  for(int i=0; i<15; i++)
  {
    somma = somma + valori[i]; //sommo i 20 valori rilevati
  }

    media = somma / 15; // calcolo la media dei 20 valori


      Serial.print("---media=");
      Serial.println(media); //stampo la media

  // in base al valore della media, quindi a seconda se contraggo o meno il muscolo, si muove o meno il servo

    if (media>135)
    {
    myservo.write(180);
    delay(15);
    }

    else if(media<130)
    {

    myservo.write(0);
    delay(15);
    }

     somma=0;
     media=0;

}
```

Depending on the value detected, the Servo motor is started or not and consequently the prosthesis moves.

Modifies the muscle contraction threshold values to modulate the correct activation of the servo motor.

5.4. Tutorial 4. Smart Leaf

Author: Davide Canepa, Emanuele Micheli, Michela Bogliol, Scuola di Robotica, Italy

A. Scenario

Francesco is an 11-year-old boy with a passion for gardening. Every day he enjoys planting new plants, but he has a problem.

He has tried several times to plant a particular plant that needs a particular temperature and high humidity and it has not lasted more than a week, but it has died.

So, we try to make a device that can keep under control the humidity in the ground where the plant is planted. In this way Francesco will have a better chance of not withering the plant.

B. Description

Today exist devices on the market, which can capture from the ground the data of:

- Humidity
- Temperature
- Brightness

These information are sent to the user on their device to check the status of a plant or ground, for example to see if it needs to be watered.

Fig. 25 Examples of devices which captures from ground data

Starting from these examples we try to build a low cost and home-made device able to detect this information and ensure the best growth status of the plant.

The parameters you want to check will be chosen first.

Then a leaf will be drawn, to be inserted in the ground, with 3D CAD software and finally it will be made smart through the inclusion of the electronic components.

In this way we can respond to Francesco's need and allow him to periodically check the plant without causing it to die.

C. Required materials:

- 1x Arduino or other shields

- 1x USB cable
- 1x Humidity sensor
- Led
- 1x 9v battery
- A plant as a test

D. Steps

Step 1. Using 3D CAD software (i.e Tinkercad, knowledge gained in O1) design a Leaf, an example is presented in the following figure. After creating the small 3D models, it is necessary to export and print with 3D printers. In the design of the leaf there must be the spaces for the battery, the Arduino board and the humidity sensor.

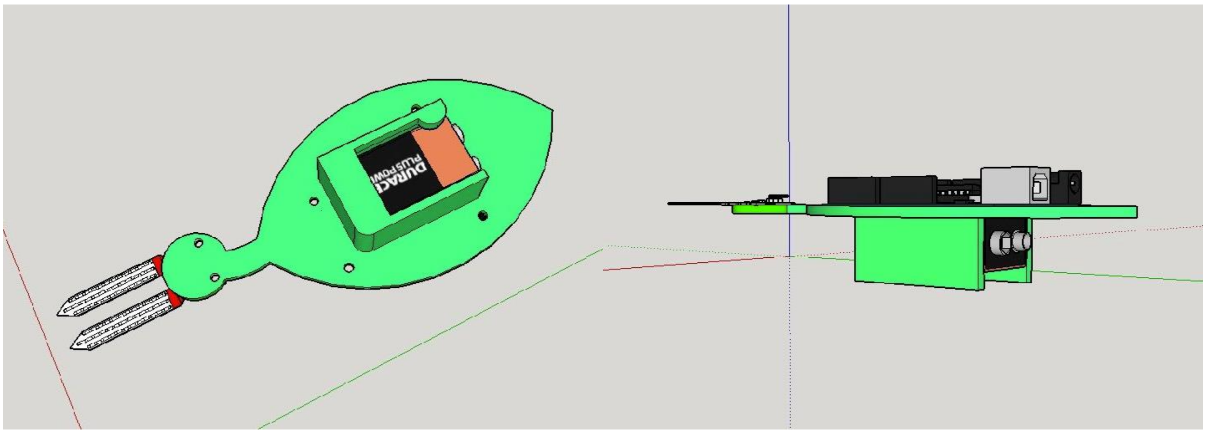


Fig. 26 Example of leaf 3D model

Step 2. Choose the Humidity sensor, it must have the following features:

- 5v
- Analog sensor(0-1023)
- Easy connection

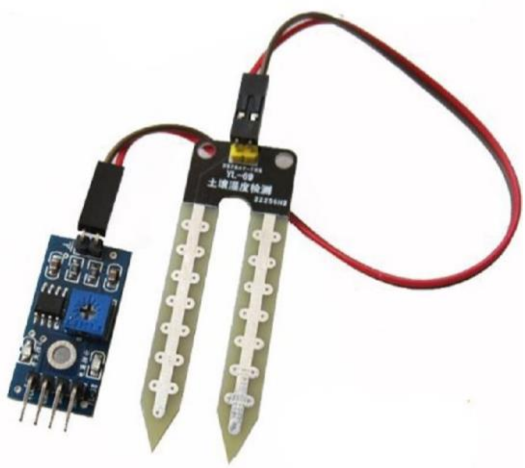


Fig. 27 Example of humidity sensor

Step 3. Connect the Arduino board to the sensor as report in the figure below, where there is also a possible PCB.

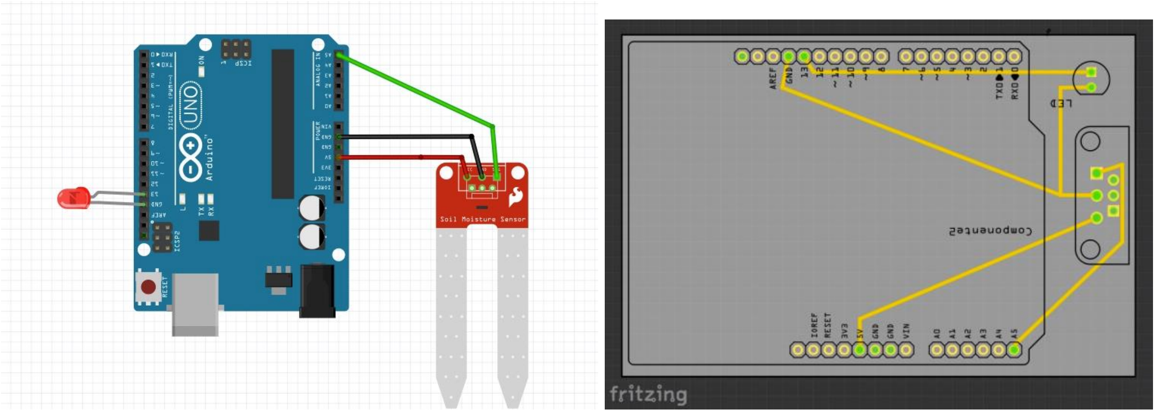


Fig. 28 Connections to be made

Step 4. Connect the Arduino to the computer with the USB cable.

Go to the programming of the Arduino board through the Arduino IDE that allows you to program Arduino using the C++ programming language. An example is reported in the following figure.

```
int PinLed = 13;  //led di allarme manca acqua
int PinSensore= A5;
int valSensore=0;

void setup()
{
  pinMode(PinLed, OUTPUT);
  Serial.begin(9600);
}

void loop()
{
  valSensore = analogRead(PinSensore);
  Serial.print("Umidita = " );
  Serial.println(valSensore);

  if (valSensore < 300)
    {
    digitalWrite(PinLed, HIGH);
    delay(500);
    digitalWrite(PinLed, LOW);
    delay(500);
```

Step 5. Assemble all components together: the 3D leaf and the electronic components

Step 6. Test the functionality of the Smart Leaf in a plant

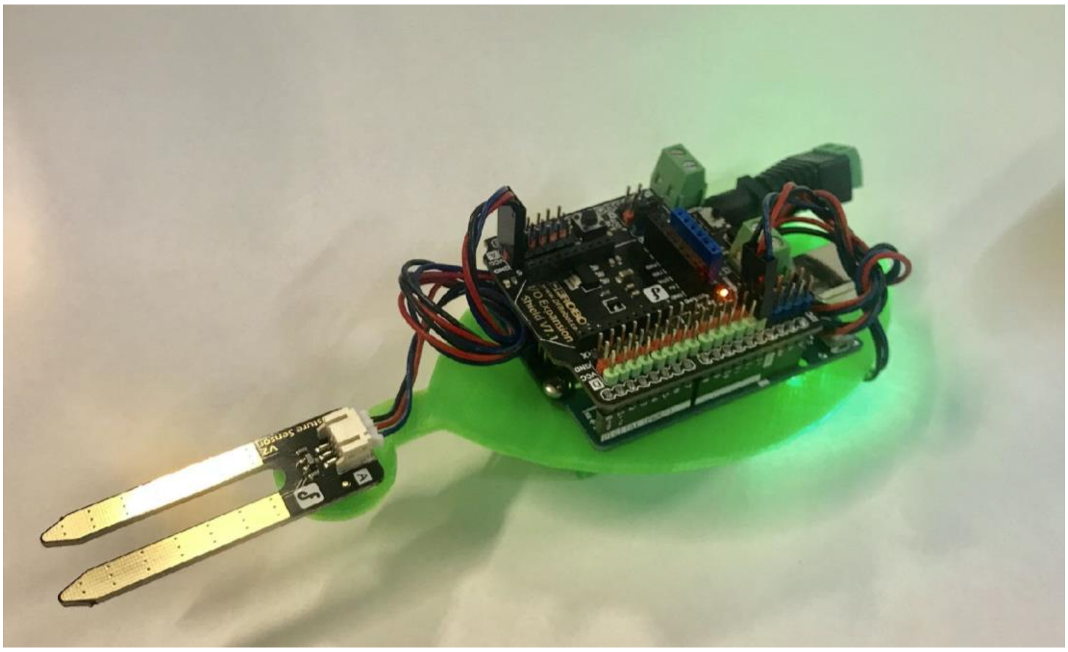


Fig. 29 Final device

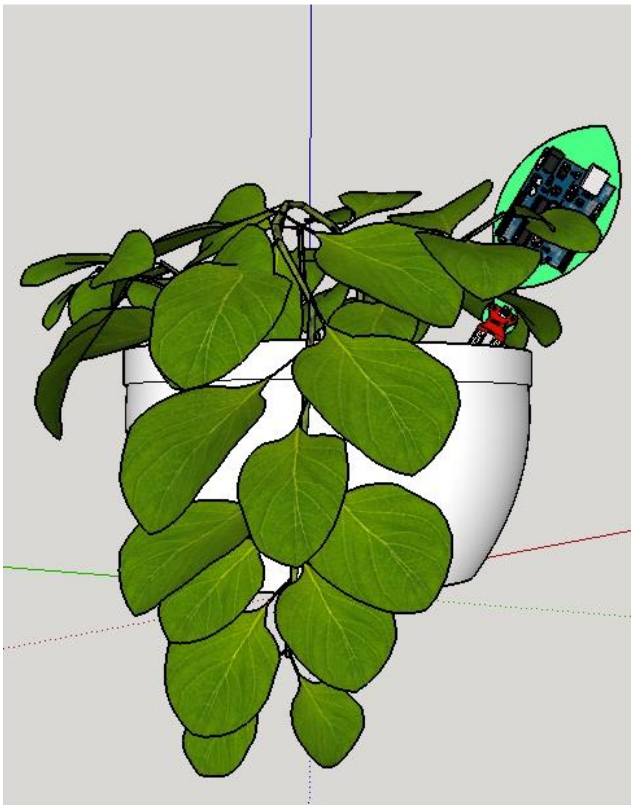


Fig. 30 Example of use

5.5. Tutorial 5: Visualizing emotions with electrodermal activity

Autor: Thomas Jörg, Johannes-Kepler-Gymnasium Weil der Stadt, Germany

A. Scenario

Audrey and Brian want to debate.

Audrey and Brian want to discuss the next class trip at school. Everyone has an accurate idea of where it is most exciting and the most beautiful leisure opportunities. The problem with this is that the discussion quickly becomes heated and emotional, and what one might overlook in such situations: to insult the other with careless words and thus destroy the discussion.

So that both do not get into such a situation, they decide to make the feelings of the other visible with the help of an electronic device. A device that allows a good inference about the wearer's current emotional world via body reactions such as sweat on the skin. This allows Audrey and Brian to know early enough whether they have chosen their words wisely or may be hurting their partner.

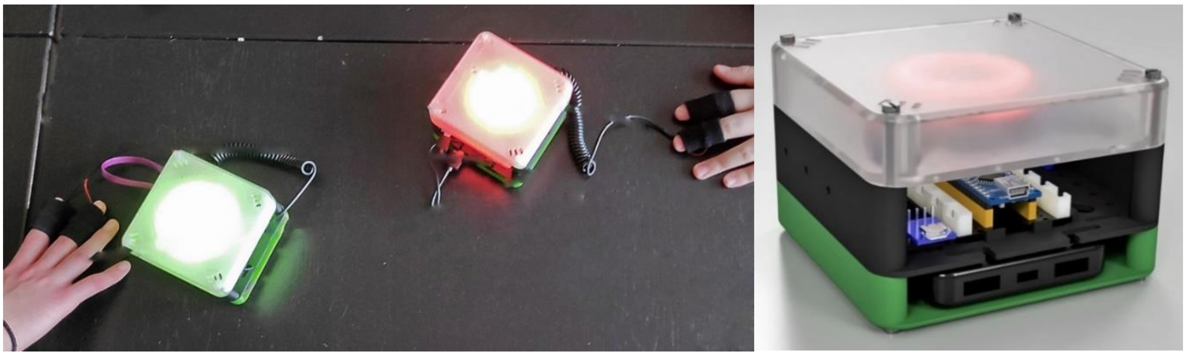


Fig. 31 EDA Cube

B. Description

The EDA Cube is a simple electronic instrument that can be used to measure a person's skin reactions, like a lie detector. If you know the biological or physiological connections, one can indent from the skin reaction of the wearer to the emotional arousal state. The Wikipedia article on electrodermal activity gives a good first insight: https://en.wikipedia.org/wiki/Electrodermal_activity

C. Required materials

To build the device, you need some electronic components. All parts are connected to an Arduino nano microprocessor:

- Arduino Nano
- Seeed Studio Grove Nano Shield
- Adafruit RGB-LED-Ring
- Seeed Studio Grove GSR Sensor
- Seeed Studio Grove Cable
- *Possibly two Zigbee modules or two Wemos D1 Mini, for wireless connection*
- *Possibly a 3D-printed enclosure with M3 screws an Nylon hex spacers*
- **Mandatory: An external power supply with a maximum of 7.4 volts.
  NEVER put any person on 230V (or 110V) power supply**

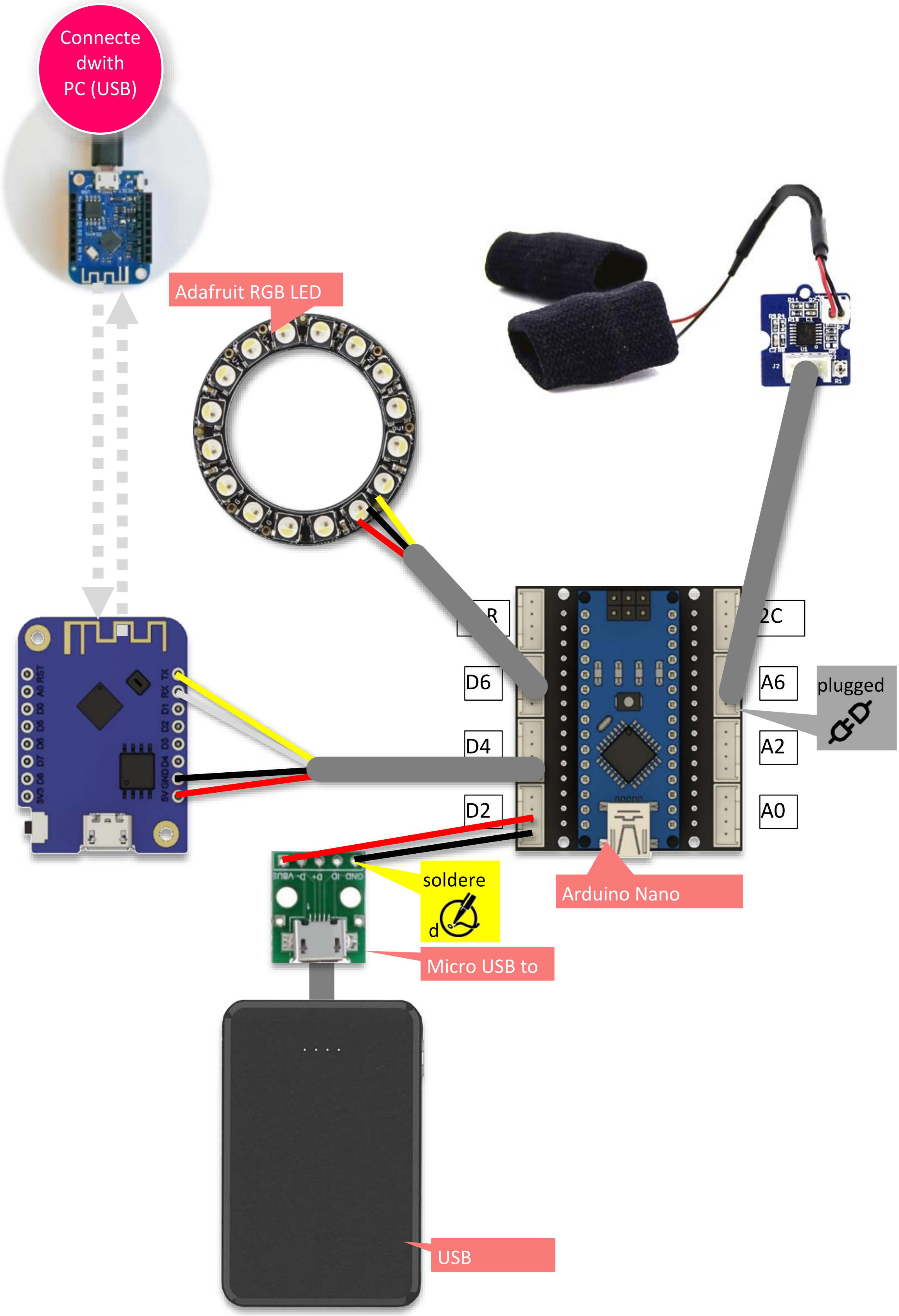


Fig. 32 Components

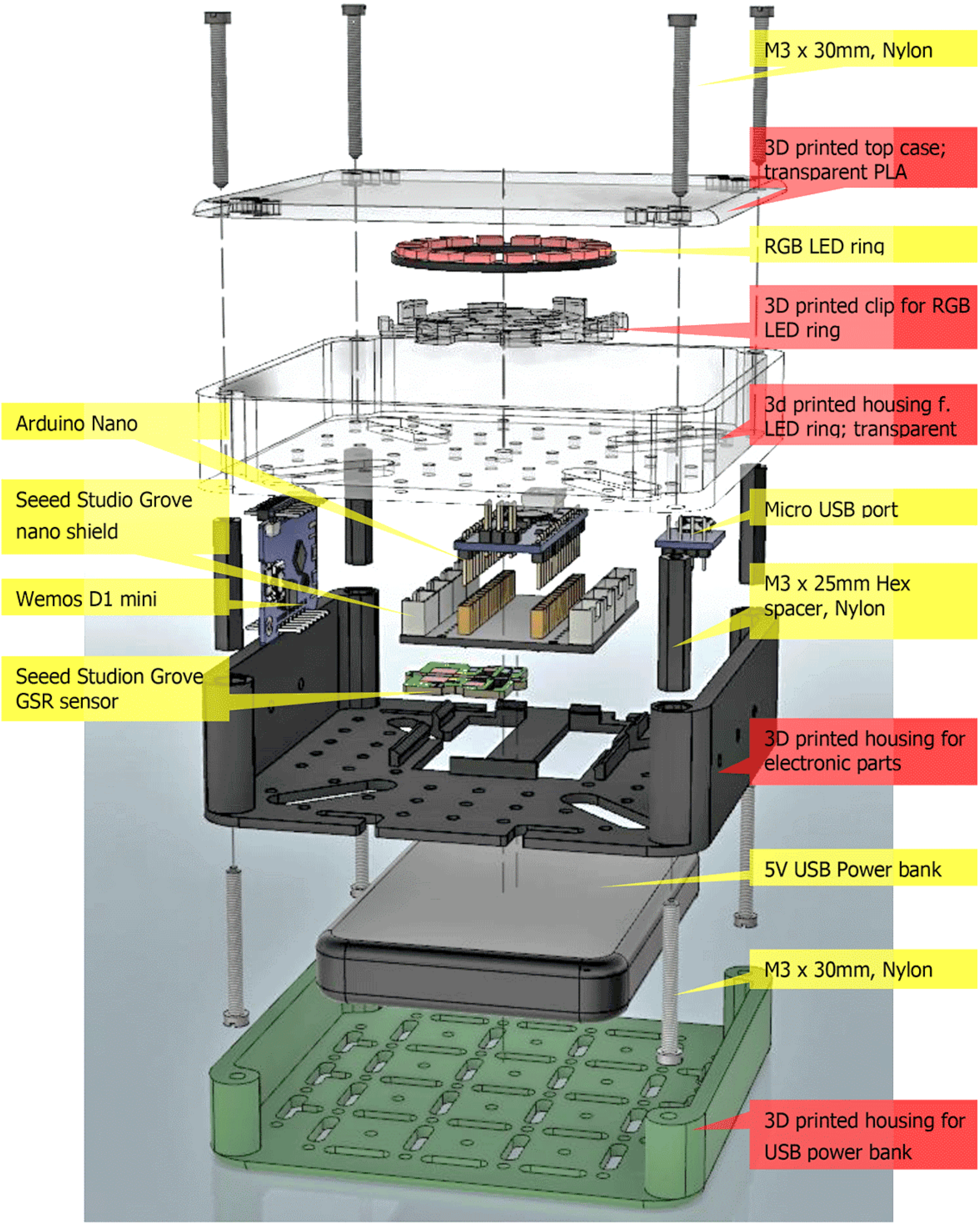


Fig. 33 Assembly of the EDA Cube

D. Arduino programming

```
#include <Adafruit_NeoPixel.h>
#define NEOPIXELPIN  6
#include <SoftwareSerial.h>
SoftwareSerial Serial_45(4, 5);
```

```
Adafruit_NeoPixel pixels(16, NEOPIXELPIN, NEO_RGBW + NEO_KHZ800);
const int GSR = A6;
long sum = 0;
int gsr_average, sensorValue, r, g, gsr_alt, delta = 0;

void setup() {
  Serial.begin(9600);
  Serial_45.begin(9600);
  pixels.begin();
  pixels.clear();
}

void loop() {
  pixels.clear();
  sum = 0;
  for (int i = 0; i < 20; i++)
  {
    sensorValue = analogRead(GSR);
    sum += sensorValue;
    delay(5);
  }
  gsr_average = sum / 10;
  delta = abs(gsr_average - gsr_alt);
  delta = constrain(delta, 0, 255);
  gsr_alt = gsr_average;
  Serial.println(gsr_average);
  Serial_45.println(gsr_average);
  r = 255 - (int) ((gsr_average - 600) / 3.125);
  g = (int) ((gsr_average - 600) / 3.125);
  for (int i = 0; i < 16; i++) {
    pixels.setPixelColor(i, pixels.Color(g, r, 0, delta));
  }
  pixels.show();
  delay(10);
}
```

E. Testing the device

To test the mode of action of the device, Audrey and Brian can put themselves in various emotionally exciting situations and get used to the device and their own body reactions. How to react when, for example:

1. The teacher Brian looks at hard and threatens to query the last vocabulary?
2. Watching a short film about a roller coaster ride?
3. You listen to your favorite music?

A possible scenario to test your own reaction might also look like this:

Audrey gets a secret message from Zoe that Audrey has to keep secret for as long as possible, for example, where something is hidden in the classroom. Brian's job is to question Audrey until he knows the answer. And in doing so, he has to try to find out with the help of the FDFA cube if Audrey is lying or hiding something.

F. Using the device

Programming can be further refined for the respective carrier. Experience shows that each person reacts in his own way. One is more agitated, the other is rather casual. There are people with higher skin moisture and people with dry skin. Therefore, the source code shown above is only a star point. Another possibility would be to send the operator's response with radio to a computer, record and evaluate it over a longer period of time. Here, however, one quickly reaches the limits of data protection: How far can one go with the monitoring of unconscious emotional reactions? What is still ethically acceptable and where is the limit?

5.6. Tutorial 6: Wireless communication with Calliope Mini

Autor: Thomas Jörg, Johannes-Kepler-Gymnasium Weil der Stadt, Germany

A. Scenario

Computer science lessons can sometimes be very boring. Who wants to memorize all sorts of codings? That's why Alice and Benny set out to secretly send messages to each other. And as the talented computer science student does, they don't use paper letters, they use the two microcontrollers they got from school and who fortunately master the art of wireless Bluetooth communication! 😉

B. Description

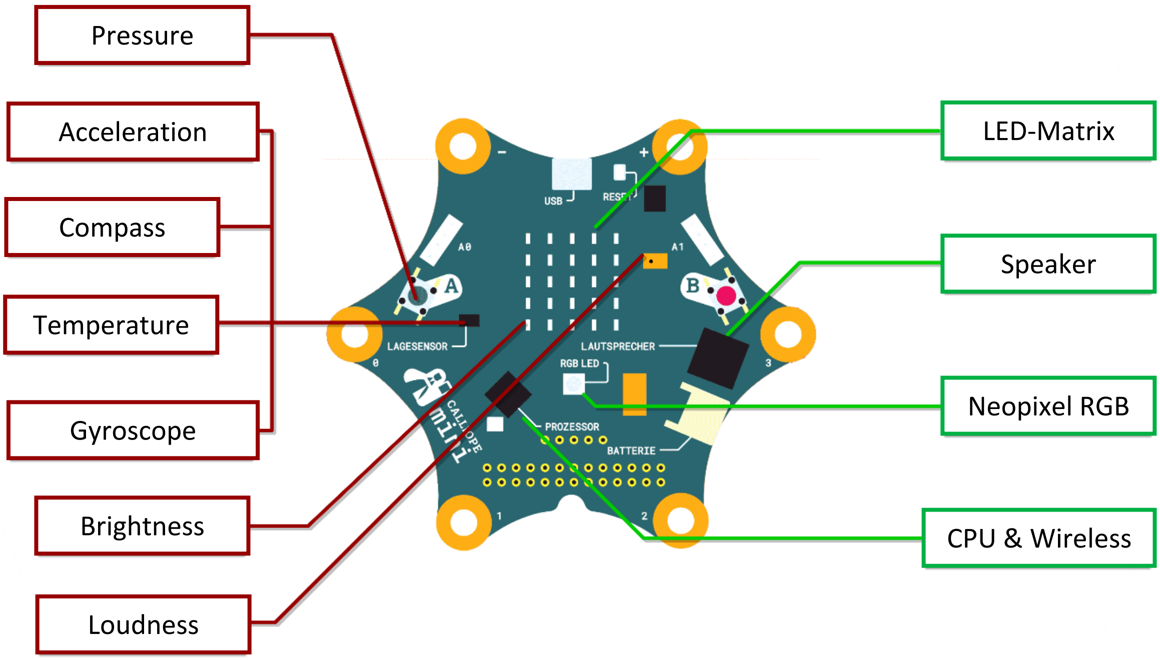


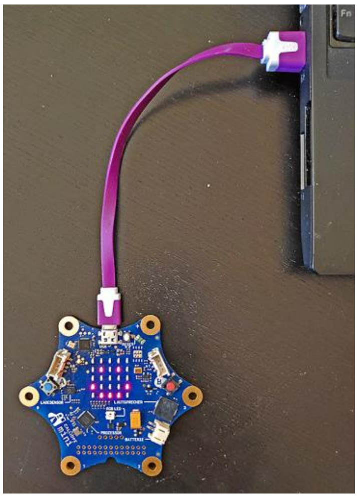
Fig. 34 Calliope features

The Calliope is a so-called single-board computer designed for the first contact of young students with digital technology. It contains an ARM Cortex processor on a common board that connects different actuators and sensors and makes them programmable.

The Calliope can be programmed child-friendly with a graphical programming language "Makecode", similar to the Micro:Bit, because: The Calliope can be seen as a further development or extension of the Micro:bit.

1. Communication between two Calliope boards is working via Bluetooth 4.0, using an ARM-Cortex M3 Chip equipped with BLE.
2. the communication of Calliope and the computer takes place via serial interface at a baud rate of 115200.

C. Required Materials



The following utensils are required to carry out the experiments:

1. Two Calliope Mini
2. Two PCs with internet connection
3. Two micro USB cables to connect Calliope and PC
4. The software "Makecode" for programming
5. The software "CoolTerm" for the serial connection

D. Steps

Step 1: Program for communication with the PC

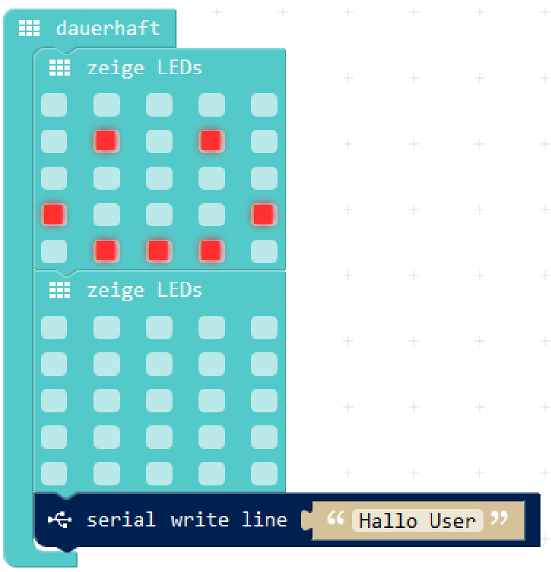


Fig. 35 First program on Calliope

We want to try out if we can talk to the Calliope. In the browser we enter the following first program:

This program gives a message to our computer via the USB connection cable **(a so-called serial connection).** The small program CoolTermWin lets us read this message as described in the next section.

Step 2: Read the Serial Message with PC / CoolTermWin

If the **calliope** is sending messages, we start in **CoolTerm**. There we look into the "Options" and click "**Re-Scan Serial Ports**". **Important: Baud rate at 115200!**

Set the correct COM port (if it wasn't found by itself) and click "**ok**". Then you try to connect by clicking on **" Connect**".

If this does not work, we will cut the connection with "**Disconnect",** go back to the options and try out the next COM port. If it worked, you can see the following inside the message window of CoolTerm:

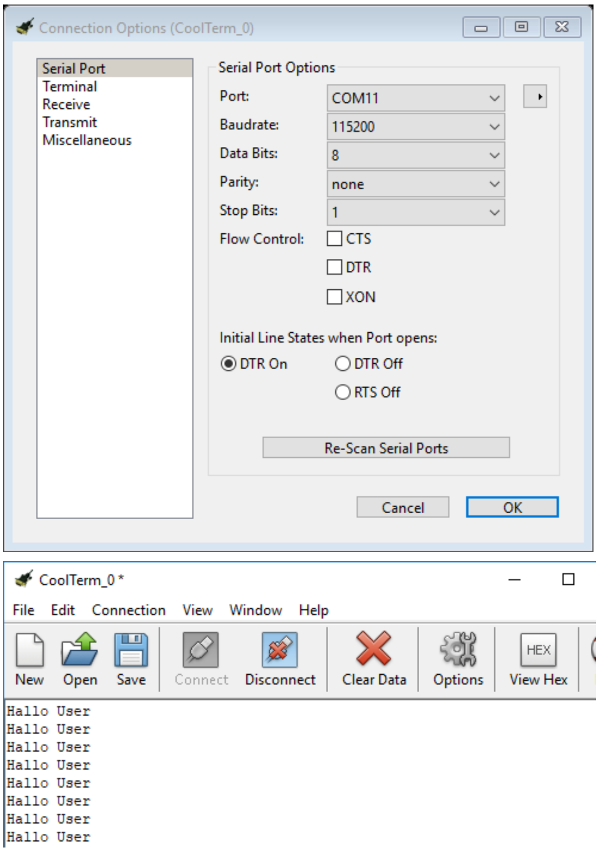


Fig. 36 The message window of CoolTerm

Step 3: Some simple programs to get started

I) When you press a button, a different smiley face appears

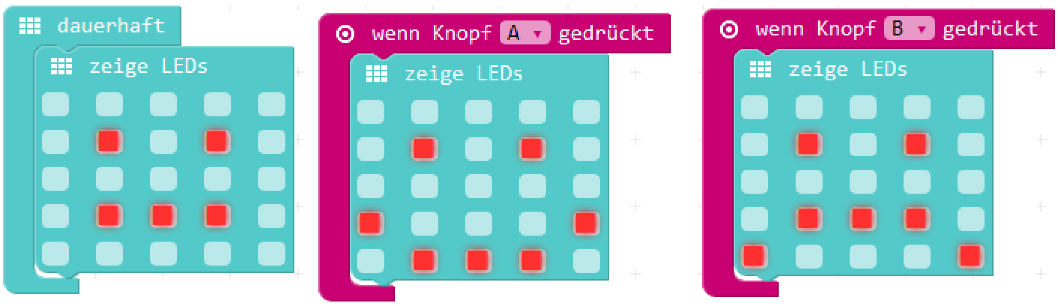


Fig. 37 Examples of simple programs to get started

II) Measure volume: If the volume is too high, the LED turns red. The measured values are output via Coolterm:

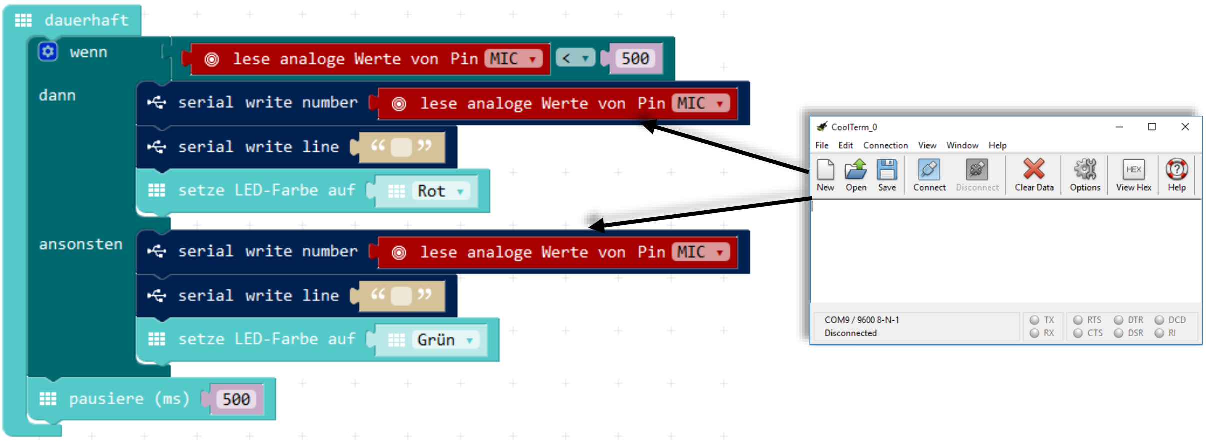


Fig. 38 Measuring volume

III) A water scale: If the inclination is not exactly horizontal, the smiley face is unhappy. The values are output again via Coolterm:

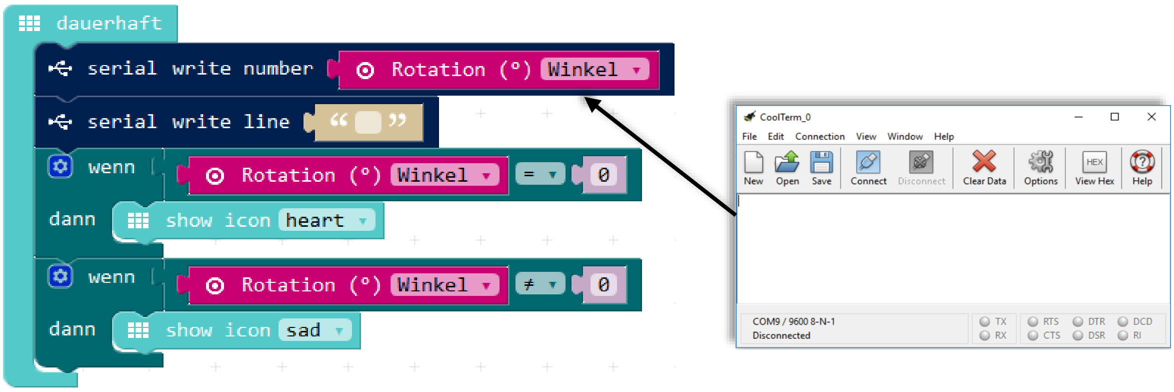


Fig. 39 A water scale

Step 4: Wireless connection

Once we have successfully completed these first exercises, we can start using the radio connection. On both Calliope runs the same program (for really secret messages you leave the control tone away, of course):

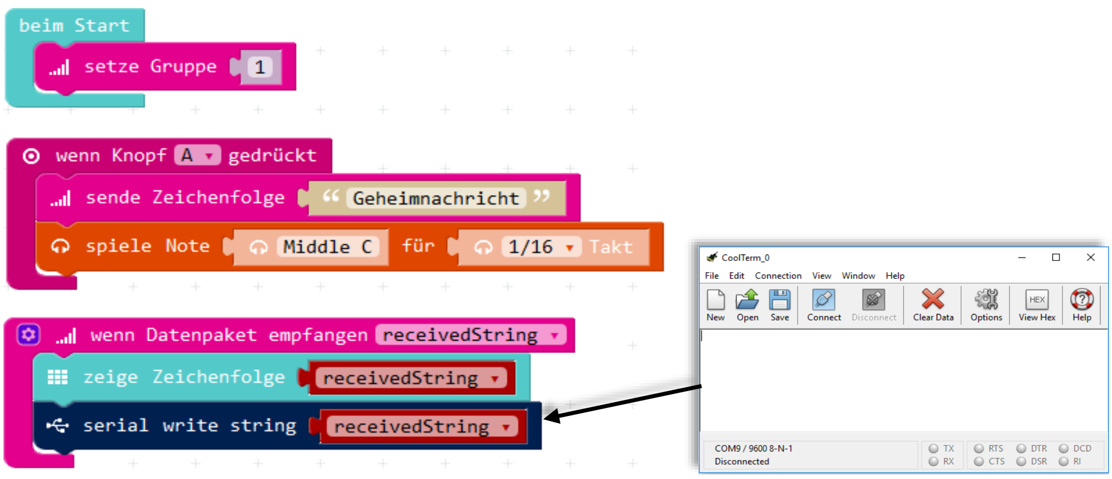


Fig. 40 Wireless connection

Step 5:

And if all this has become too boring for us, then we can also use the Calliope to let us be constantly informed about many different sensor values by radio. And almost the Calliope becomes a weather station, which sends its readings to a second calliope:

Sender:

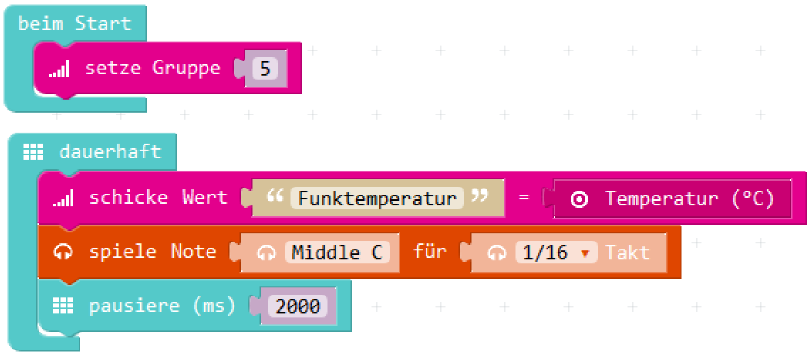


Fig. 41 Calliope sender' s code

Receiver:

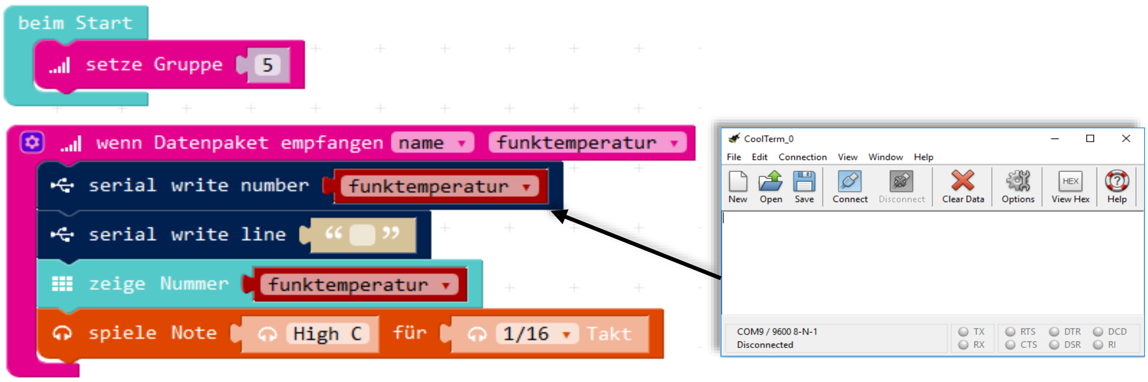


Fig. 42 Calliope receiver' s code

6. References

Alfrey, J. (2019, June). *6 Keys to Choosing Between Wi-Fi or a Hub for Connecting Your Devices.* Retrieved January 2020, from Residential Tech Today: https://restechtoday.com/choosing-between-wifi-or-a-hub/

Alimisis, D. (2013). Educational Robotics: Open questions and new challenges. *Themes in Science and Technology Education, 6*(1), 63-71.

Aqeel-ur-Rehman, Kashif, M., & Ahmed, B. (2013). Communication Technology That Suits IoT – A Critical Review. In F. Shaikh, B. Chowdhry , H. Ammari , M. Uqaili , & A. Shah (Eds.), *Wireless Sensor Networks for Developing Countries. WSN4DC 2013. Communications in Computer and Information Science* (Vol. 366). Springer, Berlin, Heidelberg.

Berry, R., Bull, G., Browning, C., Thomas, C., Starkweather, G., & Aylor, J. (2010). Use of digital fabrication to incorporate engineering design principles in elementary mathematics education. *Contemp. Issues Technol. Teach. Educ, 10*, 167–172. Retrieved from https://www.learntechlib.org/p/35289/

Blikstein, P. (2013). Digital Fabrication and 'Making'. In J. Walter-Herrmann, & C. Büching (Eds.), *Education: The Democratization of Invention. FabLabs: Of Machines, Makers and Inventors.* Bielefeld: Transcript Publishers.

Burgess, M. (2018, February). *What is the Internet of Things?* Retrieved 2020, from WIRED: https://www.wired.co.uk/article/internet-of-things-what-is-explained-iot

Chery, D., Mburu, S., Ward, J., & Fontecchio, A. (2015). Integration of the arts and technologyin GK-12 science courses. *Frontiers in Education (FIE) Conference .* El Paso, TX, USA: IEEE.

Codomo. (2017, August 21). *Micro:Bit vs Calliope Mini*. Retrieved July 2020, from Codomo: https://medium.com/codomo/micro-bit-vs-calliope-mini-160015182c41

Constine, J. (2020, March). *Immutouch wristband buzzes to stop you touching your face.* Retrieved from TechCrunch: https://techcrunch.com/2020/03/09/dont-immutouch/

Cook, K., Bush, E., & Cox, R. (2015). Creating a prosthetic hand: 3D printers innovate andinspire and maker movement. *Science and Children*, 80-86.

DataFlair. (2018, September). *IoT Technology & Protocols – 7 Important IoT Communication Protocols.* Retrieved from DataFlair: https://data-flair.training/blogs/iot-technology/

Dumond, D., Glassner, S., Holmes, A., Petty, D., Awiszus, T., Bicks, W., & Monagle, R. (2014). Pay it Forward: Getting 3D Printers Into Schools. *2014 IEEE Integrated STEM Education Conference.* Princeton, NJ, USA: IEEE. Retrieved from https://ieeexplore.ieee.org/document/6891015

European Commission. (n.d.). *Horizon 2020 Programme.* Retrieved from https://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society

Ferron, E. (2019, November). *What is Z-Wave?* Retrieved January 2020, from Safety.com.

Ford, S., & Minshall, T. (2019). Invited review article: Where and how 3D printing is used in teaching and education. *Additive Manufacturing, 25*, 131-150.

Holbrook, J. (2011). *PROFILES Guidebook for CPD Providers: The PROFILES Concept.* Estonia, Tartu: UTARTU.

Holbrook, J., & Rannikmäe, M. (2007). Nature of Science Education for Enhancing Scientific Literacy. *International Journal of Science Education, 29*(11), 1347-1362.

Horowitz, S., & Schultz, P. (2014). Printing space: using 3D printing of digital terrain models in geosciences education and research. *J. Geosci. Educ., 62*, 138–145. Retrieved from https://www.tandfonline.com/doi/full/10.5408/13-031.1

Jacobs, S., Schull, J., White, P., Lehrer, R., Vishwakarma, A., & Bertucci, A. (2016). e-NABLING education: curricula and models for teaching students to print Hands. *2016 IEEE Frontiers in Education Conference (FIE)* (pp. 1-4). Erie, PA, USA: IEEE. doi:10.1109/FIE.2016.7757460

Kastrenakes, J. (2019, December). *Z-Wave is making a huge change so it doesn't get left behind in the smart home wars.* Retrieved January 2020, from The Verge: https://www.theverge.com/2019/12/19/21029661/zwave-open-standard-radios-smart-home-multiple-vendors-silicon-labs

Knowles, B., Beck, S., Finney, J., Devine, J., & Lindley, J. (2019). A Scenario-Based Methodology for Exploring Risks: Children and Programmable IoT. *DIS '19: Proceedings of the 2019 on Designing Interactive Systems Conference* (pp. 751-761). San Diego: ACM. Retrieved from https://dl.acm.org/doi/pdf/10.1145/3322276.3322315

Macharla, M. (2018, December). *Commonly used Sensors in the Internet of Things (IoT) devices and their application.* Retrieved January 2020, from IoT4beginners: https://iot4beginners.com/commonly-used-sensors-in-the-internet-of-things-iot-devices-and-their-application/

Mahil, S. (2016). Fostering STEM+ education: Improve design thinking skills. *2016 IEEE Global Engineering Education Conference (EDUCON)* (pp. 125-129). Abu Dhabi: IEEE. doi:10.1109/EDUCON.2016.7474542

MakerBot. (n.d.). *The Top 5 Benefits of 3D printing in education*. Retrieved June 2020, from https://www.makerbot.com/: https://www.makerbot.com/stories/3d-printing-education/5-benefits-of-3d-printing/

Makino, M., Suzuki, K., Takamatsu, K., Shiratori, A., Saito, A., Sakai, K., & Furukawa, H. (2018). 3D printing of police whistles for STEM education. *Microsystem Technologies, 24*, 745–748. Retrieved from https://doi.org/10.1007/s00542-017-3393-x

McClelland , C. (2019, May). *What Is IoT? – A Simple Explanation of the Internet of Things.* Retrieved from IoT for all: https://www.iotforall.com/what-is-iot-simple-explanation/

Noor, N., Jamaludin, A. A., Azizan, A., Abas, H., Kamardin, K., & Yakub, M. (2018). Arduino vs Raspberry Pi vs Micro Bit: Platforms for Fast IoT Systems Prototyping. *Open International Journal of Informatics (OIJI), 6*(1). Retrieved from https://www.academia.edu/41579612/Arduino_vs_Raspberry_Pi_vs_Micro_Bit_Platforms_for_Fast_IoT_Systems_Prototyping

Papert, S., & Harel, I. (1991). *Constructionism.* NY: Ablex Publishing Corporation.

Pretty, B. (2018). *Wi-Fi, Zigbee, and Z-Wave: What's the difference?* Retrieved January 2020, from mysa: https://getmysa.com/blog/home-automation/wifi-zigbee-zwave/

Rocard, M., Cesrmley, P., Jorde, D., Lenzen, D., Walberg-Herniksson, H., & Hemmo, V. (2007). *Science education NOW: A Renewed Pedagogy for the Future of Europe.* Brussels, Belgium: Office for Official Publications of the European Communities. Retrieved from http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Roscoe, J., Fearn, S., & Posey, E. (2014). Teaching computational thinking by playing gamesand building robots. *2014 International Conference on Interactive Technologies and Games.* Nottingham, UK : IEEE.

Schon, S., Ebner, M., & Kumar, S. (2014). The Maker Movement Implications from modern fabrication, new digital gadgets, and hacking for creative learning and teaching. *Laia Canals, P.A.U. Education (Ed.) eLearning Papers Special edition*, 86-100.

Stables, J. (2019, December). *Zigbee explained: Super-charged tech powering your smart home devices.* Retrieved January 2020, from The Ambient: https://www.the-ambient.com/guides/zigbee-devices-complete-guide-277

Suduc, A. M., Bîzoi, M., & Gorghiu, G. (2018). A Survey on IoT in Education. *Revista Românească pentru Educaţie Multidimensională, 10*(3), 103-111.

Tillman, M., & Hall, C. (2019, October). *What is Zigbee and why is it important for your smart home?* Retrieved January 2020, from Pocket-lint: https://www.pocket-lint.com/smart-home/news/129857-what-is-zigbee-and-why-is-it-important-for-your-smart-home

Trna, J., Trnova, E., & Sibor, J. (2012). Implementation of Inquiry-Based Science Education in Science Teacher Training. *Journal of Educational and Instructional Studies in the World, 2*(4), 199-209.

Turner, R. (2008). Why We Teach School Science, and Why Knowing Why Matters. *Keynote Address to the CRYSTAL Atlantique Annual Colloquium, Fredericton, New Brunswick, Canada*.

Tytler, R. (2007). *Australian Education Review: Re-imagining Science Education Engaging Students in Science for Australia's Future.* Victoria, Australia: ACER Press.

Z-Wave Alliance. (2020). *About Z-Wave Technology.* Retrieved January 2020, from Z Wave Alliance: https://z-wavealliance.org/about_z-wave_technology/