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Opportunities of Raspberry Pi's Use in Education Raspberry Pi felhasználási lehetőségei az oktatásban

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Absztract–**Egyre inkább „digitalizálódó” világunkban sokszor felmerül a technológia kapcsán az informatikát oktatókban és a szülőkben is a kérdés: „Milyen hardver-/szoftvereszközökkel és hogyan integráljuk az új technológiák használatának tanulását az oktatásba?” Ehhez a kérdéshez kapcsolódóan választották az előadók a Raspberry Pi informatikai eszközcsaládot, amelynek kezdeti célcsoportja a diákság, illetve az egyetemi hallgatóság volt, de mára széles körben elterjedt a saját számítógépüket teljes mértékben megismerni és annak specialitásait kihasználni akarók körében is. Ezen nyílt, mobilplatformú kártyaszámítógépek ára és mérete töredéke a PC-ének/laptopénak, mégis teljes értékű számítógépként használhatók, a játékos tanulástól az otthonautomatizálásig.**

Kulcsszavak: kártyaszámítógép, Raspberry Pi, matematika-oktatás, programozás-oktatás, IoT.

Abstract—**In our ever more “digitalizing” world the question arises among in IT teachers or parents often: “With what hardware / software tools and how we should integrate the studying of the use of the new technologies into the education?” In connection with this question, the lecturers selected the Raspberry Pi. The initial target group of this IT family consisted of students, but now it widely used among who want to fully understand their own computers and to make use of their specialties. The price and size of these open, mobile platform card-PC-s are a fraction of the PC / laptop, still they can be used as a full-fledged computer, from playful learning to the core of home automation.**

Keywords: card computer, Raspberry Pi, mathematics education, programming education, IoT.

I. Introduction

The Raspberry Pi Small Card PCs were created by the English Raspberry Pi Foundation in 2012 [1]. With their product a new segment emerged on the market. Today, the company has a wide product range and development is ongoing. The last model was released this year in 2018, traditionally on Pi-day, that is, March 14 [2].

In these devices, each hardware is ARM-based mobile platform, under GNU[1] license. The aim of the initiative was to create a platform with a fully open, transparent architecture.

This allows students to choose from more than one and a half dozen operating systems, including many Linux distributions. They can learn software development on their own PC card in different programming languages. It will help them learn about the IoT (Internet of Things) ecosystem and the Microsoft-sponsored software and IoT development capabilities (Windows IoT core, free programming of the Minecraft Pi Edition game) [3]. In addition, the platform provides opportunities for learning cloud technology and learning cloud programming, for example.

In the other chapters of the lecture we will first review the story of Raspberry Pi and compare it with the traditional PC. The open platform provides a wide range of options for operating systems. Then we present further potential educational using of the Raspberry Pi by some examples. Finally, an IoT device case study is presented, in which a heat and humidity measurement system was built. In this connection, we outline the possibility of integrating IoT projects into education.

II. History of Raspberry Pi card PC

Raspberry Pi is a palm-sized, inexpensive, low-power card computer (Figure 1) all can be realizable that a desktop computer. Although our system will not be as fast, but it will cost a fraction of the price of a PC, and it can also be used as a central unit of systems embedded in its consumption and size. In many cases, such as a home server, noise-free operation is also important.

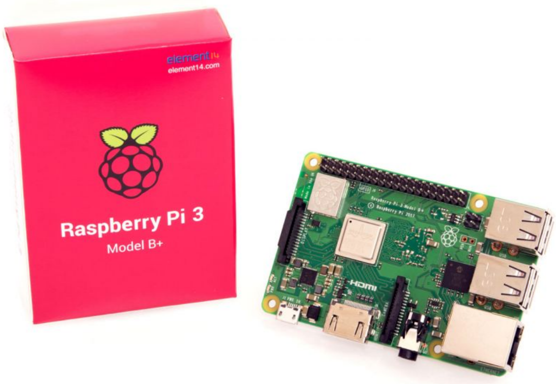

Figure 1. Raspberry Pi Model 3 B+ [4]

It has long been missing some of the computing community's platform, that it can be fully understood by means of a proper work efficiency as well as tools of the “heroic age” and can be further developed hardware and software. Raspberry Pi has filled this gap.

[1] GNU: GNU's Not Unix.

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At the beginning of development, the company thought the user community as a student and the field of use would be education as well as the developing countries. Therefore, EBEN UPON, the Raspberry Pi Foundation's agent, asked teachers, researchers and computer enthusiasts to design a system that would make children more familiar with computer science [5] [6].

The first plans were ready in 2006, and in April 2012 the first version of Model 1 B came out. More and more versions are born with increasing capabilities – with the exception of the Zero series, which has been marketed for low performance tasks at even lower prices.

According to our requirements, we can choose among the models from the palette, taking into account some differences (such as number of USB ports, SDRAM memory size, storage size, network access, low level peripherals to be handled, device power consumption, weight). Each model includes GPU[2], video input and output, audio output. Their size – excluding the Compute Module – 85,60 × 56,5mm (excluding the protruding connectors).

We need a power supply to use it, and it's good that we get a house to protect the panel. If we want to connect an external hard disk, because the Raspberry Pi power supply does not provide adequate current, we need an external HDD or external dock with an external power connection. Monitor, HDMI cable, keyboard and mouse are needed for configuration and work with raspberry Pi [3].

III. COMPARISON OF THE RASPBERRY PI AND THE TRADITIONAL PC

The common characteristic of the Raspberry Pi family is that each mobile platform is based on ARM[3]. That's what makes the platform free and transparent, because today most smartphones, tablets, and smart mobile devices are built on ARM architecture too.

Contrary to the traditional PC, Raspberry Pi does not have either BIOS[4] or UEFI[5]. But then how does the operating system boot from the microSD card?

The SD card write-ready an operating system from image file before the first use. We can configure the settings of Raspberry Pi on the memory card in the `config.txt` file now created. The device then booting is done by starting the necessary files, data entered into the microSD card into the CPU / GPU.

The main benefits of Raspberry Pi for the PC are the following:

- Small size and easy portability.
- Low price, great value for money (up to $ 35).
- Analogue television can also be used as a monitor.
- High software support (mainly under your own Raspbian operating system).
- The platform can be used universally. (Depending on the system on the microSD card, how it is used.)
- Fully provide the basics of today's PCs (for example, using office software, image editing, browsing, mailing, filming, etc.).
- Noise-free operation.

The main disadvantages of Raspberry Pi on the PC:

- Certain target tasks still have poor hardware. (For example, the Blender 3D modeling software for Raspberry Pi 2.72 does not run fast enough for convenient work because the integrated mobile GPU and memory of the platform are not enough.)
- Because of hardware weaknesses and the underdevelopment of this area of IT, you still cannot become a true companion of PCs on the market.

IV. RASPBERRY PI PLATFORM OPERATING SYSTEMS

A community “product”, which users will particularly stress the importance of software freedom, cannot have an “official” version of the operating system. We can choose from the Linux distributions available under the GNU license – but which one is worth? The one which has widest range of support, great documentation; continuously improving software bugs active user community, many learning descriptions and tutorials.

The Raspberry Pi operating system is also a lucky choice, because the “official” – supported and recommended operating system by the Foundation – is a sub version of Debian distribution with good support. Some software components in Debian have been replaced specifically, or some default settings have been modified to create the optimal Raspbian for hardware. The sub version, the “descendent” Raspbian, can thus be utilized by any development of its ancestor. When Debian is upgraded, only deviations must be resubmitted from its successor, Raspbian. Debian's support for it shows that the most widely used in the PC Linux distribution, Ubuntu Linux is its version.

The operating systems that are developed for Raspberry, besides Rasbian, are as follows:

- Minibian (a minimal operating system based on Raspbian)
- Pidora (Fedora Remix Raspberry Pi optimized version)
- OpenELEC (Code / XBMC based media player optimized operating system)
- OSMC (Open Source Media Center, formerly known as RaspBMC, which is a Debian and Kodi-based Alpha state media outlet)
- Risc OS (non-Linux based system)
- Retropie (Emulation Station and Raspbian based OS for emulation of old consoles)
- Plan 9 (a distributed operating system for Bell Labs)
- Inferno (Bell Labs distributed operating system and runtime environment)
- Openwrt (Linux System-based embedded operating system)
- FreeBSD (Unix-like free operating system)
- NetBSD (Unix-like free operating system)
- Windows 10 IOT Core

We can download dozens of operating systems from the official site of Raspberry Pi [7].

[2] GPU: Graphical Process Unit.
[3] ARM: Advanced RISC Machine. A family of processors with RISC (Reduced Instruction Sets Computer) processor.
[4] BIOS: Basic Input Output System. Interfész a számítógép szoftveres és hardveres része között. A nonvolatile firmware, which perform the hardware initialization at computer startup, and provides runtime services for the operating system and programs.
[5] UEFI: Unified Extensible Firmware Interface. Specification that defines a software interface between the operating system and the firmware platform. It is intended to replace the BIOS firmware interface.

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V. Examples of Using Raspberry Pi in Education

A. Raspberry Pi Platform as a Teacher Workstation

We've already mentioned that the Raspberry Pi is a universal computer. It can be a full functioning computer, media player, or weather station – depending on the content of the microSD card.

But let us focus on usability in education! In an educational establishment, lectures are often required in smaller or larger classrooms. The problem may often arise that the teacher computer or programs installed on it do not suit us fully.

Now consider special needs, such as specialized software, talk about inadequate virtualizations and hardware utilization. In most cases, the current virtual machine on which the slide show is running can be run from a host operating system. If the host operating system is not selected correctly, you may encounter a lack of physical memory and a bottleneck in the write / read speed of the hard disk, so the presenter computer will be slow. In the right case, there is enough physical memory in the machine for virtualization, but the hard drive's read / write speeds are still bottlenecking for two operating systems running simultaneously (for example, two Windows issues from version 7 up).

Why and what can Raspberry Pi do in the classrooms? In terms of price, the smallest Raspberry Pi Zero W (Figure 2) starts at HUF 10,000, while the larger and the strongest version, the Raspberry Pi model 3B+ starts from HUF 13,000. They are available in a very wide range of prices depending on the package, but they are considerably cheaper compared to a new PC.

What's the advantage of Raspberry Pi at an affordable price? Thanks to the microSD card, we get a great deal of freedom in terms of operating systems. Considering that today the price of the 8 GB microSD card is approx. HUF 2000 to 3000, we can take advantage of the possibilities of choosing the operating system.

That's why even any instructor can teach in his own environment on his own preconfigured operating system.

Figure 2. Raspberry Pi Zero W

What is the attribute that we can even speak to Raspberry Pi with traditional PCs in the lecture halls? Space saving! In addition to having similar input / output peripherals (monitor, mouse, keyboard, etc.), the entire device fits in the pocket of the instructor. If the instructor has his own Raspberry device, he / she can carry it and have a presentation of it, he / she only need to have an HDMI cable, some adapters and a power supply, which can even be a charger with a micro USB connector. Other necessary peripherals are usually found in the room.

As mentioned, these tiny devices are full-featured computers. The Raspbian has a classic Linux graphical user interface, it is pre-installed open source LibreOffice office suite, we can use it to manage files (install NTFS, exFAT support, etc.), install it for Gimp image editing and lots of software that has been developed for Debian or Ubuntu.

Since the primary target audience of the Raspberry Pi Foundation were the students, the following chapters will show some areas of application and programs that can be incorporated into education.

B. Teaching Programming

Nowadays, jobs on the IT market are also well-priced and their number is constantly growing. But what languages do we have in programming this little "gadget"? An example of these shows is shown in Figure 3.

Figure 3. Learning programming languages on Raspberry Pi

Let's start with the whole young generation, with elementary school students, or high school students who are just getting familiar with programming. For them the Scratch or the Sonic Pi are recommended. While in Scratch, blocks can help to get familiar with programming thinking, logic, and create algorithms, until they can "acquire music" under a similar principle under Sonic Pi. During this composition, there is no classical Mozart symphony or Armin Van Bureen's Trance genre, but the 1990s, a few bits of Mario or Tetris sound melodies. Of course, anyone who has time and desire can do anything from these few bits, almost fantastic tunes!

For the more advanced, programmer students (starting with the opportunities offered by Raspbian), Java can be programmed in BlueJ, Geany and Greenfoot IDE environments. Netbeans IDE is also available, which is a relatively popular free Oracle product, but is not recommended for its hardware needs. Also, Python[6] can be used as a programming language, which is partially suitable for programming GPIO[7] legs, and we can also program in C / C ++ languages (for example, in Code Blocks). It is also worth mentioning the Arduino IDE development environment, which allows us to program a great number of microcontrollers (alongside Arduino products) in high-level C / C ++ language.

C. Teaching of Mathematics

Teaching / learning mathematics by knowing the nature of Raspberry Pi is a particularly exciting and interesting area.

[6] On behalf of Raspberry Pi, Pi refers to Python programming language. The reason for this was that at the beginning of the platform design, one of the main aspects was to program it in Python and to help students learn programming. It was thought that due to their poor performance, they would not be able to develop it in other languages. The raspberry name was chosen because traditionally computer manufacturers often use fruit names for their products [3].
7 GPIO: General Purpose I/O, i.e. general-purpose input / output. Depending on the version of Raspberry Pi, it contains programable inputs and outputs. The aim of the designers with GPIO was to use a variety of external cards, synchronous adapters and analog I / O modules without soldering the panel.

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GeoGebra can be installed freely on the platform by those attending the training. Wolfram Engine and Mathematica (Figure 4) is standard software of Raspberry Pi. Mathematica's standard cloud service is £ 12 / month or £ 90 / year – which means that we can buy a Raspberry Pi from a 3-4-month subscription fee, which will give Mathematica free and unlimited use.

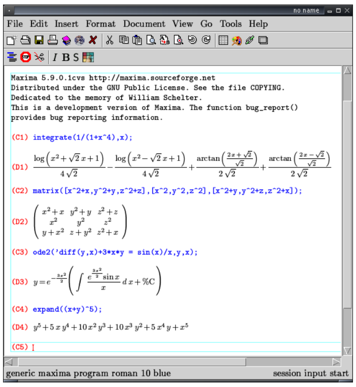

Figure 4. User side of the Mathematica program

Why is Mathematica so great? It can lead many mathematical functions, equations, matrices, and so on, even parametrically.

D. *Teaching of 3D Modeling*

The platform also offers 3D modeling. From this list, this area is slightly "out of line" due to "weak" hardware. It was not intended for designers to make a "render farm" for these small chunks. Blender (not too old) version 2.72 has been released for Raspberry Pi, which may indicate the beginning of a new era in modeling. The only question is whether it will be available for the public of Android as well.

The platform is a good way to get started: knowing the surface of Blender, acquiring basics with low-poly models, scenes with simple shaders (Figure 5). Due to the lack of computing capacity, it is not really suitable for handling shiny, more complex surfaces, but can be textured in it.

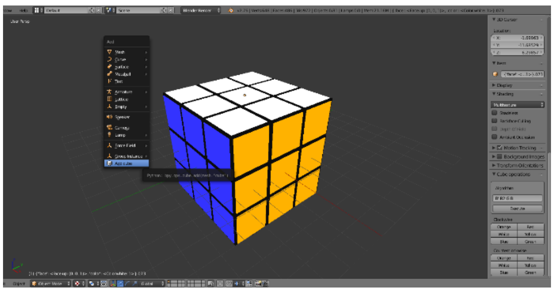

Figure 5. Modeling Rubik's Cube in Blender [8]

The above model was prepared on Raspberry Pi. This choice has been chosen because it has a relatively small number of polygons, it can be used to modify (modifiers), and can be textured on it.

We also tried to render the textured cube with traditional Blender and Cycles. It was a pleasant surprise that choosing the Cycles to produce a more realistic picture was quicker. This is indicated by the fact that the Cycles is optimized for the Paspberry Pi graphic processor.

E. *Ideas for Raspberry Pi Projects*

Before going into the IoT case study, which shows the construction of a heat and humidity measurement system, let's look at some ideas using the Raspberry Pi in home or industrial environments. These may include student project works in higher education. In many cases, small consumption is essential in these systems, which is the requirement of Raspberry Pi.

Apart from the development of Raspberry Pi IoT devices, we can apply it for industrial or home automation, robot control (such as solving Rubik's cube, drawing, painting, flying). We can manage a web camera, but we can even use for security monitoring. In eHealth, we can measure respiration, pulse, blood pressure and body temperature. As a monitoring center, we can collect data from sensors. We can commit several server functions to it, such as cloud server, print server, and can be a communication server (such as a VPN), a LAMP server, a smaller game server (such as Minecraft). Still fun to be a professional media player, HTPC[8], TV or monitor backlight.

VI. IoT Instrument Case Study: Building the Heat and Humidity Measurement System

A. *Initial Requirements for the System*

The history of our case study started as a simple project utilization of Raspberry Pi in the field of IoT. A small research was built onto the project in the next academic year. Initially it was a simple goal to create smart thermometer using microcontroller that can operate independently from the Raspberry Pi, by itself. The main aspects were the following:

- Be a "thermometer" independent, stand-alone. It works without an Internet connection or connection to a remote server.
- This unit can transmit measured data over an Internet connection to a remote server (which is Raspberry Pi) so that data can be processed later.
- Make a display that shows the measured information to the user.
- The system should be made using cheap solutions / elements available on the market.
- Low power consumption.
- Stable the system.

The schematic diagram of the whole measuring system is shown in Figure 6.

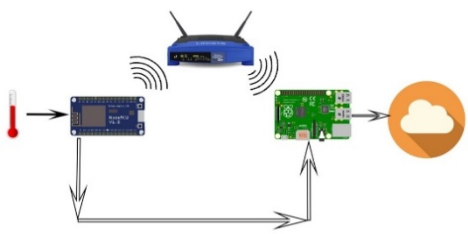

Figure 6. The schematic diagram of the whole measuring system

To build the system, the basic units to be bought on the Internet were to be chosen. Meanwhile the requirements were further expanded: since it was a temperature measurement, it seemed logical to measure the humidity as well, since it also

[8] HTPC: Home Theater Personal Computer.

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determines the comfort of man. In the case of the humidity sensor, the choice was primarily the price, and in fact, it had to look for cheap, “student money”.

The price was also important for the individual components because it was the aim of examining the alternatives and tools available on the market for temperature and humidity measurement, which can be much cheaper than the available ready-made solutions with little time and energy input.

A next and final choice was the digital operation, so you do not have to make an analog-digital conversion and program it. As it turned out later in the research, it would be worthwhile to build the same functionality with analogue sensors.

The sensors in Figure 7 are digital heat and humidity meters. The main difference between DHT-11 and DHT-22 is that the last is 10 times more accurate and can display measurable data with one-tenth accuracy.

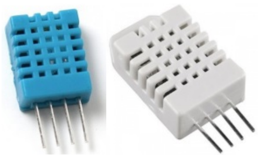

Figure 7. DHT–11 and DHT–22-es sensors [9] [10]

In the specification, it was decided that the solution would be independent of Raspberry Pi. During the research, the ESP866 microcontroller architecture today has become a popular choice, which made the project more useful: it was possible to get acquainted with its programming.

The ESP866 microcontroller was programmed in Arduino IDE development environment in C++, as the NodeMCU DevKit V0.9 developer panel (see Figure 8) is an inexpensive Arduino clone capable of connecting to WiFi.

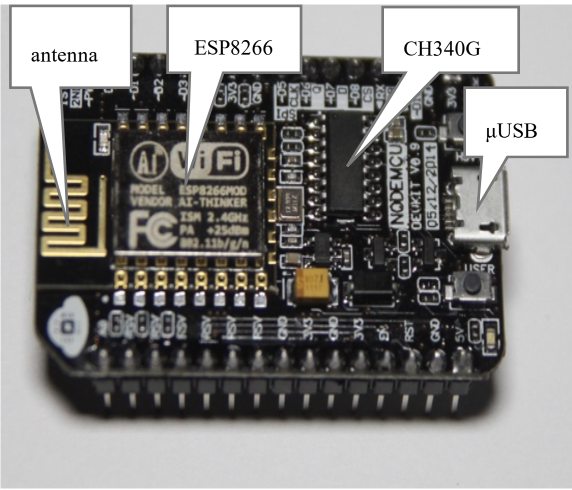

Figure 8. NodeMCU DevKit V0.9 development panel

B. *Implementing the System*

Implementing the task requires complex knowledge, skills and motivation because it is necessary:

- Linux user and operational knowledge to configure Raspberry Pi;
- SQL, including MySQL knowledge to create a database and create a user by which the microcontroller uploads the data into the database;
- Appropriate level of programming knowledge to program the microcontroller to handle, operate the sensor;
- Network knowledge for communicating with a dedicated Wi-Fi network and fixed IP addresses;
- Simulation tests, modeling, knowledge gained in the measurement and control engineering course; last but not least;
- English language skills, as research and problem solving requires many English-language documents, web-based forums, product and company portfolios.

When the system was implemented, first the 2x16 character display (see Figure 9) had to be started. It is operated by the microcontroller.

Then the program code had to be programmed to operate the sensor. The next step was to prepare the server page on Raspberry Pi to prepare the data reception. To do this, we had to install Apache2, MySQL server and phpMyAdmin, then configure them, then create a database for the data, and a user with which ESP8266 can connect to the database.

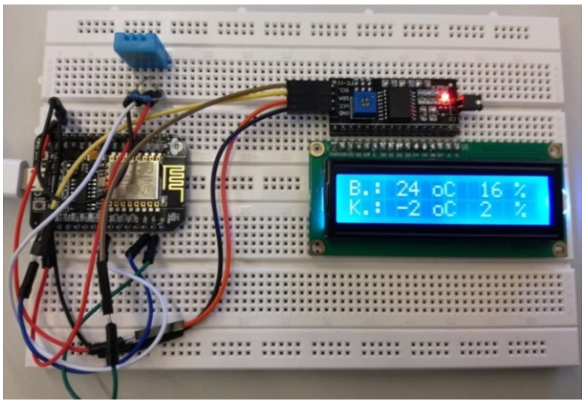

Figure 9. The finished IoT thermometer

The next step was to create a wireless network or to occupy IP addresses on an existing network so that NodeMCU and Raspberry Pi could communicate with each other. After that, the microcontroller side had to be supplemented with the code for the Wi-Fi connection, and it had to be resolved to connect and write to the MySQL database. This in itself was not a ready solution, because the biggest mistake possible lay in a state of Wi-Fi network. It was necessary to disconnect the temperature measurement from the WiFi connection, state and database connection, status, and it was also necessary to resolve the reconnection to both. Since there was no multifaceted CPU on a physical core and because internal timers were not exploited, writing your own internal timer program also caused many puzzles.

After these, the prototype of the “finished product” had a vase. In the next phase, the accuracy of the sensor was tested. By developing a sensor model, it has been demonstrated that the minimum of features a sensor needs to use for regulatory design can be used as feedback. Here, the usable subject was the measurement and control technique. Since we were working on the DHT-11 sensor's published catalog data, we thought we knew the sensor properly. However, measurements have shown that these data do not correspond to reality. It could have been known that, since digital sensors are concerned, the analog-to-digital conversion chips connected to the analog input, which is responsible for communication, generate noise along with transformation and can influence the

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degree of resolution and resolution of the transformation (for example, integer or decimal).

Our simulation studies have shown that the accuracy of the sensors greatly influences the originally measured analog values being re-drawn from the digital data obtained. Due to the cheaper DHT-11 sensor and its high quantization noise[9], it is unsuitable to be part of an intelligent controller (such as a thermostat connected to the Internet). Compared to DHT-22's properties and measured results, the latter can be used much more effectively.

VII. Integration Opportunities of IoT Projects to Education of the Computer Engineering

In the shown heat and humidity measurement system project, which has become a research topic, we have applied complex areas of IT and information technology (see Chapter VI. C).

Research based on the presented project was the subject of the first author of this article in his 2017 TDK thesis. The thesis can be a good basis for IT students in the measurement and control engineering course as an additional theoretical and practical tutorial. The research can serve as a case study for students, from which they can learn a lot about the development environment and the use of Raspberry Pi. Using the measured data of the project, students could practice sensory modeling and regulatory planning with the finished model. After getting to know the case study and preparing the models, they could make their own IoT application project. In an adequate online environment, many opportunities and great free space for the IoT can be provided to students and trainers.

It is important to note that with the development and the modeling of the sensor, students can obtain a lot of practical experience that can be used well later. They synthesize, deepen their acquired knowledge in complex IT projects covering a large number of IT disciplines, while gaining vast amounts of new theoretical and practical knowledge. As a result, their engineering approach is evolving.

Gréczi and Szandtner summarized her experience in a Raspberry Pi education in a one academic year seminar organized by a group of college students, outside the classroom. [11]. It is worth getting to know the part of their case study that determines at the beginning of the academic year, what needs, and preconceptions are for students, and in what direction, how to start with their project work.

The Raspberry Pi Student Workshop was launched at the Dennis Gabor Talent Point (GDT) at the beginning of the 2016/17 academic year. The purpose of this is to let interested in the platform students to know and to experience the development potential of the card computer in practice. Quickly and naturally arose in the group needs for development of IoT applications.

One of the major tasks to be solved in connection with the workshops and the subsequent home-work was that how the members with different preliminary knowledge support each other in necessary IT knowledge acquisition. The solution was that groups were organized in the community with both beginners and advanced in Linux operating and programming skills members.

Another self-evident aspect was to be grouping of members who came up with the established idea of what they want to achieve and who with general interest only. At the beginning of the projects, it was an important task to keep within the limits ideas and to narrow down the projects so that the members worked on a well-defined, specified task. The demands of the general interest were fulfilled by elaborating the tasks already specified, which were previously carried out. So, they could find good solutions and traceable patterns. Knowing the platform and the preparation of each IoT application had to solve many minor or major problems, as in chapter the VI.

After that, the first academic year of the GDT Raspberry Pi Workshop was very good. In the workshops and at home, the interested members of our projects have gained a lot of practical and theoretical experience. Complex, multifunctional IoT systems have been set up, and relying on them several of their members entered for the Magda Kovács Prize[10] in the academic year. The workshop's ever-expanding experiences have been continuously published, for example, in informative lectures and practical sessions.

VIII. Summarize

Appearance examples show that Raspberry Pi can be used in education of students of high school, IT engineering or hobbyist groups. The palm-sized card computer can inspire kids, students, teachers to learn more about hardware / software tools and IT technologies, IoT ecosystems and to create their own applications.

Acknowledgments

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References

[1] J. D. Brock, R. F. Bruce és M. E. Cameron, „Changing the world with a Raspberry Pi — tutorial presentation”, in *The Journal of Computing Sciences in Colleges*, vol. 29, ISSN 1937-4771 print, 1937-4763 digital. pp. 151–153. 2013.

[2] MadAdmin, „Raspberry Pi 3 model B+ teszt”, 19 03 2018. URL: http://www.madadmin.com/raspberry-pi-3-model-b-teszt-2/, visited: 10 05 2018.

[3] E. Upton és G. Halfacree, Raspberry Pi User Guide, Wiley, 2016, ISBN 1119264367, 9781119264361. p. 312.

[4] Kiwi electronics, „Kiwi electronics”, URL: https://www.kiwi-electronics.nl/raspberry-pi-3-model-b-plus, visited: 201805.09.

[5] J. Moorhead, „Raspberry Pi device will reboot computing in schools”, 09 01 2012. URL: https://www.theguardian.com/education/2012/jan/09/raspberry-pi-computer-revolutionise-computing-schools, visited: 09 05 2018.

[6] R. Cellan-Jones, „A 15 pound computer to inspire young programmers”, 2011.05.05. URL: http://www.bbc.co.uk/blogs/thereporters/rorycellanjones/2011/05/a_15_computer_to_inspire_young.html, visited: 10 05 2018.

[7] raspberrypi.org, „Downloads”, URL: https://www.raspberrypi.org/downloads/, visited: 2018.05.10.

[8] solivero, „GitHub”, URL: https://github.com/solivero/kuben, visited: 09 05 2018.

[9] Kvantálási zaj: analóg-digitális átalakítás során keletkező zavar. (*Quantization noise: anomaly caused by analogue-digital conversion.)*

[10] http://ilias.gdf.hu/goto.php?target=pg_43283_63833&client_id=ilias-ha

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DOI: 10.26648/JAM.2018.3.001

[9] Thinkersphere Hobby Electronics, „Thinkersphere Hobby Electronics”, URL: http://tinkersphere.com/sensors/428-humidity-and-temperature-sensor-for-arduino-raspberry-pi-b-rht01-dht11.html, visited: 09 05 2018.

[10] RobotShop, „RobotShop”, URL: https://www.robotshop.com/ca/en/humidity-temperature-sensor-dht22.html, visited: 09.05 2018.

[11] P. Gréczi and Z. Szandtner, „Raspberry PI és IoT az oktatásban”, Inspiráció, year 24, No 4, pp. 12–19, 2017. URL: https://isze.hu/wp-content/uploads/2016/12/Inspira%CC%81cio%CC%812017_4.pdf, visited: 09 05 2018.

[12] G. Wong, „Build your own prototype Raspberry Pi minicomputer”, Ubergizmo, 24 10 2011. URL: http://www.ubergizmo.com/2011/10/build-raspberry-pi-minicomputer/, visited:04 06 2017.

[13] S. J. Vaughan-Nichols, „Who writes Linux? Almost 10,000 developers.”, 16 szeptember 2013. URL: http://www.zdnet.com/article/who-writes-linux-almost-10000-developers/, visited: 10 05 2017.

[14] B. Seidl, „Operating systems used on top 500 supercomputers”, 2009.02.09. URL: https://commons.wikimedia.org/wiki/File:Operating_systems_used_on_top_500_supercomputers.svg, visited: 08 10 2017.

[15] Free Software Foundation, „Overview of the GNU System”, 2017.06.16. URL: https://www.gnu.org/gnu/gnu-history.en.html, visited: 01 07 2017.