INFORMATION AND COMMUNICATION TECHNOLOGIES LABORATORY OF TURIBA UNIVERSITY

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Abstract

The paper presents results on establishment and development of Information and Communication Technologies Laboratory at Turiba University. The aim of the laboratory is to provide IT department students the possibility to study and gain practical skills on the development and operation of digitally controlled devices which is currently one of the mainstream technologies in modern society. The paper provides an analysis of typical tasks which are in demand while developing digitally controlled devices, and describes laboratory equipment targeted to meet necessary requirements. The main aims of the laboratory establishment as well as the equipment used and skills which could be acquired with the use of this equipment are described. The students' projects implemented with the use of laboratory equipment in the Spring semester of 2022 are also described in this paper. All the equipment developed along with other laboratory facility are practically used to improve both knowledge and practical skills of the IT department students, which can help them to be more competitive at the labour market after graduation.

Keywords: ICT laboratory, IoT, microcomputers, software, hardware, control, sensors

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Introduction

The underlying idea of a laboratory was to provide the possibility both for students and researchers to work with equipment used in modern IT systems. The work on the laboratory infrastructure started in November 2021.

First of all, the most intensively developing areas of life where information technologies could be practically used were analysed. These are smart technologies, such as Smart Buildings, Smart Cars, Internet of Things, Robotics, Computer Vision and many others which involves deep integration of hardware and software.

Aiming to provide students practical experience in work with such systems, the basic equipment for Internet of Things (IoT) course, such as set of different sensors, small bots, such as line follower, RC-car, small-sized microcomputers such as Raspberry PI and Arduino, Robotic Arms, etc. were purchased.

With these sensors and additional equipment students can develop their small projects within the scope of the IoT course, as well as use them in student research works.

Another important aim of this laboratory is the possibility to carry out research work in IT-related field. A set of hardware equipment was purchased which is planned to be used for research on AI implementation in the field of industrial automation, computer vision, indirect measurements, etc.

To be more flexible in gaining necessary parts and components for devices, the laboratory is equipped with 3D-printer, which itself is also an object of research: its control algorithm written in C++ can be modified to research on different operation modes and their efficiency can be compared.

All these assumptions were taken into account during the laboratory establishment and will be described in more details in the following chapters.

1. Basic principles of Turiba University ICT laboratory

Modern society implies deep integration of digital technologies with the all other technologies, such as electrical, mechanical, hydraulic and other devices, decision making processes, automation solutions etc. One of the most important advances in the use of digital technologies is possibility to integrate all engineering and control technologies into a single environment able to perform itself autonomously with the minimum involvement of a human interaction. Such approach is considered as the most promising nowadays, as it is aimed to replace the human labour with the machine being controlled with the use of digital technologies. This solution allows one to eliminate the probability of human errors during performance, improve the quality of operations, decrease human labour expenses, – thus, it is considered as a proper solution both from technical and economic points of view (Shafique et al., 2020).

Such changes in social and industrial trends requires novel specialists with the modern skills, who are able to design, develop and maintain digitally integrated systems. These specialists should, on the one hand, get all necessary knowledge to work with digital systems, such as be familiar with different programming languages, algorithms, computer system architectures, etc., and, on the other hand, should have at least basic knowledge of computer hardware, sensors and actuator basic operation principles.

With all these modern trends in mind, Turiba University established the Information and Communication Technologies Laboratory (ICTL), which is equipped with a basic set of a hardware, sensors and actuating devices and aimed at teaching students necessary elementary skills needed to integrate digital technologies with other engineering technologies.

One of the most widely spread areas which implies such cooperation, is the Internet of Things (IoT), which represents itself as a physical object equipped with sensors, processing device, software and other technologies aimed at exchanging data between interconnected devices using communication technologies such as the Internet (Madakam et al., 2015). Thus, Turiba University IT department introduced a related course into curriculum, aiming to use ICTL facility for acquiring practical skills.

2. Laboratory Hardware

To get students acquainted with the basic principles of hardware control with the use of microcontrollers, a set of simple digitally controlled electromechanical devices are used in the ICTL. They are Line Following cars, Spider Robot, automatic planting system EcoDuino and Robotic Arms. In order to learn basic principles of developing both simple and sophisticated control algorithms for IoT devices, the ICTL uses single-board computers such as Raspberry PI, Arduino and micro: bit. Also, laboratory facility include a set of different IoT sensors, such as different types of temperature sensors, humidity sensors, smoke sensors, sound sensors, motion sensors, Hall sensors and many others.

Soldering Skills

One of the necessary skills in IoT systems development is soldering. As the majority of such systems consist of semiconducting electronic elements, it's good to have some practice with soldering printed board elements. With this aim, ICTL uses do-it-yourself (DIY) Robot Kits, such as Line Follower (Latif et al., 2020). These kits contain detailed instructions for device assembling, soldering and testing. The image of the assembled line follower is presented in Figure 1.

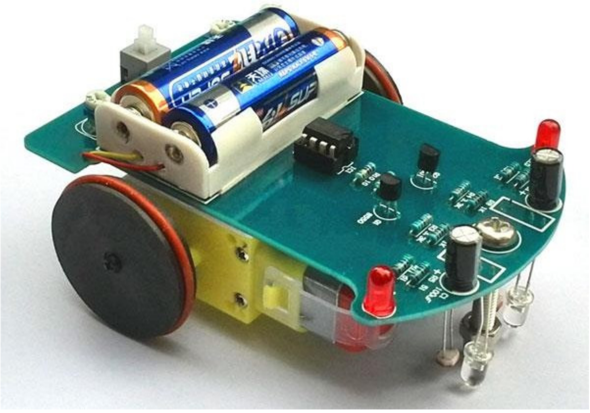

Figure 1. **Appearance of line following bot**

This robot includes two low-power electric motors to drive the robot wheels on both sides, LED and photoreceptor which forms sensor circuit, and LM393 chip with the control software algorithm. Car driving is based on the principle of the light reflecting difference between white and black items. Photoreceptors sense the length of the light wave reflected from the surface of a certain colour, and sends "on" or "off" signal to one of the wheel driving motors. As it states from its name, the robot should "follow" the black line drawn on a white surface, while this line should remain between the robot wheels (Figure 2). If the line curves, one of the sensors senses black coloured surface, and sends "off" signal to the wheel motor placed at the same side as the sensor, while the opposite wheel still rotates. Once sensors sense white surface again, it sends "on" signal to the motor wheel.

This is how the robot can make a turn, and this basic algorithm is programmed within LM393 chip.

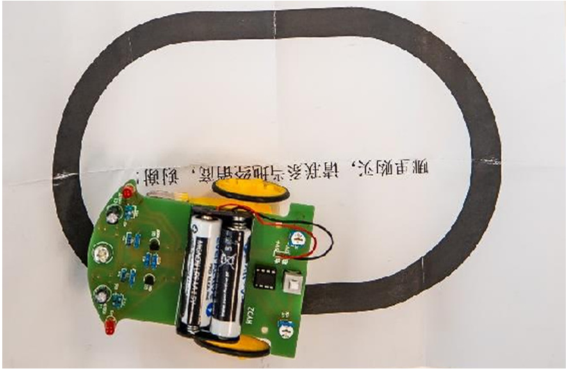

Figure 2. **Line following bot tracking black line route**

With the use of this robot kit, students could not only learn soldering and basic electronics principles, but also, with the use of additional programmer device, they can modify control algorithms and compare their efficiency.

The use of sensors

Another important skill in the IoT is the use and processing of data from sensors. With the aim to provide this type of knowledge, ICTL uses kits such as EcoDuino automatic planting system (Alvarado Moreno et al, 2018). This system could use different types of sensors, such as humidity, temperature, light intensity etc. To control the plant growth process, it could use different types of microcontrollers, such as Atmega32U4, or single board microcomputers such as Arduino or Raspberry PI. With this kit, students could learn signal processing, starting from collecting analogue signals, representing them in digital form with the use of analogue-digital converters (ADC), adjusting them to real-life values, processing signals or representing the values to users, computing and performing control signals. In the simplest case, the planting system uses single soil moisture sensor, which should be installed in the soil near the plant, and an electrically driven pump installed in the water tank. Sensors analyses soil moisture, and, depending on software settings, produces a control signal to start or stop pumping. Students can trace the signal transformation route starting from its analogue form, coming from the humidity sensor, then its transformation into digital form with the use of inner ADC, signal processing with the use of control software, computing control signal to the pump and sending it back to physical device. Additionally, the system could be equipped with networking devices, such as WiFi or ZigBee modules to send all information to remote PC for representation with the user interface. The image of EcoDuino is presented in Figure 3.

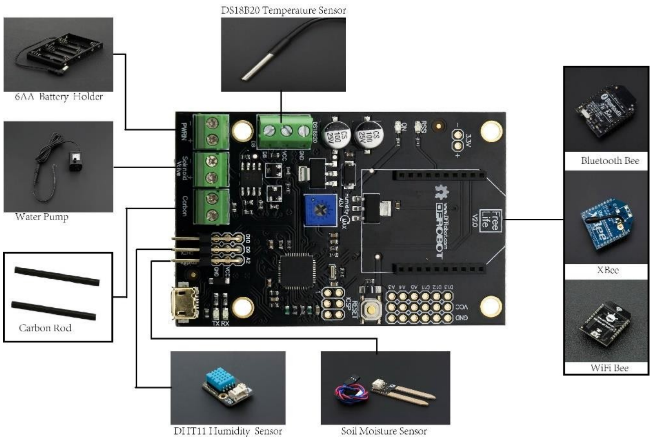

Figure 3. **EcoDuino system components**

Study of control algorithms

Another one important component in developing IoT systems is understanding the principles of development of control algorithms. One of the most popular solutions to meet this aim is the use of robotic arms. The robotic arm represents itself as a mechanical programmable device resembling a human arm. Nowadays typically it is an electronic device, with the use of electrical stepper motors to perform arm movements and a processing device to perform control algorithm execution. Typically, robotic arms could have 2 to 7 degrees of freedom, which determines the complexity of their control algorithms and operation performance. Robotic arms currently are widely used in different industries; thus, the study of their operation principles could help students to gain some practice with typical real-life tasks.

ICTL is equipped with two different robotic arms: simple Robot Arm Kit for micro:bit and more advanced Arexx RA-1-PRO robot arm.

The first one is a special kit designed to operate with either micro:bit or Raspberry PI single board microcomputers (Ball et al., 2016). Apart from the microcomputer, this kit contains 16-channel servo drive control board to control arm movements in different directions. The micro:bit microcomputer could be programmed with the use of one of the popular programming languages, such as Python or JavaScript. After source code designing, it translates into *.hex file, which could be sent to the microcomputer with the use of a USB connection. Additionally, the micro:bit is equipped with a Bluetooth module, which allows one to establish remote control to the device. Also, Bluetooth allows students to develop smartphone-based software to control robotic arm movements. The image of micro:bit Robot Arm Kit is presented in Figure 4.

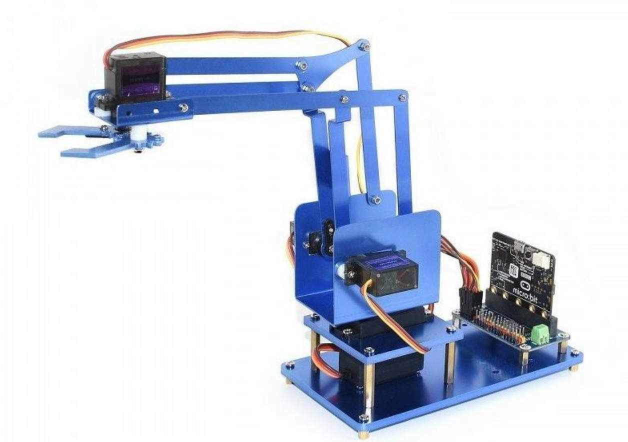

Figure 4. **Appearance of micro:bit Robot Arm Kit (assembled)**

The second device is more complex, larger in its dimensions and can perform more complex operations. It contains 6 servo motors, control board and adapter for programming in C language via USB (Buck et al., 2019). This arm could provide students the possibility to gain real experience with lower level programming, paying attention to direct interaction with the hardware of the robotic arm. The image of Arexx robotic arm is presented in Figure 5.

Figure 5. **Arexx robotic arm**

Another solution which could be used to study control algorithms, is Totem Maker Gripper Bot. This device provides the possibility to study remote control algorithms, with the use of Bluetooth data transmission, and also it could be used as a base for developing small- sized sample of a self-driving robotic car while equipped with video camera and more powerful control device, such as Raspberry PI.

Study of computer vision systems

Modern IoT systems could also provide the possibility to recognize shapes and even more complex images, which could be used for different purposes, such as developing software for security systems, self-driving car algorithms, shape and object recognition, indirect dimensions computation etc. With this aim, ICTL uses web-cameras and specialized Raspberry PI cameras, which allows to carry out research such as the study and research of image recognition algorithms and systems.

The use of 3D printer for the laboratory needs

An important thing for successful ICTL development is the possibility to have all the necessary parts and components for IoT devices. However, it is not always possible to purchase them and get them as quickly as needed. To evade this restriction, ICTL uses 3D printer, which, on the one hand, is used to create the parts necessary for IoT devices, and, on the other hand, could be used itself in student research projects to investigate its control algorithms, modify them and compare their efficiency. Also, students have the possibility to learn principles of developing drawings for 3D printing, use design and control software with different settings.

3. Student Projects

As result of the first 5 months of ICTL existence, several student projects were implemented within the IoT course, which were presented during the final exam. Figure 6 shows micro:bit Robot Arm controlled project with the use of Android application operating via Bluetooth, and Figure 7 shows a sample of a developed control algorithm script.

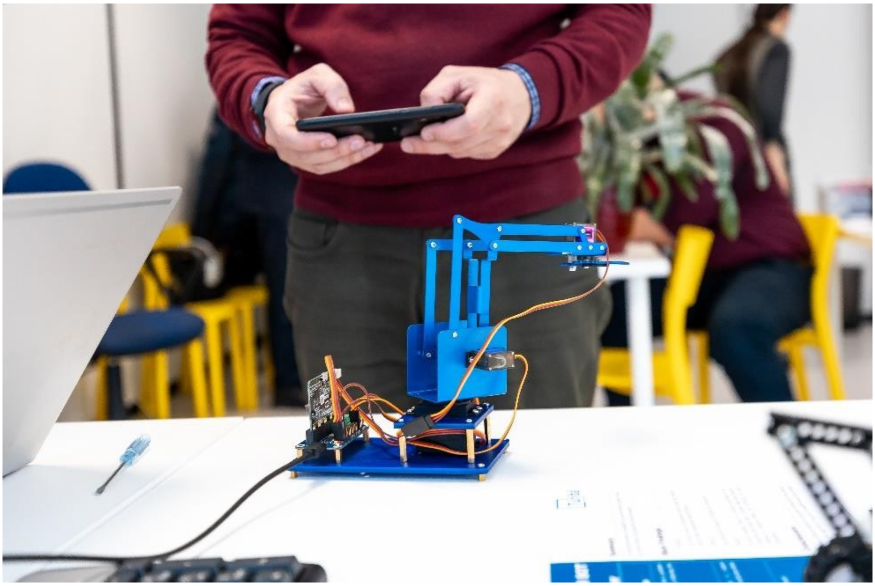

Figure 6. **Testing of micro:bit Robotic Arm project**

Figure 7. **Sample of developed control algorithm script for micro:bit Robotic Arm**

Figure 8 shows line following bot projects. Two independent students have implemented this project with the separate development kits.

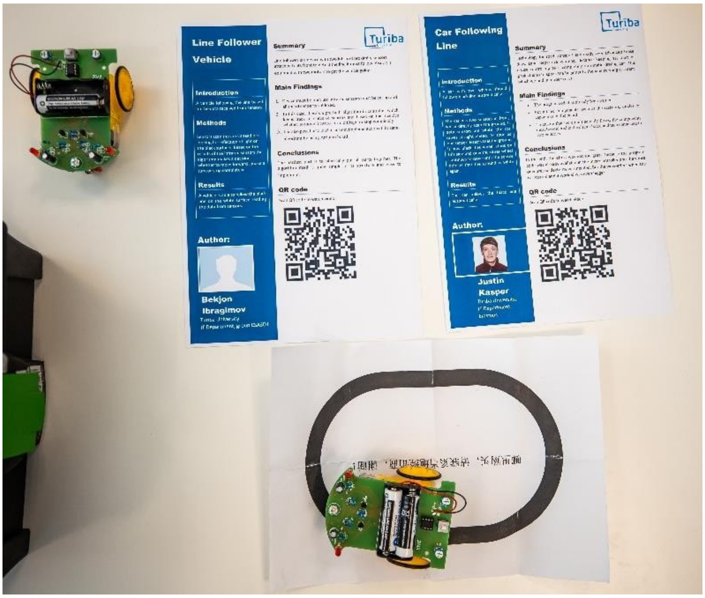

Figure 8. **Line follower project**

Implementation of the EcoDuino project involved a lot of hardware debugging and adjusting operations, as this was one of the most complex projects during this course (Figure 9).

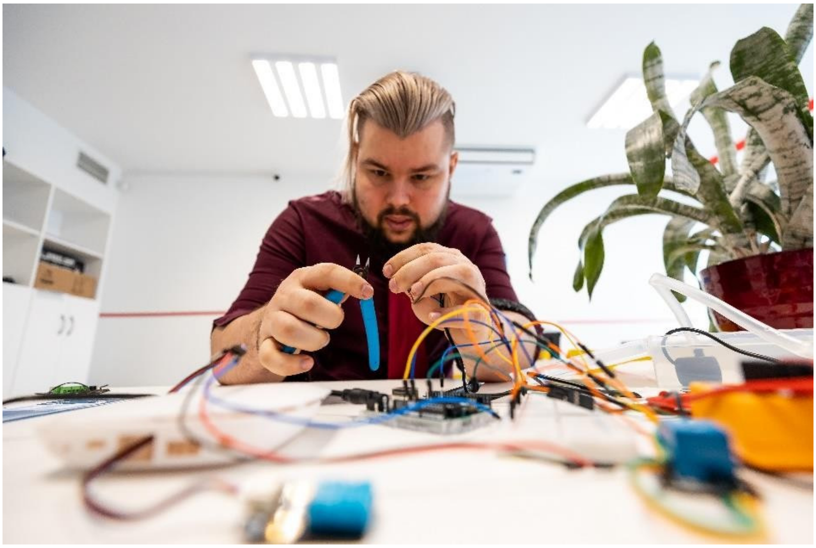

Figure 9. **Debugging process during EcoDuino project implementation**

Another project implemented during this course relates to Gripper Bot remotely controlled with a Bluetooth Android application (Figure 10).

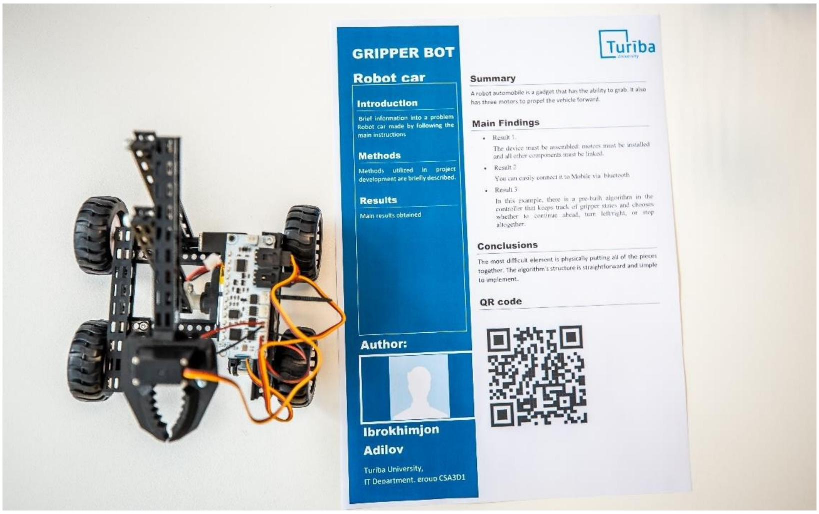

Figure 10. **Gripper Bot project**

4. Researches based on ICTL

Another important aim of the laboratory is the possibility to use its facilities to provide scientific research work. Thus, ideas that arose during the laboratory infrastructure establishment, were realised as 2 published scientific papers and another 2 papers submitted for publication. Another research direction relates to the investigation of different types of sensors within the ideas of Smart Buildings and Self-driving cars. The main control algorithm for such systems typically could be implemented within microcontrollers or microcomputers, such as Raspberry PI or Orange PI, which have enough computing resources to perform preliminary processing and control signals, and also to transmit information to more powerful computing device via network. Currently, the laboratory infrastructure is used to provide experimental work on the use of computer vision for providing indirect object dimensions measurement, which could be practically used in different areas of the industry where there is a problem or complexity in direct measurements implementation.

Conclusions

The paper presents an overview of the results obtained during establishment of ICT laboratory at Turiba University and its operation during the first five months of its existence. The idea of the laboratory establishment as a media to provide students practical skills in development, operation and maintenance of digitally controlled devices, which have become one of the most rapidly developing mainstream technologies in IT society during last decade, was justified. The basic knowledge and skills which could be gained in the laboratory while working with different types of technologies, was explained and substantiated. The results obtained during student project implementation within the scope of IoT course were demonstrated. The necessity of the laboratory in development IT-related scientific work at Turiba University, was shown. In general, the results gained could be considered as a good starting point for the laboratory, which allows students gain necessary knowledge to be more competitive in the modern IT labour market.

References

Alvarado Moreno, J. D., Luis Garcia, L. C., Hernandez, W. C. & Barrera Obando, A. M. (2018). Embedded Systems for Internet of Things (IoT) Applications: A Review Study. *2018 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI)*, 1–6. DOI: 10.1109/CONIITI.2018.8587092

Ball, T. et al. (2016). Microsoft Touch Develop and the BBC micro:bit. *2016 IEEE/ACM 38th International Conference on Software Engineering Companion (ICSE-C)*, 637–640

Buck, T., Matthews, A. & Alba-Flores, R. (2019). Robotic Arm Control Through the Use of Human Machine Interfaces and Brain Signals. *2019 SoutheastCon*, 1–4. DOI: 10.1109/SoutheastCon42311.2019.9020526

Latif, A., Agus Widodo, H., Rahim, R., & Kunal, K. (2020). Implementation of Line Follower Robot based Microcontroller ATMega32A. *Journal of Robotics and Control (JRC), 1*(3), 70–74. DOI: https://doi.org/10.18196/jrc.1316

Madakam, S., Ramaswamy, R. & Tripathi, S. (2015). Internet of Things (IoT): A Literature Review. *Journal of Computer and Communications*, 3, 164–173. DOI: 10.4236/jcc.2015.35021

Shafique, K., Khawaja, B. A., Sabir, F., Qazi, S. & Mustaqim, M. (2020). Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends and Prospectsfor Emerging 5G-IoT Scenarios. *IEEE Access,* Vol. 8*,* 23022–23040. DOI: 10.1109/ACCESS.2020.2970118