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PYTHON PROGRAMMING LANGUAGE AS A MEANS OF TRAINING FUTURE TEACHERS OF COMPUTER SCIENCE WHEN WORKING WITH ARDUINO

МОВА ПРОГРАМУВАННЯ PUTHON ЯК ЗАСІБ ПІДГОТОВКИ МАЙБУТНІХ ВЧИТЕЛІВ ІНФОРМАТИКИ ПРИ РОБОТІ З ARDUINO

[1]Vitalii Kyslitsyn, [2]Lyudmila Shevchenko, [3]Volodymyr Umanets
[1]Кисліцин Віталі Вячеславович, [2]Шевченко Людмила Станіславівна,
[3]Уманець Володимир Олександрович

[1,2,3]Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (Ukraine)
ORCID: [1]https://orcid.org/0009-0008-8986-8645, [2] https://orcid.org/0000-0003-4991-4949
[3]https://orcid.org/0000-0002-7237-4955
E-mail: [1]v.kyslitsyn@vspu.edu.ua, [2]l.shevchenko@vspu.edu.ua, [3]umanets@vspu.edu.ua

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Abstract. *This article explores the possibilities and advantages of using the Python programming language together with Arduino robotics kits in the process of training future computer science teachers in pedagogical educational institutions. Considerable emphasis is placed on analyzing the principles of operation of the simplest programs and devices that can be used to visualize the possibilities of using the Arduino platform and Python libraries to create robots that can be implemented in the educational process and everyday life. The authors have developed the program code and presented a working model of a robot assembled and programmed on the basis of Arduino components to measure humidity in computer laboratories and create automatic plant irrigation systems to maintain proper conditions in classrooms. The article presents an example of integrating the learning of the Python programming language with the use of Arduino robotics kits. This method is aimed at improving the quality of training of future computer science teachers, expanding their methodological arsenal and ensuring the ability to teach students using innovative means. The results of the study and the developed teaching and learning materials will help to interest students in STEM education and prepare a new generation of computer science teachers for the challenges of the modern technological world, expand their methodological arsenal and develop the ability to use integrated technical, engineering and mathematical solutions to solve theoretical and practical problems. In addition, this study can serve as a guide to popularize the use of Arduino and Python in educational institutions, and encourage future computer science teachers to implement STEM and hands-on teaching methods, which will contribute to better student learning and improve the quality of professional education in the field of information technology in general. In general, the study opens up a wide range of opportunities for using modern digital technologies in professional education and stimulates interest in STEM education among computer science teachers and students, thereby contributing to the development of a new generation of engineers and technology leaders. Further research could be aimed at developing specific training courses and methods for integrating the Python programming language and Arduino robotics kits into STEM education. It is important to create interdisciplinary STEM courses with the participation of teachers of computer science, physics, mathematics, vocational education in the IT industry, etc.*

Анотація. *Ця стаття досліджує можливості та переваги використання мови програмування Python разом з наборами робототехніки Arduino у процесі підготовки майбутніх вчителів інформатики в педагогічних закладах освіти. Значний акцент робиться на аналізі принципів роботи найпростіших програм і пристроїв, які можна використовувати для візуалізації можливостей застосування платформи Arduino та бібліотек Python для створення роботів, що можуть бути впроваджені в освітній процес і повсякденне життя. Автори розробили програмний код і представили працюючу модель робота, зібраного та запрограмованого на основі компонентів Arduino для вимірювання вологості в комп'ютерних лабораторіях та створення систем автоматичного поливу рослин для підтримання належних умов у навчальних аудиторіях. У статті наведено приклад інтеграції вивчення мови програмування Python із використанням наборів робототехніки Arduino. Цей метод спрямований на підвищення якості підготовки майбутніх вчителів інформатики, розширення їхнього методичного арсеналу та забезпечення здатності навчати учнів за допомогою інноваційних засобів. Результати*

дослідження та розроблені навчально-методичні матеріали допоможуть зацікавити учнів STEM-освітою та підготувати нове покоління вчителів інформатики до викликів сучасного технологічного світу, розширити їхній методичний арсенал і розвинути вміння використовувати інтегровані технічні, інженерні та математичні рішення для вирішення теоретичних і практичних завдань. Крім того, це дослідження може слугувати керівництвом для популяризації використання Arduino та Python у навчальних закладах, а також заохочуватиме майбутніх вчителів інформатики впроваджувати STEM та практичні методи навчання, що сприятиме кращому засвоєнню студентами матеріалу та підвищенню якості професійної освіти в галузі інформаційних технологій загалом. Загалом, дослідження відкриває широкий спектр можливостей для використання сучасних цифрових технологій у професійній освіті та стимулює інтерес до STEM-освіти серед викладачів інформатики та студентів, тим самим сприяючи розвитку нового покоління інженерів і технологічних лідерів. Подальші дослідження можуть бути спрямовані на розробку конкретних навчальних курсів та методик інтеграції мови програмування Python і наборів робототехніки Arduino в STEM-освіту. Важливо створювати міждисциплінарні STEM-курси за участі викладачів інформатики, фізики, математики, професійної освіти в IT-галузі тощо.
Keywords: Arduino; Python; STEM education; Arduino programming; computer science teacher.
Ключові слова: Arduino; Python; STEM-освіта; програмування Arduino; вчитель інформатики.

INTRODUCTION

Nowadays, robotics and programming are becoming more and more popular and integrated into education. Robots are becoming an integral part of our daily lives and education. For example, we use them to process Bigdata or to observe phenomena that require round-the-clock monitoring.

This also applies to education, as the inclusion of robotics in educational programs guides us to understand the principles of robotics and programming for computer science teacher education. This study also takes into account the importance of integrating STEM (science, technology, engineering, math) technologies into the educational process.

STEM is an approach to education that combines various sciences, technologies, engineering creativity and mathematical thinking. Interdisciplinarity is an important concept in STEM education and is considered a pedagogical innovation. The main challenge in developing STEM curricula is the integration of related but independent disciplines. This requires careful consideration of established ontologies. Science as a way of knowing that helps to understand the world around us.

- Technology as a way to improve the world, which is sensitive to social changes;
- Engineering as a way to create and improve devices for to solve real-world problems;
- Mathematics as a way of describing the world (analyzing the world and real problems with the help of numbers)" [1].

STEM is a favorable field for the acquisition of scientific knowledge and engineering skills, stimulating the development of critical thinking and innovative solutions in the field of technology and science. The introduction of STEM technologies creates a hands-on learning environment that supports the development of creativity and technical abilities in both students and teachers. STEM is an educational concept that emphasizes the scientific, technological, engineering and mathematical components of learning. This approach aims to develop students' critical thinking, problem-solving, creativity, and practical skills, laying the groundwork for future scientific and technological innovations. STEM education not only trains a new generation of science and technology professionals, but also raises the intellectual level of society and contributes to the development of engineering solutions to various global challenges. This approach is widely used in modern educational programs and promotes creative and innovative solutions to complex problems in all spheres of life. The level of development of educational systems achieved in developed countries is a significant factor in their intellectual, economic, social, scientific, technical, innovative, technological and cultural progress, which largely ensures the stability and evolutionary nature of development in these countries, improves the quality of life, deepens democratic processes, and gradually increases the spiritual and material level of peaceful, creative life of the population - the main goal of progressive development of man and society[2].

According to the methodological recommendations for the implementation of STEM https://zakon.rada.gov.ua/rada/show/v1470777-17#Text (Access mod) , one of the most relevant areas of modernization and innovative development of natural-mathematical and humanitarian education profiles is a STEM-oriented approach to learning, which promotes the popularization of engineering and technology professions among young people, raising awareness of their career opportunities in the engineering and technology field, and forming a sustainable motivation to study the disciplines on which STEM education is based.

Robotics is one of the fields of application of STEM education. It is an applied science that deals with the creation of automated technical systems. In the educational process, robotics is implemented through the use of modular kits that, with the help of information and communication technologies and educational tools, enable students to acquire skills in designing robots and writing programs to control them.

LITERATURE ANALYSIS

Research results and numerous publications show the significant potential of using the Python programming language to control robots on the Arduino platform. This topic has been addressed by such scientists as V. Krushynskyi, Y. Lebedieva, V. Loshak, D. Montefusco, E. Chornyi, E. Myronenko, and O. Lysenko.

Python is a widespread programming language that simplifies the project development process. It has a large user base and many libraries suitable for programming Arduino robots. Many publications provide code examples and explain how Python and Arduino interact, allowing you to extend the functionality of robots and create new programs.

In addition, using Python to control Arduino robots has great potential in STEM education. Python is a programming language accessible to beginners, making it easy to learn coding and programming skills for robots. Python is widely used in educational projects and robot programming programs, which demonstrates its popularity in this area.

Arduino is a popular platform for developing electronic projects, and using Python in conjunction with it simplifies and improves the development process of such projects. The Python programming language is known for its simplicity and accessibility, making it an ideal choice for both beginners and experienced developers. Another significant advantage is the large Python user community and various functional libraries that facilitate interaction with Arduino, expand the capabilities of robots, and allow you to create new programs. A large number of publications and code examples are available, making the process of learning and developing for Arduino with Python clear and informative.

OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of this study is to explore the potential benefits of using the Python programming language in combination with the Arduino platform in STEM education. The study examines how this combination of tools can be useful for computer science teachers and create an interactive and hands-on learning environment for students.

The study of the use of Python and Arduino in STEM education is an urgent task. Currently, the level of digital competence among teachers does not fully meet the requirements of the modern technological era. The introduction of programming and robotics in schools creates the prerequisites for training qualified engineers and technicians in the future. STEM education enables the organic integration of natural sciences, technologies, engineering and mathematical knowledge to solve practical problems. This helps develop the ability to apply knowledge in practice, stimulates interest in science, and improves logical thinking.

The Arduino platform is an ideal tool for STEM education due to its accessibility, simplicity, and versatility. Arduino boards can interact with a variety of sensors and devices to collect environmental data and control motors, lights, pumps, and more. Programming these devices using Python opens up great opportunities for interactive and project-based learning. Students can create weather stations, smart home systems, robots, and more.

The study aims to analyze the application of Arduino and Python in educational projects, specifically in creating a system for measuring humidity and an automated irrigation system. The study will focus on the principles of collecting sensor data, processing them in Python, and controlling actuators to enhance the understanding of software and hardware interactions. This text demonstrates the potential of using Arduino and Python to create solutions for real-life tasks.

The study's results will serve as methodological guidelines for teachers on the use of programming and robotics in STEM education. The proposed projects can be modified and adapted to different age categories and used to teach computer science, physics, mathematics, engineering, and technology. Involving schoolchildren in the creation of such solutions can increase motivation and develop logical and computational thinking, as well as skills in the exact sciences and engineering. Therefore, studying the use of Python and Arduino has significant practical significance for improving the quality of STEM education, developing effective teaching methods, and training IT teachers.

RESULTS

This study was conducted within the framework of the research laboratory on the use of information technology in education at Vinnytsia State Pedagogical University (VSPU) and the Institute of Digitalization of Education of the National Academy of Pedagogical Sciences of Ukraine. This issue is relevant for the development of education in general. During theresearch, itwasconcludedthat the Arduino platform can be used to developcontrolsystemsfor switches and sensors. Such systems can control a widerangeof indicators, motorsand other devices; Arduino-based modules are autonomous and can interact with software running on a computer. Thus, Pythonassoftwarecanbeusedto implement a wide variety of projects that benefit society. Therefore, various Python librariescan be usedto work with Arduino, including the following:

- PySerial - this library allows you to communicate between Python and Arduino using the Serial port. It allows you to open, close, and configure the Serial port, as well as transfer data from Python to Arduino and back.
- Firmata - this library allows you to use the standard Firmata protocol to communicate between Python and Arduino. It allows you to control the pin outputs and read data from sensors using common Firmata commands.
- PyMata is a Python wrapper for the Firmata library. It allows you to use a more convenient and simpler interface to interact with Arduino. PyMata allows you to control pin pins, read data from sensors, control servos, and much more.
- Arduino - this library allows you to write code for Arduino directly in the Python environment. It allows you to rewrite Arduino sketches in Python and use them to control your robot.
- Johnny-Five is a library that allows you to interact with Arduino and other boards using JavaScript. It supports many different sensors and devices, and has a convenient and simple interface for interacting with them.

An example where we used Python libraries and Arduino sensors is to collect data on indoor humidity and save this data in a text file.

The main element for collecting data on indoor humidity is a humidity sensor. One of the most common humidity sensors is the DHT11. We can connect this sensor to the Arduino and use PySerial to collect the data and write it to a text file.

Below is the code to collect the humidity data using the DHT11 sensor and save the data to a text file (Fig. 1.).

```python
import serial
import time

ser = serial.Serial('COM3', 9600)

while True:
    try:
        data = ser.readline().decode().strip()
        if data:
            humidity, temperature = data.split(',')

            with open('humidity_data.txt', 'a') as file:
                file.write(f'{time.time()}, {humidity}, {temperature}\n')

    except KeyboardInterrupt:
        ser.close()
        break
```

Fig. 1. Code for collecting indoor humidity data

Thus, when you start the program and our robot, the process of data processing takes place. Our library connects to the Arduino board and starts a loop to process the data received from the DHT11 sensor and the end result is a file in which we will have data on time, humidity and temperature (Fig. 2.).

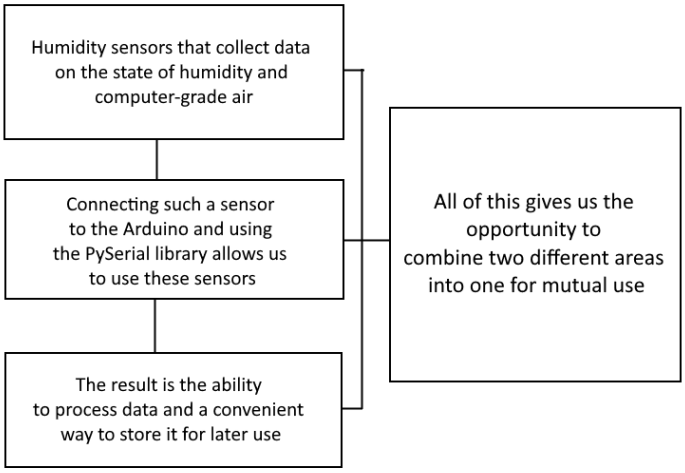

Fig. 2. Arduino and Python interaction scheme for controlling robots

Another example is an automatic garden irrigation system using Arduino, soil moisture sensors, and pumps (Fig. 3).

```python
import serial
import time

ser = serial.Serial('COM3', 9600)

def pump_on():
    ser.write(b'H')
    print("Pump ON")

def pump_off():
    ser.write(b'L')
    print("Pump OFF")

while True:
    moisture_data = ser.readline().decode().strip()
    moisture = int(moisture_data)

    if moisture < 400:
        pump_on()
    else:
        pump_off()

    time.sleep(1)
```

Fig. 3. Code for an automatic irrigation system

An automatic garden irrigation system uses a variety of elements and components. The main components for this are:

- Arduino - a microcontroller that is responsible for controlling the system and collecting data from the sensors.
- Soil moisture sensors - they measure the moisture level in the soil and transmit the data to the Arduino.

Soil moisture sensors are used to measure soil moisture, which are capable of determining moisture based on measuring the resistance between two electrodes installed in the soil. Soil moisture sensors can have different moisture measurement ranges, accuracy, and response speeds.

The most popular soil moisture sensors are:

- Capacitive Soil Moisture Sensor
- Resistance Soil Moisture Sensor
- Frequency Domain Reflectometry Soil Moisture Sensor

Any of these soil moisture sensors can be used for an automatic garden irrigation system, depending on the specific needs and requirements.

- Pumps - used to provide watering, with their operation controlled by the Arduino.
- Relays - These are used to control the pumps to turn on and off depending on the moisture level in the soil.
- Power supply - power supplies for Arduino, sensors, and pumps are used.
- Communication elements - USB cables and Bluetooth modules can be used to provide communication between the Arduino and a computer, as well as to program the microcontroller.
- Housing and other materials - a variety of materials such as plastic, metal, wood, etc. can be used to create an irrigation system, as well as tools and small parts to assemble and configure the system.

Also, to develop professional competencies, you can find many resources on the Internet for creating various projects based on the Arduino platform.

- https://www.arduino.cc/en/software - the official website with the software
- https://all3dp.com/2/most-useful-arduino-projects/ - Arduino projects
- https://projecthub.arduino.cc/ - Arduino projects on the official website

The use of these innovative and informational [5-6] technologies to provide future skilled workers with constant access to educational materials makes it possible to work on the educational material independently at a convenient time and in a convenient mode, allows you to free up time in the classroom for the educational process of high-quality professional training of future skilled workers in the service sector [4].

CONCLUSIONS

This research explored the possibilities and benefits of using the Python programming language in combination with the Arduino platform for training computer science teachers and creating interactive learning environments in the context of STEM education. The study analyses the principles of Python libraries, such as PySerial, Firmata, and PyMata, that facilitate communication between Python and Arduino, control of pins, and reading of sensor data. The text provides specific examples of projects that use Arduino and Python, such as a humidity measurement system that uses a DHT11 sensor and saves data to a text file, and an automatic garden irrigation system that uses soil moisture sensors. The importance of integrating STEM technologies into the educational process is emphasised, as it promotes critical thinking, the development of creative and practical skills, and the creation of innovative approaches to problem-solving. The study concluded that the combination of Python programming language and the Arduino platform aligns with the principles of STEM education.

It holds promise for both the educational process and for creating useful inventions and projects for the benefit of society. These technologies are simple and accessible, making it possible to develop innovative approaches in education and to encourage interest in STEM among teachers and students.

The results of the study indicate that the educational materials developed using Arduino and Python have the potential to enhance vocational teacher training, expand their methodological arsenal, and develop their ability to teach using innovative technologies [7-9].

Further research could focus on developing specific training courses and methods for integrating Python, Arduino, and STEM into educational programs for both teachers and students. Creating interdisciplinary STEM courses with the participation of teachers from computer science, physics, mathematics, and other related fields is crucial. Such courses can aid in the development of well-rounded specialists for the future.

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