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Original scientific paper

DIGITAL DEVELOPMENT BOARD FOR SHORT RANGE OBJECT DETECTION WITH STEGANOGRAPHIC DATA HIDING TECHNIQUES

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A b s t r a c t: This scientific paper discusses the application of single-board computers in performing various projects focusing on the practical development of a radar system for detecting objects at short distances using the digital development electronic board Arduino Mega 2560, that contribute to the development of electronic technology, microcomputers and microprocessors and their application for educational purposes. An overview of various literary sources related to the development of digital electronics, microprocessors, digital forensics as an important scientific discipline within the security of sharing various information and their application during the development of various educational projects has been used. Additionally, various methods and techniques used in steganography are illustrated, a study of the implementation of those techniques, and a demonstration of the implementation process of one of the steganography techniques using the QuickStego steganography tool. The development of the radar system for the detection of objects at short distances was carried out by programming the ultrasonic radar system using the tools Arduino IDE, Processing PDE, Matlab and Simulink, which offer support for the Arduino hardware.

Key words: microprocessors; Arduino Mega 2560; QuickStego; Arduino IDE; processing PDE

ДИГИТАЛНА РАЗВОЈНА ЕЛЕКТРОНСКА ПЛОЧА ЗА ДЕТЕКЦИЈА НА ОБЈЕКТИ НА КРАТКИ РАСТОЈАНИЈА СО СТЕГАНОГРАФСКИ ТЕХНИКИ ЗА КРИЕЊЕ НА ПОДАТОЦИ

А п с т р а к т: Во овој научен труд се разгледува примената на компјутерите со една плоча при изведување различни проекти, фокусирајќи се на практичната изработка на радарски систем за детекција на објекти на кратки растојанија со помош на дигиталната развојна електронска плоча Arduino Mega 2560, што придонесува за развојот на електронската технологија, микрокомпјутерите и микропроцесорите и нивната примена за образовни цели. Користени се и даден е преглед на различни литературни извори кои се однесуваат на развојот на дигиталната електроника, микропроцесори, дигитална форензика како важна научна дисциплина во рамките на безбедноста на споделувањето на различни информации и нивната примена во текот на изработка на различни образовни проекти. Дополнително се илустрирани различни методи и техники кои се користат во стеганографијата, проучување на имплементацијата на тие техники и прикажување на процесот на имплементација на една од техниките за стеганографија со користење на стеганографската алатка QuickStego. Изработката на радарскиот систем за детекција на објекти на кратки растојанија е извршена со програмирање на ултразвучниот радарски систем со помош на алатките Arduino IDE, Processing PDE, Matlab и Simulink, кои нудат поддршка за хардверот Arduino.

Клучни зборови: микропроцесори; Arduino Mega 2560; QuickStego; Arduino IDE; processing PDE

1. INTRODUCTION

The topic of this scientific paper has a wide application in the field of digital electronics and digital forensics as important scientific branches in the digital world. At the same time within the framework of programming and the use of algorithms which are key elements in the course of the development of the practical part within the scientific paper, i.e. the creation of a ultrasonic radar system for the detection of objects at short distances using the Arduino Mega 2560 digital development electronic board. The scientific paper shows the importance of the application of single-board computers in various educational processes and areas that are key factors for development and scientifically advancements in technology today. Digital forensics is also considered as a scientific discipline for collecting, storing, and analyzing information and data that are transmitted or stored in digital form and represent a certain importance for an organization or an individual that proves a certain veracity of the information and data itself. Through various literary sources are explained the importance of information security in order to carry out communication between the users themselves in a protected form. The scientific paper itself presents certain methods and techniques used in steganography to hide information and data in various digital formats using the QuickStego steganographic tool that allows all information and data to be transmitted safely without compromising their security, study of the same techniques and a practical presentation of the implementation process of the steganographic technique itself. Through the practical development of the Ultrasonic Radar System for the detection of objects at short distances (furthermore: URSAD), in this scientific paper is showed the way to successfully connect the Arduino Mega 2560 digital development electronic board (programmed with the Simulink simulation tool or with the Arduino IDE tool) with a personal computer using a program made with the Processing PDE software. It allows to finally display on the computer screen the presence of a certain object detected by the short-range object detection ultrasonic radar system. The integration of the Arduino Mega 2560 digital development electronic board with the digital electronic platform, i.e., the integrated development environment Arduino IDE and the processing development environment Processing PDE, which enables the programming of the Arduino Mega 2560 digital development electronic board and display on the computer screen, is also shown.

Further it's demonstrated the practical implementation of the steganographic technique for hiding information in an image with the received data from the serial port of the Arduino IDE tool for the distance and angle for the detected object from the short-range object detection ultrasonic radar system to enable that information securely to be sent over the communication channel [15].

2. SINGLE BOARD COMPUTERS

A single-board computer is a device or digital component that contains only the most necessary circuitry needed to operate as a machine. These boards, or single-board computers, are often shipped without cases and other accessories in order to keep the selling price low. A single-board computer is also called a digital development electronic board or a development board, because they can be programmed and connected to various digital electronic platforms that allow the construction of various systems or devices that develop the scientific branch itself as a scientific discipline in today's digital science. The most important component, the heart of a single-board computer, is the microprocessor. A microprocessor is a unit that has several General-Purpose Input/Output (GPIO) ports that can be used for different digital applications, platforms, and can be programmed to work in a certain way. There are many manufacturers of microprocessors available in the market and each manufacturer and brand has its own main purpose and purpose with which they differ in selling price, capabilities, features that offer users opportunities to use them for making and experimenting with various projects and scientific experiments from different disciplines and fields [6, 7, 8, 9, 15].

Today's single-board computers are supported by a large Internet community around the world, where hobbyists and professionals share projects, scientific experiments, scientific journals and papers, and help each other solve various problems encountered during their construction, projects or scientific experiments. The large community is also an important factor when it comes to educational purpose. Information and data are easy and most likely someone has already done a similar thing, which can be a source of inspiration. Very often the source codes are provided (open source), which makes it easy for anyone interested to start a project or a particular experiment.

Depending on the application, different board specifications are required. Some boards, or digital development boards, are designed as multimedia players and therefore need a microprocessor that can handle video and audio acceleration. Another popular single board computer is the Arduino digital development board. It was started as a school project with the main goal of developing a cheap solution that could be learning programming and electronics. This approach was quickly liked by amateurs and researchers who found large areas of use, which contributed to the development of the community around the platform. The Arduino digital development electronic board is designed to be programmed within their own integrated development environment (IDE – Integrated Development Environment) and uses the C^{++} programming language as a simple learning language for students in the educational process. It also has the ability to expand with compatible shields. A shield is a complete add-on circuit that can be placed directly on the Arduino board and can be programmed and used with various applications. Such an example is a shield for network communication between controllers (CAN BUS – Controller Area Network) which enables the Arduino protocol and the Servo Motor Shield which makes the Arduino capable of controlling servo motors. Arduino is one of the most prominent platforms on the market and an open access board, which means that anyone can buy the parts separately, download the schematic and build it at home. Since the digital development circuit board is open source, there are many different variants of the main board. The Arduino Nano-digital development board is the smallest board, which has very low power consumption and can be used for applications that do not require a lot of expandability. The Arduino Uno-digital development board is one popular development board in the Arduino family of digital development boards. There are several different types of integrated protocols, but there is no video output as a standard option. It is often used as a prototype for projects and products before the board is scaled down and adapted to the application [2, 3, 9, 15].

The Arduino Corporation initiated a collaboration with Intel and developed a new board, that is, a digital electronic development board called the Arduino Galileo. The Arduino Galileo digital development board has been launched as an Internet of Things (IoT) development board and has a more powerful processor than its predecessor and also has the ability to run a Linux operating system. It has the same physical form factor as the Arduino Uno-digital development board, which means it can be used with most existing shields and code with minor modifications [9, 12, 15, 16].

The Arduino digital development circuit board was a turning point for the concept of single-board computers as we know them today. It has been proven useful in many applications and has a lot of support from the Internet community. Thanks to the open source, various versions have been developed and extended to different application areas. There are several development boards available in the market with different specifications and vendors. This has also led microprocessor manufacturers to add more features to the processor itself [9, 10, 11, 15, 17].

3. ARDUINO MEGA 2560 DIGITAL DEVELOPMENT ELECTRONIC BOARD

Arduino Mega 2560 is shown in Figure 1 and it represents a platform based on the Atmel ATMega 2560 microcontroller. In addition to the microcontroller, it also contains a number of elements and components necessary for its proper operation. Programming and communication with the computer is done using a USB port. It is compatible with a number of other Arduino boards and with the Duemilanove and Diecimila platforms. The Arduino Mega 2560 digital development electronic board, unlike other Arduino boards, has more inputs to which sensors can be connected. The technical specifications of the Arduino Mega 2560 digital development electronic board are shown in Table 1 [4, 13, 15].

Fig. 1. Arduino Mega 2560 single board computer [2, 15, 18].

The operating voltage that can enable this microcontroller through a pin, as with most Arduino boards, is 5 V. The limit value of the input voltage has a range from 6 to 20 V, and the recommended voltage at which this microcontroller works is from 7 to 12 V. There, are 54 digital input/output pins, 14 of which support pulse-width modulation. It also has 16 analog inputs and a 16 MHz crystal oscillator. It can be powered by a USB port or an external source [3, 4, 13, 15].

4. DIGITAL ELECTRONIC COMPONENTS AND PARTS FOR THE PRACTICAL PART

In this section are shown all the digital electronic components and parts that were used for the practical part of URSAD for object detection in short range (see Table 2).

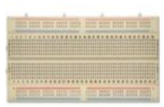
Table 1

Technical specifications of the digital single board computer Arduino Mega 2560 [14, 15, 18]

Microcontroller	*ATmega2560*
Operating voltage	5 V
Recommended input voltage	7 – 12 V
Input voltage limit values	6 – 20 V
Digital input/output pins	54 (15 of which provide PWM output)
Analog input pin	16
DC input/output pin	20 mA
DC for 3.3 V pin	50 mA
Polarity of external adapter	The middle part is positive
Number of digital outputs	14 (6 of which have PWM capability)
Number of analog outputs	6
Input/output amperage	40 mA
Flash memory	256 kB of which 8 kB used by the bootloader
SRAM	8 kB
EEPROM	4 kB
LED_BUILTIN	13
Operating frequency	16 MHz
Dimensions	101,52 x 53,3 mm
Mass	37 g

Table 2

Used digital electronic components and parts for the practical part [15]

Components	**Name of components**
	Arduino Mega 2560
	USB cable
	Breadboard
	Jumping Wires
	Light-emitting diode (LED)
	Servo Motor
	Ultrasonic Sensor HC-SR04

5. ALGORITHMS FOR FUNCTIONS IN THE INTEGRATED DEVELOPMENT ENVIRONMENT

The code in the Arduino IDE integrated development environment is done with a combination of the C and C^{++} programming languages. As already mentioned earlier in this paper, the code of the integrated development environment consists of two main functions void setup() and void loop() [1, 15, 18, 19, 20].

In the Figure 2 is depicted the algorithm for the functionality of the servo motor, which allows to rotate from 0 to 180 degrees and with that the ultrasonic sensor can detect the objects in the range of 40 cm by appearing the detected objects in the screen of the laptop. In the Figure 3 is shown the algorithm for the function calculateDistance that is used in the code, which precisely gives the mathematical equation of the way of measuring the distance of the object.

6. ALGORITHMS FOR FUNCTIONS IN THE PROCESSING DEVELOPMENT ENVIRONMENT

Figure 4 illustrates the algorithm written in Processing code within the Processing Development Environment. This code facilitates the creation of the URSAD display and enables the visualization of potential detected objects on the PC screen.

Furthermore, in the Figure 5 is shown the model development in Simulink, which practically allows to integrate the digital electronic board Arduino Mega 2560 with the Processing Development Environment (Processing PDE).

Since a lot of things happen in the background, the algorithm for the void setup() and void loop() functions will be presented. First we have the definition of variables and constants, then the value $i = 15$ is sent to the loop that checks if it is less than or equal to the value 165, if the answer is yes then that value is sent to the servo motor where there is a short stop process of 30 microseconds and those values along with the distance are sent to the computer program and finally the value of i will increase by one more value and thus this cycle will repeat where the servo motor turns from 15 to 165°, if the answer is no then the value of $i = 165$ where the condition is checked if it is greater than the number 15, if the answer is no then that value is sent to the servo motor where there is a short stop process of 30 microseconds and those values along with the distance is sent to the computer program and finally the value of *i* will decrease by one less value and thus this cycle will repeat where the servo motor turns from 165 to 15°, if the answer is no then we go back to the previous function from the algorithm. These two functions of the Arduino code are shown with an algorithm in Figure 2.

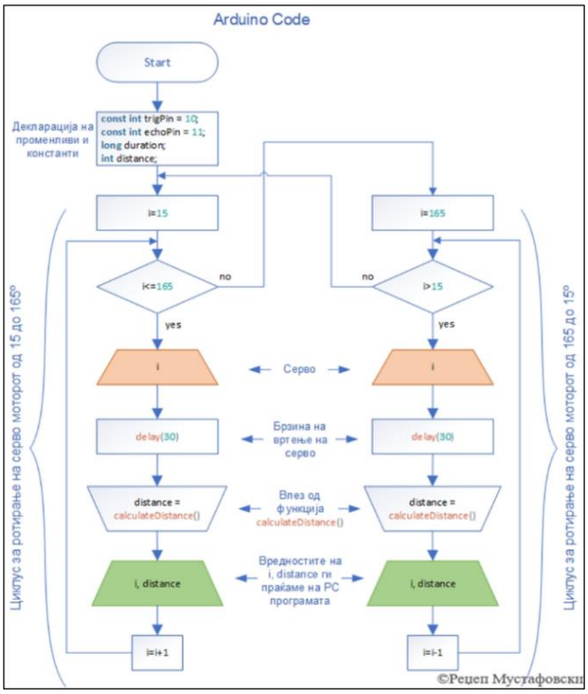


Fig. 2. Algorithm for void setup() and void loop() functions [15]

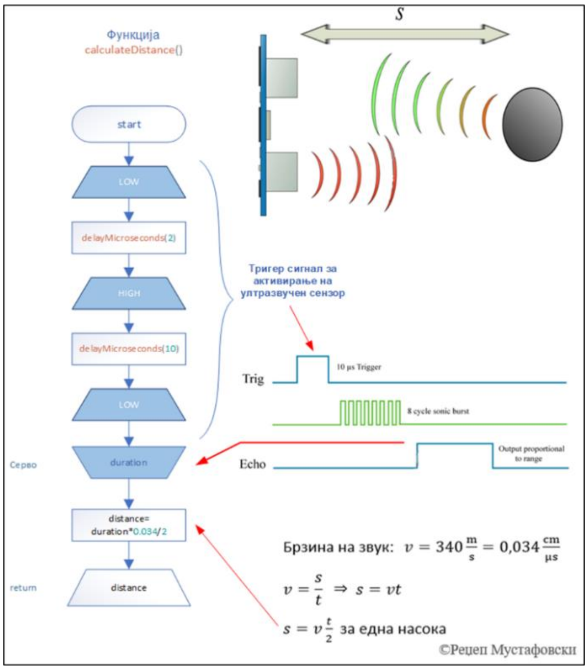


Fig. 3. Algorithm for the calculateDistance process [15]

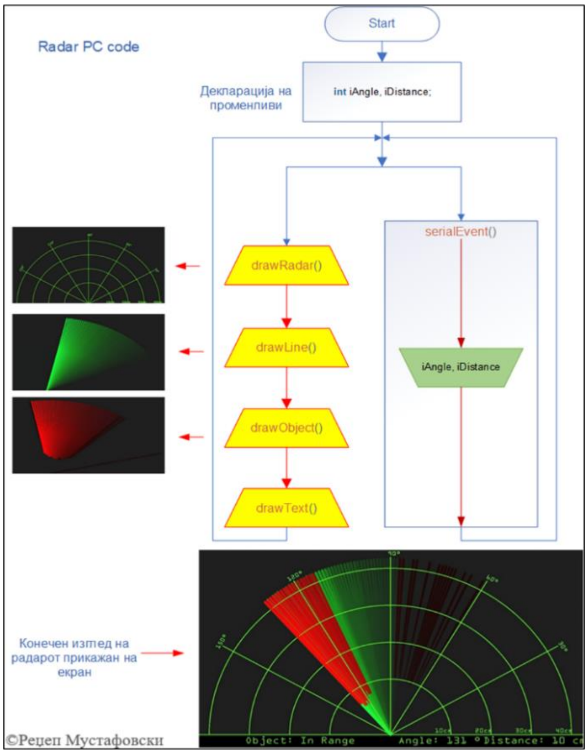


Fig. 4. Algorithm for Processing's code [15]

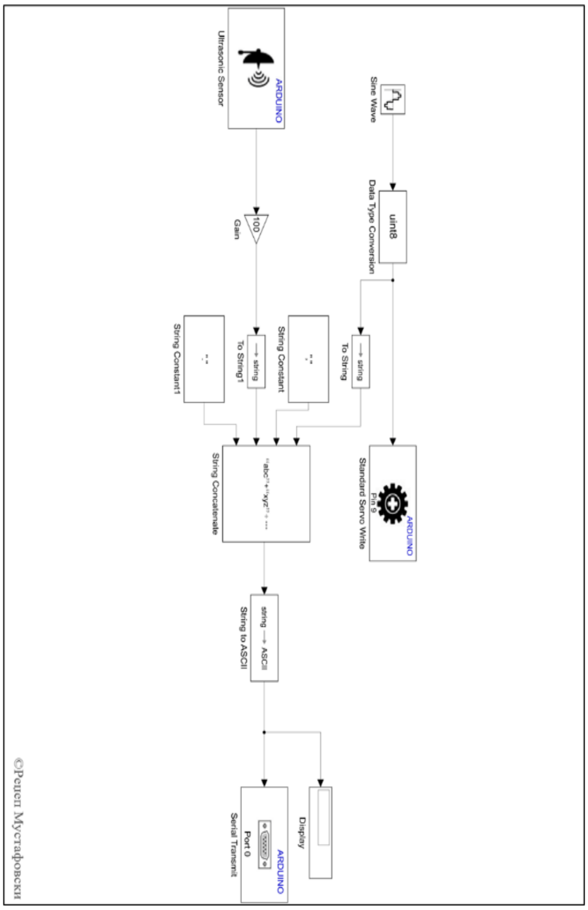


Fig. 5. Appearance of the model in the Simulink simulation tool [15]

As an additional process that is mentioned in the explanation of the void loop() and void setup() functions, and is very important, is the process for calculating the distance, i.e., calculateDistance(). This process is mainly performed by the ultrasonic sensor. A trigPin is given as an output value, if the emitted signal is not rejected it means that we have no target, and then a new signal is emitted again.

When the signal is rejected, then echoPin is at logic zero. The distance calculation process is shown by the equation distance = duration*0.034/2, where the distance for each object can be different. The complete distance calculation process is shown by the algorithm in image no. 3.

7. PRACTICAL APPEARANCE AND CONNECTION OF THE URSAD

From the information presented thus far, we've developed a conceptual understanding of the ultrasonic radar's potential appearance and functionality. This section will specifically show the appearance of the URSAD and its function through pictures.

Through the graphic display shown in Figure 6, a visual representation of what the URSAD looks like in reality is obtained. The difference in reality is that the ultrasonic sensor itself is attached to the servo motor.

The Figure 6 presents the connection of different colored wires, usually the black wire is used to connect the common end or the minus, the red wire is used to connect the positive pole of the power supply, while the rest of the wires can be chosen as desired. What is important when connecting the rest of the parts and the various wires is visibility during the connection. Transparency in connectivity allows for easier inspection of connected elements [15].

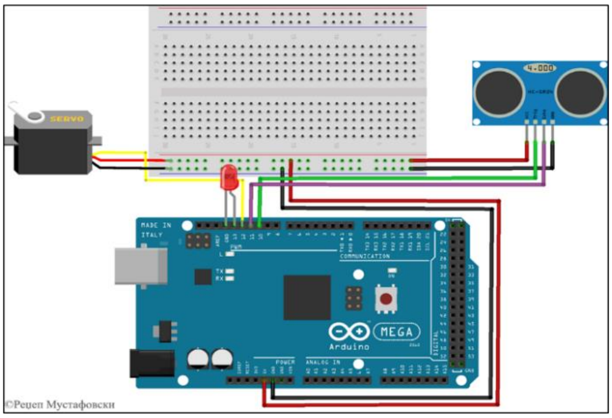


Fig. 6. Connecting the components of the URSAD [15]

The Processing program created in the processing development environment plots the URSAD surface based on the information and display of the detected target. The developed URSAD for the detection of objects at short distances as part of this paper in our laboratory is shown in Figure 7.

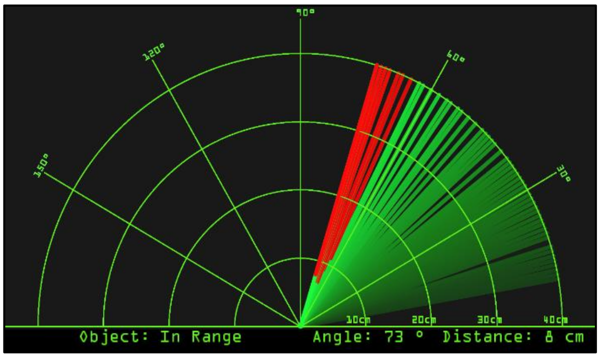


Fig. 7. The realistic appearance of the URSAD system for detecting objects at short distances [15]

8. PRACTICAL DEMONSTRATION OF HOW TO HIDE INFORMATION IN AN IMAGE USING THE QUICKSTEGO TOOL

In the following section with practical demonstration are explained the steps of how-to code and decode the information using the QuickStego tool.

a) *Coding or encryption of information*

In this part of the paper are explained the following steps of coding or encryption of information:

1) Open QuickStego tool to implement image steganography. Now click on the "Open image" button to open the image [5, 15].

2) To select the cover image, click any image that will act as our cover image to implement steganography to hide our secret data. In our case, the cover image marked as a test image will be selected, on which text will be hidden [5, 15].

3) After selecting the cover image, it is loaded into QuickStego [5, 15].

4) Now we can write our secret message on the cover image displayed on the tool on which the steganography will be performed.

This message is written in the black message box on the right side of the cover image. The data, i.e., the information that will be hidden in the image, then will be taken from the output of the serial port of the integrated development environment Arduino IDE for the angle and distance of the object detected by the URSAD system [5], [15]. Figure 8 displays the results regarding the detected angle and distance of the object as captured by the ultrasonic sensor.

5) Click the “Hide text” button to hide the text and save it on the image, otherwise it will not be saved. Then the text message is hidden in the image as shown in Figure 9 [5, 15].

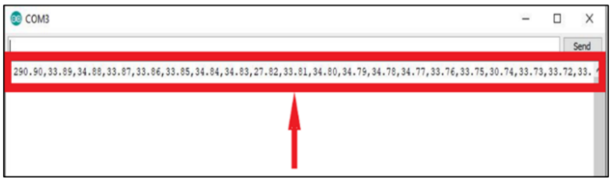


Fig. 8. Angle and distance data of the detected object from the URSAD system [15]

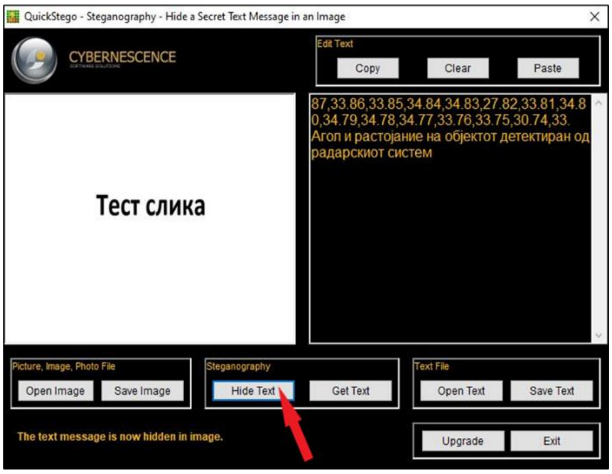


Fig. 9. Hiding the secret message in the cover image [15]

6) Clicking the "Save image" button to save the image allows QuickStego users to select the location where the image containing the hidden data will be saved [5, 15].

This is the file that when transferred will appear to be any normal image, but actually has some secret data hidden inside the image itself.

b) *Decoding or decryption of information*

1) Open the QuickStego tool and then click "Open image" to open an image [5, 15].

2) On the picture select the header or cover image that was received from the sender [5, 15].

3) The selected cover image is now opened in QuickStego tool which will display the hidden text message in black screen [5, 15].

4) In case the text is not displayed, it can be obtained by clicking the "Get text" button to display the hidden text from the title image [5, 15].

9. FUTURE WORK

In order to enhance the Arduino Mega 2560 radar system for short-distance object detection, we should consider these future steps [19, 15]:

1. Enhance Detection Accuracy: Refine radar sensitivity and signal processing for more accurate object detection.

2. Expand Object Recognition: Develop algorithms for recognizing specific objects detected by the radar.

3. Optimize Hardware Setup: Streamline connections and components for better efficiency and reduced size if applicable.

4. Implement Range Adjustment: Enable adjustable range settings for versatile detection capabilities.

5. Enable Remote Monitoring: Investigate ways to monitor detections remotely, possibly via wireless connectivity.

6. Develop User Interface: Design a user-friendly interface for intuitive system control and data visualization.

7. Test and Validate: Conduct thorough testing under various conditions to validate and refine the system's performance.

10. CONCLUSION

In this paper, we present several achievements with the application of digital development electronic boards or single board computers. Their application in many other different scientific fields and branches or combination with new codes or models allows controlling, operating and giving instructions to all digital development electronic boards and digital components to build different systems with specific functions and capabilities.

In the overall work of this scientific paper, the flexibility, characteristics and possibilities of digital development electronic boards, their open code and their application for various scientific fields, through which their unlimited connection and combination with other digital development electronic boards, components, software and computers are shown. These digital development electronic boards, i.e., single-board computers, have a price that is accessible to everyone, offer advanced features, while being simple and can be used by students in the educational process, for various other scientific projects and experiments in other scientific fields and disciplines. Digital electronic boards can be used in the educational process and the study process, which are an important factor for the development of education itself, and can also be used in the industry to carry out various processes with which they save certain human and time resources. Steganography, a subset of digital forensics, employs diverse methods to securely transmit crucial information, playing a pivotal role in technology's advancement for safe communication and data transfer.

The URSAD system detects nearby objects and connects with the Arduino Mega 2560 board through the Arduino IDE and Processing PDE. The configuration shows cases for object detection on a computer screen by utilizing data gathered from the Arduino Mega 2560 hardware, summarizing the accomplishment achieved with the short-range ultrasonic radar system for object detection. It was also shown how to connect the Arduino Mega 2560 digital development board with the Simulink simulation tool.

Practical implementation of the steganographic technique for hiding information in an image using the steganographic tool QuickStego with the data obtained from the serial port of the Arduino IDE tool for distance and angle for the detected object from the short-range object detection URSAD system was also shown in practice. Moreover, the framework presented here enables the information to be sent securely over the communication channel [15]. Also, the URSAD system demonstrates promising potential in short-range object detection, showcasing a practical fusion of hardware and software capabilities to enable precise and efficient identification of nearby objects, marking a significant stride in innovative technological advancements.

In the near future, radar systems for detecting nearby objects will see improvements through various strategic advancements focused on refining methods and system design. These efforts aim to achieve better precision, superior outcomes, and overall system advancement.

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