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Development of Digital Distance Measurement Instrument Based on Arduino Uno for Physics Practicum

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ABSTRACT
Measurement in physics is absolute because it affects the results of theoretical and experimental proofs. Retrieval of distance measurement data for physics experiments also requires high accuracy and a relatively long time because the accuracy in the measurements determines the valid results. Sometimes the available measurement instrument is difficult to access for novice researchers because of the high cost of these measurement instruments. These problems often result in errors and limitations in the implementation of measurements. The relatively long time also slows down data retrieval. This study aims to develop a digital distance measurement instrument based on Arduino Uno for physics practicum. This research is qualitative research using library research methods, field research, designing instruments, and testing hardware and software instruments. Instruments and materials used in this research include the ultrasonic sensor HC-SR04, Arduino Uno r3 kit, LCD, potentiometer, and Arduino IDE software. The result of this research is the digital distance measurement instrument based on Arduino Uno for physics practicum can be a solution for measuring objects with large distances and lengths. This measurement instrument has the smallest value of 1 cm. The design of the Arduino uno-based digital distance measuring device for physics practicum is a practical measurement instrument with the smallest measuring value of 1 cm which can assist students in measuring distances in physics practicum.

INTISARI
Pengukuran dalam fisika bersifat mutlak karena mempengaruhi hasil pembuktian teoritis dan eksperimental. Pengambilan data pengukuran jarak untuk eksperimen fisika juga membutuhkan ketelitian yang tinggi dan waktu yang relatif lama karena ketelitian dalam pengukuran menentukan hasil yang valid. Terkadang instrumen pengukuran yang tersedia sulit diakses oleh peneliti pemula karena mahalnya instrumen pengukuran tersebut. Permasalahan tersebut seringkali mengakibatkan kesalahan dan keterbatasan dalam pelaksanaan pengukuran. Waktu yang relatif lama juga memperlambat pengambilan data. Penelitian ini bertujuan untuk mengembangkan alat ukur jarak digital berbasis Arduino Uno untuk praktikum fisika. Penelitian ini merupakan penelitian kualitatif dengan menggunakan metode penelitian kepustakaan, penelitian lapangan, perancangan instrumen, dan pengujian perangkat keras dan perangkat lunak. Instrumen dan bahan yang digunakan dalam penelitian ini antara lain sensor ultrasonik HC-SR04, kit Arduino Uno r3, LCD, potensiometer, dan software Arduino IDE. Hasil dari penelitian ini adalah alat ukur jarak digital berbasis Arduino Uno untuk praktikum fisika dapat menjadi solusi untuk mengukur benda dengan jarak dan panjang yang besar. Alat ukur ini memiliki nilai terkecil yaitu 1 cm. Perancangan alat ukur jarak digital berbasis arduino uno untuk praktikum fisika merupakan alat ukur praktis dengan nilai ukur terkecil 1 cm yang dapat membantu mahasiswa dalam mengukur jarak pada praktikum fisika.

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A. Introduction

Physics is the study of natural phenomena and what happens in them. In physics, there are theoretical and experimental sciences which are the two main factors in supporting it [1-2]. The theory is a system of concepts that shows the relationship between other concepts to help understand the phenomenon. Meanwhile, experimental science is an activity to prove and apply physical theory in real-life reality [3]. Experimental activities are support in increasing understanding and proving the concept of physics material. Furthermore, experimental activities in physics are also often termed practicum activities to practice the truth of physical theories that have been proposed by physicists. Furthermore, the use of experimental or practicum activities can train students' 3 skills, namely cognitive, affective, and psychomotor skills [4-5].

In physics practicum activities, the activity of measuring physical quantities will involve the use of measurement instruments. This is by the statement submitted by Yudha and Sani [6] that measurement is a process to obtain information on the physical quantity of an object in the form of numbers because of comparison with a standard quantity. In carrying out measurements, measurement instruments need to be calibrated first so that the physical quantities measured produce valid data [7]. Furthermore, physics practicum activities are usually not only carried out once but are carried out repeatedly to a certain extent. This is done to avoid research subjectivity and obtain accurate and precise research data.

One type of measurement is measuring length using a ruler, tape measure, or other distance measurement instrument. The use of a distance measurement instrument is usually used to measure the distance, length, and height of objects. The use of rulers and meters in measurement will be effective if the distance, length, or height of the object is relatively small [8-10]. However, if the object being measured has a large length, then using a ruler and tape measure to measure the length of the object will be ineffective and will take a long time. This will certainly interfere with the implementation of physics practicum activities.

Apart from physics practicum which requires a variety of manual measurement instrument such as rulers or meters, there are also electronics-based physics measurement instruments. One of the physics measurement instrument based on electronics is the Arduino Uno. Arduino Uno can be set according to the wishes of users and researchers according to the purpose of measuring physical quantities [11-12]. Furthermore, the Arduino Uno can assist researchers in simplifying and shortening the duration of data collection in practical activities or physics experiments. Arduino Uno is a platform for physical computing that functions as a developer instrument and a measurement instrument for physics that requires a programming language [13-15]. In addition, Arduino Uno is also one of the small ATmega328 microcontroller-based board instrument complete with breadboard support [16]. The display of Arduino Uno can be presented as shown in Figure 1 [17].

Figure 1. Display of Arduino Uno

One example of the use of Arduino Uno in the field of physics research is that it is used in the manufacture of the digital distance measurement instrument. The use of digital distance measurement instrument in practicum can make the physics learning process run effectively and require a short time. In addition, the use of a digital distance measurement instrument can also measure distant objects and the length of objects that have large values. Therefore, the researcher conducted research that developed a digital distance measuring device based on Arduino Uno for physics practicum. It is hoped that by taking advantage of the development of electronics in physics research and learning, students will be helped in conducting practical measuring distances and lengths of objects.

B. Method

This research is qualitative research with library research methods, field research, designing measurement instruments, and testing measurement instruments in the form of hardware and software. The library research method is carried out by conducting a preliminary study which includes a study of various literature sources regarding the development of distance measurement instrument, physics practicum, and Arduino Uno. The stage of library research is to carry out the coding process by designing a distance measurement instrument based on Arduino Uno according to the results of a literature review. After obtaining various explanations regarding the development of the distance measurement instrument based on Arduino Uno, the next step is to conduct a review of the availability of object distance measurement instrument in the laboratory. After obtaining data regarding the distance measurement instrument which is dominated by a simple distance measurement instrument in the form of a ruler or meter, the next step is to develop a distance measurement instrument based on Arduino Uno.

The stages involved in developing the measurement instrument are making the design of the measurement instrument, determining the design of the measurement instrument, determining the components needed, and assembling all the components

according to the design that has been developed. Meanwhile, the components needed to support the manufacture of digital distance measurement instrument based on Arduino Uno include the ultrasonic sensor HC-SR04, Arduino Uno r3 kit, LCD (liquid crystal display), potentiometer, and Arduino ide software. After all these components are assembled, the next step is to make a programming language or often called the coding process. After the coding stage has been completed, it is continued with the testing stage of the development measurement instrument. The testing stage is carried out in several stages starting from pushing the on/off button and adjusting the position of the measurement instrument. After this step, the sensor will detect the distance followed by data processing on the Arduino. In the next stage, the LCD will display the results of measuring object distances and processing the measurement data manually. Furthermore, the workflow for developing a digital distance measurement instrument based on Arduino Uno can be presented in Figure 2.

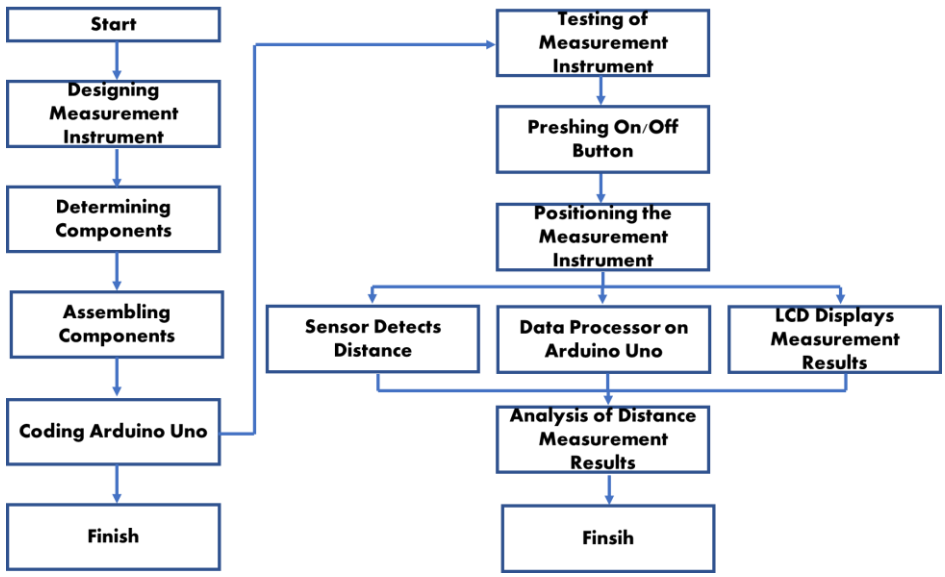

Figure 2. Workflow of the digital distance measurement instrument

C. Results and Discussion

Research on the development of a digital distance measurement instrument was carried out using the main components in the form of an ultrasonic sensor HC-SR04 and Arduino Uno. The development of this digital distance measurement instrument uses the HC-SR04 proximity sensor with the reason that the sensor functions in detecting distance using objects or obstacles that are used as reflecting fields when pulses are sending and receiving processes [18]. Furthermore, the display of the results of components series for measurement distances digitally can be presented in Figure 3.

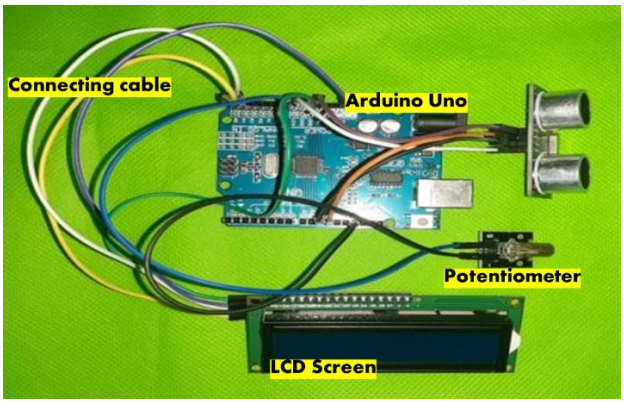

Figure 3. The results of components series for measurement distances digitally

Based on Figure 3, it can be shown that the main components used to digitally assemble the object distance measurement instrument include the ultrasonic sensor HC-SR04, Arduino Uno, LCD screen, connecting cable, and potentiometer. Furthermore, the digital object distance measurement instrument developed in this study has several advantages over the distance measurement instruments already available in the laboratory or the market. One of the advantages is that this digital distance measurement instrument based on Arduino Uno can measure the distance of distant objects and the length of objects that have large values. This digital distance measurement instrument can increase students' understanding of the process of developing a measurement instrument, strengthen science process skills, and introduce students to the coding process. Meanwhile, the display of the results of developing a digital object distance measurement instrument based on Arduino Uno can be presented in Figure 4.

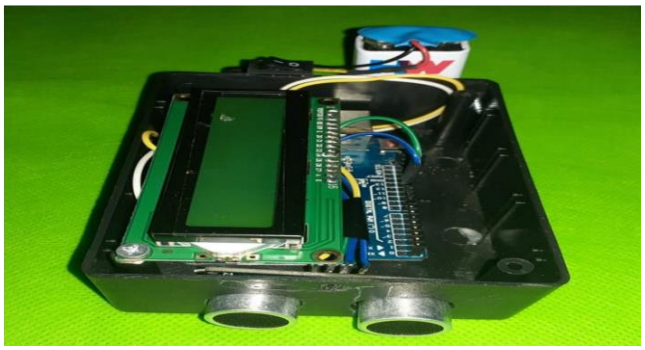
Figure 4. Display of digital distance measurement instrument based on Arduino Uno

The developed digital distance measurement instrument as shown in Figure 4 can be used as a variety of measurement instrument in student practicum activities in the laboratory. This distance measurement instrument can be used to measure distances quickly, accurately, and precisely than other distance measurement instrument. Meanwhile, after the digital object distance measurement instrument based on

Arduino Uno has been developed, the distance measurement instrument is ready to be used in measuring distance. The steps taken to measure the distance of objects using a measurement instrument resulting from this development are by directing the ultrasonic sensor part of the HC-SR04 towards the object to be measured. After that, the object distance will be detected by the ultrasonic sensor HC-SR04 and display the results through the LCD screen. The display of a digital object distance measurement instrument when used to measure object distance can be presented in Figure 5.

Figure 5. (a) display of object distance measurement and (b) display of comparison of distance measurement instrument digitally with a ruler

Based on Figure 5, it can be seen that the arrangement of the distance measurement instrument digitally with the object to be measured is displayed. The position of the object distance measurement instrument can be changed according to the will of the researcher to measure how far away the object is. Meanwhile, Figure 5. (b) shows the comparison of a digital object distance measurement instrument with a ruler that is used simultaneously to measure the distance of the same object. The two distance measurement instruments are used simultaneously to know the accuracy of the results of measuring object distances. Furthermore, the results of measuring object distances using a digital object distance measurement instrument with a ruler can be shown in Table 1.

Table 1. Results of distance measurements using digital distance measurement instruments and ruler

Distance Measurement	Object Distance	
	Digital Distance Measurement Instrument	Ruler
First	2 cm	3 cm
Second	8 cm	9 cm
Third	11 cm	12 cm
Fourth	14 cm	15 cm
Fifth	18 cm	19 cm

Based on Table 1, it can be observed that the digital object distance measurement instrument based on Arduino Uno has the smallest measuring value of 1 cm. It can be shown in Table 1 that according to the results of measuring the distance of objects using a digital distance measurement instrument and a ruler, the difference in results is 1 cm. The results of measuring the distance of objects using a distance measurement instrument digitally show the measurement results whose value is 1 cm smaller than

measuring the distance of objects using a ruler. Therefore, when the digital object distance measurement instrument is used by researchers or students in physics practicum activities, it is necessary to add a value of 1 cm from the distance measurement results listed on the LCD screen. This is done with the aim that the results of measuring object distances using a digital object distance measurement instrument are as accurate as of the results of measurements using a ruler. This means that the digital object distance measurement instrument based on Arduino Uno has limitations which include being less accurate in measuring object distances as far as 1 cm. This is also like the findings of Putranta et al. [19] who developed an object distance measurement instrument based on Snell's law of reflection of light with measurement results that have less accurate limitations of 0.75 cm than using a ruler.

This digital distance measurement instrument based on Arduino Uno can be used as a variety of measurement instrument in physics practicum activities. This is because this digital object distance measurement instrument is practical in its use. In addition, this Arduino Uno-based digital object distance measurement instrument is also capable of measuring the distance of objects that are quite far away that ordinary rulers cannot measure. However, the digital distance measurement instrument has limitations which include less precision in measuring distances with a difference of 1 cm in precision than using a ruler. That is, when measuring the distance of objects using the digital measurement instrument, the value listed on the screen cannot be directly used as the object distance value and this value must be added to the value of 1 cm. Furthermore, this digital distance measurement instrument can be used to support object distance measurements in the fields of physics education, civil engineering, and land affairs. Through the use of this digitally developed object distance measurement instrument, it can facilitate and provide variations on measurement instruments in physics practicum activities. This digital distance measurement instrument can be used to measure the length and width of buildings and land.

D. Conclusion

This research was conducted to design or develop a digital object distance measurement instrument based on Arduino Uno that can be used in physics practicum activities. This digital distance measurement instrument was developed by combining hardware including a series of electronic components and software including Arduino IDE. This Arduino IDE-based software is used to run programs that have been coded according to the plan to measure object distances. All devices in the development of this digital object distance measurement instrument are combined into a single unit in the form of a box with an LCD screen on the front. This digital distance measurement instrument can be used to measure distance, height, and other units of length. Based on the results of testing and measuring object distances, the results of measuring object distances using a digital distance measurement instrument whose value is almost close

to the results of distance measurements using a ruler with a difference of 1 cm. This study has several advantages which include measuring the distance of digital objects that are practically used in physics practicum activities because the measurement instrument is in the form of a box and makes the measurement time more efficient. Researchers or students only need to point the sensor at the object to be measured and then can see the data generated through the LCD layer. Meanwhile, the limitations of this study include the selection of the type of ultrasonic sensor that is not suitable for use in measuring object distances, the unavailability of a water pass as a differentiating instrument for measuring physics with other measuring devices. Future research can be carried out by replacing the ultrasonic sensor type HC-SR04 with type Y401 and equipping the instrument box with a water pass so that the measured distance results have a small difference from the distance measurement results using a ruler.

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