Real-time data acquisition of dynamic moving objects

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Abstract. The problem frequently encountered in physics practicum activities is measuring instruments in limited reading data variable time of dynamic moving objects. In practical exercises needed the accuracy of measurement data to avoid a mistake in analysis and interpretation data. R-TDA of Dynamic Moving Objects measurement tool is expected to be a solution to overcome these problems. The electronic components used are Infra-Red Obstacle Sensor, connector cable, NodeMCU. The principle of this device is to send a recording time of modulo infrared to the cloud server and accessed via a smartphone and Personal Computer. The results show the sensor a responsive time of 6.8 x 10⁻¹¹ seconds, and the effect of gravity acceleration of 9.70 m/s² close to universal gravity acceleration 9.81 m/s² with an average relative error of 1.22%. The R-TDA of Dynamic Moving Objects has a high response time and accuracy in recording the time of dynamic moving objects.

1. Introduction

The laboratory is a room or place that equip with facilities, tools, and materials for conducting an investigation. The role and function of the laboratory are significant to describe theoretical content that is verification to prove the theories, concepts, and laws of physics studied [1]. The laboratory can also be used by students to conduct investigative activities in solving physical problems that learned through practical exercises.

The problem frequently encountered in physics practicum activities is measuring instruments in limited reading data variable time of dynamic objects so that the measurement results obtained become inaccurate [2]. In essence, scientific inquiry activities, valid and tested data, are needed so that the practitioner avoids the misunderstanding of interpreting the measurement data. For example, the topic about speed and acceleration, pendulum vibrations, petals vibrations, and inclined plane recording time variables to positions are still done manually using a stopwatch. Time measurement using a stopwatch for an object which is relatively moving cannot do manually. As a result, time recording done three times, the average value is taken. So, it is needed to support the laboratory equipment or tools by ICT. Thus, the problem can be resolved.

Utilization of Microcomputer Base Laboratory can solve challenging problems in laboratory experiments [3]. Arduino, as a microcontroller device, can be developed as innovative physics experiment tools, easily obtained, and very affordable in terms of price[4, 5]. The microcontroller is a chip or IC (integrated circuit) that can be programmed using a computer. The aim is to embed the
program in the microcontroller so that the electronic circuit can read the input, input process, and produce the desired output. The use of Arduino as a physics measurement tool has been widely developed on physical physics topics such as pendulum oscillation [6, 7], free-fall motion [8]. However, the measuring instrument developed still found several limitations, such as access to data readings limited on the LCD screen or computer via a USB connection, and cannot display the movement of objects in the form of graphs of position (x) against time (t) in real-time.

Information technology advanced in industrial revolution 4.0 utilizes the internet as a global network in access data and information limitless by time and space. Arduino, as a processor, sends the data to a user via the internet. The device (WiFi Shield) needed as a transmitter. Thus, the internet can be used as a medium to send data from sensors to distant places using the principle of the Internet of Things (IoT). IoT or Internet of People (IoP) is an interconnection system between devices, sensors, and people to connect and communicate with each other through a web server [9]. Thus, a smartphone or PC can use as a measurement tool for reading the results of recording sensor data output. The use of smartphones in the implementation of physics practicum can increase motivation and preferred by students [7].

The purpose of this writing is to test the effectiveness of measuring tools in Real-Time Data Acquisition (R-TDA) of Dynamic Moving Objects by terms of accuracy and responsiveness of sensors in reading the measurement data. Besides that, we also discussed how the system works and how to test the system.

2. Methods
2.1. electronic components

The electronic components used for this prototype design are as follows: Infra-Red Obstacle Sensor, Cable Connector; Node MCU V3-Lolin, and Adaptor 9 Volt. The sensor circuit design is designed using fritzing software and present in figure 1 below.

![Figure 1. Schematic image and prototype R-TDA of dynamic moving objects measurement tool](image-url)

Figure 1 shows that the tool used a microcontroller, the Nodemcu v3.0 Lolin module. This Nodemcu is a microcontroller that widely used for the Internet of Things (IoT) project, where Nodemcu has built ESP8266, which can function as a client or as a server. The R-TDA of Dynamic Moving Objects system uses 7 infrared sensor modules, the IR Obstacle Sensor module, which works at a voltage of 3.3 volts, to connect the sensor module with the Nodemcu module, a USB 2.0 port used. The programming language used for this system is the C program language that is built-in Arduino software.
2.2. work system flowchart

Figure 2 shows the reading system of the Infrared Obstacle Sensor (IR obstacle sensor) using the transmitter and receiver principle. Sensors at the first path serve as a trigger of initial time, while sensors at the last road serve as time stop.

![Figure 2. Flowchart system R-TDA of dynamic moving objects](image)

Figure 3. Sensor reading system

Figure 3 shows that the R-TDA of Dynamic Moving Objects system had a Client to Server method. Nodemcu serves as a client that sends time recording data generated by the infrared module to the cloud server and can be accessed by smartphones (Android and MacOS), Personal Computer (PC) as an output device. The workflow of the R-TDA of Dynamic Moving Objects system, where the response of each sensor passed in the form of a counter time made by each sensor, which sent to Nodemcu. Nodemcu sends to the database server and then presented on the website and can access by portable devices (mobile) and desks for both Android, Mac, and Windows systems. In terms of giving the output data, it is needed to program the website based on Hypertext Preprocessor (PHP).

2.3. data collection techniques

To find out the R-TDA of Dynamic Moving Objects system is running as expected, testing did through data collection by placing 7 sensor modules along the rail with a range of 15 cm for each sensor. Next, conduct a controlled experiment by varying the height of the incline starting from 5 cm, 10 cm, 15, 20, and 25 cm. Each treatment is done repeatedly three times. Then calculate the velocity, acceleration, and acceleration of Earth’s gravity based on the time recording data that passes through the sensor, as well as calculating the relative error of Earth’s gravitational acceleration.

2.4. data processing technique

Figure 4 shows the distance between the IR transmitter and IR receiver separated at a distance of 0.5 cm, while the distance of the sensor to the object as far as 1 cm. For analogous, it formed a triangle pattern. Where the contact response between the object and the sensor can be solved by using equation 2 below:

\[ r = \sqrt{(0.55)^2 + h^2} \]  

(1)

Figure 4. Flowchart system R-TDA of dynamic moving objects output
The value of \( r \) is the hypotenuse of the reading from object to sensor, \( S \) is the distance between the two IR obstacle sensors, while \( h \) is the perpendicular distance from the object to the sensors [10]. The value of \( r \) is then entered into equation below:

\[
\vec{v} = \frac{\vec{r}}{t} \tag{2}
\]

\( \vec{v} \) is the responsive speed of the sensor that will be calculated in this study. The Relative Error (\( R_E \)) of the result of gravity measurement is made by comparing the value of the acceleration of the measured gravity (\( \vec{g}_{\text{Measure}} \)) with the value of the acceleration of universal gravity (\( \vec{g}_{\text{Theory}} \)) using the equation below.

\[
R_E = \left( \frac{\vec{g}_{\text{Measure}} - \vec{g}_{\text{Theory}}}{\vec{g}_{\text{Theory}}} \right) \times 100\% \tag{3}
\]

3. Results and Discussion

3.1. Research Result

Testing of sensor responsive level is done using equation (5) obtained \( r - \text{value} \) of 1.0307 cm, the value of \( r \) is entered in equation (6) where \( \vec{v} \) is the speed of light \( 3 \times 10^8 \text{m/s} \). In order to obtain the required time for reading in each sensor is \( 6.8 \times 10^{-11} \text{ seconds} \). Thus, it can be assumed that the sensor has a rapid response.

Next, done measurements of the time moving an object on an inclined plane. Measurements are done by three times for different angles to observe the consistency and accuracy of sensors in reading the measurement data. Time recording on each sensor (figure 9) for varying heights illustrated in a graph of displacement relationship (\( s \)) against time (\( t \)) using Origin9 Pro, as in Figure 8. The trend graph shows the object’s movement accelerated on a straight line, evidenced by the curve of the chart, which is pointing increasingly toward the positive y-axis. Moreover, time travel of object the less when the angle of inclination enlarged. it can be concluded that the device R-TDA of Dynamic Moving Objects had an accuracy sensor and excellent response and high accuracy in reading the data in reading the Inclined Plane dynamic object. The response and sensor efficiency very seen both from the trend of chart that tends to stable for how it starts to move.

![Figure 5. The graph of the displacement relationship and time and the display of the time sensor on the PC](image-url)
The graph of movement and time relationships above then calculated the polynomial coefficient—second-order ($b_2$) using the Origin9 Pro software. The results of the calculation of the acceleration value can plot in a graph of acceleration relationship with tilt angle ($\sin \theta$), and the figure of acceleration relationship with the time for different tilt angles.

![Figure 6. Relationship of displacement (m) to time (s)](image)

![Figure 7. Relationship of acceleration with Sin $\theta$](image)

Graph Effect of Tilt Angle Variation Against the Acceleration of Objects on Inclined Plane Based on the Graph (6), the greater the angle of inclination of the more the acceleration. The R-Square reach 0.999 or 99.9%, there is a powerful influence of the inclination angle ($\theta$) against the acceleration ($\vec{a}$). Furthermore, in Graph (7) it can be seen that the greater the acceleration the shorter the required time for the object to reach the base of the inclined plane. It can be concluded that the R-TDA of Dynamic Moving Objects measuring instrument has a high degree of accuracy in reading the time variable data of objects moving in an inclined plane.

While the results of the calculation of the object's velocity on an inclined plane for angular variations are shown in the graph below:

![Figure 8. Velocity chart (v) against time (T) at varied angles](image)

The trend of velocity graph against time in figure 8 tends to be linear and increasingly steep or closer to the y-axis when the tilt angle is enlarged. It can be concluded, the velocity of the object moved in the inclined pane is more significant if the slope of angle is enlarged.

Furthermore, the results of the calculation of the acceleration due to gravity are as shown in the Table 1 below.

| Sin ($\theta$) | Acceleration ($m/s^2$) | Acceleration of Gravity Measurement ($m/s^2$) | Acceleration of Gravity Theory ($m/s^2$) | Relative Error (%) |
|---------------|------------------------|---------------------------------------------|----------------------------------------|-------------------|
| 0.05          | 0.53                   | 9.53                                        | 9.81                                   | 2.85              |
| 0.11          | 1.07                   | 9.64                                        | 9.81                                   | 1.73              |
| 0.16          | 1.64                   | 9.82                                        | 9.81                                   | 0.10              |
| 0.22          | 2.15                   | 9.68                                        | 9.81                                   | 1.33              |
| 0.27          | 2.73                   | 9.83                                        | 9.81                                   | 0.20              |
| Average       | **1.26**               | **9.70**                                    | **9.81**                               | **1.22**          |
The average value of gravitational acceleration obtained from the experiment was 9.70 m/s² different from the universal gravitational acceleration constant of 9.81 m/s² with a measurement relative error index of 1.22%. Acceleration of gravitational acceleration is very good at 15 cm slope height of 9.82 m/s² and at 25 cm height of 9.83 m/s² with relative error measurement levels of 0.10% and 0.20% while at slope height of 5 cm, 10 cm, and The acceleration due to gravity is 9.53 m/s², 9.64 m/s² and 9.68 m/s² with a relative measurement error index of 2.85%, 1.73%, and 1.33%.

3.2. discussion
In general, the R-TDA of Dynamic Moving Objects measuring device consists of 3 main parts, and they are the launcher rail, the sensor set rod, and the Nodemcu microcontroller as a timer. The second part consists of a server equipped with a database and domain to display the measurement results in the time table that is recorded by each sensor, and graph of distance respect to time for irregular linear motion. The third part is the user of the instrumentation system; in this case, the user is the practitioner.

The working principle of this system seen from the workings of the sensor and the number of sensors installed on the sensor set bar. The sensor used is an Infrared Obstacle Sensor (IR obstacle sensor), which works using the principle of transmitter and receiver. On the sensor, rod is placed 7 sensors that have a distance between the sensors as far as 15 cm. Two of them put at the first path server as a trigger of start timer, and the second path serves as a stop time for the whole sensors. The reading speed of the sensor is affected by the distance of the object to the sensor. The average length of the object to the sensor is ± 1 cm. Another factor that influences the reading speed of the sensor is the speed of infrared light emitted (transmitter) and the receiver on the sensor.

The response reading of sensors is 6.8 x 10⁻¹¹ s. So it can be assumed that the sensor is too responsive. The existence of an object in front of the sensor has “push,” meaning it gives a “true” signal from a “false” state. In the “true” state, the sensor has a value of 1, which means the sensor starts to record the time. Whereas in the “false” state, the sensor gives a value of 0, which means the sensor stop in counter time. The time recorded on Nodemcu, which is the main controller in the instrumentation system of this measuring instrument. After the object passes all sensors, the data recorded on Nodemcu it sends to the database located on the server. The average time needed to send measurement results is 3 to 5 seconds, but the database response time ranges from 10-15 seconds. The delay in Nodemcu's response to the server is influenced by several factors, which is the broadband network response that Nodemcu uses in sending data and replay responses from the server. The delay when the input data process in the server database sent by Nodemcu does not affect the reading results of each sensor. This is because the recording of each sensor was previously recorded on Nodemcu and sent collectively to the database.

Trend graph changes in position (s), velocity (v), and acceleration (a) concerning time (t), according to the Newton's Law II concept, when objects move on an inclined plane with constant acceleration. The acceleration and velocity of the object in the inclined plane are affected by the tilt angle, the higher the height of the inclined plane, the greater the acceleration produced.

The value of gravity acceleration obtained in the experiment is 9.70 m/s² close to the universal gravitational constant, which is 9.81 m/s². The relative defeat of the measurement of the gravitational acceleration of 0.0122 or 1.22% shows the R-TDA of Dynamic Moving Objects measuring instrument has a high degree of accuracy. The difference of acceleration value due to the short distance of the track used (90 cm), so that the time recorded on the sensor becomes very short and seems less significant, as well as the friction of tire dynamics with relatively small rails is ignored in the experiment.

4. Conclusion
In general, the R-TDA of Dynamic Moving Objects measuring instrument used in motion experiments on the inclined plane has a high degree of accuracy, as evidenced by the average relative error of the results of measurements of Earth's gravitational acceleration of 1.22%. The sensor response time is also high, ranging from 3-5 seconds to send time recording data to the database server via a wireless network connection. This measuring instrument is very practical, effective, and efficient to be applied in physics practicum activities.
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