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[Research Article]

DEVELOPMENT OF ONE-DIMENSIONAL MOTION EXPERIMENT TOOLS AND DATA PROCESSING USING RASPBERRY PI AND PYTHON

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ABSTRACT

In this study, we try to propose a simple electronic computational experiment of one-dimensional motion, which combines physics and computer science. Our experimental setup is based on the Raspberry Pi3 model B with the Raspbian operating system. The ultrasonic proximity sensor is the HC-SR04, which can be powered using the +5V DC output of the Raspberry Pi. An ultrasonic proximity sensor is used to obtain the position of a selected target along a linear path with a Raspberry Pi and simple Python code. Another simple script is proposed to calculate velocity and acceleration and for a graphical presentation of the results. Our results show that motion can be qualitatively and quantitatively defined, and the experiment is suitable for undergraduate or younger students. Several methods are also available for calibrating various setups, depending on the level of accuracy required.

Keywords: Raspberry Pi, Python, Experiment, One-dimensional motion.

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1. INTRODUCTION

The fourth industrial revolution, or ir4.0, is a development of the 21st century that affects both industry and education (Ismail et al., 2020). As a result, the educational process in this period requires the development of contemporary abilities (Samiha et al., 2022). The purpose of implementing the fourth industrial revolution in education is to produce the next generation of a superior country capable of competing worldwide (Prayogi, Asih, et al., 2022).

According to the 2013 curriculum, knowledge is no longer the primary objective (Ozcan & Uzunboylu, 2015). The significance of connecting new experiences (Ana et al., 2022), occurrences (Ragustini et al., 2022), and facts with previously understood ideas are emphasized in meaningful learning (Mariska et al., 2022). In order to learn physics, science process skills need to be developed (Hamdani et al., 2022). Students are encouraged to learn actively growing abilities because practice/practicum makes it easier to master complex and complicated concepts (Zainuddin et al., 2022).

The Raspberry Pi is a single-board, low-power computer system that uses an ARM processor architecture to run Linux (or several other operating systems) (Bolton, 2009). An 8 GB SD card is more than enough to hold the operating system and a large amount of data because the system boots from an SD card (Serhane et al., 2019). The system can run on a basic 5V phone charger with a micro USB connection because the power requirements are so low (Pathade & Yeole, 2014). Many general-purpose I/O pins (GPIO) are accessible for integration with external devices, and the software is relatively stable (Prayogi et al., 2022). The low-cost Raspberry Pi has several desktop computer functionalities and an input/output port that may be used to connect various types of sensors.

We use an ultrasonic distance sensor managed using the Python package gpiozero. The value of the distance between the sensor and the target and the matching value of time since a chosen start are provided in a few lines of code (Ewert et al., 2006). Thus, it is feasible to graph and evaluate the values of an object's coordinate x as a function of time, after which the velocity and acceleration may be determined. Several features of this experimental activity might spark discussions.

2. METHOD

This study uses the Design-Based Research (DBR) method, which refers to the ADDIE model. Through the DBR method, it is hoped that it will be able to create the latest innovations in the form of learning media products that can be used in the teaching and learning process in high schools and at the university level (Dziuban et al., 2018). The steps used in the DBR research method are; 1) Analysis, 2) Design, 3) Development, 4) Implementation and Evaluation (Nichols Hess et al., 2016). In this study, only three stages were used: analysis, design, and development. The type of data used in this study is descriptive data used to describe the validity level of the learning media that the researcher has created (Herlina et al., 2022). The type of research used is qualitative-quantitative, with the help of instruments to obtain all the necessary data.

The research procedure is divided into three stages, namely the analysis stage, the design stage, and the development stage (Qureshi et al., 2020). The analysis phase includes the preparation stage. Some of the activities carried out are analyzing the needs of learning media innovation, reviewing essential competencies in physics mechanics courses, analyzing tools and materials to be used in making learning media, analyzing journals, determining learning media to be developed, and analyzing the needs of learning media used in making one-dimensional motion experiment tool (Handhika et al., 2018).

The design stage is the implementation stage which consists of several activities, including making flowcharts, making the initial design of a one-dimensional motion experiment tool, making a storyboard, and making the components needed in a one-dimensional

motion experiment tool and ending with consultation with related experts. The next stage is the development stage. The development stage consisted of the initial product made by the researcher in the form of a one-dimensional motion experimental device, and a validation test was carried out. Three experts from Pertamina University, Medan State University and Syiah Kuala University have validated this one-dimensional motion experiment tool. The validation results obtained suggestions for improvement and validity of the one-dimensional motion experimental device. At this stage, research reports, data processing, and data analysis were prepared (Prima et al., 2018).

The data collection technique in this study was carried out by distributing validation questionnaires to three expert validators. The instruments used in the validation test include flowcharts, storyboards, explanatory videos of one-dimensional motion experiment tools and validation test questionnaires (Bujang et al., 2022). The validation test questionnaire sheet contains several indicators, including 1). The physical appearance of the one-dimensional motion experiment tool, 2). Tool efficiency, 3). The functioning of the tool, 4). Level of practicum design implementation, 5). Security aspect, 6). Conformity with learning, 7). Economic aspects, 8). Environmental aspects.

Data analysis techniques are adapted to the type of instrument used and the type of data obtained. The data obtained are in the form of qualitative data and quantitative data. Then statistical data processing was carried out for quantitative and descriptive data processing for qualitative data (Sugiyono, 2010). After obtaining the data from the validation test results, a comparison analysis of the validation value with the specified $_{critical}$ is carried out. The $_{critical}$ is generally used to identify the validity limit of an instrument set at 0.30 based on a 5% error rate (Miller et al., 2010).

3. RESULT AND DISCUSSION

Our experimental setup is based on the Raspberry Pi3 model B with the Raspbian operating system. The ultrasonic proximity sensor is the HC-SR04, which can be powered using the +5V DC output of the Raspberry Pi shown in Figure 1. An ultrasonic proximity sensor is used to obtain the position of a selected target along a linear path with a Raspberry Pi and simple Python code.

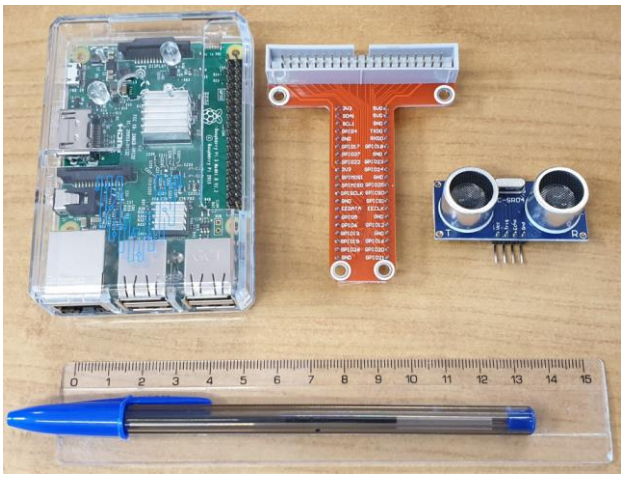

Figure 1. Raspberry Pi 3 model B, expansion board, ultrasonic sensor HC-SR04.

The Raspberry Pi serves as the foundation for detecting distance using the ultrasonic sensor HC-SR04. A micro-SD memory card with a capacity of 16 GB and a maximum reading speed of 95 MB/s is used to store both the operating system and the data. The appropriate GPIO interface pins could accept a direct connection from the ultrasonic sensor (Prayogi et al., 2021). An extension board connected to the GPIO via a 40-pin extension cable may be used for simpler operations. According to the Raspberry literature, the sensor's wiring uses two resistors (330 and 470) as a voltage divider, shown in Figure 2. The sensor has a resolution of 0.003 m and can measure distances between 0.02 m to -4 m. Screens for data collecting and analysis are run using the Thonny Integrated Development Environment or the command line.

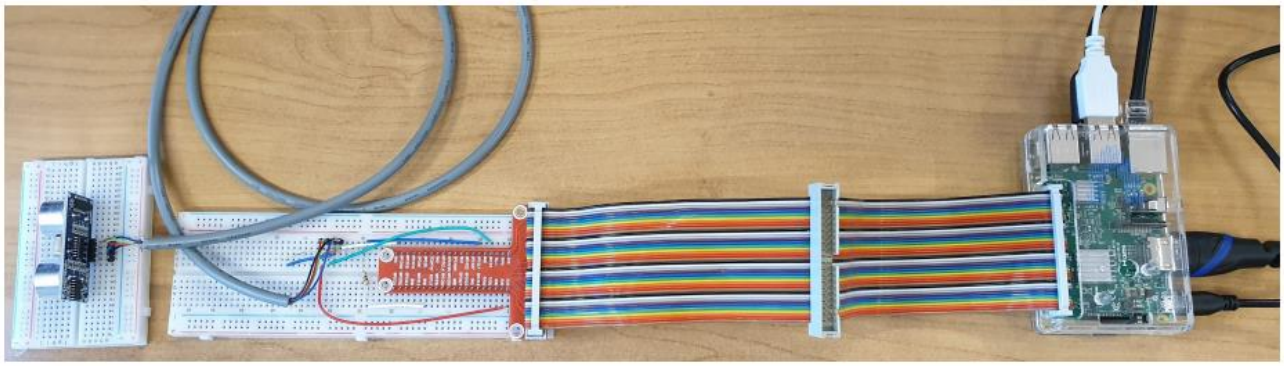

Figure 2. A possible realization of the setup using a solderless breadboard. A four-wire cable is used to place the sensor in the desired position, even far from the Raspberry Pi.

As an illustration, we suggest looking at the motion of a toy car on a 2 m track sloped at a specific degree as it was measured using a smartphone and the Phyphox app. First, the ultrasonic sensor's functionality and the measured distance's accuracy were verified using the ultrasonic shots.py script. The distance as a function of time was then measured by running the distance recorder.py program. There was a 200ms sleep period between each consecutive distance measurement (Ikbal & Hasanah, 2022). The toy car stopped at the bottom of the incline due to the soft packaging material. Figure 3 shows the measurements made for an inclination of 11 degrees.

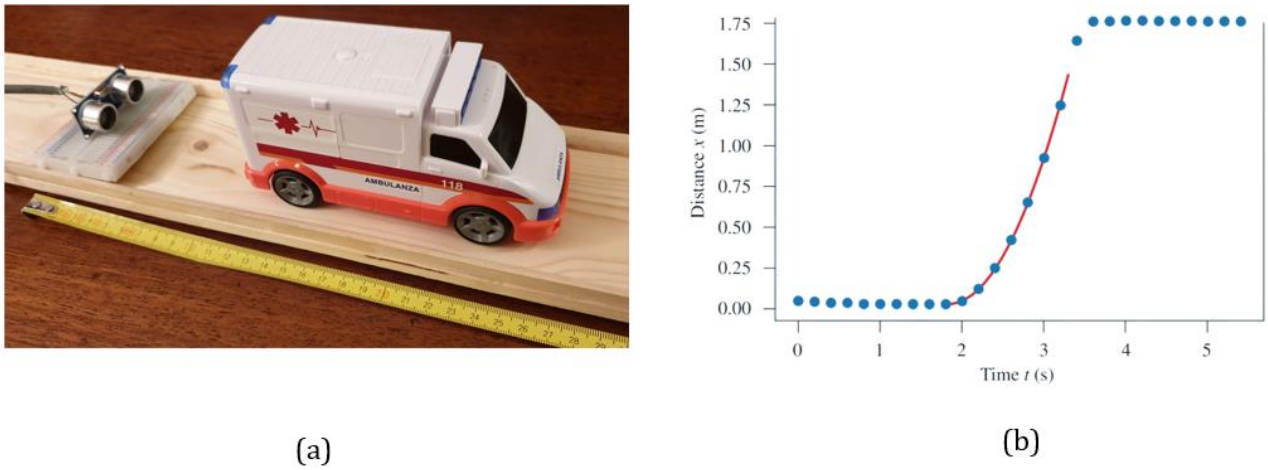

Figure 3. (a). This procedure helps to choose a suitable target for studying the motion along the track. (b) Distance of a toy car from the ultrasonic sensor along an inclined track versus time

An automated script using the Numpy library determines the average speed for each period (Gupta & Agarwal, 2017). Using the Matplotlib tool, the outcomes were plotted as shown in Figure 4. For intervals between 1.9*s* and 3.3*s*, a subset of the velocity data was subjected to linear regression, with the assumption that for a constant acceleration, *a,* as seen in equation 1.

$$v = a\left(t - t_0\right) \qquad (1)$$

The research was carried out utilizing the linear fit.py software, based on, provided a = 1.3 m s^{-2}. For comparison, a body rolling down a frictionless incline should have a constant value of $a = g \sin\theta$. For $\theta = 11^{o}$ this would give a = 1.9 m s^{-2}, in reasonable agreement with the experimental findings, accounting for the influence of the friction forces on the motion of the sample.

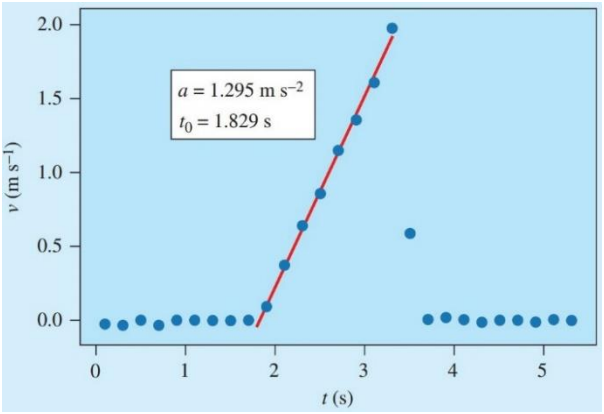

Figure 4. The toy car's velocity over time.

On the other hand, using the velocity numbers in Figure 4 as a reference, the average acceleration for each accessible time frame was assessed. With the assumption of constant acceleration in the 2-3 s time range, the computed values, as shown in Figure 3, are comparable. In addition, the linear fit's acceleration value can be utilized to simulate how x behaves over time, as shown in Figure 2.

$$x = x_0 + \frac{1}{2}a\left(t - t_0\right)^2 \qquad (2)$$

For example, this arrangement could be used as a laboratory exercise for undergraduate computer science students or for a high school student's introduction to velocity and acceleration.

The results of the one-dimensional motion experimental tool validation test, the validator assesses the one-dimensional motion experimental tool based on the aspects contained in the validation questionnaire, including aspects of appearance, security, tool efficiency, environment, practicality of practicum design, suitability with learning, and functioning/non-functioning of the tool. The average $r_{calculated}$ for validating this one-dimensional motion experiment is 0.82, more significant than the critical 0.3. This shows that the one-dimensional motion experiment tool that has been made is declared valid (Sugiyono, 2010). The highest $r_{calculated}$ is 1, so it is declared valid, which is obtained from the indicator of the application of Lambert-Beer's law theory and environmental indicators, namely the use of tools that can reduce the number of chemicals used. At the same time, the lowest $r_{calculated}$ is equal to 0.75, which is obtained from the tool function indicator.

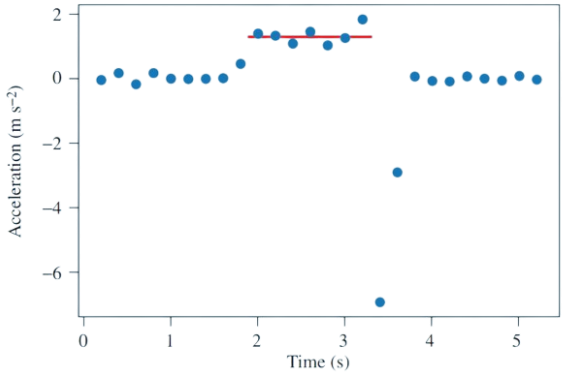

Figure 4. The toy car's average acceleration over time

The value of the calculation results obtained on the design indicator for this one-dimensional motion experimental device has been corrected according to the suggestions of the validator. This is following research from (Saphet et al., 2017). The criteria for the advantages of a one-dimensional motion experimental tool include an attractive physical appearance, not easily damaged and safe when used. Recapitalization of the validation results of one-dimensional motion experiments can be seen in Table 1.

Table 1. Recapitulation of the validation results of the one-dimensional motion experimental apparatus

No	Assessment Indicator	$r_{calculated}$	$r_{critical}$	Results
1	*The physical appearance of the one-dimensional motion experiment tool:*			
	a. The design of a one-dimensional motion experiment is interesting	0.82	0,3	Valid
	b. The series of tools are arranged in a rapport	0.91	0.3	Valid
2	*Tool efficiency:*			
	a. Easy-to-assemble tool	0.82	0.3	Valid

No	Assessment Indicator	$r_{calculated}$	$r_{critical}$	Results
	b. Easy-to-use tools	0.82	0.3	Valid
	c. Easy-to-clean tools	0.76	0.3	Valid
	d. Easy disassembly	0.82	0.3	Valid
3	*Tool functionality:*			
	a. Produces uniform, straight motion as a function of time	0.75	0.3	Valid
	b. The floor track used is smooth	0.75	0.3	Valid
	c. Integrated experimental tools and electronic instruments	0.82	0.3	Valid
4	*Level of practicum design implementation:*			
	a. Practicum using this tool will be easy	0.82	0.3	Valid
5	*Security aspect:*			
	a. This tool is harmless to users	0.76	0.3	Valid
	b. The primary material for making the tool is harmless to the user	0.82	0.3	Valid
6	*Compatibility with learning:*			
	a. This tool is needed in the practical analysis of one-dimensional motion experiments	0.82	0.3	Valid
	b. This tool makes the practitioner more skilled and thorough	0.82	0.3	Valid
7	Economic aspect:			
	a. The cost required in making this tool is cheap	0.92	0.3	Valid
	b. The cost of making this tool can be reached by institutions and institutions	0.92	0.3	Valid
8	Environmental aspects:			
	a. The manufacture of these tools reduces the quantity of expensive tools and materials.	1	0.3	Valid

There are several suggestions for improvement from the validator for the one-dimensional motion experiment tool, namely the need to make a manual explaining the function of each component and how to use the one-dimensional motion experiment tool. This aims to facilitate using one-dimensional motion experiment tools to investigate rectilinear motion.

4. CONCLUSION

In summary, the Simple Experiment based on the Raspberry Pi, the HC-SR04 ultrasonic proximity sensor, and a linear path offers a practical, affordable instrument for experimentation in one-dimensional motion. Managing data collecting, displaying outcomes, and data analysis are all possible with Raspberry Pi. It is possible to create qualitative and quantitative motion descriptions that are appropriate for undergraduate or younger students. The validation test results of the eight aspects assessed showed a rcalculated of 0.75 with an average $r_{calculated}$ of 0.82. This shows that this simple experimentation in one-dimensional motion is valid. Because according to theory, if the $r_{critical}$ value is 0.30, then the instrument is declared valid, and if the rcalculated value is less than the $r_{critical}$ value of 0.30, then the instrument is declared invalid. In this study, the value of $r_{calculated}$ was more than 0.30 so that it could be declared valid.

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