Camera-equipped Smart Measuring Device as an Alternative Surveying Equipment in Civil Engineering Construction

Richelle E. Apalla[1], Sharmaine Joyce B. Bartolome[1], Ritchelle P. Hermenegildo[1], Rosalie M. Orpiano[1], Jhun M. Jacinto[1]

[1]*School of Engineering, Aurora State College of Technology, Barangay Zabali, 3200, Baler Aurora, Philippines*

Corresponding Author: richelleapalla10@gmail.com

***Abstract*: As advancement and technology continually rise, many improvements and innovations also arise. The construction industry doesn't exclude innovation and advancement. The Camera-equipped Smart Measuring Device can be useful when it comes to measuring such distances. Civil engineers have faced difficulties estimating distances between sites accurately and quickly for hundreds of years. One of the tools for measuring distances is the surveyor's wheel, it consists of a single wheel affixed to a handle that may be dragged or pushed by a person walking. Typically, several measurements along the ground have followed the use tapes, either steel or cloth, which require two people to manage, are cumbersome to handle, and require calculating. Construction techniques and research have improved over the previous few decades continuously utilizing new technology to enhance project performance in terms of quality, safety, and productivity this includes the measuring wheel, laser scanner and etc. However, majority of those studies regarding measuring certain distances lack on camera equipped devices and automated devices, some still needs effort to use. The Camera-equipped Smart Measuring Device aims to measure certain distances by controlling the device using your android or IOS phone. The application also shows the path traveled by the device because it is equipped with a camera. The device measures the distance it travels and transmit the data measured from the device to your android or IOS phone. The study will use accuracy testing in able to compare and determine the accuracy of using the Camera-equipped Smart Measuring Device and the usual measuring device which is the surveyor's wheel or measuring wheel and tape measure.**

***Keywords*: Smart measuring device, construction, automated equipment, surveying, programming.**

1. Introduction

Advancement and innovation can be a factor for improvement in construction industry. Numerous inventions, breakthroughs, and developments also occur as progress and technology continue to increase. In the realm of civil engineering construction, the precise and efficient process of surveying plays a role, in completing projects. Innovation and progress are welcomed in the construction sector, leading to increased productivity and decreased labor expenses. It is feasible to improve construction tools and equipment with the aid of technology, as it constantly advances and beyond our expectations.

When it comes to measuring such distances efficiently and accurately, a smart measuring equipment with a camera might be helpful. The utilization of measuring devices equipped with cameras in civil engineering construction brings advantages over traditional surveying equipment. These devices are equipped with algorithms and software that can automatically process collected data eliminating the need for calculations, and performing measurements in real-time, providing instant feedback to construction personnel. Nevertheless, it is still necessary to compare the effectiveness and caliber of this equipment to the standard manual measuring wheel utilized by the building company.

Camera-equipped smart measuring device is a tool that can be vital in the advancement of surveying equipment in civil engineering construction. This device is far more advanced from the usual measuring device such as the measuring wheel. Camera-equipped smart measuring device is a tool for measuring horizontal distance that is controlled (forward, backward, left, right) using an android and IOS phone. Visual of the area traveled by the device is seen in the controller along with the measurement of the distance traveled. The device aims to measure distances on curve, horizontal, and slope roads.

A. Conceptual Framework

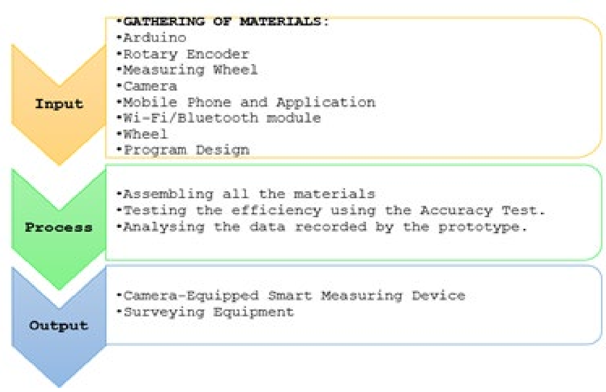

Fig. 1. Conceptual framework

Figure 1 shows the conceptual framework of the study which includes the input, process, and output.

B. Objectives of the Study

1. To evaluate the efficiency and accuracy of camera-equipped smart measuring device compared to conventional surveying equipment.
2. To assess the usability and user-friendliness of camera-equipped smart measuring devices.
3. To develop and improve the advancement of construction surveying equipment.
4. To ascertain the range of terrain that the camera-equipped smart measuring device can traverse in terms of road slopes, curves, and concrete and asphalt pavement.
5. To compare the speed and time efficiency of the device with the conventional measuring wheel in civil engineering construction.

C. Statement of the Problem

The following questions were addressed by this research to evaluate and gain information and knowledge to the study.

1. What is the difference in terms of accuracy between camera-equipped measuring device and the usual measuring device?
2. What is the device's speed and time efficiency compared to the standard measurement wheel in road construction?
3. In terms of road slopes, curves, asphalt and concrete pavement, what can the camera-equipped smart measuring device traverse?

D. Scope and Limitation

This study will be conducted by creating a camera-equipped smart measuring device for experimentation and comparative on the usual measuring device. The researchers will use experimentation to evaluate the efficiency and accuracy of the equipment. With the assistance of a remote-control application, the device can move a predetermined distance, can follow a straight line, curve around obstacles, go behind you, and go through places that are hidden by turning from a certain place. The device is limited only to measure and record the distance in meter counter attached in the prototype. It can also display the route followed by the device, but only in the region where the camera can see. It cannot accept numerous users operating it; it can only be operated by a single device with the associated application. Android phones and IOS devices are compatible with this application. Furthermore, in situations where the surrounding environment is dim (such as in the evening), the path may not be visible to the device's camera, and in heavy rain, the gadget may sustain damage that prevents it from functioning as intended. The device can operate for about one and a half hour (1 ½) continuous use. The maximum range of the device from the controller is a distance of about 30 meters. Barangay South and North Poblacion, Dipaculao Aurora, Barangay Cabituculan East, Maria Aurora, Aurora and Barangay Zabali, Baler, Aurora's roadways surrounding the ASCOT Zabali Campus will be the site of the study's testing. On other studies a minimum of Fifteen (15) different locations will be measured [17], In this study, we will evaluate forty (40) locations. These locations will be divided according to the characteristics of the roads, including road curves, slopes, asphalt and concrete pavement. Ten (10) of each distinct roads will be evaluated in terms of their concrete and asphalt pavement, slopes, and curves. A total of forty test locations will be carried out. Three researchers will be measuring, noting, and validating during the procedure [17]. So, there will be three (3) trials in each test location to ensure accuracy and this results to a total number of one hundred twenty (120) trials.

2. Literature Review

This section reviews relevant material that would be very helpful in gaining knowledge for the subject. It also presents the process of conducting the literature review and highlights research gaps that have been identified in earlier studies and where answers and solutions may be located.

Pertaining to the researcher's area of interest. This literature review procedure is used as evidence to support the answer to the questions that are listed below.

RQ1: What are the possible effects of using camera-equipped smart measuring device as an alternative surveying equipment in construction?

RQ2: What is the difference in terms of efficiency and accuracy between smart measuring device and the usual measuring device?

RQ3: What are the advancements in civil engineering construction equipment?

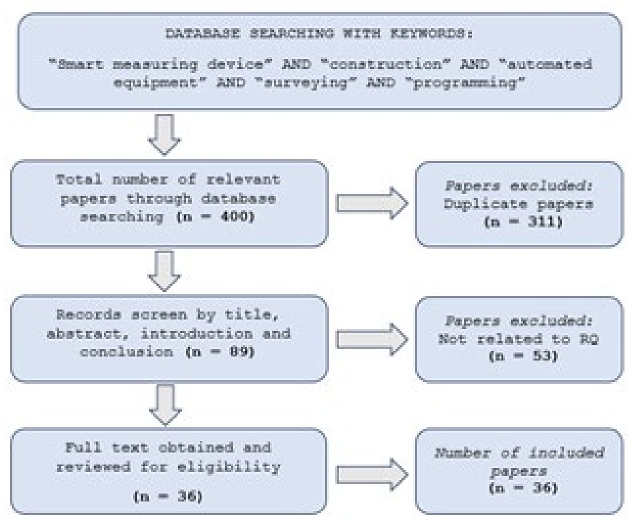

Fig.2. Literature review process

A. Efficiency of Work, Time, and Human Effort

The development of the construction sector is significantly impacted by improvements in surveying technologies, which have produced many improvements and simplified work. A survey was conducted in Gauteng region of South Africa using questionnaires among construction professionals from construction and consulting firms regarding effects of automation in construction industry. The article proposes that automation does not fully replace human skills, but rather assists in areas such as planning, distribution, maintenance, and additional tasks. The ultimate goal is to improve the safety and well-being of individuals at risk of injury during work-related tasks [3]. Therefore, automation in construction not only expand and enhance the construction industry but also has a significant impact in the economy's growth. Compared to an automated measuring instrument, measuring manually over a large distance can be time-consuming, productive, and effort-intensive. An article provides a summary of relevant studies regarding automation in construction suggests that through automation, the industry has the potential to enhance productivity, safety, quality, and global competitiveness, in addition to that, higher productivity might reduce the high labor cost share by 40% or more, and automated equipment allows building sites to run year-round [1]. Automating machinery is a very efficient way to increase output. One of the related literatures found to support the study. The paper's result demonstrates that construction innovation can improve living standards, corporate images, and the rationality of future decisions as well as customer satisfaction [2]. Recent research has demonstrated that the automation of construction equipment has a major impact on worker effort, time, and productivity.

B. *Advancement in Construction Equipment*

Civil engineering construction surveying equipment is always evolving. The laser measuring instrument is one of the most well-known innovations in surveying equipment. It has demonstrated numerous positive benefits for the construction sector by simplifying and improving measurement. The two most popular 3D laser scanning methods at the moment for mapping and surveying are *Aerial Laser Scanning* (ALS) and *Terrestrial Laser Scanning* (TLS), both of which have shown to provide excellent reality capture in an outside setting [4]. A study about Terrestrial Laser Scanner (TLS) shows that over the past thirty years, TLS has been successfully implemented gradually in the Architecture, Engineering, and Construction sector, as laser scanner performance has continued to improve. Many research has been carried out, particularly in the previous 10 years, to confirm the possible application of TLS, which has shown to be a promising approach [5]. In light of this, laser scanners are important in the engineering industry.

Earthmoving machines like *backhoe, bulldozer*, and *excavator*, which made construction considerably easier, are another notable innovation in construction equipment. In recent times, earthmoving companies have been increasingly utilizing automated machine guidance and control and integrated fleet management systems due to their shown ability to enhance productivity and save operating expenses [6]. These technologically assisted automated machines contribute to the advancement of construction equipment developments in the civil engineering sector

These days, the majority of individuals have smartphones that they use on a daily basis, and smartphones contribute to society. Several studies have been carried out, which have resulted in the usage of smartphones as a tool for measuring certain distances. In order to generate and measure the distance of particular locations and objects, many apps were developed. One of the studies involves creating a *mobile application* that uses portable electronics, such tablets or smartphones, to measure the size and distance of things. Prior studies have demonstrated that smart phones can be used to estimate the size of things and can yield an accurate measurement [7].

With the aforementioned remarks, it is evident that construction equipment is constantly evolving and seeing several developments.

C. *Effects of Advancement in Construction Equipment*

Automation and digitization are possible keys to increasing productivity upgrade in construction [8]. The construction sector has undergone a revolution because of the advancements in construction equipment, which have also made working easier and requiring less effort. However, even with less work hours, quality assurance is guaranteed. Automation is an automated procedure that uses computers to accomplish a range of tasks [9]. Choosing the right construction equipment is crucial to provide a quality of work. The most logical parameters that improve operational effectiveness, productivity, cost reduction, and the welfare of people and the environment must be taken into consideration while choosing construction equipment [10]. With this in mind a positive effect brought by choosing the right construction equipment is guaranteed.

Laser scanning offers a novel solution to cut expenses and to optimize the time spent on indoor mapping applications [4]. This device helps in reducing the time and effort spend during

Table 1
Effects of different measuring device/equipment

Equipment	Key Result	Reference
Terrestrial laser scanning (TLS)	Has a significant potential to reduce superfluous labor and improve the accuracy of quality assessments.	[13]
Robotics	Provide the building business several benefits.	[13]
automated machine guidance and control/ integrated fleet management systems	Demonstrated efficacy in raising output and cutting operating expenses.	[14]
Mobile Applications	Has made measuring distances easier. Accuracy and comprehensiveness with which users accomplish predetermined objectives	[15]
Digital Surveying Wheel	Test findings indicate a high degree of accuracy when comparing measurements made with a digital surveyor's wheel and a measuring tape.	[15]

construction. Another advancement in construction equipment is the *material handling equipment,* this innovation has led to various positive effects such as, less expensive, quicker, safer, more effective, and easier to move materials between processing stages without the need for manual handling by using material handling equipment [11]. Technology plays a crucial part in the advancement of construction equipment. One of the main benefits of using digital technology in building is that it can save construction time by up to 30 to 50 percent when compared to traditional methods [12]. These studies proves that advancement in construction equipment have a significant effect to the construction industry and this study proves that innovation, development, and enhancement are factors that help in the advancement of construction sector.

Table 1 presents a tabulation of the effects of various measuring devices and equipment. Column 1 lists the various measuring devices and equipment used in earlier studies, along with column 2's key findings. Column 3 lists the citation from which the study was obtained.

D. The Cost of Utilizing Construction Equipment

It is true that the faster and easier construction and building processes require the use of construction equipment. But, for equipment to function, financial resources must also be accessible. The cost of equipment might range from 25 to 40 percent of the overall project cost in civil engineering construction projects. The equipment required to complete the project must be included in the project's cost [14]. Innovations could account for improvements in cost effectiveness such as reduction in costing, safety, quality of working conditions, productivity, and competitiveness [16]. Innovation could result in lower equipment costs for civil engineers. Taking this into consideration, innovations aid in the advancement of equipment while also assisting engineers and contractors in reducing project costs.

Since construction equipment is a vital component of the industry, long-lasting devices are sought after, particularly when the equipment is expensive. Techniques utilizing terrestrial laser scanners are ultimately more cost-effective and time-efficient [13]. Using smart measuring devices, then, provides financial benefits that could eventually lower the cost of ongoing purchases. Similar to the ALS, although the camera-equipped smart measurement device may result in a greater initial cost, it will ultimately save money on construction.

E. Accuracy Testing

One of the testing's used to measure the effectiveness of certain surveying equipment is the use of Accuracy Testing. Some researchers used this kind of test to identify the significance of a measuring equipment and to be able to compare it to another measuring devices that are present. A literature review conducted measurements using three different tape measures, with accuracy verified by a ruler and measuring application. The study found that tape measurement is affordable and simple, but requires training and time for accuracy. The stationary whole-body scanner is the most expensive, but has user-friendly technology [17]. However, both have provided significant result in terms of measuring distance. A study was conducted comparing the accuracy of ultrasound measurement devices and measuring boards for measuring the heights of children aged two to five in rural Lao People's Democratic Republic. The study found that both methods were similarly precise and accurate, but the ultrasound instrument had a slight bias of 0.1 cm. The study was carried out by 12 trained health workers [18]. The study to measure tree heights using the direct approach (tape measures) and the indirect way (using the ultrasonic-based device Vertex IV) is another article that goes along with the usage of accuracy testing. Results were compared to remote sensing data for statistical analysis. The strong correlation between the tape measurements and indirect Vertex measurements suggests a reliable method for measuring tree height [19]. The following studies showed that use of accuracy test as a method for testing the efficiency and accuracy of measuring devices.

Table 2
The results of accuracy testing in different measuring equipment

Testing Procedure (Accuracy Test)	Key Result	Reference
Materials: Measuring tape, metal ruler, measuring application	Provided significant result in terms of measuring horizontal distance	[17]
Materials: measuring board, ultrasound measurement device	Ultrasound instrument had 0.1 cm bias after measuring heights of Lao children	[18]
Materials: tape measure, Vertex Clinometer	When measuring tree heights, the results from the tape measure and vertex clinometer are identical.	[19]

A tabulation of the accuracy test results across various measuring devices is shown in Table 2. Column 1 shows the type of test that have been conducted which is the accuracy test, along with column 2's key findings. Column 3 lists the citation from which the study was obtained.

F. Programming

Programming is one area of great attention when it comes to technical equipment growth. Devices such as the Camera-Equipped Smart Measuring Device needs a complex variety of programming, it involves numerous programming codes especially when it requires a lot of memory usage. The majority of programming ideas involving memory devices have a comparatively high level of complexity [20]. Therefore, a high level of complexity programming is required to construct a program that transfers and stores data using a programmed memory. One well-known programming language that is frequently utilized in numerous devices and technical equipment is Python. It gained its popularity because Python is used in a far greater variety of applications, including software and game development, database access, desktop graphical user interfaces, scientific computing, and Internet and website

Table 3
Various programming software

Programming Software	Key Result	Reference
Alice Software	The utilization of Alice software leads to more efficient outcomes compared to traditional programming languages.	[23]
Phyton	Type of programming that can be applied to a significantly wider range of applications.	[21]
Java Programming	Java is a programming language that is widely used for various applications, including mobile, web, desktop, and games. It is platform independent, making it an ideal choice for developing complex and high-performance software systems.	[24]

Table 4
Tabulation of research gaps

No.	Research Gaps	Citation
1	Guaranteed quality of work in construction surveying	[28]
2	Matters related to improving construction innovation in terms of surveying equipment	[3], [15], [26]
3	Development of construction equipment and technology in construction surveying	[15]
4	Surveying equipment equipped with a camera	[25], [1]
5	Smart measuring equipment for surveying advancement	[25], [27]

creation [21]. Python offers an educational learning kit that will be beneficial to researchers who's conducting studies that involves programming. The Python Scikit-learn package comes highly recommended for certain entry-level machine learning application [21]. One well-known component utilized in the creation of remote-controlled devices is the Arduino, which requires several programming approaches to function. Arduino employs a more straightforward version that makes programming simpler and offers a more user-friendly environment by encapsulating the micro-controller's features in a more manageable container [22]. The process of designing an Arduino-based device requires programming. The Arduino platform and programming techniques work together to create remarkable devices.

The Table 3 below presents various programming software currently in use, along with their respective outcomes from numerous studies.

G. Research Gap

Following a thorough assessment of the identified literature reviews, the following gaps in the articles were discovered:

3. Methodology

A. Research Design

The researchers will use quantitative research approach to carry out the investigation. Generally, systematic observations and experiments are covered. Quantitative research involves the collection and analysis of numerical data to identify trends, calculate averages, evaluate relationships, and draw broad conclusions. It is applied in many disciplines, such as the social and scientific sciences. Statistical methods are used in quantitative data analysis to process and evaluate numerical data. This is experimental study, and the project is being carried out through experiments, analysis, and observation. Camera-equipped measuring device efficiency, effectivity, and accuracy will be tested and compared in the usual measuring device. Researchers make sure the data is free of bias and interpret the results based only on the experiment. The data obtained will be based exclusively on the experiment's outcome.

B. Flowchart of Research Design

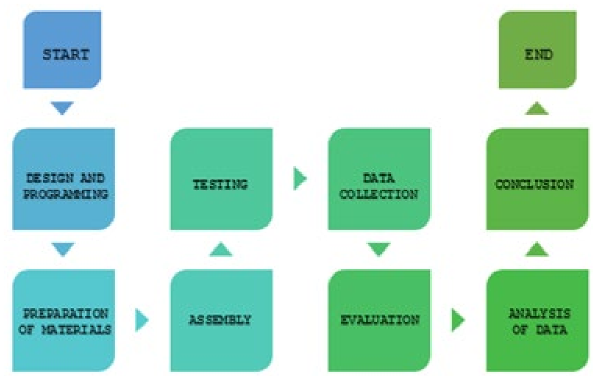

Fig. 3. Flowchart of research design

The figure above shows the process or flowchart of research design. The process of this research starts from collecting materials such as the measuring device and control devices, the raw materials will be collected and construct.

C. Description of Research Instrument Used

This experimental study is to investigate the efficiency, accuracy, and effectiveness of camera-equipped smart measuring device as an alternative surveying equipment. Furthermore, the researchers' goal is to develop new ideas and innovations for construction equipment is what drives the study. The purpose of this is to innovate and help into the advancement of construction industry and equipment. The accuracy and efficiency of camera-equipped smart measuring device will be compared and identify. By providing alternative and advance construction equipment for projects that can assist the environment in addition to the construction industry, the findings will benefit the engineering community and engineering students. The data gathered will be interpreted by Microsoft Excel which includes the results in each trial, the average calculation for each test, and the result of accuracy and percent of error. Descriptive Statistical Analysis will be used which summarizes data in the form of tables and texts.

D. *Research Process*

The steps of the experimental process are described in this section of the study. Below is a discussion and presentation of the research process in sequential order.

1) *For Camera-Equipped Smart Measuring Device*

Step 1: Collect and assemble the raw materials such Arduino board, wireless camera, rotary encoder, Wi-Fi module, and measuring rolling wheel device.

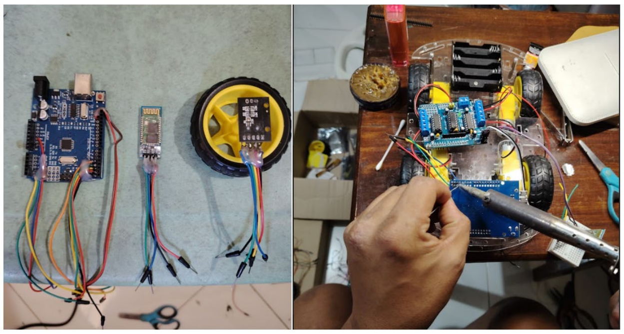

Fig. 4. Gathering and assembling of raw material

Step 2: Input the wheel/measuring device to the Arduino board. Upload the program to the Arduino board.

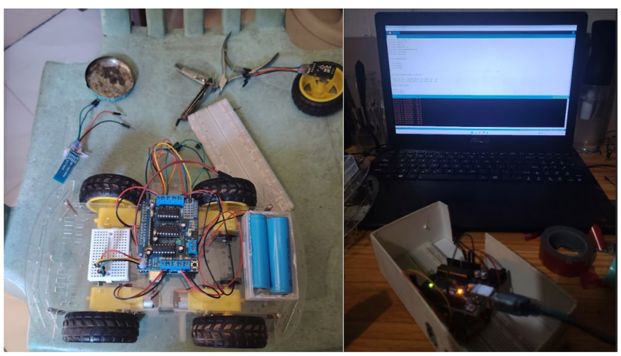

Fig. 5. Inserting program code to the device

Step 3: Put the wireless camera on the Arduino board and connect it into a device.

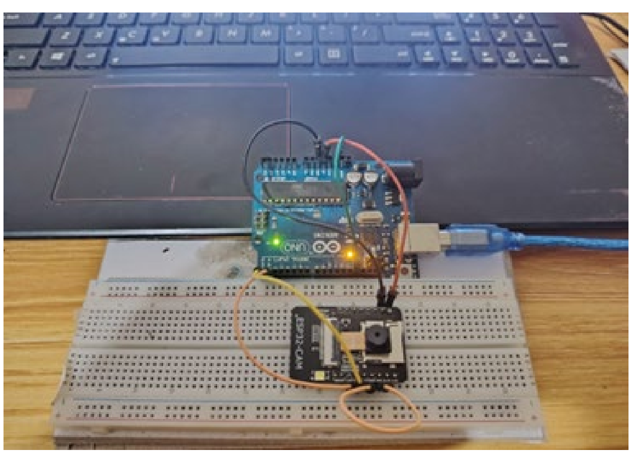

Fig. 6. Connecting camera to the device

Step 4: Set up the device and connect it to a mobile phone.

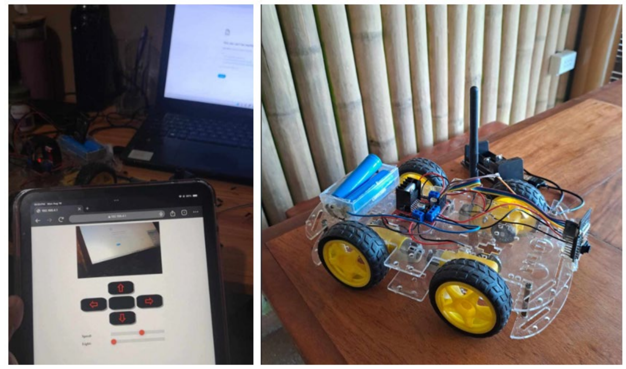

Fig. 7. Setting up the device

Step 5: Conduct a test using the camera-equipped smart measuring device and the usual measuring device.

Fig. 8. Collection of data

E. *Product Design*

This portion of the paper showcases the detailed drawing or the schematic diagram of the device. The following are the proposed design of the product, note that possible changes may occur with the products design upon the creation of the product itself, maybe due to the availability of materials or other unforeseen events that might occur.

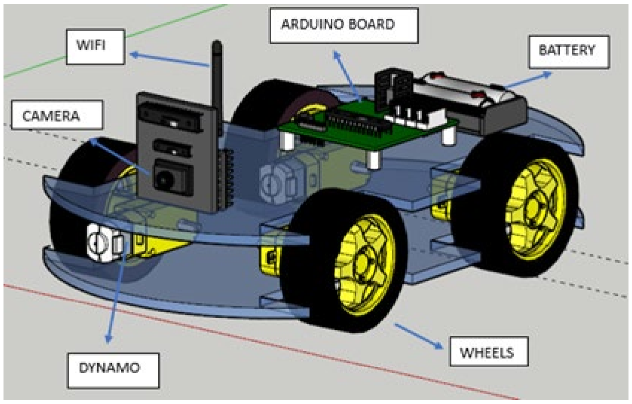

Fig. 9. Detailed drawing of the device

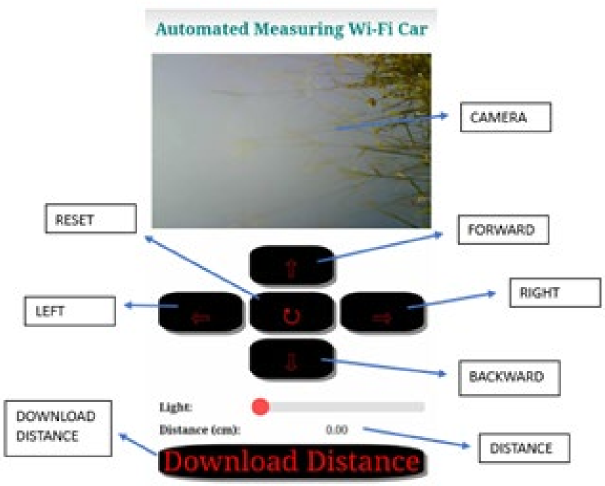

Fig. 10. Design of the device controller

F. Program Design

The programming procedure that will be utilized to transfer data from the device itself to the phone that will act as the controller is demonstrated in this research chapter. The device will be controlled by an Arduino board, and data collected from the device will be transmitted to the controller via programming codes. A Wi-Fi module will be used to transmit data, and a wheel with a rotary encoder will be used to measure the device's traveled distance. A help of a license programmer is needed in transmitting the data collected. Because the software will be based on a certified programmer's design, it should be noted that changes to the design may be necessary. Potential modifications to the program design of the camera-equipped smart measuring device may occur as a result of discussions with the programmer regarding trial-and-error procedures to determine what programming code is appropriate to utilize.

G. Program Code

The program used are the following: C++, C, C#, Java, Javascript. For the camera, three programs were used, meanwhile for the application/website the Java program is utilized. While the C++, and C program are used for the Arduino in able to detect the camera. The link below contains the program code of this device.

https://tinyurl.com/rkfrhxsa

H. Experiment/ Test

The researchers will employ a comparative test to evaluate the difference between camera-equipped smart measuring device and usual measuring device. This test will identify the accuracy, efficiency, and effectivity of the measuring device. The two-measuring device will be tested on the field at a certain distance and will identify the accuracy and the conveniences of the camera-equipped smart measuring device compared to the usual measuring device. The testing will be conducted at forty distinct locations, which will be categorized in terms of road roughness, bends, slopes, and concrete pavement. In each location, three measurement trials will be carried out, a total of one hundred twenty (120) trials will be conducted. To compute the accuracy and precision of the measuring devices, the researchers will collect the measurements gathered and find the average and the percent of error.

1) Accuracy test procedure

1. Place the measuring device on a field area.
2. Start to measure a certain distance using the camera-equipped measuring device and the usual measuring device
3. Analyze and compared the collected data measurements gathered
4. Analysis obtained

2) Data Calculation

There will be three (3) trials to be conducted in the forty (40) chosen area at Barangay South and North Poblacion, Dipaculao Aurora, Barangay Cabituculan East, Maria Aurora, Aurora and Barangay Zabali ASCOT, Baler, Aurora in terms of road curves, slope, and concrete and asphalt pavement. A total of one hundred twenty (120) trials will be conducted. For each trial, we will be using a measuring wheel, pace factor, and the researcher's prototype. The average within those trials will be recorded and will be compared to each instrument used in order to identify its accuracy [18]. A percentage of error will then be calculated in order to determine the degree to which the measured and actual values are similar.

Formula for Computing Accuracy:

$$n = \frac{T1 + T2 + T3}{3}$$

Where:

n – average
T1 – measurement for the first trial
T2 – measurement for the second trial
T3 – measurement for the third trial

Formula for computing Percentage of Error:

$$\vartheta = \left|\frac{Va - Ve}{Ve}\right| * 100\%$$

Where:

ϑ – percent error
Va – actual value measured
Ve – expected value or true value

4. Result and Discussion

Table 5
Result for concrete pavement

		TRIAL 1	TRIAL 2	TRIAL 3	ACCURACY	% ERROR	
1	Measuring Wheel	30	30	30	30.00	8.56	measuring wheel to device
	Pace Factor	50	51	50	30.00	8.56	pace factor to device
	Device	27.3	27.4	27.6	27.43		
2	Measuring Wheel	30	30	30	30.00	16.28	measuring wheel to device
	Pace Factor	51	50	50	30.00	16.28	pace factor to device
	Device	24.25	25.6	25.5	25.12		
3	Measuring Wheel	30	30	30	30.00	22.39	measuring wheel to device
	Pace Factor	50	51	50	30.00	22.39	pace factor to device
	Device	24.6	22.55	22.7	23.28		
4	Measuring Wheel	30	30	30	30.00	13.83	measuring wheel to device
	Pace Factor	51	51	52	30.00	13.83	pace factor to device
	Device	25.55	25.85	26.15	25.85		
5	Measuring Wheel	30	30	30	30.00	10.83	measuring wheel to device
	Pace Factor	50	51	50	30.00	10.83	pace factor to device
	Device	26.9	26.35	27	26.75		
6	Measuring Wheel	30	30	30	30.00	7.28	measuring wheel to device
	Pace Factor	50	49	50	30.00	7.28	pace factor to device
	Device	28.4	27.6	27.45	27.82		
7	Measuring Wheel	30	30	30	30.00	16.22	measuring wheel to device
	Pace Factor	51	50	50	30.00	16.22	pace factor to device
	Device	24.35	25.4	25.65	25.13		
8	Measuring Wheel	30	30	30	30.00	9.50	measuring wheel to device
	Pace Factor	50	50	51	30.00	9.50	pace factor to device
	Device	27.45	27.75	26.25	27.15		
9	Measuring Wheel	30	30	30	30.00	15.33	measuring wheel to device
	Pace Factor	50	49	49	30.00	15.33	pace factor to device
	Device	25.75	25	25.45	25.40		
10	Measuring Wheel	30	30	30	30.00	7.39	measuring wheel to device
	Pace Factor	51	50	50	30.00	7.39	pace factor to device
	Device	27.3	26.8	29.25	27.78		

The table above shows that out of 30 trials, the computed highest percentage of error is 22.39% and the lowest is 7.28%.

Table 6
Result for concrete pavement with standard deviation

CONCRETE PAVEMENT	TRIAL 1 (SD)	TRIAL 2 (SD)	TRIAL 3 (SD)	mean	pace factor	ACCURACY	% of Error	
Measuring Wheel	30.00 (0)	30.00 (0)	30.00 (0)			30	12.76	measuring wheel to device
Pace Factor	50.4 (0.49)	50.2 (0.75)	50.2 (0.75)	50.27	0.6	30	12.77	pace factor to device
Device	26.18 (1.40)	26.03 (1.48)	26.3 (1.64)			26.17		

The average percentage of error in concrete pavement is 12.76% (measuring wheel to device) and 12.77% (pace factor to device).

Table 7
Result for curved roads

		TRIAL 1	TRIAL 2	TRIAL 3	ACCURACY	% ERROR	
1	Measuring Wheel	30	30	30	30.00	2.56	measuring wheel to device
	Pace Factor	51	50	50	30.00	2.56	pace factor to device
	Device	28.15	28.6	30.95	29.23		
2	Measuring Wheel	30	30	30	30.00	9.06	measuring wheel to device
	Pace Factor	49	49	48	30.00	9.06	pace factor to device
	Device	27.3	26.6	27.95	27.28		
3	Measuring Wheel	30	30	30	30.00	10.06	measuring wheel to device
	Pace Factor	50	50	50	30.00	10.06	pace factor to device
	Device	26.65	28.3	26	26.98		
4	Measuring Wheel	30	30	30	30.00	2.89	measuring wheel to device
	Pace Factor	50	50	51	30.00	2.89	pace factor to device
	Device	31.2	28.7	27.5	29.13		
5	Measuring Wheel	30	30	30	30.00	0.44	measuring wheel to device
	Pace Factor	51	50	50	30.00	0.44	pace factor to device
	Device	29.7	29.8	30.1	29.87		
6	Measuring Wheel	30	30	30	30.00	-6.67	measuring wheel to device
	Pace Factor	51	51	50	30.00	-6.67	pace factor to device
	Device	32.6	31.9	31.5	32.00		
7	Measuring Wheel	30	30	30	30.00	-3.44	measuring wheel to device
	Pace Factor	50	51	51	30.00	-3.44	pace factor to device
	Device	31.1	31.1	30.9	31.03		
8	Measuring Wheel	30	30	30	30.00	-2.22	measuring wheel to device
	Pace Factor	49	50	51	30.00	-2.22	pace factor to device
	Device	29.9	30	32.1	30.67		
9	Measuring Wheel	30	30	30	30.00	5.78	measuring wheel to device
	Pace Factor	50	49	50	30.00	5.78	pace factor to device
	Device	28.5	26.5	29.8	28.27		
10	Measuring Wheel	30	30	30	30.00	6.00	measuring wheel to device
	Pace Factor	50	50	49	30.00	6.00	pace factor to device
	Device	28.1	28	28.5	28.20		

The table above shows that out of 30 trials, the computed highest percentage of error is 10.06% and the lowest is 0.44%.

Table 8
Result for curved roads with standard deviation

CURVE ROAD	TRIAL 1 (SD)	TRIAL 2 (SD)	TRIAL 3 (SD)	mean	pace factor	ACCURACY	% of Error	
Measuring Wheel	30.00 (0)	30.00 (0)	30.00 (0)			30	2.44	measuring wheel to device
Pace Factor	50.10 (0.70)	50.00 (0.63)	50.00 (0.89)	50.03	0.6	30	2.43	pace factor to device
Device	29.32 (1.81)	28.95 (1.68)	29.53 (1.87)			29.27		

The average percentage of error in concrete pavement is 2.44% (measuring wheel to device) and 2.43% (pace factor to device).

Table 9
Result for slope roads

		TRIAL 1	TRIAL 2	TRIAL 3	ACCURACY	% ERROR	
1	Measuring Wheel	30	30	30	30.00	15.22	measuring wheel to device
	Pace Factor	53	47	51	30.00	15.22	pace factor to device
	Device	26.8	22.6	26.9	25.43		
2	Measuring Wheel	30	30	30	30.00	1.61	measuring wheel to device
	Pace Factor	50	51	50	30.00	1.61	pace factor to device
	Device	28.8	29.7	30.05	29.52		
3	Measuring Wheel	30	30	30	30.00	4.28	measuring wheel to device
	Pace Factor	51	52	50	30.00	4.28	pace factor to device
	Device	27.8	29.05	29.3	28.72		
4	Measuring Wheel	30	30	30	30.00	15.89	measuring wheel to device
	Pace Factor	48	50	51	30.00	15.89	pace factor to device
	Device	25.25	23.6	26.85	25.23		
5	Measuring Wheel	30	30	30	30.00	2.00	measuring wheel to device
	Pace Factor	50	50	49	30.00	2.00	pace factor to device
	Device	33.2	27.7	27.3	29.40		
6	Measuring Wheel	30	30	30	30.00	3.67	measuring wheel to device
	Pace Factor	51	50	50	30.00	3.67	pace factor to device
	Device	28.9	29.1	28.7	28.90		
7	Measuring Wheel	30	30	30	30.00	1.78	measuring wheel to device
	Pace Factor	50	51	50	30.00	1.78	pace factor to device
	Device	29.5	28.8	30.1	29.47		
8	Measuring Wheel	30	30	30	30.00	5.56	measuring wheel to device
	Pace Factor	50	49	50	30.00	5.56	pace factor to device
	Device	28.3	27.8	28.9	28.33		
9	Measuring Wheel	30	30	30	30.00	6.00	measuring wheel to device
	Pace Factor	50	50	51	30.00	6.00	pace factor to device
	Device	29.1	27.2	28.3	28.20		
10	Measuring Wheel	30	30	30	30.00	3.67	measuring wheel to device
	Pace Factor	49	50	50	30.00	3.67	pace factor to device
	Device	28.6	28.9	29.2	28.90		

The table above shows that out of 30 trials, the computed highest percentage of error is 15.89% and the lowest is 1.61%.

Table 10
Result for slope roads with standard deviation

SLOPE ROAD	TRIAL 1 (SD)	TRIAL 2 (SD)	TRIAL 3 (SD)	mean	pace factor	ACCURACY	% of Error	
Measuring Wheel	30.00 (0)	30.00 (0)	30.00 (0)			30	5.97	measuring wheel to device
Pace Factor	50.20 (1.25)	50.00 (1.26)	50.20 (0.60)	50.13	0.6	30	5.97	pace factor to device
Device	28.63 (1.94)	27.45 (2.30)	28.56 (1.14)			28.21		

The average percentage of error in concrete pavement is 5.97% (measuring wheel to device) and 5.97% (pace factor to device).

Table 11
Result for asphalt pavement

		TRIAL 1	TRIAL 2	TRIAL 3	ACCURACY	% ERROR	
1	Measuring Wheel	30	30	30	30.00	5.33	measuring wheel to device
	Pace Factor	51	49	50	30.00	5.33	pace factor to device
	Device	29.6	28.8	26.8	28.40		
2	Measuring Wheel	30	30	30	30.00	-7.33	measuring wheel to device
	Pace Factor	50	51	50	30.00	-7.33	pace factor to device
	Device	30.8	33.8	32	32.20		
3	Measuring Wheel	30	30	30	30.00	0.11	measuring wheel to device
	Pace Factor	50	51	50	30.00	0.11	pace factor to device
	Device	32	29.2	28.7	29.97		
4	Measuring Wheel	30	30	30	30.00	8.56	measuring wheel to device
	Pace Factor	50	51	50	30.00	8.56	pace factor to device
	Device	27.3	27.6	27.4	27.43		
5	Measuring Wheel	30	30	30	30.00	6.72	measuring wheel to device
	Pace Factor	49	51	50	30.00	6.72	pace factor to device
	Device	29.25	26.8	27.9	27.98		
6	Measuring Wheel	30	30	30	30.00	7.11	measuring wheel to device
	Pace Factor	50	49	50	30.00	7.11	pace factor to device
	Device	27.6	28.1	27.9	27.87		
7	Measuring Wheel	30	30	30	30.00	4.11	measuring wheel to device
	Pace Factor	51	50	51	30.00	4.11	pace factor to device
	Device	29.2	28.6	28.5	28.77		
8	Measuring Wheel	30	30	30	30.00	7.39	measuring wheel to device
	Pace Factor	50	51	50	30.00	7.39	pace factor to device
	Device	28.3	27.6	27.45	27.78		
9	Measuring Wheel	30	30	30	30.00	7.11	measuring wheel to device
	Pace Factor	50	51	49	30.00	7.11	pace factor to device
	Device	27.56	27.94	28.1	27.87		
10	Measuring Wheel	30	30	30	30.00	3.67	measuring wheel to device
	Pace Factor	49	50	50	30.00	3.67	pace factor to device
	Device	29.3	28.5	28.9	28.90		

The table above shows that out of 30 trials, the computed highest percentage of error is 8.56% and the lowest is 0.11%.

Table 12
Result for asphalt pavement with standard deviation

ASPHALT PAVEMENT	TRIAL 1 (SD)	TRIAL 2 (SD)	TRIAL 3 (SD)	mean	pace factor	ACCURACY	% of Error	
Measuring Wheel	30.00 (0)	30.00 (0)	30.00 (0)			30	4.28	measuring wheel to device
Pace Factor	50.00 (0.63)	50.40 (0.80)	50.00 (0.45)	50.13	0.6	30	4.27	pace factor to device
Device	29.09 (1.42)	28.69 (1.82)	28.37 (1.35)			28.72		

The average percentage of error in concrete pavement is 4.28% (measuring wheel to device) and 4.27% (pace factor to device).

After finalizing the findings of the study, the researchers discovered a measurement accuracy difference ranging from 2% to 13%. They found that various road surfaces also impact the accuracy of the device's measurements. For instance, on sloped surfaces, the device's speed fluctuates, affecting its precision. It tends to measure more accurately on uphill roads than on downhill roads. Additionally, the error percentage is lower on curved roads compared to straight paths.

Straight surfaces, such as concrete pavement, have a higher percentage of error, indicating a need for improvement in measurements. Furthermore, the device can traverse through different road surfaces such as asphalt pavement, concrete pavement, slopes, and curved roads.

5. Conclusion

Based from the results of the study, the researchers drawn the following conclusions. The device can traverse through asphalt pavement, concrete pavement, slopes, and curved roads. Using ultrasonic sensors for distance measuring devices can be effective; however there has been a percentage error difference compared to surveying wheel. The device battery can only last for about one and a half hours (1 ½) of continuous use. The maximum range distance of the camera-equipped smart measuring device from the user controller is about 30 meters before the connection from the device-to-controller becomes unstable. The average error of the device ranges from 4% to 13% which is quite high for distance-measuring.

6. Recommendations

Based from the findings of the study and the above stated conclusions, the researchers offer the following recommendations both for groups and individual:

- Improve the program code of the device for more accurate results (instead of using ultrasonic sensor for measuring device try other methods such as using rotary encoder, RPM Counter, Tachometer, etc.)
- Modify the device's appearance to make it more aesthetically pleasing.
- Provide high quality of materials to save higher maintenance costs.
- Provide a water-resistant cover.

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