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IoT-Based Oscillation Counter Using a Tracker Sensor

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ABSTRACT

The development of Internet of Things (IoT) technology has enabled measurement and monitoring systems to be accessed remotely through the internet. In oscillation experiments, the number of oscillations is generally determined through direct observation, which requires continuous monitoring and may be affected by human observation errors. This research aimed to develop an IoT-based oscillation counter using a tracker sensor and evaluate its accuracy and precision. The system consisted of a tracker sensor, Arduino Uno, Ethernet module, and web interface. The research stages included system design, hardware and software implementation, sensor characterization, and performance testing. The tracker sensor operated based on infrared reflection using active-high logic, producing HIGH and LOW outputs for detected and non-detected objects, respectively. The sensor produced average output voltages of 3.276 V for detected objects and 0.001 V for non-detected objects. The oscillation-counting accuracy reached 100% with 0% error for $n = 2, 4, 6, 8$, and 10. The precision test at $n = 10$, based on 10 measurements, also achieved 100% precision. The counting data were processed by the Arduino Uno and transmitted to the server for real-time display on the web interface. The results indicate that the developed system can accurately and consistently count oscillations while supporting remote monitoring through an IoT-based web interface.

1. INTRODUCTION

Current technological advancements have encouraged the development of electronic systems that improve the effectiveness and efficiency of monitoring and measurement activities [1]. In automation and measurement systems, sensors play an important role in detecting physical events and converting them into signals that can be processed by electronic devices. The ability of a sensor to detect an object accurately and consistently is particularly important when the detection signal is used as the basis for recording repetitive motion [2]. In motion-monitoring applications, therefore, the selection and characterization of a sensor are important to ensure that the detected events can be reliably converted into measurement data.

One technology that supports the development of modern monitoring and measurement systems is the Internet of Things (IoT). IoT enables electronic devices to communicate through a network, allowing data to be acquired, transmitted, stored, and monitored remotely [3]. The integration of IoT with sensor-based measurement systems allows measurement results to be accessed without requiring users to be physically present at the observation site [4]. This capability provides greater flexibility in monitoring and supports the availability of measurement data in real time. In laboratory applications, IoT-based systems can therefore be used to extend conventional measurement systems toward remote monitoring and data access.

Oscillation is a repetitive motion in which an object moves back and forth around an equilibrium position. Information on the number of oscillations is important for observing and analyzing repetitive motion [5]. In conventional measurements, the number of oscillations is commonly obtained through direct observation and manual recording. However, manual counting can be affected by human error, particularly when the motion is repetitive, occurs continuously, or requires prolonged observation [6]. An automatic detection and counting mechanism is therefore required to convert repeated motion events into quantitative oscillation-counting data. Previous developments in simple harmonic motion experiments have employed sensors and microcontrollers to acquire motion-related parameters. For example, sensor-based experimental systems have been developed to measure oscillatory motion and obtain parameters such as displacement, period, and other motion characteristics. A previous simple harmonic motion experimental setup using an Arduino Uno and photodiode sensor has also been reported, in which the photodiode was used to count the number of oscillations of a spring system [7]. Other systems have used ultrasonic sensors to measure the position of a mass attached to a spring as a function of time, with Arduino-based data acquisition and computer interfaces used for experimental analysis. These studies indicate that sensor-based measurement can reduce dependence on direct observation and support the acquisition of oscillatory-motion data.

Although these systems have demonstrated the feasibility of sensor-based oscillation measurement, their measurement approaches are primarily directed toward acquiring motion parameters or counting oscillations within a local experimental setup [8]. The integration of automatic oscillation counting with sensor characterization and remote IoT-based monitoring remains an important aspect to be addressed. In particular, a counting system requires a sensor that can consistently distinguish between the presence and absence of the oscillating object within a defined detection region. Without adequate characterization of the sensor response and detection range, changes in sensor position or object distance may affect the reliability of the detected events. Therefore, sensor characterization is necessary before the sensor is implemented as the main input for an automatic oscillation counter [9].

One sensor that can be used for close-range object detection is a tracker sensor module. The sensor operates by emitting infrared light and receiving infrared light reflected from an object. When an object enters the effective detection region, the reflected infrared signal is detected and converted into an output signal indicating the detection status [10]. By varying the distance between the object and the sensor, the detection status and effective detection range can be evaluated. This characterization is important for determining the appropriate sensor position so that each intended movement of the oscillating object can be detected consistently.

The tracker sensor was selected in this study because its simple design, compact form, low power consumption, relatively low cost, and suitability for close range detection make it appropriate for an oscillation counting application [11]. Its digital output can be processed by a microcontroller to identify changes in the detection state as the oscillating object passes through the sensing region [12]. Each valid change in the detection state can then be interpreted as a motion event and processed into oscillation-counting data. This approach differs from systems that use sensors primarily to obtain continuous displacement or position data because the proposed system focuses on converting discrete detection events directly into the number of oscillations.

The performance of an automatic counting system is strongly influenced by the characteristics of the sensor and the reliability of the detection process. Previous sensor-based and IoT-based monitoring systems have demonstrated the use of sensors for object detection and remote data monitoring [13]. However, object detection is commonly used to provide information regarding the presence or absence of an object, whereas repetitive-motion applications require the detection signal to be processed further so that successive motion events can be converted into an oscillation count [14]. Consequently, the performance of the counting process must be evaluated rather than relying solely on the ability of the sensor to detect an object. Accuracy is required to determine the agreement between the measured oscillation count and the reference count, while precision is required to evaluate the consistency of repeated measurements.

Based on these considerations, the research gap addressed in this study is the limited integration of sensor characterization, automatic oscillation counting, and IoT-based remote monitoring within a single measurement system**.** Existing sensor-based simple harmonic motion systems have demonstrated the measurement of oscillatory parameters and, in some cases, the counting of oscillations; however, the approach developed in this study emphasizes a tracker sensor as a discrete motion detector, evaluates its detection characteristics before implementation, and integrates the counting process with network-based data transmission and real-time web monitoring.

Therefore, this study aims to develop an IoT-based oscillation counter using a tracker sensor, an Arduino Uno, an Ethernet module, and a web interface. The study includes characterization of the sensor based on its detection status and response at different object distances. The developed system is then used to detect repetitive motion, automatically count oscillations, transmit measurement data through an Ethernet network, and display the results in real time through a web interface. The performance of the oscillation-counting system is evaluated in terms of accuracy and precision.

The contribution of this study is the development of an integrated measurement system in which the tracker sensor is first characterized to establish an appropriate detection condition and operating range, and its detection output is subsequently used as the basis for automatic oscillation counting. The counting results are transmitted through an IoT-based network and presented through a web interface, enabling real-time remote monitoring. In addition to functional testing, the proposed system is evaluated using accuracy and precision tests to determine the reliability and consistency of the resulting oscillation counts. Thus, the developed system provides an alternative approach to automatic oscillation measurement that combines discrete sensor-based detection, automatic counting, and remote monitoring in a single system.

2. MATERIAL AND METHODS

This research was conducted as engineering research, focusing on the design and testing of an IoT based object detection system to produce a functional product whose performance can be tested. This research can be carried out using various methods, depending on the objectives of the design to be developed. The steps undertaken in this research ranged from the development of the system concept, hardware assembly, and the integration of the tracker sensor with the microcontroller and the IoT system, to the testing of the sensor performance [15]. This research was carried out at the Electronics and Instrumentation Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University. The research period ran from February to July 2026. The research variables consist of independent variables, dependent variables and control variables. The independent variable is the object detection distance. The dependent variables are the output voltage and the condition of the object. Meanwhile, the control variables include the Arduino microcontroller and the electronic components used.

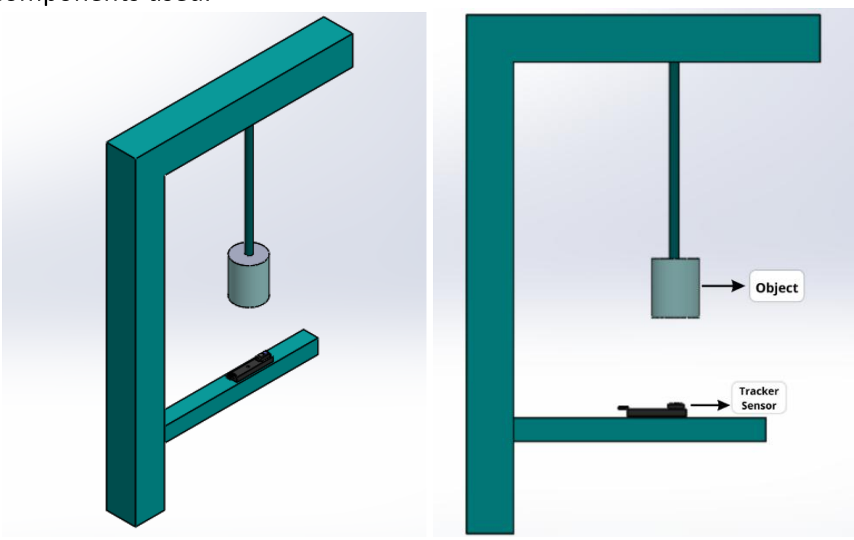

Figure 1 *Hardware of tracker sensor*

The hardware design is shown in Figure 1. The proposed system consisted of a mechanical frame, an oscillating object, a tracker sensor, an Arduino Uno microcontroller, an Ethernet module, and a web-based monitoring interface. The microcontroller used in the system was an Arduino Uno R3, which functioned as the central unit for processing sensor signals and controlling the oscillation-counting process [16]. The tracker sensor was used to detect the presence of the object as it passed through the sensor detection area [17]. The Ethernet module served as the communication medium between the microcontroller and the network, allowing the counting data to be transmitted to the web-based monitoring system [18]. The system configuration was designed to integrate the detection, signal processing, oscillation counting, and data transmission processes.

Before being implemented for oscillation counting, the tracker sensor is characterized based on its detection status and response at different distances between the object and the sensor. The characterization is performed to determine the effective detection range of the sensor and the appropriate sensor position for detecting the movement of the oscillating object. When the object is within the effective detection range, the sensor produces an output indicating that the object has been detected. Conversely, when the object is outside the effective detection range, the sensor output indicates that no object has been detected.

In the oscillation-counting process, the sensor output is used as the input for identifying the movement of the object through the detection area. Each valid detection event is processed according to the counting algorithm to obtain the number of oscillations. The resulting counting data are subsequently transmitted through the Ethernet network and displayed in real time on a web-based interface [17]. This arrangement allows the oscillation count and measurement results to be monitored remotely.

The performance of the proposed oscillation counter is evaluated by comparing the number of oscillations recorded by the system with the number of oscillations obtained through real-time observation. The evaluation includes accuracy and precision testing to determine the correctness and consistency of the oscillation-counting results. The software design is illustrated using a flowchart. The software flowchart describes the sequence of system operations, starting from sensor initialization and object detection, followed by signal processing, detection-event identification, oscillation counting, data transmission through the Ethernet network, and real-time data display on the web interface. The software flowchart of the proposed IoT-based oscillation counter is shown in Figure 2.

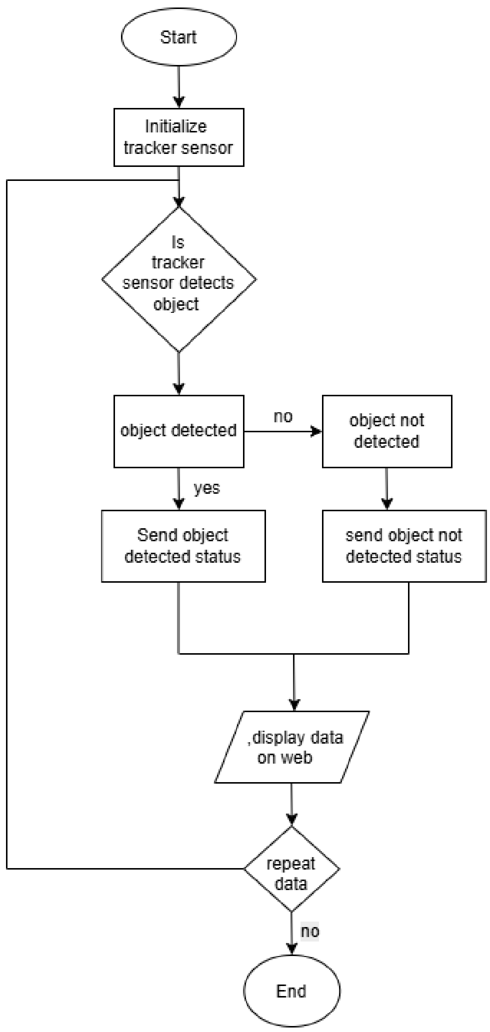

Figure 2 Flowchart of tracker sensor

Accuracy is defined as the degree of closeness between the measured value and the actual value [19]. In this study, the accuracy of the oscillation count is determined by comparing the number of oscillations recorded by the sensor, as calculated using Equation 1.

$$Accuracy\% = \left(1 - \left|\frac{Y_n - X_n}{Y_n}\right|\right) \times 100\% \quad (1)$$

Where (Y_n) represents the reference number of oscillations obtained through real-time observation, while $\bar{X}$represents the mean number of oscillations from all measurements. The percentage of precision can be calculated using the Equation 2.

$$Precision\% = \left(1 - \left|\frac{Y_n - \bar{X}}{\bar{X}}\right|\right) \times 100\% \quad (2)$$

Precision is defined as the degree of closeness of values obtained from repeated measurements of a data point for example (X_n), measurements performed repeatedly ten times [20]. Where $\mathrm{X_n}$represents the value obtained from the n-th measurement and $\bar{X}$denotes the mean value of all measurement results, as determined using Equation (3).

$$\bar{X} = \frac{1}{n}\sum_{n-1}^{n} X_n \quad (3)$$

3. RESULTS AND DISCUSSION

In this study, the HW-006 tracker sensor was first characterized by varying the distance between the object and the sensor to evaluate its detection status and effective detection range. The sensor operates by producing two output states, a high signal when an object is detected and a low signal when no object is detected. The detection signal was subsequently used to identify the movement of the oscillating object as it passed through the sensor detection area. Each valid detection event was processed by the system to count the number of oscillations. Figure 3 shows the hardware used in the study.

Figure 3 hardware tracker system

3. 1 Characterization of the tracker sensor

The tracker sensor was characterised by comparing the sensor output voltage under both conditions using a multimeter set to volts (V). The results indicate that the effective detection range of the tracker sensor was limited to approximately 1 cm under the test conditions. This limitation can be attributed to the characteristics of the infrared reflection mechanism, particularly the distance between the sensor and the object, the position and surface characteristics of the object, as well as the ambient lighting conditions in the measurement environment [21]. As the object moves farther from the sensor, the intensity of the reflected infrared light received by the detector decreases, which can cause the sensor output to change from the detection to the non detection condition. Therefore, maintaining the object within the effective detection range is important to ensure reliable detection during the oscillation-counting process. The test was conducted at different object sensor distances to observe the sensor output voltage at each distance. The results of the tracker sensor output voltage measurements are shown in the table below.

Table 1. Object Detection Status at Different Distances

No	Distance (cm)	Status
1.	1	Detected
2.	0.8	Detected
3.	0.6	Detected
4.	0.4	Detected
5.	0.2	Detected
6.	1.2	Not detected
7.	1.4	Not detected
8.	1.6	Not detected
9.	1.8	Not detected
10.	2	Not detected

Based on the test results presented in Table 1 show the sensor when the object was detected at distances of 0.2–1.0 cm. At distances of 1.2-2.0 cm, indicating that the object was not detected. These results indicate a clear difference in the sensor output between the detected and undetected conditions and suggest that the sensor effective detection range is approximately up to 1.0 cm.

Table 2. Tracker sensor characterisation data

No	Distance (cm)	Output Voltage (V)
1.	1	3.27
2.	0.8	3.27
3.	0.6	3.279
4.	0.4	3.278
5.	0.2	3.271
6.	1.2	0.001
7.	1.4	0.001
8.	1.6	0.002
9.	1.8	0.01
10.	2	0

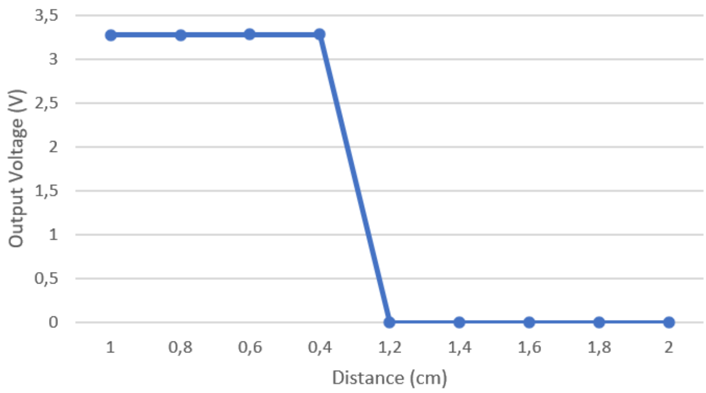

Figure 4 Graph variation of sensor output voltage with object distance

Based on the test results presented in Table 2 and Figure 4, the sensor output voltage is affected by the distance between the sensor and the object. At distances of 0.4-1.0 cm, the sensor produces a relatively constant output voltage of approximately 3.27 V, although small differences occur between distances. This condition indicates that the object is still detected. These small differences may be influenced by measurement conditions, such as variations in the object position, surface characteristics of the object, and characteristics of the sensor circuit. Meanwhile, at distances of 1.2-2.0 cm, the output voltage decreases to nearly 0 V, indicating that the object is not detected. Therefore, the sensor effective detection range under the test conditions is approximately up to 1.0 cm.

3.2 Accuracy of Osillation Counting

The accuracy of the oscillation count was evaluated by comparing the number of oscillations recorded by the tracker sensor with the number of oscillations obtained through real-time observation.

Table 3. Accuracy and error of oscillation counting

No	n_s	n_r	Accuracy(%)	Error(%)
1.	2	2	100	0
2.	4	4	100	0
3.	6	6	100	0
4.	8	8	100	0
5.	10	10	100	0

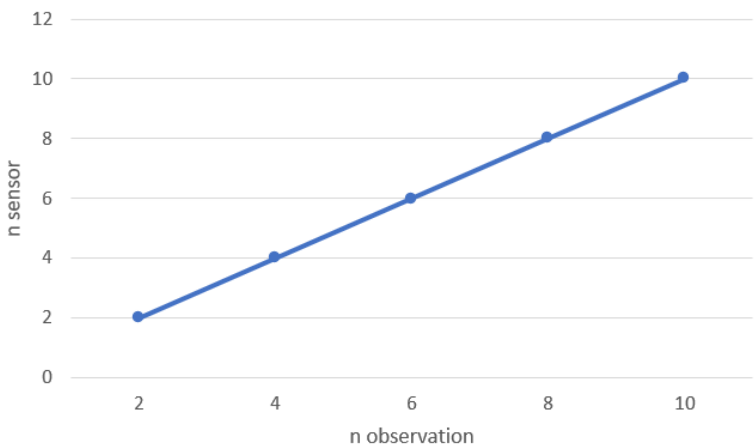

Figure 5 Graph accuracy and error of oscillation counting

Table 3 and figure 5 presents the results of the oscillation count accuracy test by comparing the oscillation count recorded by the sensor-based system (n_s) with the reference oscillation count obtained through real-time observation (n_r). The test was conducted for five different oscillation counts, namely 2, 4, 6, 8, and 10 oscillations. The results show that the recorded number of oscillations was identical to the reference number under all test conditions. Consequently, the system achieved an accuracy of 100% and an error rate of 0% for each measurement. These results indicate that the proposed tracker sensor-based system was able to accurately count the number of oscillations under the tested conditions, with the distance between the sensor and the object maintained at 2 cm.

3.3 Precision of Osillation Counting

Precision test was conducted to evaluate the consistency of repeated measurements of the number of oscillations. The test was performed at a target a value of (n = 10) oscillations, with 10 repeated measurement. The result of the precision test are presented in Table 4.

Table 4. Precision of oscillation counting

Trial	N	Precision (%)
1.	10	100
2.	10	100
3.	10	100
4.	10	100
5.	10	100
6.	10	100
7.	10	100
8.	10	100
9.	10	100
10.	10	100

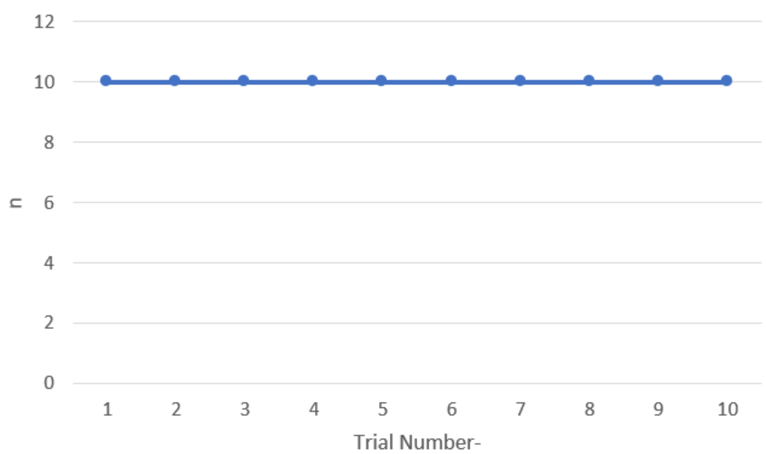

Figure 6 Graph precision of oscillation counting

Based on the test results presented in Table 4 and Figure 6 show all ten trials recorded the same number of oscillations, namely (n = 10). The number of oscillations remained constant throughout the repeated measurements, indicating that the measurement results were highly consistent. The absence of variation among the ten trials indicates that the system provided stable and repeatable oscillation counting results. Therefore, the precision test showed that the system was able to consistently detect and count 10 oscillations in each trial.

Sistem Deteksi Objek Berbasis IoT

No	Status Objek
1	Not Detection
2	Not Detection
3	Not Detection
4	Not Detection
5	Not Detection
6	Detection
7	Detection
8	Detection
9	Detection
10	Detection

Figure 7 Data sensor tracker on web

The following image shows the web interface of the IoT-based object detection system, which is used to monitor sensor readings in real time via an Ethernet network. The web page displays a table consisting of two columns: Number (No) and Object Status. The Number column indicates the sequence of data readings, whilst the Status column shows the sensor detection results regarding the presence of objects.

Figure 7 displays ten observation records. The data for numbers 1 to 5 show the status “Not Detection,” indicated in red, while the data for numbers 6 to 10 show the status “Detection,” indicated in green. These results indicate that the tracker sensor was able to distinguish between detected and non-detected object conditions under the test conditions. This finding is consistent with previous studies reporting that the tracker sensor can be used to detect the presence of objects based on infrared reflection [22]. In addition, the test determined the logic characteristics of the sensor output, namely the active-high condition when the sensor produces a HIGH output when an object is detected and the active-low condition when the output is LOW. Unlike previous applications that primarily focused on object detection, the present study further integrates the tracker sensor with a microcontroller and a web-based interface to detect oscillating objects, count the number of oscillations, and display the results in real time. Thus, the developed system extends the application of the tracker sensor from object detection to automated oscillation counting and remote monitoring.

4. CONCLUSION

An IoT-based object detection system using a tracker sensor was successfully designed and implemented. The sensor operates using infrared reflection with active-high logic, producing an average output voltage of 3.276 V when an object was detected and 0.001 V when no object was detected. The accuracy test achieved 100% accuracy with 0% error for (n = 2, 4, 6, 8, 10). The precision test using 10 repeated measurements at (n = 10) also achieved 100% precision, indicating consistent detection results. The detected data were successfully processed by the microcontroller and transmitted to the server for real-time display on a web page.

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DECLARATIONS

Authorship contribution

Vika Okrian Safitri: Conceptualization, methodology, formal analysis, software and writing-original draft.
Mona Berlian Sari and Nofi Yendri Sudiar: Validation, Writing-review and editing.

Competing Interest

The author **declare** no conflict of interest in this study.

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Ethical Clearance

There are no human subjects in this manuscript, and informed consent is not applicable.

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