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Analyzing Physics Experiment using Sensor Smartphone in Traveling Carnival

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Abstract: Smartphone integration for high school students has significant potential in physics learning. This research aims to analyze smartphone sensor data in the context of physics experiments carried out at traveling carnivals. This research uses experimental methods to compare smartphone sensor data collected via the Phyphox application with video analysis data obtained using Tracker software. The research results show the effectiveness of smartphone sensors in several carnival games, including simple leg swings, bicycle spins, kora-kora vehicles, and merry-go-rounds. Smartphone sensors can show graphs of simple harmonic motion, angular velocity, and centripetal acceleration on the game vehicle. However, limitations arise in the case of Ferris wheels and mini Ferris wheels, where smartphone sensors show reduced effectiveness caused by the instability of passenger seats during the ride. This research suggests avenues for further exploration by computing physical quantity values derived from smartphone sensor data, offering insights into potential improvements and applications in dynamic environments such as theme parks.

Keywords: Physics experiment; Sensor smartphone; Traveling carnival

Introduction

The difficulties encountered in learning physics are often reflected in the high percentage of students struggling to comprehend the material, unable to respond when questioned by the teacher, and facing challenges in understanding sample problems (Ady & Warliani, 2022). The primary focus of these learning difficulties lies in students' limitations in arithmetic, grasping concepts, and comprehending physics formulas (Daun et al., 2020). Learning methodologies relying solely on lectures tend to exacerbate this situation as students only have theoretical knowledge and conceptual understanding. Direct learning experiences through practical activities emerge as the key solution to address this issue. Students can apply understood concepts in solving real-life physics problems through a hands-on approach (Nova & Lestari, 2021; Sahrudin et al., 2019; Sarjono, 2018).

The facilities supporting physics laboratory practices face significant challenges, particularly in remote or underprivileged areas ("3T regions"). Many schools in these areas need help with physics experiment facilities and equipment (Istinganah et al., 2021). The laboratory equipment in these schools is generally minimal and of low quality, resulting in a lack of precision (Qusthalani, 2019). Schools in these 3T regions also grapple with issues such as the absence of stable internet access and various instructional media. These problems collectively hinder the implementation of practical physics learning experiences in schools in remote or underprivileged areas (Budiarti & Lumbu, 2021).

To overcome the limitations of laboratory equipment, schools can leverage technological advancements for learning, with smartphones being a prevalent tool among students (Raharja & Kusiana, 2020). The increased utilization of smartphones for educational purposes in schools has the potential to

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enhance students' knowledge and improve their learning outcomes (Masriah & Setiawati, 2023). This prevalence of smartphone usage is often accompanied by a reduced reliance on laptops and desktop computers in personal contexts (Salim et al., 2023). Additionally, smartphones positively foster higher-order thinking skills (HOTS) among students (Putranta et al., 2021). However, a well-thought-out policy regarding the appropriate use of smartphones in schools must be formulated to mitigate any adverse impacts of their usage (Machmud, 2018).

Smartphones offer distinct advantages in physics education owing to their embedded sensors for data collection, including accelerometers, gyroscopes, light sensors, magnets, GPS, and pressure sensors. These technological features allow for more efficient and accurate processing of experimental data in physics (Countryman, 2014). Leveraging smartphone technology enables the manipulation and presentation of experiment data in a highly effective manner. Specifically, these sensors have been utilized in various physics experiments such as free fall motion, circular motion, Atwood's machine, moment of inertia, and other related experiments (Monteiro et al., 2015; Raharja & Ishafit, 2021; Vogt & Kuhn, 2012; Yasaroh et al., 2021). Using smartphone sensors enhances the practical application of physics concepts by providing a platform for conducting experiments and analyzing data, thereby augmenting the learning experience in the subject.

An application called Phyphox, specifically designed to utilize smartphone sensors, has emerged as an efficient virtual laboratory catering to diverse educational needs (Putri et al., 2023). This innovative solution facilitates remote connectivity to a computer, enabling real-time data transmission from a separate location (Carroll & Lincoln, 2020). Phyphox presents data graphically and incorporates user-friendly features, encouraging students to engage in smartphone-based experiments enthusiastically (Yasaroh et al., 2021). Students perceive experiments conducted through this application as enjoyable and a means to foster self-reliance in conducting experiments (Coramik, 2023; Mayampoh et al., 2021). Moreover, the application's reliability as a measuring tool has been validated, exhibiting a relatively low error rate within scientifically acceptable experimental margins (Radu et al., 2022).

Video analysis software like Tracker serves as a valuable tool to verify the accuracy of smartphone sensor data. Additionally, utilizing Tracker Video Analysis facilities contributes significantly to enhancing Computational Thinking skills (Handayani & Lestari, 2023). This software enables students to develop measurement skills and data analysis capabilities, fostering more meaningful learning experiences (Isabel et al., 2023). Furthermore, Tracker's functionalities extend to analyzing parameters related to wave characteristics, linear motion, Tracking Parabolic Trajectories, and various other physics experiments (Syafitri et al., 2023; Tobaja & Gil, 2023; Yoanda, 2023). This comprehensive software empowers students to delve into diverse physics experiments, facilitating a deeper understanding of concepts through practical applications and analytical processes.

Based on the problems and potential above, researchers are interested in researching and Analyzing Physics Experiments using Smartphone Sensors in Traveling carnivals. This research aims to verify smartphone sensor data when collecting data at a traveling carnival compared to video analysis tracker data. The research is essential as it addresses challenges in physics education, particularly in remote areas, proposing smartphone-based solutions to enhance understanding. It recognizes infrastructure hurdles in underprivileged schools and emphasizes the potential of smartphones as educational tools where traditional lab equipment is lacking. The study validates smartphone sensor data during a traveling carnival, ensuring reliability. It also highlights the role of technology in promoting student self-reliance and higher-order thinking skills. Overall, the research contributes to improving science education accessibility and quality, especially in resource-constrained regions.

Previous studies conducted by researchers such as (Coramik, 2023; Coramik & Ürek, 2021), have already delved into verifying data consistency between smartphone sensors and video analysis trackers. However, the novelty of the current research lies in its unique setting—the Traveling Carnival. The choice of this location introduces a distinctive set of challenges and variables not previously explored in similar studies. A Traveling Carnival's dynamic and unpredictable environment adds an extra layer of complexity to the verification process, considering factors like varying light conditions, mobile structures, and the constant movement inherent to such events. By focusing on data verification in this unconventional setting, the research aims to contribute valuable insights into the reliability and adaptability of smartphone-based experiments in real-world, dynamic scenarios, providing a nuanced understanding of the technology's applicability beyond controlled laboratory environments.

Method

This research uses an experimental method by carrying out 2 data collections simultaneously. The data is in smartphone sensors using the Phyphox application, and video analysis is done using tracker software. The flow of this research is as in Figure 1.

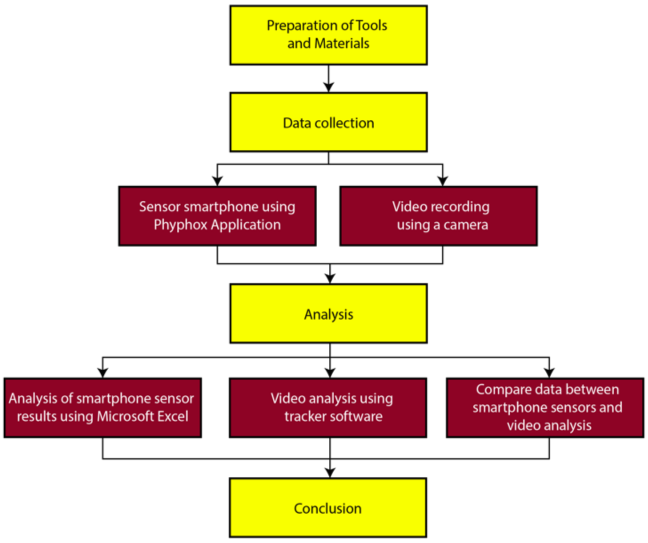

Figure 1. The research flow

In the initial stage, researchers prepared tools and materials to carry out this experiment. To collect data, tools and materials are needed as in Figure 2.

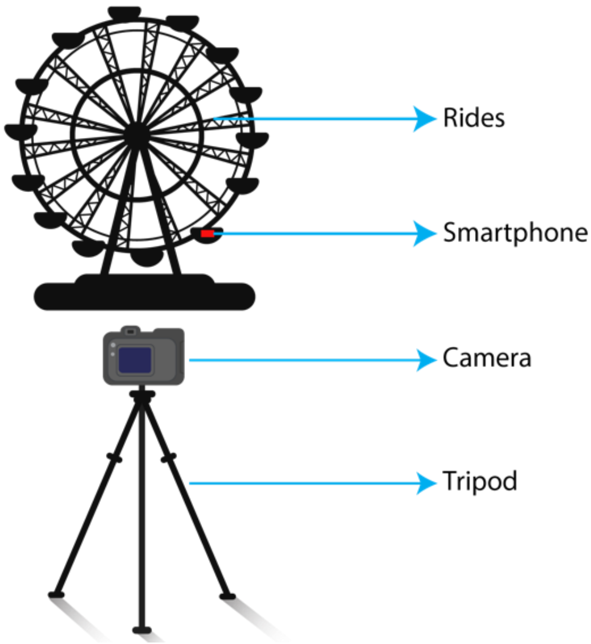

Figure 2. Data collection method

In data collection, the smartphone is placed on the game vehicle, while the camera is placed to capture the entire image of the game vehicle. On smartphones, data is collected using the Phyphox application using accelerometer and gyroscope sensors. Meanwhile, in video analysis, the data obtained is in the form of tracking the movement of objects on tracker software. Analysis of these two data was then carried out using Excel software. The analysis is carried out by comparing graphic images between data from smartphone sensors and data from video analysis trackers. Research design and method should be clearly defined.

Result and Discussion

Six rides at the Traveling Carnival were researched. The six rides are simple leg swings, bicycle spins, kora-kora vehicle, ferris wheels, mini ferris wheels, and merry-go-rounds, as in Figure 3.

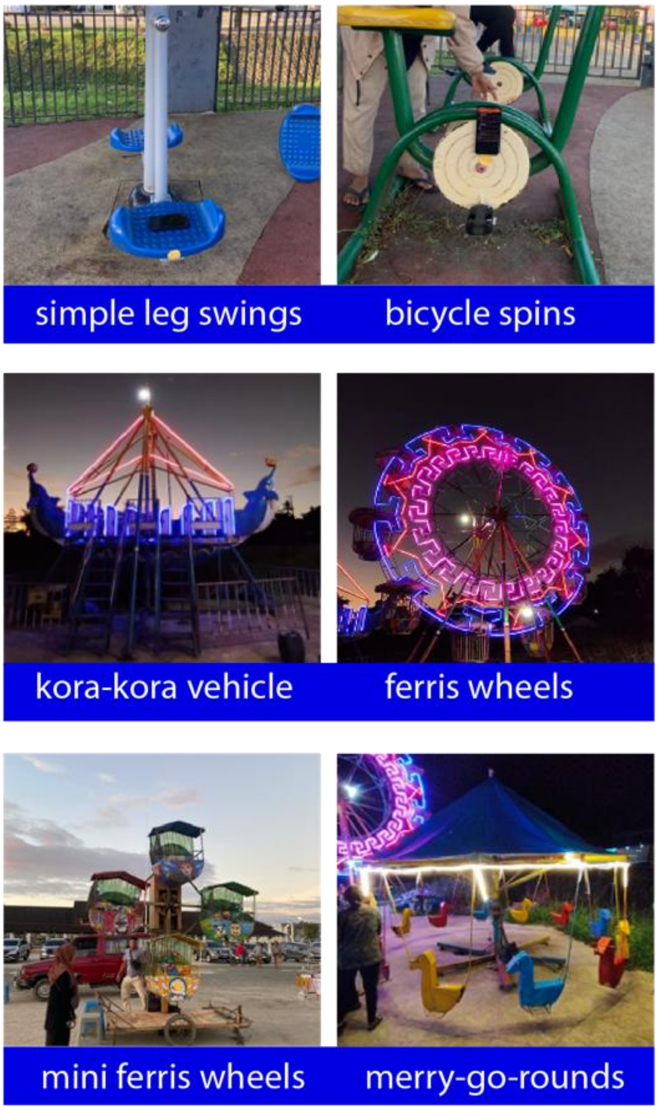

Figure 3. Six rides at the traveling carnival

Simple Leg Swings

In this game, objects move harmoniously manually with the push of the hand. The smartphone is placed on the footrest and measures the swing movement of the foot. Data obtained on gyroscope sensor from smartphone is as in Figure 4.

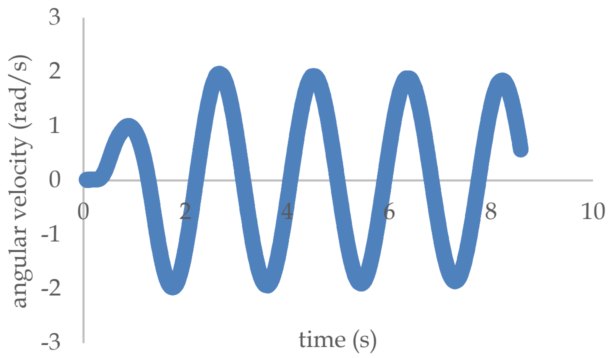

Figure 4. Smartphone sensor data on simple leg swings

Meanwhile, data was obtained in the video tracker analysis as in Figure 5 below.

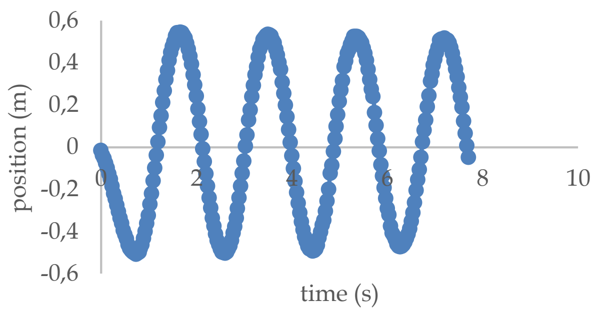

Figure 5. Tracker video analysis data on simple leg swings

Based on the two data above, smartphone sensors can measure physical phenomena in this simple leg swing game. Measurements can be made by calculating the object's oscillation period and the time between peak and peak. The swinging motion follows a sinusoidal pattern, resembling a smooth oscillation, and is defined by key parameters such as amplitude, period, and frequency. As the leg is displaced from its natural position, the restoring force acts proportionally to bring it back, resulting in a periodic and harmonious swinging motion. Simple harmonic motion provides a mathematical framework to understand and describe the rhythmic nature of leg swings and other similar repetitive motions. To calculate the period, it can be done by calculating the number of oscillations (*n*) and the time required (*t*), mathematically formulated:

$$T = \frac{n}{t} \tag{1}$$

Bicycle spins

In this game, the smartphone is placed vertically attached to the bicycle. Data obtained on accelerometer sensor from smartphone is as in Figure 6.

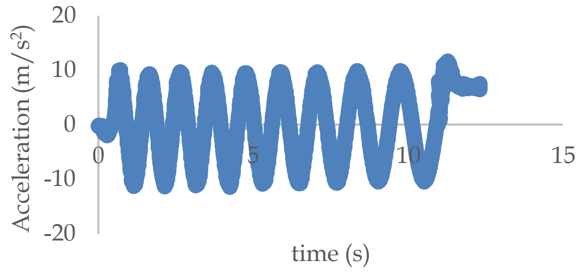

Figure 6. Smartphone sensor data on Bicycle spins

Meanwhile, data was obtained in the video tracker analysis as in Figure 7 below:

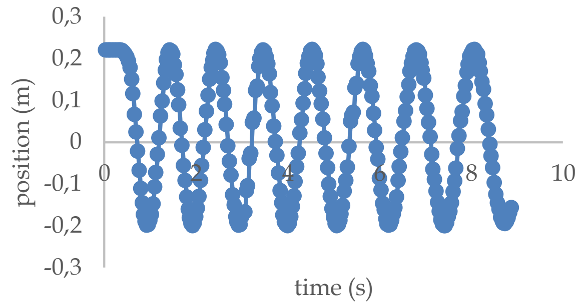

Figure 7. Tracker video analysis data on Bicycle spins

Based on the two data above, smartphone sensors can measure physical phenomena in circular motion, such as centripetal acceleration and angular velocity. The bicycle spin travels along a circular trajectory centered around a fixed point, which is the axis of rotation. Angular velocity (ω) is related to the period (T), which is the time it takes for one complete revolution or cycle of a rotating object. The relationship between angular velocity and period is given by the formula:

$$w = \frac{2p}{T} \tag{2}$$

This formula indicates that the angular velocity is inversely proportional to the period. As the period increases, meaning it takes more time for one complete revolution, the angular velocity decreases, and vice versa. The factor represents the angular displacement per unit time in radians per second, providing a measure of how quickly the rotation occurs.

Centripetal acceleration is related to the period (T), which is the time it takes for one complete revolution of a rotating object, through the following formula:

$$a_c = \frac{4p^2 r}{T^2} \tag{3}$$

This formula indicates that centripetal acceleration is inversely proportional to the square of the period and directly proportional to the radius. As the period increases, meaning it takes more time for one complete revolution, the centripetal acceleration decreases. Conversely, as the radius increases, the centripetal acceleration also increases, reflecting the relationship between these variables in circular motion.

Kora-kora Vehicle

In this game, the smartphone is placed on the passenger seat of the kora-kora, which swings from left to right. Data obtained on accelerometer sensor from smartphone is as in Figure 8.

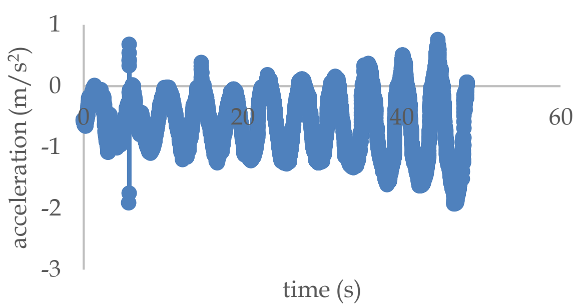

Figure 8. Smartphone sensor data on kora-kora vehicle

Meanwhile, data was obtained in the video tracker analysis as in Figure 9 below:

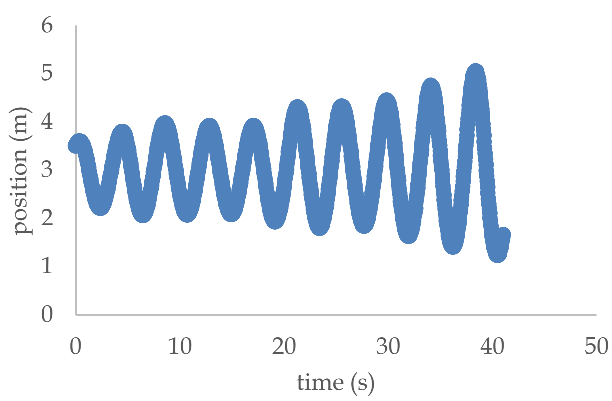

Figure 9. Tracker video analysis data on kora-kora vehicle

Based on the two data above, smartphone sensors can measure physical phenomena in kora-kora vehicle. Measurements can be made by calculating the object's oscillation period and the time between peak and peak. In essence, the kora-kora vehicle's movement follows a pendulum-like swinging motion. A motion repeating within consistent time intervals is termed periodic motion. Furthermore, if a motion occurs regularly and systematically, it is described as harmonic motion (Septyaningrum et al., 2021). The mathematical representation of the pendulum's period and frequency is captured in the following equation:

$$T = 2p\sqrt{\frac{l}{g}} \tag{4}$$

Ferris wheels

In this game, the smartphone is placed on the passenger seat of a rotating Ferris wheel. However, the passenger seat in this Ferris wheel moves unstablely. Data obtained on accelerometer sensor from smartphone is as in Figure 10.

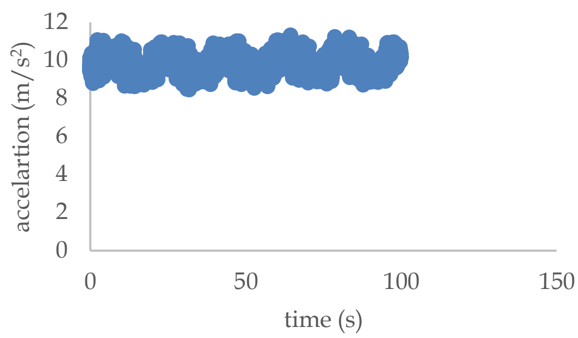

Figure 10. Smartphone sensor data on feris wheels

Meanwhile, data was obtained in the video tracker analysis as in Figure 11 below:

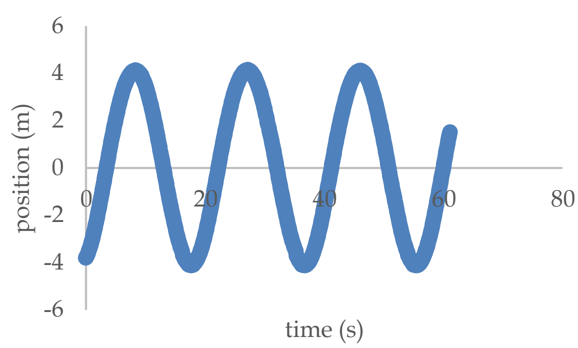

Figure 11. Tracker video analysis data on ferris wheels

Based on the two data above, the smartphone sensor only partially shows the phenomenon of circular motion in the Ferris wheel. This is due to the unstable position of the smartphone while the Ferris wheel is rotating.

Mini Ferris wheels

In this game, the smartphone is placed on the passenger seat of a rotating Ferris wheel. Data obtained on accelerometer sensor from smartphone is as in Figure 12.

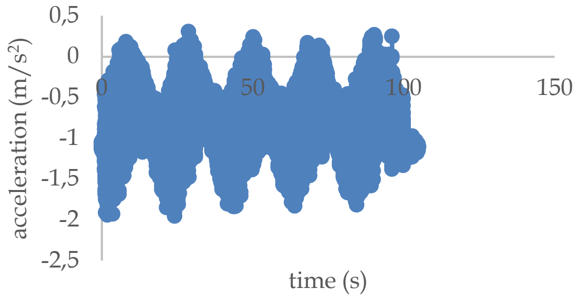

Figure 12. Smartphone sensor data on mini ferris wheels

Meanwhile, data was obtained in the video tracker analysis as in Figure 13 below:

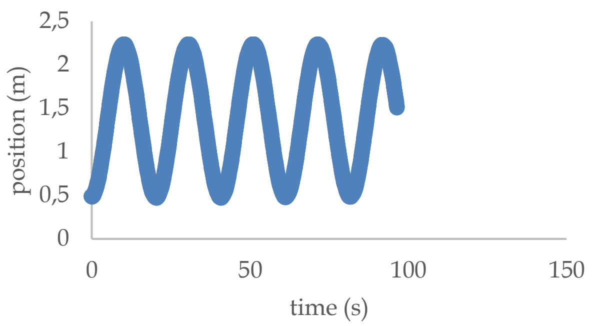

Figure 13. Tracker video analysis data on mini ferris wheels

Based on the two data above, the smartphone sensor only partially shows the phenomenon of circular motion in the mini ferris wheel. This is due to the unstable position of the smartphone while the ferris wheel is rotating.

Merry-go-rounds

In this game, the smartphone is placed on a horse statue that moves in a circle. However, because it is difficult for the camera to take a view from above, this game only takes data from the smartphone. Data obtained on accelerometer & gyroscope sensor from smartphone is as in Figure 14 and 15.

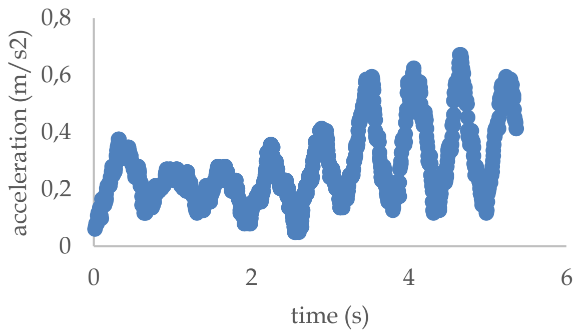

Figure 14. Accelerometer sensor data on Merry-go-rounds

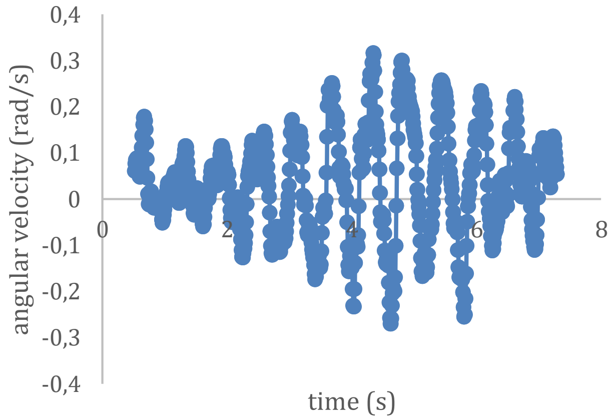

Figure 15. Gyroscope sensor data on Merry-go-rounds

Based on the two data above, smartphone sensors can measure physical phenomena in circular motion, such as centripetal acceleration and angular velocity.

Discussion

Based on the data obtained, smartphone sensors can be used on rides at traveling carnivals. The smartphone sensor worked well on simple leg swings, bicycle spins, kora-kora vehicles, and merry-go-rounds. However, on Ferris wheels and mini Ferris wheels, the sensors work less well due to the instability of the passenger seats on these rides.

Some physics theories can be taken from several rides at traveling carnivals. In simple leg swings, the motion follows a simple harmonic pattern. The sensors can accurately capture this rhythmic back-and-forth movement as it involves a predictable and regular oscillation. Similar to leg swings, bicycle spins exhibit circular motion. The sensors can effectively measure the acceleration and changes in orientation associated with the circular path of the spinning bicycle. The kora-kora vehicle's swinging motion involves a pendulum-like movement. The sensors work well here, capturing the periodic and harmonic nature of the ride. Merry-go-rounds involve circular motion as well, with the sensors able to detect the rotation and acceleration associated with the horses moving in a circular path.

The challenge arises in Ferris wheels due to the less predictable nature of the passenger seats. The physics involved here includes a combination of rotational and translational motion, but the instability of the seats introduces a level of unpredictability that makes sensor measurements less reliable. The motion might be more complex and less harmonic, leading to difficulties in accurate sensor readings.

In summary, the effectiveness of smartphone sensors depends on the type of motion exhibited by the carnival ride. Simple and predictable motions, such as those in leg swings, bicycle spins, kora-kora vehicles, and merry-go-rounds, allow the sensors to work well.

However, the less stable and more unpredictable nature of Ferris wheels poses challenges for accurate sensor readings. The results of this research also support previous research from (Monteiro et al., 2014) who conducted research on smartphone sensors on merry-go-rounds. This research also answers research from (Vieyra & Vieyra, 2014) , which revealed that data produced by smartphone sensors could be graphed to help create force diagrams to help students explain their physical sensations while traveling. Further research can be carried out by calculating the values of physical quantities produced by smartphone sensor.

Conclusion

Smartphone sensors prove effective in capturing motion data on various carnival rides with predictable and rhythmic movements such as simple leg swings, bicycle spins, kora-kora vehicles, and merry-go-rounds. However, challenges arise in rides with less predictable and more complex motions, as observed in Ferris wheels and mini Ferris wheels. The instability of passenger seats on these rides hinders the sensors' accuracy, highlighting the importance of considering ride dynamics and stability for reliable data acquisition.

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Author Contributions

Conceptualization, E.P.R.; Data Collection, R.S.L., C.M.L., S.M.; Data analysis, E.P.R., M.I.; writing and editing; E.P.R., M.I. All authors had real contributions in completing this manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

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