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Development of distance measurement accuracy technology in physical activity tracking applications with a reward point system

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Abstract

In the digital era, physical activity tracking applications have become increasingly popular as tools to monitor body health and encourage healthy habits. However, the accuracy of distance measurements used by many of these applications still faces challenges, especially in environments with GPS signal interference. This research aims to develop a system that integrates GPS technology and accelerometer sensors to improve the accuracy of distance measurements in physical activity tracking applications. The developed system was tested through a prototype to evaluate the effectiveness of combining these two technologies in improving measurement results. Additionally, this research also designs a database system for efficient physical activity data management, enabling real-time monitoring. To enhance user motivation, a reward point system was applied as a gamification element to encourage further engagement in physical activities. The results of this research show that the combined use of GPS and accelerometers was able to improve measurement accuracy, with errors ranging from 2.4% to 4.2%, depending on the type of activity performed. Walking activities demonstrated higher accuracy compared to running. The reward point system was also proven to be effective in motivating users to be more active. This research provides an important contribution to the development of more accurate, efficient health applications that can improve both physical and mental well-being.

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Introduction

Regular physical activity has a significant impact on both physical and mental health. The World Health Organization (WHO) recommends that every adult individual engage in at least 150 minutes of moderate physical activity or 75 minutes of intense physical activity each week to maintain heart health, reduce the risk of obesity, and prevent other chronic diseases (Bull et al., 2020). Although there is an increasing awareness of the importance of physical activity, in reality, many individuals still struggle to maintain this habit. One of the solutions that has rapidly developed in recent years is the use of applications for tracking and monitoring physical activity (Kirwan et al., 2013). Such applications not only allow users to track their physical activities but also offer incentives through features like the reward point system, which is aimed at enhancing motivation (Ahn et al., 2019).

The inaccuracy of distance measurement is considered a crucial factor that significantly affects user trust over time. Initially, minor discrepancies may be tolerated, but if inaccuracies are consistently encountered such as distances being recorded shorter than the actual ones the application may be perceived as unreliable. Such a perception may result in decreased motivation, especially among users whose fitness goals are based on the provided data. Inaccurate results can lead to frustration, as users' efforts are not proportionally reflected. Therefore, accuracy is regarded as essential for maintaining user trust and determining the long-term success of the application (Kirwan et al., 2013).

However, despite the availability of many health applications, the main challenge that is still faced is the accuracy of distance measurements, which can affect the results of physical activity tracking. The Global Positioning System (GPS) is the primary technology used in such applications, but the accuracy of GPS can be greatly disrupted by factors such as tall buildings, trees, and bad weather, which result in distance measurement errors (Jafargholi & Fleury, 2024). Several other studies have shown that under certain conditions, GPS accuracy can decrease due to other factors, which can certainly disadvantage users who rely on this data to monitor their progress (Merry & Bettinger, 2019). In response to this issue, many studies have attempted to integrate other technologies, such as accelerometers, to improve the accuracy of distance measurements (Altini et al., 2017). Accelerometer sensors are able to detect body movements and measure the user's acceleration, thereby contributing to more accurate distance measurements, especially when the user moves in an irregular manner (Rakestraw et al., 2023).

However, despite the development of various technologies to improve distance measurement accuracy, the next challenge is how to integrate these technologies into applications that can be easily used by everyday users. More accurate measurement technologies, although essential for optimal results, still require further development to be efficiently implemented on mobile devices that are frequently used by users. Although GPS is quite effective in providing location estimates, its accuracy can be disrupted by the external factors mentioned earlier (Merry & Bettinger, 2019) To address this, several studies have attempted to combine GPS with accelerometer sensors to improve measurement accuracy, especially in situations where GPS cannot provide adequate results. For example, a study by (Santos et al., 2017) The integration of GPS-based location tracking technology and motion sensors (such as magnetometers and accelerometers) with vision-based tracking has been explored. This solution aims to identify locations more accurately and avoid incorrect markers. However, despite the fact that the use of additional sensors can improve accuracy, a greater technical challenge lies in how to efficiently integrate these two technologies into a mobile application that can be used by users in a simple and intuitive way. Several previous studies, such as those conducted by (Ó Breasail et al., 2021), It has been shown that although the integration of sensor technologies can provide better results, combining data from various sensor sources requires more complex algorithms and adequate data processing, which have not yet been fully optimized for mobile devices with limited computational power.

In addition to the technical issues related to distance measurement, physical activity tracking applications also face challenges in maintaining user engagement. Many users stop using fitness applications after a while because they lose motivation or do not feel significant progress. To address this, many health applications use a reward point system to maintain user engagement by providing incentives in the form of points or rewards based on the physical activities performed (Wiryaputra et al., 2016). Research by (Nurmanditya et al., 2023) has shown that gamification, including the use of reward points, can increase user participation by creating elements of competition or achievement that are more enjoyable. In their study, the reward system successfully motivated users to be more consistent in reaching their fitness targets. Furthermore, the reward system implemented in the application can also provide rewards in the form of achievements or recognition, making users feel more valued and encouraged to continue their healthy habits. However, in the context of this research, the primary focus is not only on the implementation of the reward point system but rather on the early development stage of accurate distance measurement technology. With a more accurate measurement system, users will receive more reliable data, which can motivate them to remain active, ultimately improving their overall experience with the application.

This research aims to develop a system that can improve the accuracy of distance measurement in physical activity tracking applications by integrating GPS technology and accelerometer sensors. The developed system will be tested in the form of a prototype to evaluate the extent to which this combination of technologies can improve distance measurement accuracy and encourage users to be more actively engaged in physical activities. More measurable and well-documented physical activities can contribute to the improvement of users' physical literacy, which, as revealed in previous studies, can positively affect their mental health (Nurjanah et al., 2025).

In addition, this research will also develop and integrate an efficient database system to store and manage users' physical activity data. This database allows for real-time data analysis and monitoring of user progress over time, which can provide additional motivation for users to increase their physical activity. The use of a structured database system also ensures data security and integrity, which is crucial in the management of health applications. With a more accurate system integrated with a reward feature, this application is expected to enhance user motivation to exercise, which in turn can positively impact their mental health, in line with the concept of physical literacy that has been shown to improve mental well-being. The results of this research are expected to provide a more accurate technical solution for future health applications, particularly in supporting sustainable physical activities and improving users' overall mental health.

Method

This research aims to develop and evaluate a more accurate distance measurement system for physical activity tracking applications using GPS technology and accelerometer sensors by developing a modified version of Google's Application Programming Interface (API) (Tran et al., 2022). An accelerometer is a sensor that measures acceleration or movement in three dimensions (x, y, z) and is used to detect body movement, such as foot steps when walking or running (Riaboff et al., 2022). This system is designed to help users track the distance traveled more accurately, both while walking and running. Several previous studies have shown that GPS alone is not always accurate enough in providing reliable data, especially in environments with obstacles, such as urban areas or inside buildings (Jafargholi & Fleury, 2024; Merry & Bettinger, 2019). Therefore, this research combines these two technologies to improve measurement accuracy.

The appropriate method for research focused on the development of a distance measurement system using GPS and accelerometer sensors, as well as the implementation of a reward point system, is the experimental quantitative approach (Wiley et al., 2024). The experimental quantitative approach is used to test the cause-and-effect relationships between the variables being studied, in this case, the accuracy of distance measurements, the use of a combination of GPS and accelerometer sensors, and the impact of the reward point system on user engagement in physical activities. Thus, the proposed method in this research is described as follows:

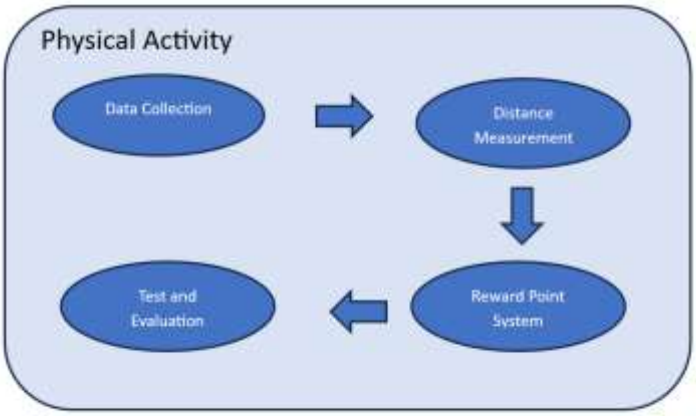

Figure 1. Proposed Method for Physical Activity Monitoring and Reward System

In Figure 1, the research is conducted by collecting data from participants who engage in physical activities, such as walking and running. This is in line with a similar research model previously used by (Henriksen et al., 2021). In this study, subjects within a specific age range and with homogeneous physical conditions were selected, namely individuals in the productive age category with similar levels of daily physical activity. Additionally, gender distribution was balanced to ensure that the results were not influenced by physiological differences that could affect movement patterns or sensor responses. Through this approach, individual variables that could potentially affect the accuracy of measurement—such as stride differences or movement intensity—were minimized, so that the data obtained would be more valid and representative of the system's effectiveness being tested.

Participants use the developed application, which is installed on their mobile devices, to record physical activity data, including distance, steps, and calories burned. Each physical activity performed by the participants is recorded using GPS to determine geographic location and accelerometers to count the number of steps taken (Radilla et al., 2020). In the research to be conducted, the application is developed to track the route traveled by the user in the form of a map that illustrates the path taken, as shown in the simulation example in Figure 2 below:

Figure 2. Simulation of Physical Activity Routes Taken by Users

The simulation in Figure 2 illustrates that the outlined route will be used to evaluate the accuracy of distance measurements generated by the system. This research procedure is conducted in stages, starting with the preparation stage of the application and devices used. Testing will be conducted by performing physical activity sessions involving walking and running in various locations. Each activity will be recorded in the form of GPS and accelerometer data. Activities performed by the participants will be monitored in real-time within the developed application, and the collected data will be extracted for further analysis (Kimm & Flynn, 2022).

Subsequently, the application will provide complete information about the user's activity, including the distance traveled, duration, steps counted, calories burned, and reward points earned. This information is based on an API that has been developed by integrating various services and device sensors to improve the accuracy of physical activity tracking. This API utilizes data from GPS, accelerometers, and other sensors (such as gyroscopes and magnetometers) to track location, calculate distance, and estimate speed in real-time during walking or running activities. When GPS experiences interference or drift, the API relies on the accelerometer to fill in the data gaps by counting the user's steps, ensuring tracking remains accurate even when GPS signals are suboptimal (Md Abdul Althaf et al., 2022).

In addition, this API also handles essential functions such as background status management on smartphones, where the application can continue running even if the user opens another app or the phone screen is turned off, as well as error handling, which sends notifications if there is an error in location data retrieval or when the activity is temporarily paused (Merry & Bettinger, 2019). With this API, the application can provide a more stable, responsive, and accurate experience to users in tracking their physical activities. To measure the accuracy of distance measurement, the data collected from GPS and accelerometers will be compared to the actual distance, which is measured using a more accurate measuring tool as a reference. This comparison allows researchers to calculate the error rate in the measurements. The formula for calculating the distance measurement error can be written as follows (Setiadi et al., 2023):

$$\boldsymbol{E} = \frac{|D_{GPS} - D_{Ref}|}{D_{Ref}} \; \boldsymbol{x}\ \mathbf{100} \quad \text{.......} \quad (1)$$

Where:

- $\boldsymbol{E}$ = Measurement error in percentage.
- $\boldsymbol{D_{GPS}}$ = Distance recorded by GPS.
- $\boldsymbol{D_{Ref}}$ = Distance measured with the reference measuring tool.

Additionally, the collected data is analyzed using statistical analysis to measure whether the use of a combination of GPS and accelerometer can result in more accurate measurements compared to the use of GPS alone. For example, research by (Tran et al., 2022) It has been shown that the use of an accelerometer alongside GPS can improve measurement accuracy in complex field conditions.

In addition to distance measurement, this research also integrates a reward point system to motivate users to be more actively engaged in physical activities. Each activity performed by users will collect points that can be exchanged as motivation for the users. This reward point system is aimed at increasing user engagement and encouraging them to continue exercising. This system is adapted from the concept of gamification, which has been proven effective in enhancing user motivation to achieve their health goals (Noori et al., 2024). Each time a user completes a physical activity, points will be awarded based on certain criteria, such as distance traveled, activity duration, or calories burned. Below is a simple formula for calculating the points awarded based on the distance traveled (Yancheng et al., 2023):

$$P = \left(\frac{D}{10}\right) X\ 2 \quad (2)$$

Where:

- P = Points awarded.
- D = Distance traveled (in meters).

With this system, it is hoped that users will feel more motivated to continue participating in physical activities. This process is simulated as shown in Figure 3 below:

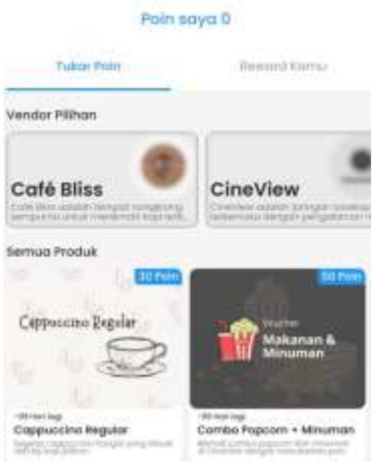

Figure 2. Design of the appearance of the Point Exchange System in the Application

The measurement results will be tested by comparing the distance recorded by the system with the reference distance. For further evaluation, statistical analysis will be performed using t-tests or regression to identify whether there are significant differences in measurement accuracy between the use of GPS and accelerometer based on the developed API. The accuracy of physical activity measurements can be calculated using the Measurement Accuracy formula, which is the comparison between the distance recorded by the application and the actual distance. The recorded distance refers to the measurement results that will be obtained from the application. Meanwhile, the actual distance is the distance measured manually or with a more accurate reference tool, which provides the basis for comparison. The Measurement Accuracy formula is calculated using the following formula (Al-Khowarizmi et al., 2023):

$$Measurement\ Accuracy\ (\%) = \left(\frac{Distance\ Recorded\ (km)}{Actual\ Distance\ (km)}\right) x\ 100 \quad (3)$$

Where:

- $Distance\ Recorded\ (km)$ = Distance recorded by the application (based on GPS and accelerometer data).
- $Actual\ Distance\ (km)$ = The actual distance, which can be measured manually or with a more accurate reference tool.

Based on this formula, it is expected that the results will provide an overview of how accurately the application records the actual distance traveled by the user during physical activity. High accuracy indicates that the application is able to record the distance precisely, while lower values indicate a deviation between the application's measurement and the actual distance. With this measurement plan, it is hoped that measurement errors, which are common in applications that rely solely on GPS, can be reduced.

Evaluation is conducted by considering different environmental conditions, such as testing outdoors (e.g., on roads or in parks) and indoors (e.g., in office buildings), to assess the impact of GPS signal interference on measurement accuracy (Merry & Bettinger, 2019). The data obtained will be processed using analysis software and compared with accurate reference data to determine measurement errors. The results will be evaluated to measure whether the use of GPS and accelerometer technology can provide accurate results. Additionally, the reward point system in the application will also be evaluated to assess its impact on motivation and user participation levels in physical activities.

Results and Discussion

Before discussing the measurement results obtained from the field experiment, it is important to provide an overview of the accuracy evaluation of physical activity measurements that has been conducted. The results to be displayed include distance measurements, total steps, duration, calories burned, reward points, and the measurement accuracy level for various types of physical activities, such as running and walking. This data is obtained through monitoring using GPS and accelerometer technologies, aimed at evaluating how accurately these technologies record physical activity data, as well as assessing the potential improvement in measurement accuracy when both technologies are combined. In Table 1, these results will be analyzed to provide a deeper understanding of the accuracy and validity of the data obtained in the context of this research.

Table 1. Physical Activity Measurement Results and Evaluation of Measurement Accuracy

No	Activity	Distance (km)	Step (Total)	Duration (Minute)	Calories Burned (kal)	Reward Points	Measurement Accuracy (%)
1	Running	1.1	1131	12:00:00	12	3	97,6
2	Running	0.4	428	09:28:00	4	0	96,4
3	Running	0.2	161	31:07:00	4	1	95,8
4	Walking	1.4	1883	31:00:00	26	6	97,6
5	Walking	1.0	1365	17:00:00	11	2	96,4
6	Walking	2.1	2854	30:10:00	45	11	96,4
7	Walking	2.0	2705	42:09:00	50	12	96,7
8	Walking	1.4	1926	30:30:00	27	7	97,6
9	Walking	2.1	2854	30:10:00	45	11	96,7
10	Walking	2.2	2967	43:08:00	59	15	96,4
11	Walking	1.0	1365	16:34:00	11	2	96,4
12	Walking	1.1	1131	11:35:00	12	3	97,6
13	Walking	3.1	4246	33:09:00	62	15	96,4
14	Walking	3.3	4460	37:23:00	73	18	96,3

Based on the testing results presented in Table 1, the developed application shows a relatively high measurement accuracy in recording physical activities, with Measurement Accuracy ranging from 95.8% to 97.7% for various types of activities. In general, the Running activity shows a slight decrease in accuracy compared to Walking. For example, in the Running 0.2 km activity, the accuracy recorded was only 95.8%, which is slightly lower than the Walking activities, most of which have accuracy above 96%. This may be influenced by the higher movement speed during running, which could cause the GPS signal to be more easily distorted or interrupted, thus affecting the accuracy of the distance measurement. Conversely, the Walking activity shows more stable accuracy, with some measurements, such as Walking 2.0 km (96.7%) and Walking 3.3 km (96.3%), indicating that the application is more effective in tracking distance at slower speeds, where GPS and accelerometer sensor data can be integrated more accurately. Furthermore, the longer duration in walking activities, such as Walking 2.2 km (43:08:00), also shows fairly good accuracy (96.4%), indicating that the application is able to maintain accuracy even in longer distance measurements. The use of accelerometers in this application works well to support measurement accuracy, especially when GPS experiences interference, either due to environmental conditions or faster user movement. Additionally, the Reward Points system implemented in the application not only motivates users to be more active but also increases their participation levels in physical activities, potentially generating more data that can be analyzed to further improve accuracy.

Discussion

In this discussion, the testing results show that the developed application successfully provides accurate measurements in tracking physical activities, with Measurement Accuracy exceeding 95% for most of the tests, especially in walking activities. Higher accuracy was recorded in activities with slower speeds, such as walking, which allows the combination of GPS and accelerometer to track movement more effectively. These results align with research by (Ó Breasail et al., 2021) Which shows that the use of dual sensor technology, namely GPS and accelerometer, can improve the accuracy of physical activity tracking, especially in conditions where GPS signals are interfered with. Conversely, in running activities, which involve faster movement, the application experiences a slight decrease in accuracy, as seen in the Running 0.2 km measurement, which only reached 95.8%. This is consistent with the findings of (Yi et al., 2024) Which indicates that environmental conditions and speed can cause measurement errors in GPS-based tracking systems, especially in conditions with signal interference.

The use of the accelerometer in the application has been proven effective in filling data gaps caused by GPS limitations, as the integration of motion sensors can reduce the negative effects of GPS interference on physical activity tracking. Additionally, the Reward Points system implemented in this application has successfully increased user motivation, which aligns with previous research showing that gamification in fitness applications can enhance user engagement and encourage them to be more active (Ahn et al., 2019). Overall, these results show that the combination of the right sensor technologies and gamification elements can produce a physical activity tracking application that is not only accurate but also capable of increasing user motivation and participation in exercise.

Conclusion

The conclusion of this research shows that the developed physical activity tracking application has the ability to provide accurate measurements with high Measurement Accuracy, particularly in walking activities, supported by the use of a combination of GPS and accelerometer technologies. This application performs better in activities with slower speeds, such as walking, where the integration of motion sensors and GPS successfully minimizes measurement errors. Although there is a decrease in accuracy during running activities, the application still provides satisfactory results. The findings of this research can provide more accurate technical solutions for future health applications, particularly in physical activity tracking. This combined technology, utilizing both sensors to improve accuracy through API development, offers great potential for more advanced and reliable health applications. Furthermore, the Reward Points system implemented can also enhance user motivation, leading to positive impacts on participation levels in physical activities. In the future, this application can continue to be developed by improving data processing algorithms, machine learning, enhancing tracking accuracy in high-speed activities, and adding gamification elements to further encourage user engagement.

After the system has been implemented, the quality of the application can be improved by enhancing the user interface (UI/UX) to make it more intuitive and engaging. The addition of a personal health reporting feature, which presents users' progress statistics, can also provide deeper insights. Integration with other platforms or devices will expand the functionality of the application. Furthermore, regular algorithm updates can improve accuracy and ensure the application remains relevant.

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