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Performance evaluation of low-cost GPS-data logger module for smart-farm tractor

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Abstract. Nowadays, IoT technologies are now implemented into a smart-farm production. Many sensors were developed and implemented into the agricultural production. GPS is one of the most used sensor even the cost of high accuracy GPS or RTK-GPS is still high. Fortunately, the cost of single unit GPS is significantly decreased. Main objective of this research is to evaluate the precision of the low-cost GPS in the performance perspective in smart farm tractor applications. A low-cost GPS-position tracking and data logger was developed. The evaluation was done by leaving the developed data logger unit stationary in three different circumstance condition; Open field; Under tree canopy and Near building. The result show that the position recorded had standard deviation of precision of 0.57, 0.85 and 2.22 m in longitude-axis and 0.29, 0.64 and 0.91 m in latitude-axis for Open field; Under tree canopy and Near building respectively. The next state of the research is to evaluate the accuracy of the developed GPS-data logger in dynamics operation together with the performance comparison with the commercial GPS data logger. The result shows that the precision level of 0.5 m is still needed to be developed. Otherwise, the integrated sensor technique must be implied.

1. Introduction

Presently, smart farm is one of the most interested research as the requirement of food increasing significantly while the labour force in agricultural section are decreasing. The implementation of agricultural robotics in outdoor environments which is well-known as smart farming can contribute to the ease of farm operation. Together with the IoT technologies are now rapidly developed and resulting in the discount of the cost of sensor for smart-farm tasks.

Lots of researches were done to accomplish smart farm operation. One of the most attracted research and development is robot vehicle for agricultural vehicles.

In the last decade, different navigation systems have been implemented, for example, dead reckoning, machine vision, LIDAR and GPS systems. Each navigation systems have their own strong and weak points. Especially, the systems reliability when implemented with outdoor navigation. Dead-reckoning or path following has a cumulative errors which could be reduced by real-time calculation. Machine vision-based control methods, which has high performance and reliability is for indoor or stationary application, still needs a proper algorithm for the variate light condition and moving application. Researches those use LIDAR or laser range finder sensor to detect the circumstance object in outdoor condition to manage a proper navigation for agricultural tractor were also developed [1-7].



GPS navigation systems have become popular for determining vehicle positions. A number of studies developed the navigation system for agricultural tractor using the GPS as a base sensor [8-12], and not only a tractor, a GPS-based rice transplanter was also developed [13]

Many control methods for the development of the autonomous vehicle were introduced, and combining them into a multi-sensor based control system brings the robustness to the navigation schemes. However, the cost of systems will be higher and cause the untouchable feeling to the small-scale farmer.

The GPS, which was one of the sensors in every autonomous vehicle researches as the position of the vehicle was the important parameter which must be known. Even that the GPS was not used as a main sensor for navigating schemes; it is still need for the navigation performance evaluation of the others-based sensor navigation.

In a few years ago, cost of the high-performances GPS or RTK-GPS which has a millimeter-accuracy (about 2-10 millimeters) still high in untouchable feeling for small-scale agricultural production. Fortunately due to the rapidly development rated of the IoT technologies, sensors price a rapidly reduced. Lots of GPS modules were deployed in commercial scale.

Anyway, these GPS modules accuracy is not quite as high as the RTK-GPS. This come the research idea of this study, main objective is to develop a reliable accurate navigation system using low-cost GPS. In the beginning state of this research, performance evaluation of the low-cost GPS is the first goal.

2. Instrumentation and methods

The main parameters to be evaluated of the low-cost GPS were accuracy and precision of the position data acquired for the GPS-module.

2.1. Instrumentation

Low-cost position data logger was developed base on a microcontroller, Arduino MEGA2560, which was used for the whole process control and calculation. A GPS module and its antenna, GPS Ublox NEO 6M, was the module that collect the position data from the satellites. The logged position data was recorded in to SD card via an SD card module. All three module were connected through a breadboard. Arduino microcontroller and the components were shown in figure 1. Wiring diagram was shown in figure 2.

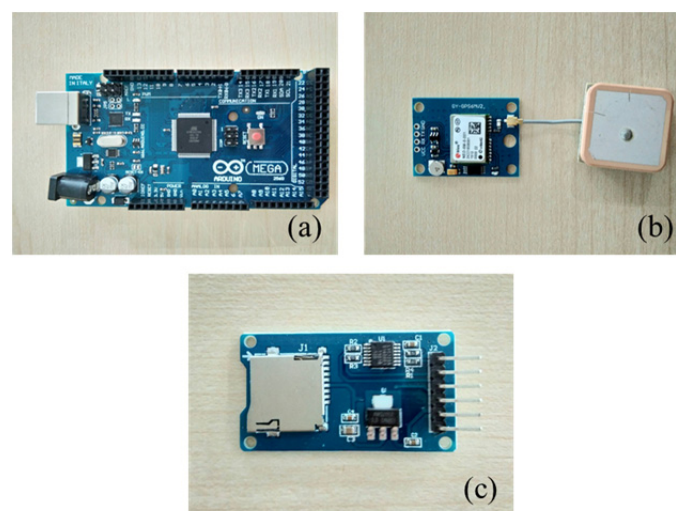


Figure 1. (a) Arduino MEGA2560, (b) GPS Ublox NEO 6M (c) SD card module.

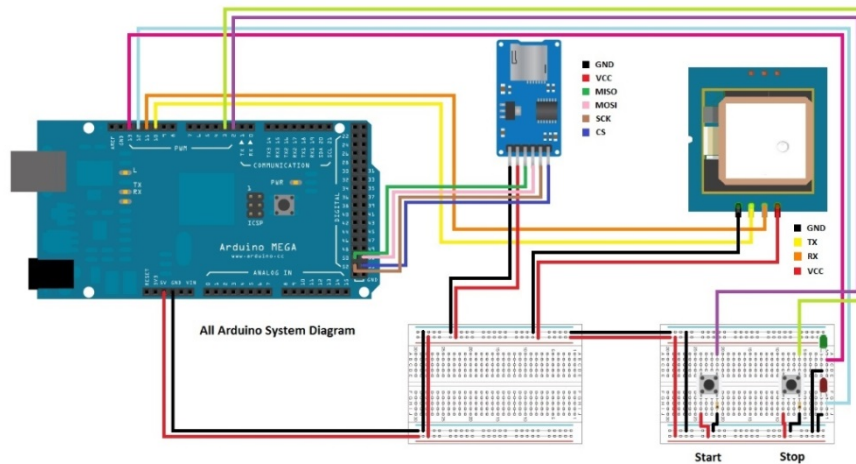


Figure 2. Wiring diagram of the developed data logger.

2.2. Software programming

Principle of the data logger code was designed as follow; at the beginning, the SD card were checked whether it is ready for file writing. Then the position data was collected and record into the SD card. The GPS-data logger sampling rate was set to 2 Hz. Flowchart of the software was shown in figure 3.

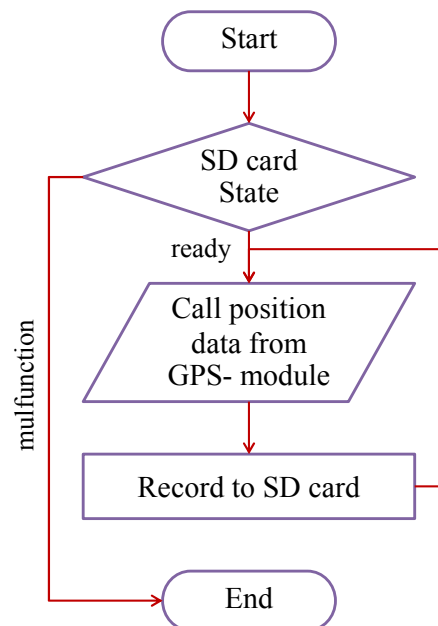


Figure 3. Flowchart of the GPS data logger program.

2.3. Methods

In order to evaluate the accuracy and the precision of the developed low-cost GPS-data logger, the static experiment was designed for this research. Circumstance condition; open field; under trees canopy and near building were set to compare the performance of the developed system.

2.3.1. Static experiments. In static experiments, the GPS-data logger was left on the spot for 5 minutes. The SD card was removed from the SD card module to save the recorded data into PC and reinserted after the data was transferred. Then the GPS-data logger was replaced to the next spot

which was 5 meter approximately away from the previous spot. Five spots were record per each experiment set.

2.3.2. Experimental Sites. Experimental sites were selected to suit the circumstance conditions; open field, the selected was a parking lot near to the evening market in Kasetsart University Kamphaeng Saen campus, as shown in figure 4.



Figure 4. Experimental site for open field condition.

The second site was selected to suit the condition under tree canopy, which was the condition that are the most challenging in using the GPS-based navigation system and this condition is the circumstance condition of horticulture plantation. The site selected was shown in figure 5.

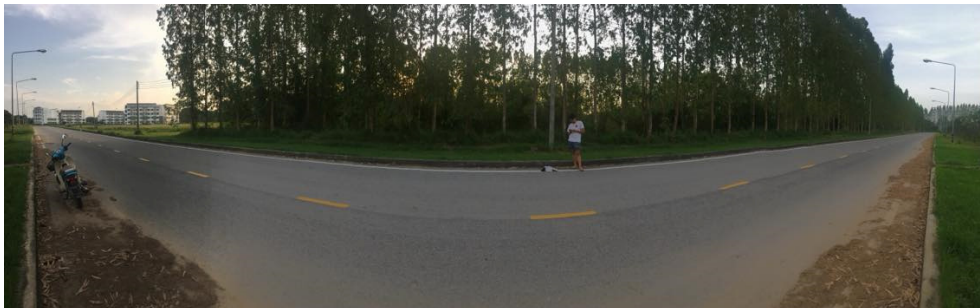


Figure 5. Experimental site for under tree canopy condition.

The third site was selected for the near building condition. This condition was selected for the agricultural field in a city as there are much more small-scale smart farms in a big city. The site selected was shown in figure 6.



Figure 6. Experimental site for near building condition.

2.3.3. Position data calculation. The collected position data were done in WGS84 format (latitude – longitude coordinate), therefore the coordinates were transform into metric for ease of understanding by finding a length of a degree of latitude in meter, Δ_{lat}^1 , and a length of a degree of longitude in meter, Δ_{long}^1 , using these equation [14, 15].

$$\Delta_{lat}^1 = m_1 + m_2 \cos(2\phi) + m_3 \cos(4\phi) \quad (1)$$

$$\Delta_{long}^1 = [\pi a \cos \phi] [180(1 - e^2 \sin^2 \phi)^{1/2}]^{-1} \quad (2)$$

$$e = \frac{a^2 - b^2}{a^2} \quad (3)$$

Where ϕ is the latitude coordinate of the reference position, e is the eccentricity of the earth ellipsoid. In this research the pin-point coordinate of the Faculty of Engineering at Kamphaeng Saen which was used for the calculation are (14.022158°N, 99.972090°E).

m_1 , m_2 , m_3 , a and b are the coefficient as shown in table 1.

Table 1. Coefficient for latitude and longitude conversion.

Coefficient	Value
m_1	111132.954
m_2	-559.822
m_3	1.175
a	6378137.0000
b	6356752.3142

2.3.4. Accuracy and precision evaluation. Accuracy is the parameter that shows how closed the measured value to a true value while precision shows how the measuring instrument measures the same value at every measuring. The concept of accuracy and precision can be described as follow; figure 7.(a) represents a low accuracy and low precision measuring system, (b) represents a high accuracy and high precision system and (c) represents a low accuracy but high precision system.

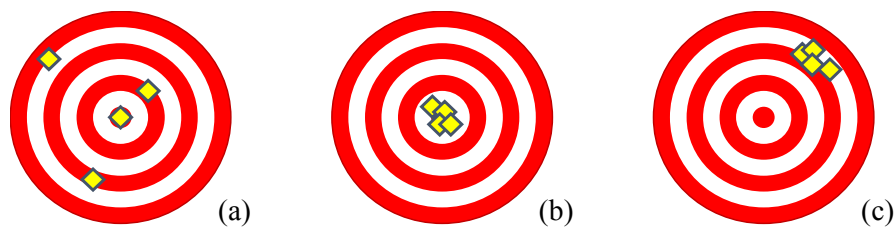


Figure 7. Accuracy and precision concept.

The precision was evaluated by calculating the standard deviation of the collected position data by the GPS-data logger developed. The standard deviation of x-axis coordinate (converted from longitude coordinate) and y-axis coordinate (convert from latitude coordinate) were perform separately.

$$\sigma_x = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}} \quad (4)$$

$$\sigma_y = \sqrt{\frac{\sum (y - \bar{y})^2}{n-1}} \quad (5)$$

3. Results and discussion

In this proceeding, the preliminary result from static test in sunny weather condition at all three experiment sites was reported.

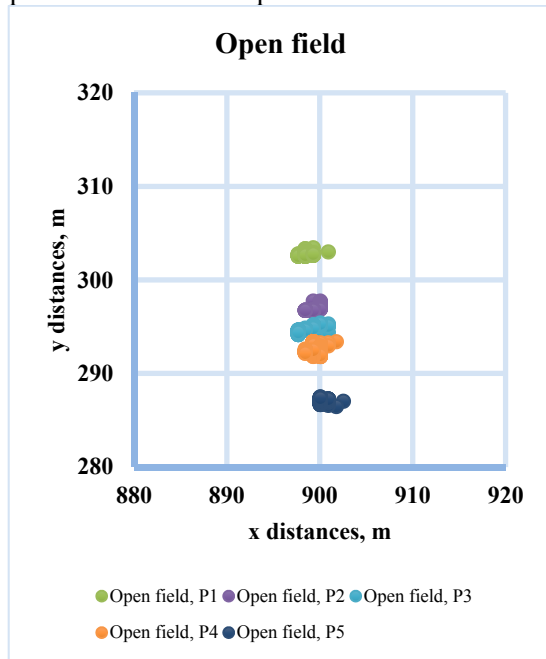


Figure 8. Position data recorded; Open field.

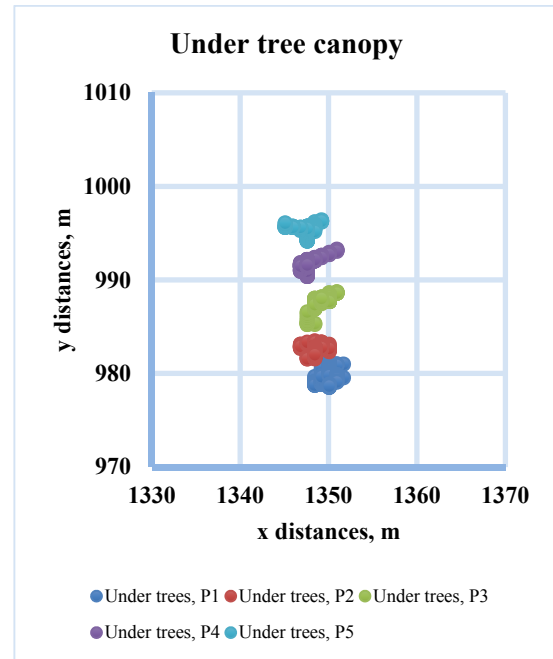


Figure 9. Position data recorded; Under tree canopy.

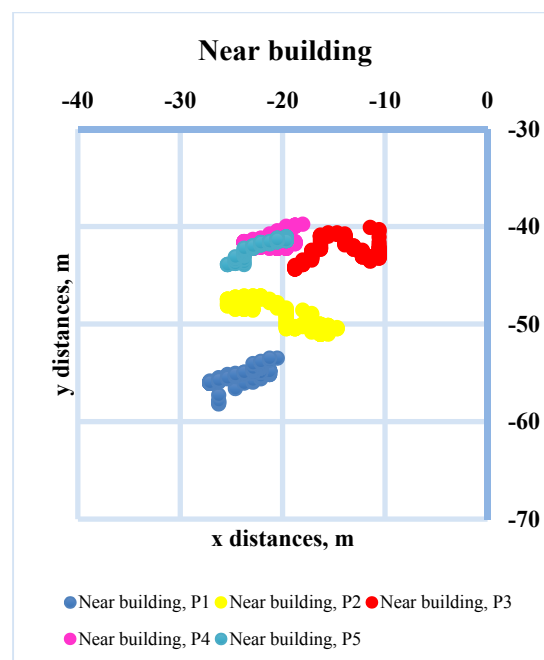


Figure 10. Position data recorded; Near building.

The results show that the circumstance condition is the main cause that affected the precision of the Low-cost GPS-data logger. In the ‘open field’ condition, the position data are not much scatter

compared to the data recorded in ‘under tree canopy’ and ‘near building’ condition. The precision of the developed low-cost GPS-data logger were reported using the standard deviation as shown in table 2.

The next state of the research is to evaluate the accuracy and precision of the developed low-cost GPS-data logger in dynamics mode of operation together with the performance comparison with the commercial model of GPS data logger.

Table 2. Precision of developed low-cost GPS-data logger.

Circumstance Condition	σ_x , m	σ_y , m
Open field	0.57	0.29
Under tree canopy	0.85	0.64
Near building	2.22	0.91

4. Conclusions

The next state of the research is to evaluate the accuracy of the developed low-cost GPS-data logger in dynamics mode of operation together with the performance comparison with the commercial model of GPS data logger.

The result shows that the precision level of 0.5 m is still needed to be developed, especially for the row plantation farm. Otherwise, the integrated sensor technique must be implied.

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