THE STUDY OF LOW-COST ROBOTICS PLATFORM FOR BEIDOU SATELLITES NAVIGATION SYSTEM

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ABSTRACT

In this study, a low-cost robot was designed for satellite navigation to promote learning in robotics and navigation satellite systems. Robot technology has been used more widely, including robots for treating disease and patients and service robots. Agricultural robots make robots play a greater role and satellite system are also used in the navigation system with robots as well. Specifically, the BeiDou satellite system was created, constructed, and tested. The BeiDou satellite system is tailored for low-cost robot applications. It utilizes components that allow for the construction of affordable and functional robotic platforms suitable for navigation using BeiDou satellites. The essential components of the low-cost robot platform for BeiDou navigation include an Arduino Nano Central Processing Unit (CPU), motor drive unit, robot structure, sensors, BeiDou satellite receiver module, and power supply. The researchers tested a robot by runing it over distances of 50 m and 100 m at low, medium, and high speeds at Sports Center King Mongkut's Institute of Technology Ladkrabang (KMITL). Tests have shown that satellite signals passing through the ionosphere cause delays that affect the accuracy of the satellite navigation system. The successfully developed low-cost robot platform for BeiDou navigation is named GNSS low-cost robotic (G-LOC robot).

Keywords: Low-cost robotics, Robotics, Robotics platform, BeiDou, Navigation satellites

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I. INTRODUCTION

Robotics is gaining popularity across various sectors, including industry, education, and robot competitions. In the realm of education, robotics integrates the study, design, construction, operation, and utilization of robots. Robotics is considered to enhance students' interest. Nevertheless, due to the high cost of robots, not all students have the opportunity to access robotics. In engineering and computer science, robotics constitutes an interdisciplinary field of study. It encompasses the examination, design, construction, operation, and utilization of robots. Robotics, coupled with Global Navigation Satellite System (GNSS) satellite applications, serves as a dependable guide and represents a novel approach to exploring natural dynamics, sensing, and navigation. Therefore, the continuous enhancement of the accuracy and reliability of the BeiDou satellite navigation system is crucial. The goal of integrating robotics into the BeiDou satellite navigation system is to create machines capable of aiding and assisting humans. Robotics in BeiDou satellite navigation system can function as a cognitive learning tool in the educational process. Robotics integrates aspects of electrical engineering, including computer engineering, mechanical engineering, and software engineering. The incorporation of robotics can involve students in collaborative problem-solving activities, but the high cost of technology robotics remains a significant challenge. The primary concern is that schools and students may face financial constraints when implementing robotics, and exploring low-cost robotics options could address this issue.

As the literature review, Elfasakhany et al. (2011, pp. 47-55) designed and developed a competitive low-cost robot arm with four degrees of freedom. Junior et al. (2013. pp. 1-7) constructed a low-cost and simple Arduino-based educational robotics kit. They succeeded in the development of educational robotics by using Arduino and applied the robotics in the educational kit. Plaza et al. (2016, pp. 282-289) designed and constructed a collaborative robotic educational tool based on programmable logic and Arduino. Eguchi (2016, pp. 692-699) used RoboCupJunior for promoting STEM education, 21st century skills, and technological advancement through robotics competition. Plaza et al. (2017, pp. 132-136) presented home-made robotic education, a new way to explore. Darrah et al. (2018, pp. 1-4) designed and developed a low-cost open-source robotics education platform which was useful for teachers and students in school on the minimum components in a low-cost robotics. Plaza et al. (2018, pp. 1-8) used Arduino as an educational tool to introduce robotics. Chicas et al. (2019, pp. 379-383) developed STEM competences by building low-cost technology robots. Ong and Ling (2020, pp. 467-473) constructed low-cost educational robotics car to promote STEM learning and 21st century Skills. Moreover, Rajapakshe and Hettiarachchi (2022, pp. 71-76) designed, constructed, and developed a research oriented GPS low-cost robotics platform with a novel dynamic global path planning approach.

In the literature review, Elfasakhany et al. (2011, pp. 47-55) designed and developed a competitive, low-cost robot arm with four degrees of freedom. Junior et al. (2013, pp. 1-7) constructed a low-cost and simple Arduino-based educational robotics kit, successfully applying robotics in the educational context. Plaza et al. (2016, pp. 282-289) designed a collaborative robotic educational tool based on programmable logic and Arduino. Eguchi (2016, pp. 692-699) utilized RoboCupJunior to promote STEM education, 21st century Skills, and technological advancement through robotics competition. Plaza et al. (2017, pp. 132-136) introduced homemade robotic education as a novel exploration method. Darrah et al. (2018, pp. 1-4) developed a low-cost, open-source robotics education platform, beneficial for teachers and students with minimal components in a low-cost robotics setting. Plaza et al. (2018, pp. 1-8) utilized Arduino as an educational tool for introducing robotics. Chicas et al. (2019, pp. 379-383) enhanced STEM competences by building low-cost technology robots. Ong and Ling (2020, pp. 467-473) constructed a low-cost educational robotics car to promote

STEM learning and 21st century Skills. Additionally, Rajapakshe and Hettiarachchi (2022, pp. 71-76) designed, constructed, and developed a research-oriented GPS low-cost robotics platform with a novel dynamic global path planning approach.

This research presents a study on a low-cost robotics platform for BeiDou navigation. The robotics platform primarily comprises an Arduino Nano Central Processing Unit (CPU), motor, wheel, motor drive, robotic body, tracker, BeiDou navigation sensors, and power supply. The study demonstrates the creation of a low-cost robotics platform specifically designed for BeiDou navigation, focusing on applications of low-cost robotics and the minimal components required building cost-effective robotics that can be explored.

II. METHODOLOGY

A. Platform Design

The methodology of study, the low-cost robotics platform was designed using a simple Arduino-based educational robotics kit, as indicated in Table 1. The low-cost robotics platform is referred to as G-LOC ROBOT, derived from the words "GNSS low-cost robotic". Table 1 illustrates the minimum components needed to construct a low-cost robotics platform, including CPU (Arduino Nano), motor, wheel, motor drive, robotic body, BeiDou navigation and tracking, power supply, and additional items such as nuts, switches, light bulbs, and wiring. The overall cost is notably low, amounting to only 8,150 Baht.

TABLE 1 Minimum price components to build a low-cost robot.

Components	G-LOC ROBOT	Cost (Baht)
CPU	Arduino Nano	220
Motor X 4 pcs	12 VDC 150 rpm	2,200
Wheel X 4 pcs	Wheel for car racing 3.5 inches	1,000
Motor drive X 2 pcs	H-bridge 12V 40A	1,500
Robotic body	Acrylic laser cut	800
Tracker sensor X 8 pcs	IR infared sensors	560
BeiDou navigation sensors	NEO6MV2 GPS & BeiDou module	120
Power supply X 2 pcs	Li-Po battery 11.1V 1800mAh	550
Others	Nut, Switch, Light bulb, and wiring	1,200
	Total	8,150

B. Platform Construction

The researchers designed the low-cost robotics platform for BeiDou navigation using the block diagram depicted in Figure 1. The components comprise an Arduino Nano as the CPU for digital and analog input/output, two 12 DCV motors, four 3.5-inch wheels, a motor drive, an acrylic laser-cut robotic body, infrared sensors as trackers, a BeiDou navigation receiver, an 11.1V 1800mAh Li-po battery for power supply, and additional items such as nuts, switches, light bulbs, and wiring. The G-LOC ROBOT was assembled with the minimum components to explore low-cost robotics, as the objective of this study, illustrated in Figure 2.

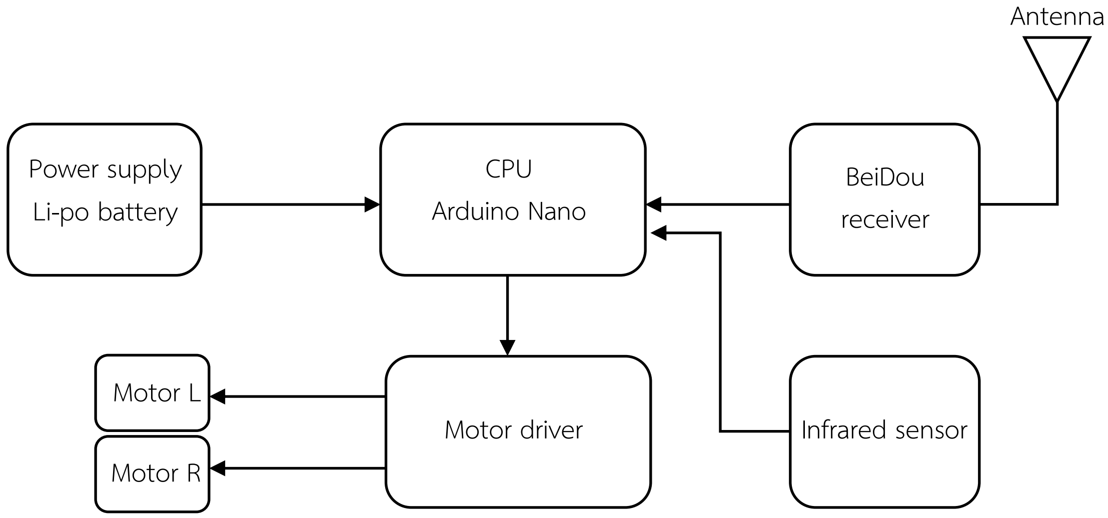

Figure 1 Block diagram of low-cost robotics platform with BeiDou navigation.

The G-LOC ROBOT was constructed with the minimum components to facilitate exploration of low-cost robotics, as depicted in Figure 2.

Figure 2 G-LOC ROBOT.

C. Platform Experiment Location

The experimental location for the G-LOC ROBOT platform for BeiDou navigation is at the soccer field, King Mongkut's Institute of Technology Ladkrabang (KMITL). There are three marked points with the same longitude 100.77177°E, for starting point with latitude 13.72976°N, 50 m point with latitude 13.73017°N, and 100 m point with latitude 13.73071°N, as shown in Figure 3.

Figure 3 The location experiments for G-LOC ROBOT.

D. Data Collection

In terms of the quality of BeiDou satellite signals, it is closely tied to the state of Earth's ionosphere propagation. The ionosphere serves as an intermediary, influencing the spread and slowing down the propagation of the signal. These changes are contingent on the ionosphere plasma density and its correlation with the sun's phase. Disruptions in the ionosphere have a direct impact on BeiDou satellites, leading to a reduction in accuracy and confidence in positioning results. Regarding ionosphere-based data collection, Reddybattula et al. (2019, p. 283) have highlighted on the positive ionospheric storms are associated with an enhancement in electron density caused by thermospheric winds, compositional changes, or the transport of ionization or electric field changes, whereas the negative storms are primarily due to compositional changes of the ionosphere (Nayak et al., 2016, pp. 7941-79601; Serafimov et al., 1982, pp. 397-399). Consequently, the data collection is segmented into four time periods: sunrise, noon, sunset, and midnight, with the G-LOC ROBOT operating at low, medium, and high speeds. The data was collected on the dates of March 29th-30th, 2023.

E. Data Analysis

BeiDou satellite signals quality is related to the state of the sun and the ionosphere propagation. The researchers make the data analysis on BeiDou navigation with the phase of the sun including sunrise, noon, sunset, and midnight. The times for data analysis are at 06.00 for sunrise time, 12.00 for noon time, 18.00 for sunset time, and 00.00 for midnight time. In addition, ionosphere is disturbed, it affects to BeiDou satellites and reduces the accuracy. Then, the researchers analyzed the BeiDou navigation with three speeds including low speed with 0.5 m/s, medium speed with 0.7 m/s, and high speed with 1 m/s.

III. RESUTLS

As indicated in Table 2, the G-LOC ROBOT during the midnight phase exhibits negative error values at both 50 m and 100 m stop points, recording -340 cm and -320 cm, respectively. During the pre-sunrise period, the low speed configuration displays the most negative value, reaching -550 cm at the 100 m stop point. At noon, the high-speed setting registers the highest value, amounting to 260 cm at both 50 m and 100 m stop points. Post-sunset times show negative error values at a 100 M distance error of -350cm for the G-LOC ROBOT. The overall trends and characteristics of errors are outlined in the presented data.

TABLE 2 The results on the experiment of low-cost robotics platform for BeiDou satellites system navigation.

Distance error (cm) Speed Time of robot test		BeiDou satellites system					
		Midnight time 00.00 (LT)	Sunrise time 06.00 (LT)	Noon time 12.00 (LT)	Sunset time 18.00(LT)	Mean	SD
Roadway	Speed level						
50 m	Low	-170	**-350**	0	**-140**	-165	143.87
	Middle	**-340**	-280	200	-110	-132.5	242.13
	High	-220	-290	**260**	-120	-92.5	245.14
	Mean	-243.33	-306.67	153.33	-123.33		
	SD.	87.37	37.86	136.14	15.28		
100 m	Low	**-320**	**-550**	200	**-350**	-255	320.05
	Middle	-140	-400	170	-240	-152.5	240.19
	High	-270	-220	**260**	-120	-87.5	239.91
	Mean	-243.33	-390.00	210.00	-236.67		
	SD.	92.92	165.23	45.83	115.04		

Table 2 shows the test results of the low-cost robot navigation by BeiDou satellites system. Test runs of 50 m and 100 m at low speed, medium speed and high speed. Perform experiments at midnight. Sunrise time, noon Sunset. The result is the distance at which the robot cannot stop in a specified position each time.

The graph of the BeiDou low-cost robotic platform satellite at a distance of 50 m as shown in **Figure 4.**

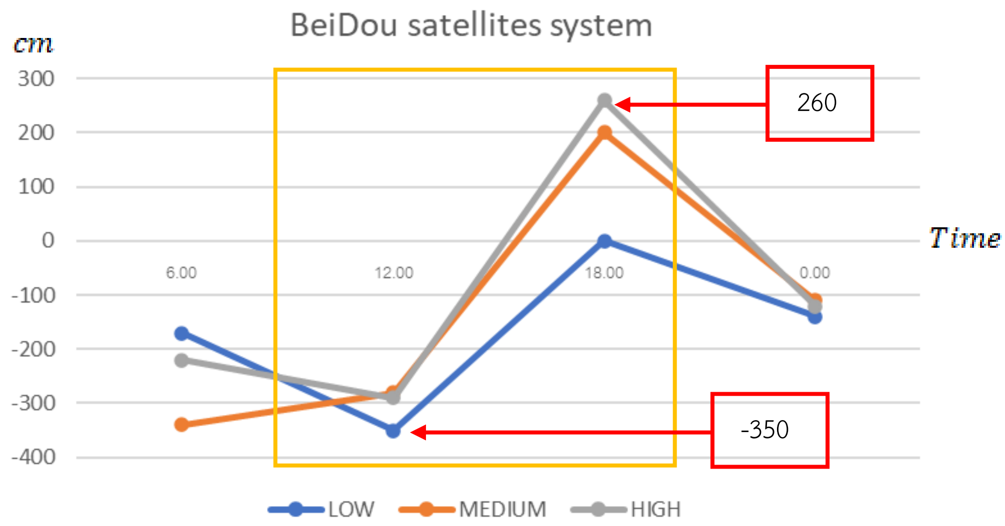

Figure 4 The result of distance of 50 m in BeiDou satellite low-cost robotic platform.

The graph in Figure 4 shows the low-cost robotic platform test error distance of 50 m with low speed, medium speed, and high speed. The results showed that the low-speed test at 12:00 noon had a maximum negative error of -350 cm and a maximum error at high speed at 6:00 p.m. by 260 cm.

The graph shows the results of a low-cost robot platform BeiDou satellites 100 m in **Figure 5.**

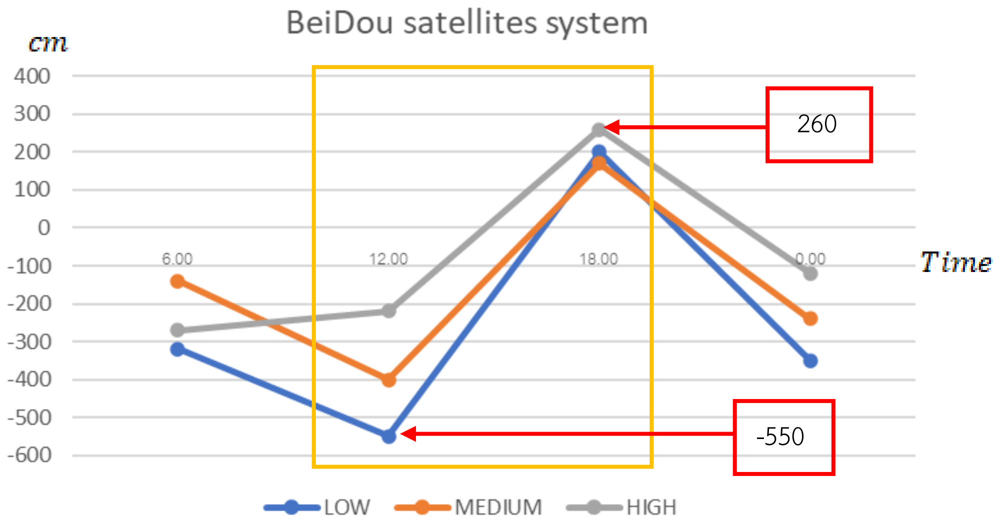

Figure 5 The result of distance of 100 m in BeiDou satellite low-cost robotic platform**.**

The graph shows the low-cost robotic platform test error distance of 100 m with test speed including low speed, medium speed, and high speed. The results showed that the low-speed test at 12:00 noon had a maximum negative error of -550 cm and a maximum error at high speed at 6:00 p.m. by 260 cm.

IV. CONCLUSION AND DISCUSSION

In the discussion, the success of the low-cost robotics platform for BeiDou navigation is highlighted, drawing parallels with previous studies such as the collaborative robotic educational tool based on programmable logic and Arduino by Plaza et al. (2016, pp. 282-289). Both the G-LOC ROBOT and the robotics platform developed by Junior et al. (2013, pp. 1-7) utilizing a low-cost and simple Arduino-based educational approach, serve as examples of effective low-cost robotic platforms. However, G-LOC ROBOT currently stands as the sole platform designed explicitly for BeiDou navigation. The experimental research introduces a novel approach to exploring robotics through home-made robotic education (Plaza et al., 2017, pp. 132-136), focusing on GPS navigation based on solar and ionospheric data. The use of Arduino as an educational tool for constructing low-cost robots is emphasized (Plaza et al., 2018, pp. 1-8) with G-LOC ROBOT serving as a dedicated platform for BeiDou navigation. Furthermore, it's noteworthy that G-LOC ROBOT was constructed at a lower cost compared to the GPS low-cost robotics designed and built by (Rajapakshe & Hettiarachchi, 2022, pp. 71-76).

In conclusion, the study successfully demonstrates the creation of a low-cost robotics platform specifically designed for BeiDou navigation. This platform is built on the principles of cost-effectiveness, utilizing minimal components that allow for exploration and experimentation. The key components of the low-cost robotics platform for BeiDou navigation include Arduino Nano, motor, wheel, motor drive, robotic body, tracker, BeiDou sensors, and power supply. The developed and effective low-cost robotic platform for BeiDou navigation is named G-LOC ROBOT. It's worth noting that the cost of G-LOC ROBOT can be further reduced by selecting alternative components while ensuring that essential capacity and performance are maintained for future use.

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