

The Data Alignment Method between GPS and IMU based on ICP for Indoor Positioning

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Abstract— We propose a method to align IMU data with GPS data to measure precise data indoors. While GPS can provide absolute coordinates, it has problems with signal strength reduction and measurement failure in indoor environments. Compared to GPS, IMU data offers high precision and less location constraint. In contrast, it does not have absolute coordinates, and cumulative errors can occur. Measurement of absolute coordinate in indoor can demand in various fields such as factories, and related research has been studied. Previously, combining GPS and IMU data was commonly used to complement real-time errors. In this paper, we propose a method that aligns IMU data with outdoor GPS data to measure indoor absolute coordinates. Simulation results confirm the successful alignment of these two datasets.

Keywords— IoT, Positioning, Communication, Location Estimation, Database

I. INTRODUCTION

We propose a method for measuring indoor absolute coordinates by utilizing the Iterative Closest Point (ICP) algorithm to align Global Positioning System (GPS) and Inertial Measurement Unit (IMU) data. GPS is a commonly used sensor for coordinate measurement, providing latitude and longitude information. However, GPS is troubled by accuracy issues, and research efforts such as GPS-RTK have been studied to address these shortcomings. Nevertheless, indoor GPS measurements remain challenging due to signal strength issues.

IMU is a sensor that combines accelerometers, gyroscopes, and magnetometers, allowing for the measurement of relative coordinates. While IMU data ensure high sampling rates and resolution, it does not provide absolute coordinates like GPS. To overcome their respective limitations, GPS and IMU are often fused using techniques such as the Kalman filter [1].

Indoor positioning requirements vary depending on the application, such as in factories, and various technologies like Ultra-wideband (UWB) and Bluetooth beacons are being researched [2]. However, these technologies also suffer from large error ranges and the inability to determine absolute

coordinates. Combining GPS and IMU technology faces challenges when used indoors.

We propose a measuring method that indoor absolute coordinates by leveraging the well-established GPS and IMU technologies. To achieve this, we employ the ICP algorithm to align GPS and IMU data and infer absolute coordinates within indoor environments.

II. RELATED WORK

GPS is commonly used for coordinate measurement, but it faces challenges when used indoors due to signal degradation caused by roofs and walls. Consequently, numerous research efforts have been dedicated to indoor positioning. Ultra-wideband (UWB) technology has been developed for this purpose, utilizing wireless communication with a bandwidth of over 500MHz. While UWB is highly effective with an error range of around 10 cm, it falls short in precision compared to IMU [3].

Research is also being conducted on indoor positioning using Bluetooth Low Energy (BLE). Through the commonly used Bluetooth module, the indoor location can be measured using techniques such as triangular positioning. However, signal information with RSSI as the criterion for positioning is sensitive to various interferences, and there is a problem that the measurement value is very unstable [4].

The Iterative Closest Point (ICP) algorithm is used to align one point with another point scanned from a different viewpoint. ICP algorithm is a widely employed technique in computer vision and robotics. It aims to align or register two sets of 3D data points. This process includes an initial estimate of the transformation (translation and rotation), finding corresponding points between the datasets, iteratively optimizing the transformation to minimize the squared differences between corresponding points, and refining it until convergence criteria are met. ICP is essential for applications like 3D reconstruction, simultaneous localization, and mapping (SLAM), and object recognition.

We propose method to measure coordinate data in constraint environment. To achieve this, it aligns the measurable GPS data with IMU data.

III. PROPOSAL METHOD

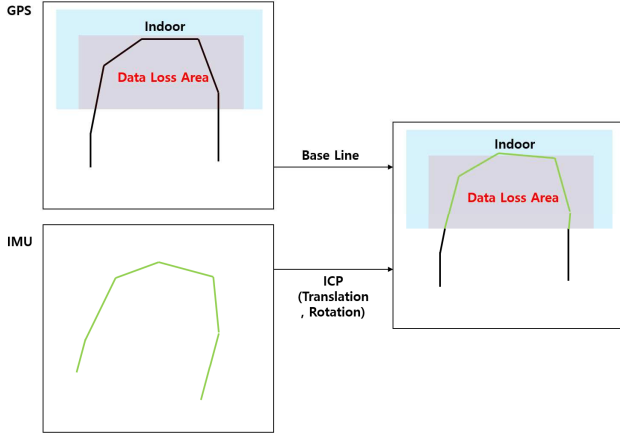


Figure 1. Indoor data measurement plan

The method we propose is specifically illustrated in Figure 1. GPS experiences a significant decrease in accuracy upon entering indoor environments. IMU remains unaffected by indoor conditions but lacks knowledge of its absolute coordinates. To compensate for this, we move and rotate IMU data using data from GPS measured outdoors as a reference point to align it with absolute coordinates. During this process, IMU data is recorded indoors and can be utilized as indoor positioning data.

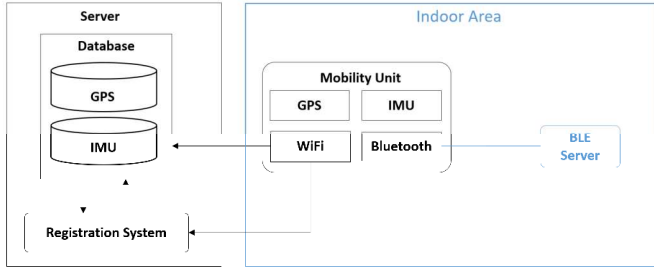


Figure 2. Functional diagram

The functional overview diagram is illustrated in Figure 2. The Mobility Unit must be capable of collecting GPS and IMU data, while also has Wi-Fi and Bluetooth functionalities. The BLE Server, upon the Mobility Unit entering an indoor area, determines indoor access through Bluetooth MAC scanning. GPS and IMU data from the mobile unit are stored in the server's database using Wi-Fi. The server interacts with the Registration System to execute the ICP alignment of GPS and IMU data.

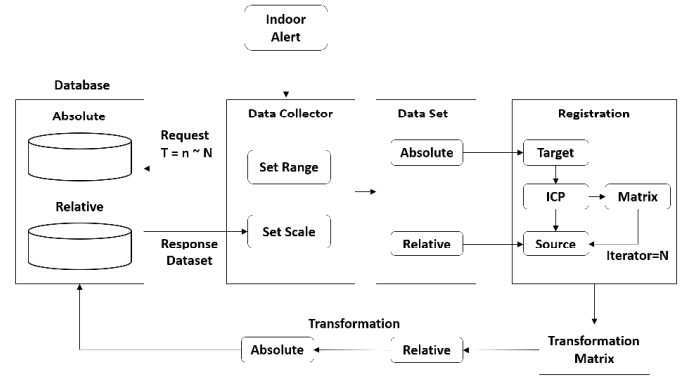


Figure 3. System configuration diagram

The system configuration diagram is presented in Figure 3. When the Mobility Unit is detected to have entered indoors, the Data Collector initiates the data shifting process. The measured latitude and longitude data from GPS and the data from IMU, which are in X and Y coordinate format, are first converted. Since ICP involves a considerable computational load, we scale both datasets relative to their respective means. Additionally, since IMU data is sampled at a much higher rate compared to GPS, it is adjusted to match the GPS sampling frequency. The reason for the higher sampling rate of IMU data compared to GPS data is due to the significantly faster measurement rate of IMU. Typically, IMUs collect data such as acceleration, angular velocity, and magnetic field at a very rapid pace. This higher data acquisition rate allows IMUs to provide more detailed and fine-grained information about movements and actions. GPS operates at a relatively slower measurement rate, with slower updates for altitude and position information. As a result, IMU data is collected at a much faster sampling rate than GPS data. It also aligns with the IMU's data range appropriately, as it calibrates using outdoor data rather than corrupted GPS data. Thereafter, ICP iterations are performed as configured.

IV. SIMULATION

The GPS data used in the simulation was taken from ETH Zurich, which provides a localization dataset for SLAM [5]. IMU data was randomly generated based on GPS data. The number of data is 1294 each for GPS and IMU.

```
pi@raspberrypi:~/Desktop/Bluetooth $ /bin/python /home/pi/Desktop/Bluetooth/c1
ient.py
Waiting for Bluetooth Server...
connect!('D8:3A:D0:3F:DF:80', 1)
received message: connection test
received message: Bluetooth connection
```

Figure 4. Bluetooth MAC scanning

The server determines indoor access by establishing Bluetooth pairing with the mobility unit. Therefore, the server must periodically scan Bluetooth MAC addresses. The results of the Server-to-Mobility unit Bluetooth MAC sensing is in Figure 4. When MAC sensing is completed, the MAC address of the mobility unit and the connected port number are shown.

Result Grid			
		Filter Rows:	
		Export:	W
Sequence	Timestamp	Latitude	Longitude
1	1696424665	36.624968333	127.45813
2	1696424666	36.624968333	127.45813
3	1696424667	36.624968333	127.45813
4	1696424668	36.624968333	127.45813
5	1696424669	36.624968333	127.45813
6	1696424671	36.624968333	127.45813
7	1696424672	36.624968333	127.45813

Figure 5. Database stored on the server

The result of storing GPS data of the mobility unit in the server's database is in Figure 5. The database stores the timestamp, latitude, and longitude information of the mobility unit. The timestamp information is stored in UNIX time format. GPS data is collected in string form and uses the NMEA 0183 protocol. Latitude and longitude data are collected in the GPGLL format among the collected data.

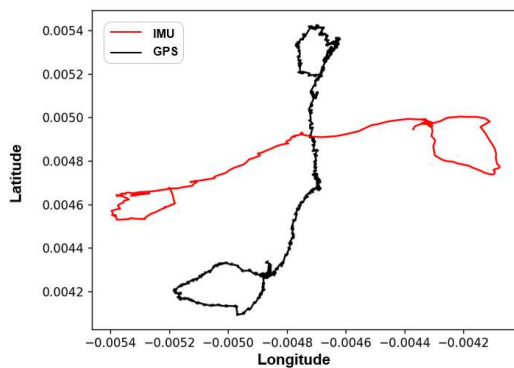


Figure 6. GPS/IMU data samples

The value of the shifted data in the IMU as much as the GPS average data is in Figure 6. The scaling of GPS data and IMU data was standardized through a process known as data shifting.

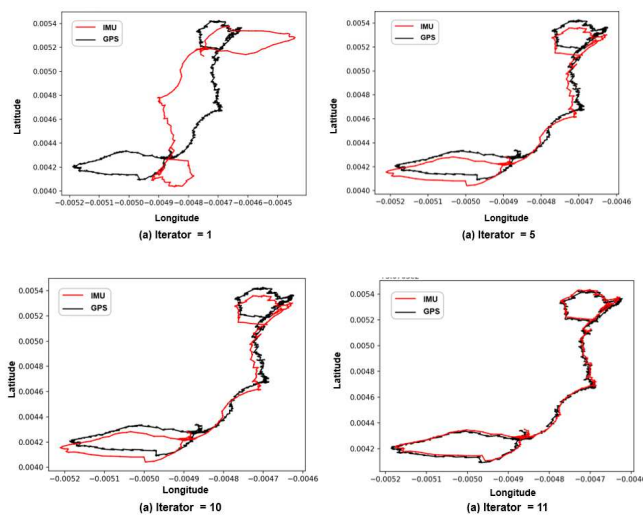


Figure 7. Alignment results by iteration count of ICP

The result of data matching by the number of repetitions of ICP is in Figure 7. From the results of this simulation, it can be confirmed that the change for matching is large when the initial ICP is performed, but the change gradually decreases as the number of times increases. It can be confirmed that the data of the two are matched when the performance of ICP is repeated 11 times.

V. CONCLUSION

We proposed a method for aligning GPS and IMU data to measure indoor positioning. To achieve this, several data preprocessing steps were carried out, followed by the iterative execution of ICP until the data alignment was reached. Simulation results confirmed the successful alignment of data from both GPS and IMU data.

IMU has the issue of accumulating errors. The method proposed in this paper can accurately determine the position upon entering indoors from outdoors, but it struggles to address accumulated errors with prolonged indoor stay. There is a need for improvement in addressing this issue, and we plan to conduct future research to explore supplementary methods, such as collaboration with other devices.

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