Feasibility of Integrated GNSS/OBD-II/IMU as a Prerequisite for Virtual Reality

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Abstract. To build accurate GIS (Geographical Information System) in urban area for advance virtual reality, accurate positioning is one of most important prerequisites. For this purpose, GNSS (Global Navigation Satellite System) is attractive since it can provide absolute coordinates to any object located on earth. However, accurate positioning is not a simple problem since any single GNSS cannot provide sufficient the number of visible satellites in urban area. To improve positioning availability in urban area for advanced virtual reality applications, this paper proposes a hybrid positioning method integrating a GPS/BeiDou receiver, an OBD-II (On-Board Diagnostics-II) device, and a MEMS IMU (Micro Electro Mechanical Systems-Inertial Measurement Unit). By an experiment result with field-collected actual measurements, the feasibility of the proposed method is evaluated.

Keywords: GIS · Virtual reality · Positioning · Urban · GNSS · OBD · IMU

1 Introduction

To build accurate GIS (Geographical Information System) in urban area for advance virtual reality, accurate positioning is one of most important prerequisites. For this purpose, GNSS (Global Navigation Satellite System) is attractive since it can provide absolute coordinates to any object located on earth. However, accurate positioning is not a simple problem since any single GNSS cannot provide sufficient the number of visible satellites in urban area.

To improve the positioning availability in urban area, more GNSS constellations need to be utilized. Undoubtedly, more constellations we use, better availability can be obtained. In addition, improved accuracy, integrity, and continuity can also be obtained.

As widely known, no matter how many constellations we use, shortage of visible satellites is unavoidable due to the limitation of radio signals depending on signal paths. To overcome this limitation, GNSS should be integrated with other aiding sensors.

To improve positioning availability in urban area for advanced virtual reality applications, this paper proposes an efficient hybrid positioning method integrating a GPS/BeiDou receiver, an OBD-II (On-Board Diagnostics-II) device, and a MEMS IMU (Micro Electro Mechanical Systems-Inertial Measurement Unit).

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In the proposed method, only the two constellations of GPS and BeiDou are considered since three constellations are far more expensive than the two constellations for common users for the time being with no significant improvement in urban area. By the simple OBD-II interface unit, moving speed can be obtained conveniently. By the MEMS IMU, attitude information can be continuously tracked.

2 Integrated GNSS/OBD-II/IMU

2.1 Embedded Linux Platform

This study utilizes a BBB (Beagle Bone Black) board [1, 2] to collect GNSS, MEMS-IMU, and OBD-II measurements with time synchronization information. Figure 1 shows the configuration of the proposed system integration utilizing the BBB board. It can support Linux and Android operating systems.

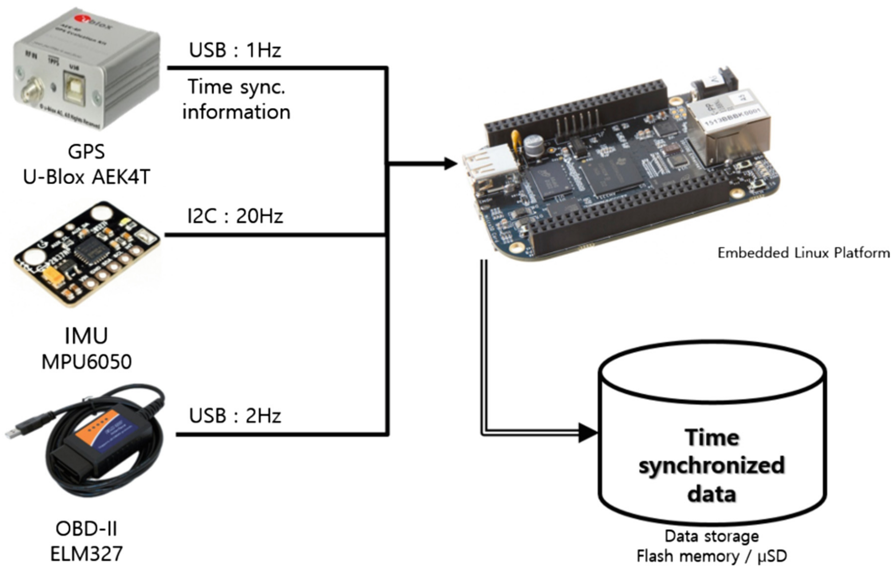

Fig. 1. Configuration of integration platform

The GNSS receiver and the OBD-II unit are connected via USB. The IMU is connected via GPIO-pin. To merge all the sensor measurements, the PPS (Pulse Per Second) information from the GNSS receiver is utilized. At first, the time synchronization information is derived from the PPS information. Next, it is utilized for different sampling rates of the three sensors. The sampling rates of the GNSS receiver, the OBD-II device and the MEMS-IMU are 1 Hz, 2 Hz and 20 Hz, respectively. In this way, the proposed method can collect the time synchronized measurements from the three different sensors.

2.2 OBD-II

OBD-II is the standard to diagnose all types of land vehicles [3, 4]. The OBD-II specification provides unified hardware interface to the vehicles from difference manufacturers. By OBD-II, state of vehicle can be checked by MIL (Malfunction indicator Lamp). OBD-II provides messages classified by PIDs (Parameter IDs). PIDs consists of 6 modes. Among them, mode 1 provides vehicle information including fuel system status, engine RPM (Revolution Per Minute), and vehicle speed. Typically, a user can obtain the messages with a scan tool. The procedure is summarized by the following steps.

(1) A user enters the PID.
(2) The PID is fed to the vehicle's controller–area network (CAN) bus through a scan tool.
(3) A device on the CAN bus recognizes the PID and returns the response to the PID.
(4) The scan tool reads the response message and displays it to the user.

2.3 Integration

The proposed method consists of four functional parts. The first part processes GPS/BeiDou measurements and extracts GPS PPS (Pulse Per Second) signal for the time synchronization, the second part collects MEMS IMU measurements, the third part extracts the speed of a vehicle by OBD-II, and the last part merges all the outputs from the former three parts based on the time synchronization information.

To integrate GNSS, OBD-II, and IMU, a loose-coupled Kalman filter is designed. The designed Kalman filter consists of 15 states to account for position errors, velocity errors, attitude errors, gyro drifts, and accelerometer biases. The filter is based on the conventional dynamics model [5, 6] for time propagations. For measurements updates, only the two types of measurements are considered. One is the position information combining GPS and BeiDou and the other is the OBD velocity. To generate position measurement, an iterated least square method is utilized considering five variables; three receiver coordinate values, a GPS clock bias, and a BeiDou clock bias. The OBD velocity measurement is modeled to consider the effects of attitude errors for the transformation from the body frame to the navigation frame.

3 Experiment

To evaluate the feasibility of the proposed method, an experiment was performed in the area where surrounding buildings form urban canyons. The experiment was performed in Teheran-ro, Gangnam-gu, Seoul, Korea. Figure 2 shows typical appearance of the experiment area. Figure 3 shows the experiment trajectory plotted by *Google Earth*.

For the experiment, three sensors were utilized; a Novatel ProPak6 as the single frequency GNSS receiver, an MPU-6050 as the MEMS-IMU, an ELM327 as the OBD-II device and a BBB board as the embedded Linux platform.

Fig. 2. Typical appearance of the experiment area

Fig. 3. Experiment trajectory

Figure 4 compares the two trajectories generated by the two different methods, respectively. The triangles correspond to the GNSS-alone method and the circles correspond to the proposed GNSS/MEMS-IMU/OBD-II integration method. By comparing the two trajectories, it can be observed that the proposed method provides more continuous and available positioning results against the urban canyon environment. Note that the proposed method compensates IMU velocity with OBD-II speed measurements even when GNSS measurements are not available. Whereas, the GNSS-only method shows unavailable periods where positioning results cannot be provided due to insufficient number of visible satellites.

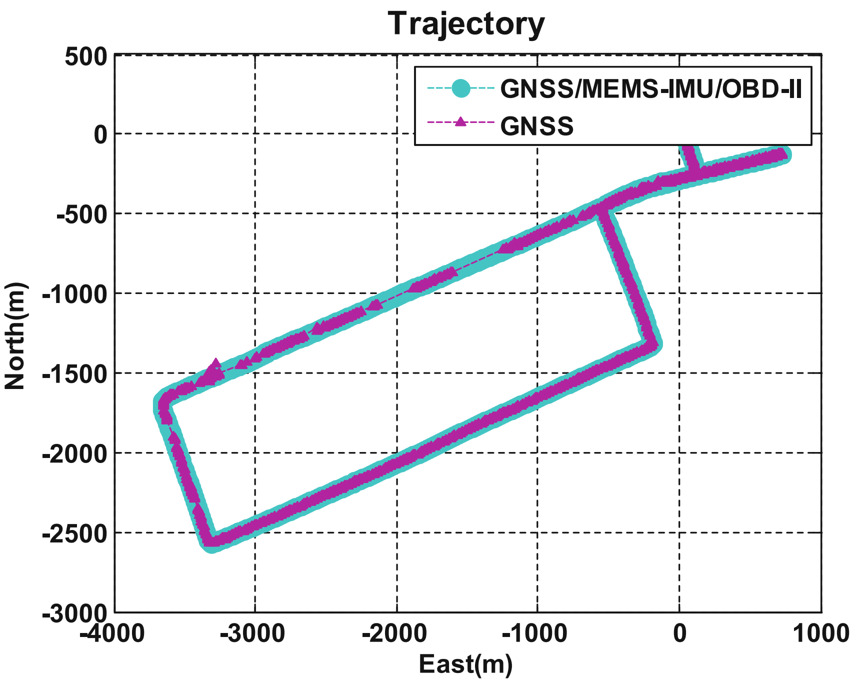

Fig. 4. Comparison of trajectories generated by the proposed method and the GNSS-only method

4 Conclusions

This paper proposed a GNSS/MEMS-IMU/OBD-II integration method against GPS-denied environments to build accurate vector maps for advance virtual reality. Since the propagation of accurate position requires accurate velocity, the proposed method utilized OBD-II speed to correct the velocity continuously. By the result, the accuracy degradation of the velocity could be mitigated even when GPS measurements were not available.

To evaluate the feasibility of the proposed integration method, an experiment was performed in the area where surrounding buildings form deep urban canyons. By the experiment result, it was shown that the proposed method is feasible to provide more accurate and reliable positioning results. However, more experiments are required to obtain meaningful performance statistics.

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