# ACCEPTED MANUSCRIPT

Title: CAR-VEHICLE NAVIGATION USING INERTIAL SENSORS ASSISTED BY ODOMETRY DATA OBTAINED FROM ON-BOARD DIAGNOSTICS SYSTEM IN NON-GPS APPLICATIONS

Authors: Piotr Prusaczyk, Leszek Baranowski, Jarosław Panasiuk

To appear in: Technical Sciences

Received 8 July 2019;
Accepted 5 February 2020;
Available online 7 February 2020.

# CAR-VEHICLE NAVIGATION USING INERTIAL SENSORS ASSISTED BY ODOMETRY DATA OBTAINED FROM ON-BOARD DIAGNOSTICS SYSTEM IN NON-GPS APPLICATIONS

***Piotr Prusaczyk, Leszek Baranowski, Jarosław Panasiuk***

Faculty of Mechatronics and Aerospace
Military University of Technology in Warsaw, Poland



**Key words:** Odometry, Inertial systems, Vehicle Positioning, Land Navigation, On-Board Diagnostics System.

Abstract

This paper describes the possibility of using the Vehicle's On-Board Diagnostics data to minimize inertial navigation errors. Authors present the results of driving tests along the traffic streets. Knowledge of the exact initial position and orientation was crucial in the navigation process. Orientation errors at the beginning lead to greater increase of the position errors. During the navigation process no GPS data has been processed in the algorithm.

## Introduction

Knowledge of actual position and velocity is essential for many applications especially outdoor vehicles. GPS is widely used for accurate and robust localization. Unfortunately, pure GPS localization can be highly inaccurate in urban environments such as tunnels and urban canyons. In specific situations the GPS can be jammed or turned off. This is the reason why development of the other navigation techniques is highly demanded (PRUSACZYK et al. 2018a). In theory best features have an inertial navigation system. It doesn't require any external signals to estimate movement of the object. It integrates the measurements of rotation and acceleration rate to estimate the position. Unfortunately, accelerometer and gyroscopes are unsuitable for accurate positioning over an extended period, due to data drift of these sensors (TITTERTON, WESTON 2004). For land navigation, wheel encoder with based odometry is a cost-effective and convenient method of determination the change of position, especially for wheeled mobile robots (KACZMAREK, et al. 2017). Information acquired by OBD (On-Board

Diagnostics) electronics systems in car vehicles that can be used in self-localization (MERRIAUX et al. 2014).

In this paper, the aim of the authors is to present a navigation method using inertial and odometry data. The XSens IMU is responsible for measuring accelerations and rotation speed. The odometry data is provided via On-Board Diagnostics system. For these experiments it is assumed that initial position and orientation is known.

The paper is organized as follows. In the next section, an overview of the inertial systems is discussed. The following section contains a short introduction to On-Board Diagnostics System. Next chapter is dedicated to the hardware implementation, where authors describe OBD Reader and XSens Inertial Measurement Unit. Methods are presented in experiment scenario subsection. In the next section the results of the road experiments are discussed.

## Inertial Navigation System

The Inertial Navigation System is entirely self-contained within the object, they do not depend on external radiation and optical information. The INS use the inertial properties of sensors mounted in the object to proceed the navigation function. The system processes the data obtained from three-dimension linear accelerations and three-dimension inertial angular velocity measurements. The system calculates the position and orientation change in time (Figure 1). Knowledge of the position and orientation at the start of navigation is crucial for inertial navigation system to be able to continuously determinate the vehicle position and velocity without the usage of external data. Modern systems of the INS have removed most of the mechanical complexity of platform systems, by attaching the sensor to the body of the object. Usage of silicon as the base material drastically reduced the size and number of elements that leads to reducing the cost. MEMS gyroscope is non-rotating device that use the Coriolis acceleration effect on a vibrating proof mass to detect inertial angular rotation. The major disadvantage is increasing computing complexity, and necessity to use sensors capable of measuring at higher rates of turn (PRUSACZYK et al. 2018a).

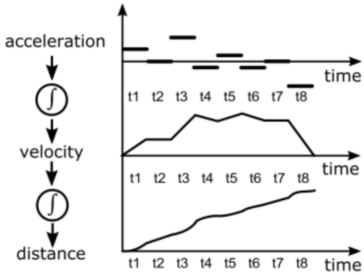


Fig. 1. Integration process

## On-Board Diagnostics system

The OBD (On-Board Diagnostics) is a computer-based system that consists of an ECU (Electronic Control Unit), which uses input from various sensors to control the actuators to get the desired performance (Figure 2). The “Check Engine” light, also known as the MIL (Malfunction Indicator Light), provides an early warning of malfunctions to the vehicle owner. A modern vehicle can support hundreds of parameters, which can be accessed via the DLC (Diagnostic Link Connector) using a device called a scan tool.

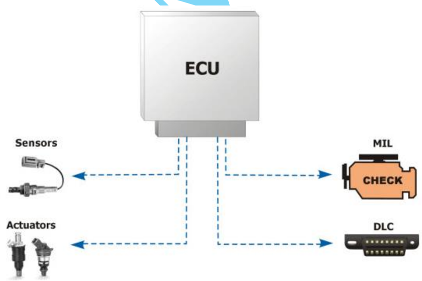


Fig. 2. Diagram of the OBD System

The first version of the on-board diagnostic system standard was introduced in 1985. The purposes for that system was to improve in-use emissions compliance by alerting the vehicle operator when a malfunction exist, and to aid automobile repair technicians in identifying and repairing malfunctioning circuits in the emissions control system (GAURI et al. 2017).

## Material and Methods

### OBD Reader

In this project, the OBD Reader is used for gathering information from the OBD System. The OBD Reader designed by the authors exports the data frames from the Car's subsystems such as ECU (Engine Control Unit), ABS (Automatic Brake System) etc. The data frames are converted and sent to PC via USB port (Figure 3). Data is converted by 8bit microprocessor and K-line interface chip (PRUSACZYK et al. 2018b).

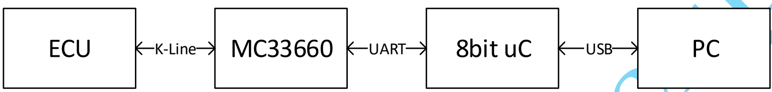


Fig. 3. OBD Reader model

### XSens – Inertial Measurement Unit

In this project, the XSens MTI-G30 is used for measuring the linear accelerations and rotational speeds acting on the object (Figure 4).

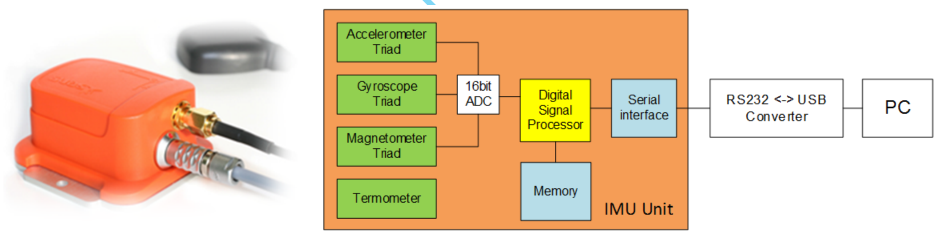


Fig. 4. XSens unit (left). Diagram of the measuring stand (right)
Source: XSens, www.xsens.com

### Hardware Integration

For this project both devices, XSens and OBD Reader, communicate by USB interface (Figure 5). Personal computer is responsible for handling those devices. (PRUSACZYK et al. 2018b).

Fig. 5. Connection model

### Experiment Scenario

In order to solution check, authors conducted an experiment in real conditions. Test route was developed based on digital map data and parameters defined below:

- Test distance around 2000 meters,
- Include several reorientation points.

Experiment data was acquired via dedicated communication software then processed in MATLAB environment. GPS-data was collected during the experiment for verification and comparison purposes as a real position data.

## Experiment Results

The tests were conducted in city traffic area. The following characteristics of the generated route have been extracted (fig. 6).

- The final reorientation of the vehicle above 360degrees.
- Several reorientation points (multiple turns).
- 2030 meters long.

Fig. 6. Planned path

The figure 7 presents orientation of the vehicle around three axes. The last one shows the heading of the vehicle. We can notice several characteristics changes of the heading while turning on the crossroad.

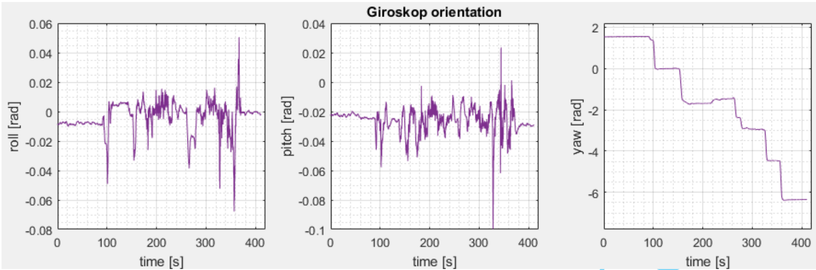


Fig. 7. Recorded orientation

The figure 8 presents three sources of the vehicle's velocity. First one comes from Inertial Navigation assisted by (Zero Update Velocity) which detects stationary states for resetting measurements from the inertial sensor. The second one comes from the On-Board Diagnostics System. The last one presents referential speed from the calibrated GPS sensor.

Velocity measurement acquired by assisted inertial navigation method consist errors in comparison with OBD assisted odometry method. Next iteration of the inertial velocity data could lead to significant differences in position estimation.

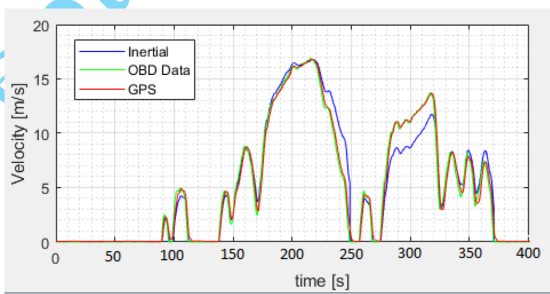


Fig. 8. Registered velocity

The inertial navigation system assisted by OBD odometry has estimate similar shape path to the GPS one (fig. 9), with some differences (fig. 10) due to errors of the measurement hardware.

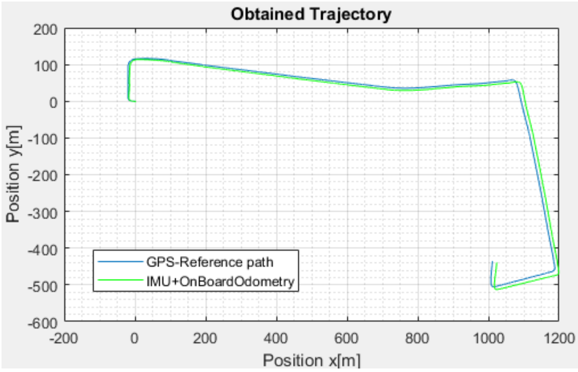


Fig. 9. Obtained trajectory

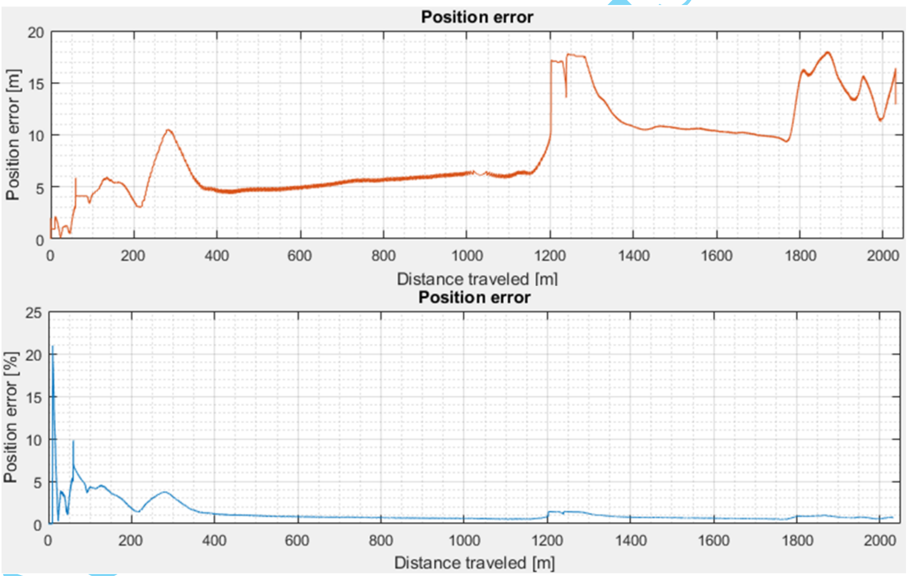


Fig. 10. Position error in meters (above) and percentage to travelled road (below)

Errors of navigation have been reduced in comparison with standalone inertial navigation system. Position error stayed stable during the experiments in time. The figure 10 presents position errors in function of road traveled.

## Conclusions

Practical application of the non-GPS navigation using inertial sensors and odometry data from the Vehicle's On-Board Diagnostics system was presented in this article. In comparison to pure inertial navigation, with the assisted odometry the errors increase only with travelled distance. Despite the fact of stable position error during the experiment, this solution still cannot be applied into long term navigation scenarios. It is necessary to include additional sources of data in order to minimize the increment of the position error.

Future works will be conducted to implement the algorithm for determination initial position without GPS signal.

## REFERENCES


TITTERTON D., WESTON J. 2004. *Strapdown Inertial Navigation Technology 2nd Edition*. The Institution of Engineering and Technology.

PRUSACZYK P., PANASIUK J., BARANOWSKI L. 2018a. *GPS-free navigation based on using inertial and odometry, data fusion and map matching algorithm*. AIP Conference Proceedings 14th International Conference Mechatronic Systems and Materials. 2029(20062).

PRUSACZYK P., PANASIUK J., BARANOWSKI L. 2018b. *Opracowanie interfejsu wymiany danych między użytkownikiem a samochodem*. Problemy Mechatroniki - uzbrojenie, lotnictwo, inżynieria bezpieczeństwa. 9(2): 147-156.

KACZMAREK W., PANASIUK J., PRUSACZYK P., BESSEGHIEUR K. 2017. *Formation control of mobile robots under ROS*. Proceedings of the 23rd International Conference – Engineering Mechanics: 138–141.

GAURI M., PARCHANDEKAR S.K., TAHIR M. 2017. *Implementation and Validation of K Line (ISO 9141) Protocol for Diagnostic Application*. International Research Journal of Engineering and Technology 04(07): 713-708.

MERRIAUX P., DUPUIS Y., VASSEUR P., SAVATIER X. 2014. *Wheel odometry-based car localization and tracking on vectorial map*. IEEE 14 : 1890-1891.

Xsens MTi-G, http://www.xsens.com (2019).