



# An Indoor and Outdoor Individual Mapping System for the Visually Impaired People

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**Abstract** -The aim of the paper is to help the visually impaired in navigation, whether indoors or outdoors. Many proposals have been suggested and some of them have been really helpful. Recently, navigation system that could be used indoors and outdoors has been designed. However, our proposed system helps one to identify the position of a person and calculates the velocity and direction of the visually impaired's movements. By collating the information, the system determines the user's trajectory, locates obstacles in the route, and offers the user navigation tips. A new look has been observed in the navigation system. In this plan, measured zero velocity durations from the ground reaction sensors are used to reset the accumulated integration errors from the accelerometers and gyroscopes in position calculation.

**Keywords:** - Indoor position; outdoor position; movement detection; navigation system; augmented object; visually impaired

## I. INTRODUCTION

It has often been noticed that due consideration is not paid to the needs of the visually disabled, i.e., partially or totally blind. For example, movement of the visually disabled on buses and trains, offices, hospitals, educational buildings and shopping malls. Sometimes objects that are used in everyday life also cause hardship to the blind people. Such as chairs, tables and climbing of stairs.

Several people have tried to address this challenge, but there have been limitations (e.g., accuracy, coverage,

usability and interoperability) and is difficult to address with the current technology. Therefore, one can take a look into this issue.

This system will primarily help the users to navigate indoors. In short, it will calculate in a fraction of a second to inform the user. For providing such information, the system must take note of all objects in the proximity that could become potential —obstacles for the blind. The aid to the blind is termed the micro-navigation system. This system will primarily address two points: (1) detection of the position and movement of the user, and (2) positioning of all objects in the surroundings.

The components of Navigation System are: an augmented white cane with various embedded infrared lights, two infrared cameras (embedded in a Wiimotes unit), a computer running a software application that coordinates the whole system, and a smart phone that delivers the navigation information to the user through voice messages (Figure 1).

## II. REQUIREMENTS OF THE SOLUTION

For the proposed navigation system, functional and non-functional requirements lists have been defined based on the authors experience and results of a conducted study. The real end-users then authenticated it. In a bid to ease the evaluation process, non-functional obligations, like privacy, security and interoperability, were not considered.

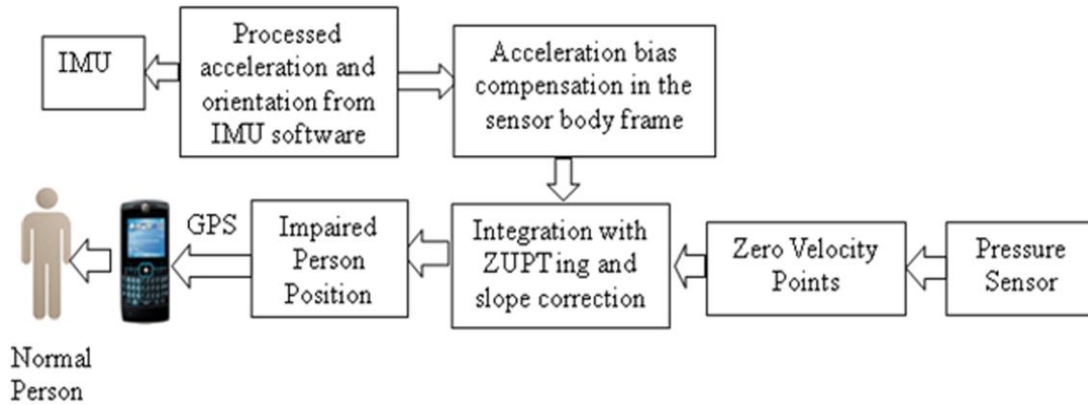


Figure 1: Mechanism of the navigation system.

The broad obligations included in the design of micro-navigation system were classified in the following categories:

- A. Navigation model. These obligations are linked only to the model. They are as follows:
  - a. Generality. The navigation model must be user friendly (with or without modifications) indoors. This will ensure that the user puts it into use in closed doors.
  - b. Usefulness. The model must clearly depict the placements of the obstacles and positioning of mobile users for accurate information to the user.
  - c. Accuracy. The accuracy information must allow the system to support the navigation of the blind in a safe way. A study done by the authors' states that in the worst scenario, there will be an error of 0.4 m. and detect the user's movement at a length of 500 ms.
  - d. Feasibility. The model implementation should be feasible using technologies that are accessible (in terms of cost, usability and availability) to the end-users.
  - e. Multi-user. The system will also look at the possibility of multi-users in the same area.
  - f. Usability. The blind must come forward to use this system.
  - g. Usefulness. Even if one is using the system for the first time, the navigation system should be useful.
  - h. Economical feasibility. It must not be very expensive for the end-users.
- B. Navigation system. The necessities for the navigation system are as follows:
  - a. User-centric. The system will also assess the users' level of blindness.
  - b. Availability: The system should be helpful to the user wherever he is irrespective of the

environment. Accordingly, the solution becomes usable indoors.

- c. Identification. The system must be able to unequivocally identify the users.
- d. Multi-user. More than one user should be able to use the navigation services in the same environment.
- e. Performance: The system should run smoothly and help the user by providing prompt navigation services, considering their speed of walking and obstacles in the area. The authors' study reveals that the response time is close to 300 ms.

### III. INERTIAL SENSOR-BASED PERSONAL NAVIGATION SYSTEMS AND ZERO VELOCITY INTERVALS

Figures and tables should be centred in the column, numbered consecutively throughout the text, and each should have a caption underneath it (see for example Table 1). Care should be taken that the lettering is not too small. All figures and tables should be included in the electronic versions of the full paper.

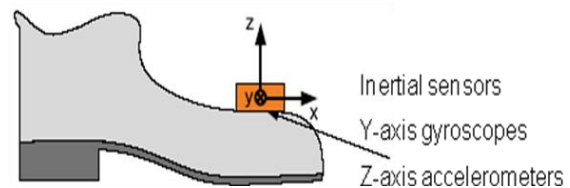


Figure.2 Boot with the pressure sensor inserted in the insole

Another remarkable navigation system that will help the blind is the boot. This boot will help fire-fighters and emergency rescuers to track the location of a person on foot. Current position-tracking technologies require an instrumented, marked, or pre mapped environment for locating a person. It is impossible to install markers or instrumentation on mobile applications in advance that will help the blind navigate. There are huge challenges

for creating robust vision-based tracker, while currently the leading contender is computer vision.

Slightly different zero detection algorithms are used in the zero velocity intervals is determined based on gyroscope and accelerometer output norms. If the outputs are less than some threshold for a predetermined time, the zero velocity intervals are decided. Similarly, algorithms are used, where the main difference is which sensor values are used. In the zero velocity intervals are determined based on z-axis accelerometer and y-axis gyroscope outputs (see Figure 2 for the coordinate frame). In the zero velocity interval is determined based on norms of gyroscope outputs. In the zero velocity interval is detected based on the variance of accelerometer values. In the zero velocity interval is detected based on norms of accelerometers and gyroscopes along with variance of accelerometers.

#### IV. THE INERTIAL MEASUREMENT UNIT (IMU)

The inertial measurement unit comprises three gyros and three accelerometers. The sensor is mounted on the foot. The sensor communicates with the host PC using the USB port. The sampling rate of the sensor data is 100 Hz. The accelerometers and the gyroscope measure the accelerations and the angular rate in the body frame coordinates. To finally obtain the result in the tangent frame, a coordinate transformation from the body's to the tangent's coordinate frame has to be processed.

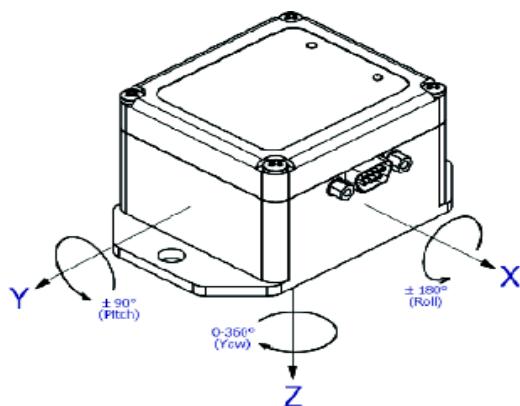


Figure 3: The IMU used in the hardware

Three -axis gyroscopes and a three-axis magnetometer compass within a low volume (26.2 x 39.2 x 14.8 mm<sup>3</sup>), which can fit within the heel. This IMU module is temperature compensated producing a lower error bias than other IMU units. Inter-Sense has developed one of the most sophisticated extended Kalman filter schemes for personal navigation. InertiaCube3 combines the aforementioned sensing elements with an integrated Kalman filtering algorithm. The unit can provide orientation and gravity compensated acceleration information aligned with earth's magnetic north.

#### V. PRESSURE SENSORS

In our walk experiments, we used a pressure sensor array, DigiTacts II Array Tactile sensors manufactured by Pressure Profile Systems (PPS), as our biomechanical GRSC sensor. DigiTacts II sensors have 24 sensing elements with sensing area of 82.3 x 45.1 mm<sup>2</sup>. These sensors use a capacitance-based sensing scheme that can detect pressures up to 140 kPa. Overall power consumption of the GRSC, was 20 mW (3.3 V/6 mA). The GRSC was a custom built unit that was calibrated prior to shipment. Pressure sensor arrays can be used to detect pressure contours that are generated by the heel if the sensor is placed between the heel of the shoe and the shoe insole. One can find the centroid velocity of the pressure contours as

$$\vec{v}(\theta, t) = \frac{d(\theta, t)}{dt} \hat{r} \approx \frac{d(\theta, t + \Delta t) - r(\theta, t)}{\Delta t} \hat{r} \quad (1)$$

$$\vec{v}_{cnir} = \int_0^{2\pi} \vec{v}(\theta, t) d\theta \quad (2)$$

where  $\vec{v}$  is the velocity of a point on the contour,  $r$  is

the radius of the contour point,  $\hat{r}$  is the unit vector that lies on the line between the center of the contour and the contour point, and  $\vec{v}_{cnir}$  is centroid velocity of the contour. The contour velocity can be used to detect the zero velocity of the shoe. We can assume that the shoe, and the IMU, is at rest when the centroid velocity is below a velocity threshold

$$\left\| \vec{v}_{cnir} \right\| \leq v_{thrsh} \quad (3)$$

#### VI. POSITION CALCULATIONS FROM THE SENSORS

The sensor data fusion scheme followed to integrate acceleration has been given in Figure 1. Firstly, acceleration and orientation information that are characterised in the navigation coordinate frame has been taken from IMU. The IMU manufacturer's Navigation coordinate frame (popular as spatial coordinate frame, or world coordinate frame) is the accepted geographic frame with its x-axis pointing north, y-axis east, and z-axis up Next, a Kalman filter (KF) is employed to find acceleration biases. This estimation is performed in the sensor's body coordinate frame and then the resultant biases are transformed to the world coordinate frame. Bias compensated acceleration from the IMU and zero velocity points from the pressure sensor. Array is used in the integration via ZUPT'ing to calculate the position of the user. Finally, a calibration is applied to correct the drifts in the calculated position. This calibration is used to correct future collected walk data.

Following is the self-explanation of the calculation

navigation coordinate frame,  $a^{nav}$ , and the matrix that defines rotation between navigation and body coordinate

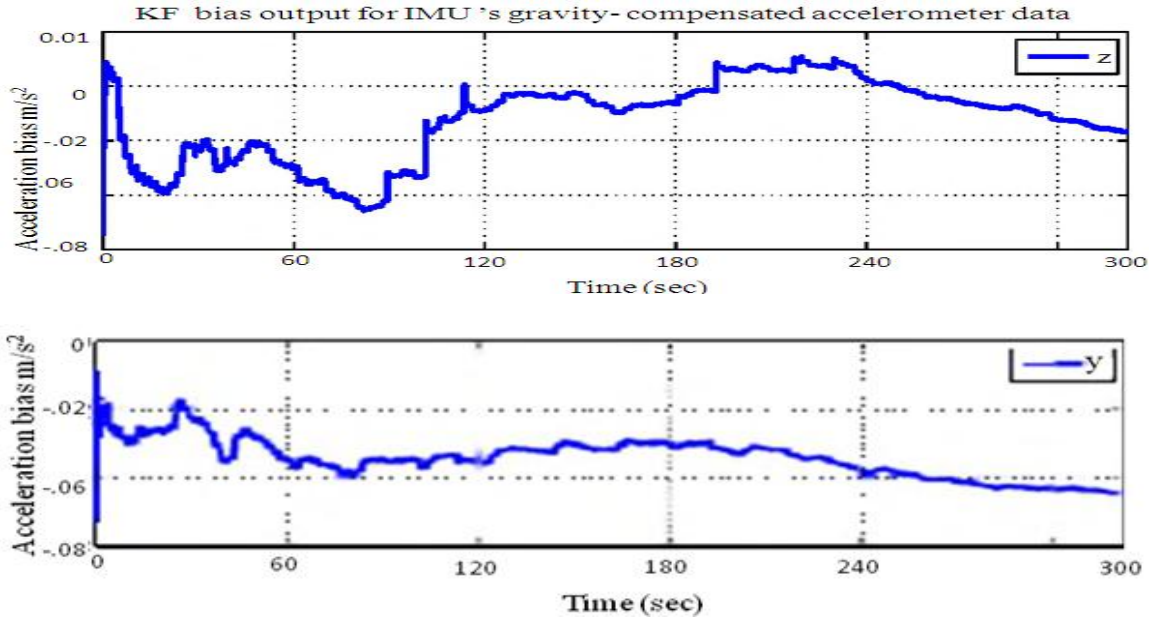


Figure 4. Kalman filter bias output for IMU's acceleration outputs.

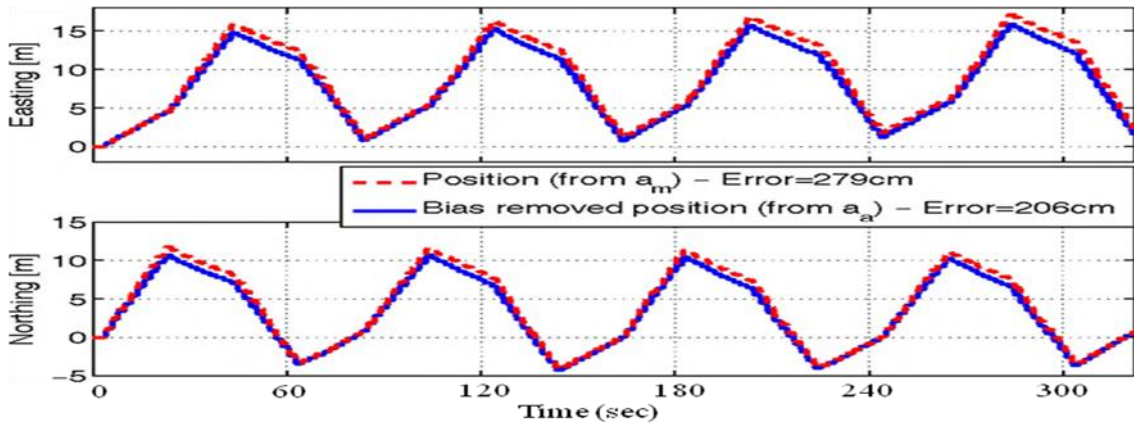


Figure5. Comparison of two positions calculated from measured and actual accelerations using ZUPT'ing scheme. Easting refers to the movement towards the east, and Northing refers to the movement towards the north.

process methodology.

A. Acceleration bias compensation The IMU software provides gravity-compensated acceleration in the

We fine tuned the IMU measurements via a bias estimator. IMU's acceleration output was processed with a Kalman filter to calculate the actual acceleration as

$$a_a^{nav}[k] = a_m^{nav}[k] - R_{nb}[k]a_b^{body}[k] \quad (5)$$

where  $a_a^{nav}$  is the measured acceleration in the navigation frame,  $a_b^{body}$  is the acceleration bias detected by the Kalman filter in the body frame, and  $a_a^{nav}$  is the actual acceleration represented in the navigation frame that exists on the heel. The bias estimation,  $a_b^{body}$  is

frames,  $R_{nb}$ . Gravity-compensated acceleration in the sensor body coordinates,  $a^{body}$ , can be calculated as

$$a^{body}[k] = R_{nb}^{-1}[k]a^{nav}[k] \quad (4)$$

performed in the IMU's body coordinate frame, and then subtracted from the measured acceleration in order to get the actual acceleration in the navigation frame.

A. The output of the KF is plotted in Figure 4. Thanks to the extra level of filtering, our tests revealed that the final position error reduced by about 5-10%. A look at Figure 5, shows comparative positions calculated from measured and actual (bias compensated) accelerations. As a result, the loop-closing error was decreased by 26%.

B. Calibration: Our tests showed that in initial loop-closing, the results tilted towards a fixed direction. Probably, this is the result of an error in the IMU's

internal gravity compensation algorithm. To avoid the tilt, we extended a calibration scheme and applied it each time while performing an experiment. We marked 40 points around an 11.7 m/edge square in the field such that the user can walk on these marked step points. Walking with uniform steps, the user completed 4 to 6 laps (Figure 6) around the square. Using this initial data, 40 lines were fitted through the position of the same step points. An average slope was determined from the linear fits, and the slope was used to correct the deviation in the future collected data.

C. Walk Experiments: We performed loop-closing Vi hour walks to test our system. First, we performed a 5-minute short walk to be used in the calibration process described earlier. Next, we performed, longer, Vi hour walks ending at the stalling point to calculate the loop-closing error for each walk.



Figure 6: Calibration step points around the square calibration loop.

## VII. CONCLUSIONS AND FUTURE WORK

In our paper, we presented a prototype of a micro-navigation system that would aid the visually impaired to walk freely in closed doors. The prototype uses few components and accessible technology. Preliminary test results proved that the solution is useful and usable in guiding the blind people indoors. Nevertheless, it is essential to carry on testing the solution in normal surroundings, involving the visually challenged and obtain their valuable suggestions for improving the navigation system.

The proposed navigation system is a cool mantra for the visually challenged as it has already read the indoor surroundings. Hypothetically taken, if a visually challenged person wants to sit or rest, it will guide him to where the sofa or bed is.

In short, the personal micro-navigation system uses inertial measurements from an IMU and zero velocity measurements from a GRSC. All design goals have been successful. However, the zero-velocity sensing bias goal was reached in a roundabout way. This is primarily because the position of the pressure sensor array in the shoe. It has been found that closer the sensor is to the ground, the detection of zero-velocity regions gets

better. Even though, the pressure sensor array in our setup was positioned below the shoe's insole, we were successful in monitoring the zero-velocity points using pressure contour velocities.

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