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Land Vehicle Navigation System Based on Low Cost Inertial Sensor

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ABSTRACT

Our goal was to implement and construct a simple land vehicle Inertial Navigation System (LVNS) using micro-electromechanical systems (MEMS) sensor. An inertial navigation (INS) system was designed using state of the commercial inertial sensors on a low cost budget. The system uses a 3 axis accelerometer, 3 axis gyros to detect the orientation, velocity and position which is calculated and displayed by the system for the user to view. This paper was performed on the assumption that this system would be used underground, inside a building, whereas global positioning data (GPS) cannot be received and so efficient inertial movement tracking is the only plausible method for the system to track current velocity and position. Without using any external device or sensor as aided system, where used (INS) in conjunction with zero velocity update (ZUPT) method to fulfil the demands of system. This paper evaluates the positioning capability of INS/ZUPT integrated systems utilizing low cost (IMU) for INS
Keywords: Inertial Navigation , Accelerometer, Gyroscope, zero velocity update (ZUPT), Micro-electromechanical systems (MEMS)

I. INTRODUCTION

Inertial navigation is used in a wide range of applications were originally developed for military application specially for navigating rockets [10]. Then later used in many applications from horizontal directional drilling up to space vehicle navigation [8]. Inertial Navigating in area where global navigation satellite system (GNSS) signals are not available [6] either blocked or poorly received for position localization[6] is one of the most inserting navigation researches today . Inertial Navigation Systems have several advantages. They are self-contained in that no external infrastructure (such as a radio transmitter network) is required; they provide continuous information; the output is available anywhere [14] (underground, underwater, inside buildings) and they are unaffected by any outside interference or jamming. However the accuracy of a standalone INS degrades with time (unbounded error) due to sensor errors, and it needs to be provided with its initial position. Accurate systems can be expensive (millions of dollars) , large and heavy; although this is changing as the technology improves.

Recent advances in the construction of MEMS devices also due their low cost and availability have made it possible to manufacture small and light inertial navigation systems [10].

These advances have widened the range of possible applications to include areas such as tracking of human, animal and any small land vehicle motion then get their velocity and position. Today became everybody is daily in touch with inertial technology for example every modern vehicle contains at least one gyro and two accelerometers for ESP (electronic stability program) [8], or more complex use three gyro with tree accelerometer which is called an inertial measurement unit (IMU)where it used in the field of vehicle navigation system .

Finally we have to know that the inertial navigation system market is estimated at $2.75 billion in 2014 and is expected to reach $4.63 billion by 2019. The inertial navigation system market for defense segment is estimated at $1.98 billion in 2014 and is expected to reach $3.33 billion by 2019. The inertial navigation system market for commercial segment is estimated at $770 million in 2014 and is expected to reach $1.29 billion by 2019[11].

II. METHODS AND MATERIAL

A. Inertial Navigation System

Inertial navigation is a self-contained navigation technique in which measurements provided by accelerometers and gyroscopes are used to track the position and orientation of an object relative to a known starting point, orientation and velocity [10]. Inertial measurement units (IMUs) typically contain three orthogonal rate-gyroscopes and three orthogonal accelerometers, measuring angular velocity and linear acceleration respectively. By processing signals from these devices it is possible to track the position and orientation of a device [10].

Implementation of inertial navigation systems (INS) is typically in so-called strap-down technology (see Fig.1), where all inertial sensors (gyros and accelerometers) are stiff mounted (strapped down) on the vehicle. In the past the systems had been designed in so-called gimbaled technology, where the gyros had been used to stabilize the accelerometers mechanically in space[8]. In strap-down systems the stabilization is done mathematically, and therefore all inertial sensors suffer the full vehicle's dynamics. Due to missing mechanical gimbals the strap-down systems are much more robust in operation than the gimbaled systems. [8]

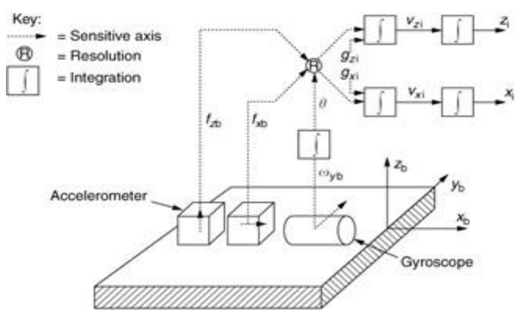


Figure 1: Strap-down inertial navigation system.[11]

B. Navigation Equations

Navigation with respect to a fixed frame In a situation where we need to navigate with respect to inertial or fixed non accelerating and non-rotating set of axis, the measured components of specific force and estimates of the gravitational field are summed to determine the components with respect to that space fixed reference frame. These quantities can be integrated once in order to determine the velocity and once more in order to determine the position in that frame. The mathematical expression of this process can be done in the following manner. Let r represent the position vector of some point P with respect to O, the origin of the reference frame, as shown on fig 2. [11]

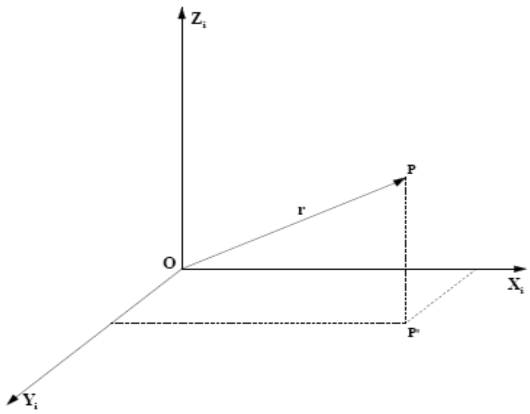


Figure 2: Position vector with respect to reference frame

The acceleration of P with respect to this space fixed axis set denoted by the Subscript i, (read inertial) is defined by:

$$a_i = \frac{d^2}{dt^2} \, r|_i \tag{1}$$

A triad of perfect accelerometers will provide a measure of the specific force acting at the point P where:

$$f = \frac{d^2}{dt^2} \, r|_i - g \tag{2}$$

in which g is the mass attraction gravitation vector. Rearranging equation (2.7) yields the following equation:

$$\frac{d^2}{dt^2} \, r|_i = f + g \tag{3}$$

This is called the navigation equation since; with suitable integration it yields the navigation quantities of velocity and position.

$$v_i = \frac{d}{td}\ r|_i \tag{4}$$

The first integral gives the velocity of point P with respect to the i-frame, whilst a second integration gives its position figure 3.

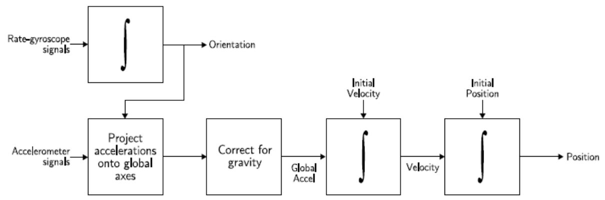


Figure 3: Strap-down inertial navigation algorithm.[10]

In practice, we often need to derive the estimates of a vehicle's velocity and position with respect to a rotating reference frame, as when navigating in the vicinity of the Earth. In this situation, additional apparent forces will be acting which are functions of the reference frame motion. This results in a revised form of the navigation equation which may be integrated to determine the ground speed of the vehicle ve, directly. Alternatively, v_e may be computed from the inertial velocity v_i, using the theorem of Coriolis, as follows,

$$v_e = \frac{d}{dt}\ r|_e\, v_i - \Omega_{ie}\ \times r \tag{5}$$

Where $\Omega_{ie} = [\,0\ 0\ \omega_{ie}]^T$ is the turn rate of the Earth frame with respect to the i-frame and × denotes a vector cross product.

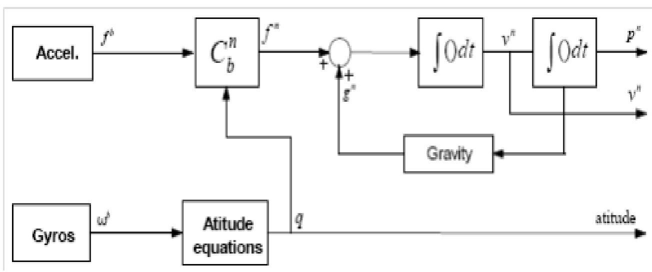


Figure 4: IN mechanization diagram - Navigation frame

For instance, when the navigation period is short the effects of the rotation of the Earth on the attitude computation process can sometimes be ignored. Coriolis corrections are no longer essential in the velocity equations to give sufficiently accurate navigation .

C. The Choice of Coordinate Frame

Coordinate frames are used to express the position of a point in relation to some reference. Some useful coordinate frames relevant to navigation and their mutual transformations [1].

- *Local level Tangent Plane (LTP),*

In navigation applications where the vehicle is navigating over a small area, the origin of the Navigation frame remains permanently fixed at the same location on the Earth's surface a (the starting location of the vehicle) and does not translate with the vehicle[13]. If the vehicle is navigating over a small enough area, then the curvature of the Earth's surface is so slight that it can be considered negligible. Because the curvature of the Earth's surface is negligible in this scenario, the navigation of the vehicle can be constrained to a single planar surface instead of a curved surface. This surface is called the Local Tangent Plane (LTP) as shown in Fig 5, and it is defined as the plane created by the X- and Y- axes of the Navigation frame. LTP is a perfectly flat surface that is tangent to the surface of the Earth at a single point (the starting location of the vehicle). Using the LTP greatly simplifies many aspects of the inertial navigation algorithm, but the downside is that it is only accurate over small areas. Using the LTP to define the position of the vehicle becomes more and more inaccurate as the vehicle travels further and further away from its starting location[13].

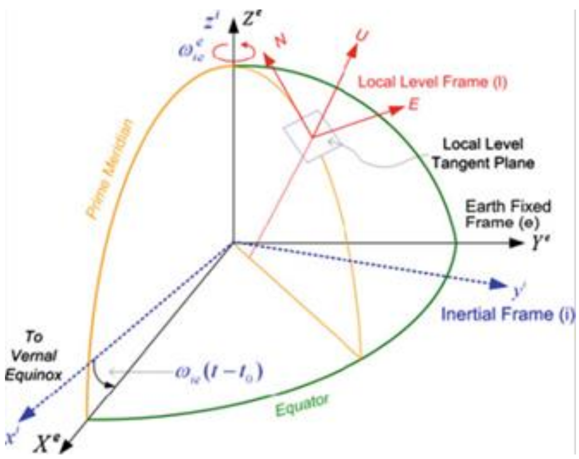


Figure 5: An illustration of some coordainates frame[1]

- *Body Frame*

In most applications, the sensitive axes of the inertial sensors are made to coincide with the axes of the moving platform in which the sensors are mounted. These axes are usually known as the body frame [1]. The body frame used in my paper is shown in Fig. 6, and is defined as:

a. The origin usually coincides with the center of gravity of the vehicle.
b. The y-axis points towards the forward direction. It is also called the roll axis as the roll angle is defined around this axis using the right-hand rule.
c. The x-axis points towards the transverse direction. It is also called the pitch axis, as the pitch angle corresponds to rotations around this axis using the right-hand rule.
d. The z-axis points towards the vertical direction completing a right-handed coordinate system. It is also called the yaw axis as the yaw angle corresponds to rotations around this axis using the right-hand rule[1].

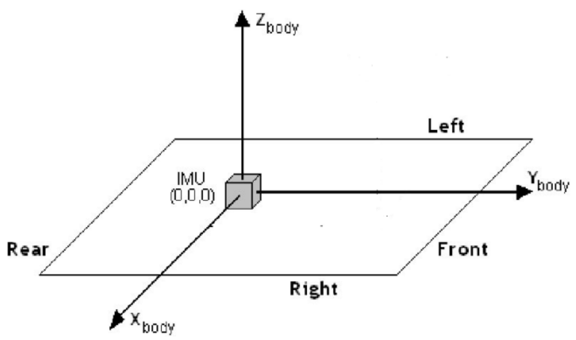


Figure 6: The body frame of a moving platform

D. Transformation between Body Frame and Local Frame

One of the important direction cosine matrices is R_l^b; which transforms a vector from the b-frame to the l-frame, a requirement during the mechanization process. This is expressed in terms of yaw, pitch and rolls Euler angles. According to the definitions of these specific angles and the elementary direction cosine matrices, R_l^b can be expressed as

$$R_b^l = (R_l^b)^{-1} = (R_l^b)^T = (R_c^d\ R_b^c\ R_a^b)^T = (R_a^b)^T (R_b^c)^T (R_c^d)^T \qquad (6)$$

Substituting the elementary matrices into this equation gives

$$R_b^l = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}^T \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos p & \sin p \\ 0 & -\sin p & \cos p \end{bmatrix}^T \begin{bmatrix} \cos r & 0 & -\sin r \\ 0 & 1 & 0 \\ \sin r & 0 & \cos r \end{bmatrix}^T \quad (7)$$

$$R_b^l = \begin{bmatrix} \cos\gamma & -\sin\gamma & 0 \\ \sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos p & -\sin p \\ 0 & \sin p & \cos p \end{bmatrix} \begin{bmatrix} \cos r & 0 & -\sin r \\ 0 & 1 & 0 \\ -\sin r & 0 & \cos r \end{bmatrix} \quad (8)$$

$$R_b^l = \begin{bmatrix} \cos y \cos r - \sin y \sin p \sin r & -\sin y \cos p & \cos y \sin r + \sin y \sin p \cos r \\ \sin y \cos r + \cos y \sin p \sin r & \cos y \cos p & \sin y \sin r - \cos y \sin p \cos r \\ -\cos p \sin r & \sin p & \cos p \cos r \end{bmatrix} \quad (9)$$

where ‘p’, ‘r’ and ‘y’ are the pitch, roll and yaw angles. With a known R_l^b; these angles can be calculated as

$$P = \tan^{-1}\left\{\frac{R_b^l\,(3,2)}{\sqrt{[R_b^l\,(1,2)]^2 + [R_b^l\,(2,2)]^2}}\right\} \quad (10)$$

$$y = -\tan^{-1}\left[\frac{R_b^l\,(1,2)}{R_b^l\,(2,2)}\right] \quad (11)$$

$$y = -\tan^{-1}\left[\frac{R_b^l\,(3,1)}{R_b^l\,(3,3)}\right] \quad (12)$$

A transformation from the l-frame to the b-frame can be achieved by the inverse rotation matrix, R_l^b; as follows

$$R_l^b = (R_b^l)^{-1} = (R_b^l)^T \quad (13)$$

E. Unaided INS & IMU Grades

Unaided INS navigation inevitably suffers from unbounded errors in velocity, position and attitude which may be unacceptable in many applications. For this reason some kind of aiding is needed to either bound or reduces these errors. Many different forms of aiding can be used giving various results. Some of the more popular aiding devices are Doppler Velocity Logs (DVL), Global Positioning System (GPS) and barometric measurements. or aided with navigation related information. Anyway the accuracy of unaided

INS are completely depends on performance or quality of inertial sensor which is called sensor grade.

Determining which type of inertial sensor is right for any application can be a difficult process due to the lack of information available pertaining to the subject. Datasheets for inertial sensors can be very confusing and make it difficult for potential buyers to compare different products.

A high grade INS can cost over 1 million dollars [4]. These systems will typically provide un-aided navigation solution drifts that are less than 1.8 km per day. These systems are typically used on ships, submarines, and some spacecraft. Navigation grade systems have slightly lower performance than the marine systems and are typically used on commercial airliners and military aircraft worldwide. A navigation grade system will typically have less than 1.5km drift per hour. These systems cost around $100,000 [4] The lowest grade of inertial sensors is often referred to as automotive grade. They are typically sold as individual accelerometers or gyros, As shown in (table.1) is an overview of the typical errors for each grade of inertial sensors. [4] by assumed that the errors in position will be caused only by the errors in the accelerometer bias.

Table.1: IMUs grades and their effect [4]

	Accelerometer Bias Error		Horizontal Position Error [m]			
Grade	[mg]		1s	10s	60s	1hr
Navigation	0.025		0.13 mm	12 mm	0.44 m	1.6 km
Tactical	0.3		1.5 mm	150 mm	5.3 m	19 km
Industrial	3		15 mm	1.5 m	53 m	190 km
Automotive	125		620 mm	60 m	2.2 km	7900 km

Errors in the position estimate will actually be caused by many factors including the gyro bias stability, accelerometer scale factor uncertainty, and many other parameters, however, the measurements from low-grade inertial sensors are huge and not easy, due to their big errors. For low cost IMU, there is a method called Zero Velocity Update (ZUPT) is often adapted to some of the errors and used to improve the time performance of position determination without aiding (no GPS, no odometer or any external sensor).

F. Zero Velocity Update Method

All inertial navigation systems suffer from integration drift, as small errors in measurement are integrated into progressively larger errors in velocity and especially position. This is a problem that is inherent in every open loop control system. Inertial navigation may also be used to supplement other navigation systems, providing a higher degree of accuracy than is possible with the use of any single navigation system. For example, if, in terrestrial use, the inertial tracked velocity is intermittently updated to zero by stopping, the position will remain precise for a much longer time, a so-called "zero velocity update" (ZUPT). [8].

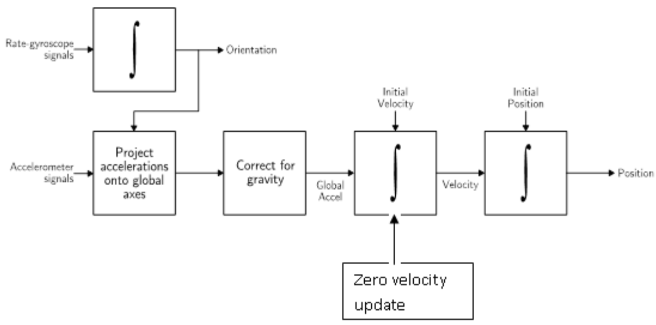


Figure 7: ZUPT aiding INS

Zero velocity updates (ZUPT), or measurements of velocity equal zero, are most often used to control the error growth in inertial navigation systems (INS). A ZUPT can be made whenever a user, such as a land vehicle or a dismounted soldier, The concept is simple: when the INS is stationary, its known velocity (zero) can be used as a measurement to update the navigation processing algorisms [14]. ZUPT can be processed continually as long as the INS is not stationary. They may be scheduled, requiring the operator to hold stationary for a short length of time. Additionally, periods of zero motion can be automatically detected by software and a ZUPT executed. ZUPT can be performed when vehicles are stopped, when soldiers are relatively stationary, or even on every footfall of a foot-mounted sensor [14].

G. Improvement of INS Using ZUPT Method

Since in this experiment had been chosen a low cost IMU which also in low performance. It is necessary to bind the errors to an acceptable level by using one of aiding systems, which is called zero velocity update in our experiment.

As we know when an inertial navigation algorithm is used, the position and velocity errors diverge by a few seconds without error resetting [6]. During normal walking cycles, a foot touches the ground almost periodically and stays on the ground for a short time (usually about 0.1~0.3 s) [6], which is called the zero velocity interval. In the zero velocity updating algorithm, this zero velocity interval is detected and thus the velocity error is reset to zero [6] for every walking cycle, this idea usually used with foot mounted sensor and ZUPT.

But for land vehicle applications the idea is to stop the vehicle from time to time and INS algorithms will update the error states and covariance accordingly. However, this idea is not practical solution. Therefore we are tried to identify some typical behavior of the zero velocity interval which when the vehicle is in driving which will allow us to use a method similar to the Zero Velocity Update with the stop movement, thus improve the time performance of position determination.

The assumption was how the system can be set to zero-velocity all x period without stop the vehicle from time to time and without aiding external device (no GPS, no odometer!).

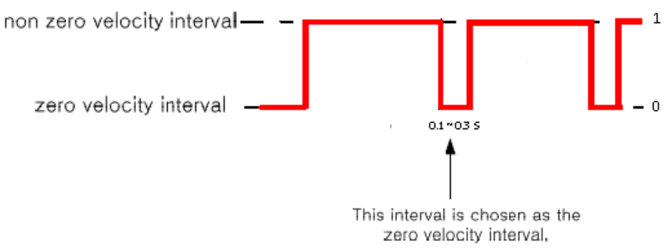


Figure 8: zero velocity updates (pulse)

The idea was by generate a pulses as zero velocity intervals (stand-still) period as shown in fig.8, which may take about 0.1 seconds each 3 seconds (matching the normal walking cycles), and compensate them in velocity integration as shown in Fig. 9 . This idea is able to rest the accumulated errors due the first integration (velocity integration) to the zero every period of time, and can improve the position performance dramatically. In case the INS is stationary its known velocity (zero), ZUPT can be processed continually as long as the INS is not stationary. Regarding our experiment, generated pulses as zero velocity intervals can be adjusted according to the velocity where it designed to work in real time mode.

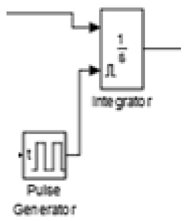


Figure 9 : zero velocity updates simulation

So, we have been succeeded to apply some of zero velocity update behaviors on land vehicle INS module without stopping the vehicle each time to reset the accumulated error, also without external device as aiding system, which does mean that is, independent system.

H. Experiment Hardware and Software

In this experiment, we decided to use the Intenseness MPU-6050 3-Axis Gyro/Accelerometer Motion Processing Unit, which is low cost (~ 60 L.D). MPU6050 combines one 3 axis accelerometer and one 3 axis gyroscope, and it has its own digital motion processor (DMP) which can process the motion data with its inside algorithm (according to owner datasheet) . Arduino-mega2560 has been selected as data acquisition board where it is low-cost, high performance electronic platform that has interchangeable hardware and software also its easy to use and adequate precision. INS model was created in Matlab/Simulink because of their ability to analyze and processing of data. The complete system was run in the (real time mode), which allowed monitor the results in best way.

Figure 10: Hardware Configuration

I. Experiment and Test Field

Once the inertial navigation algorithm has been completely prepared and coded, it had been tested using inertial data from a real-world navigation plan (matlab simulink real time mode) To acquire this data, MPU6050 together with data acquisition Arduino Mega2560 and personal laptop (Complete INS) was rigidly mounted to a small land vehicle, which was then driven through a selected test path. The land vehicle was driven through the test path many times starting and ending in the same place each time, the inertial data recorded from IMU during these tests was used to determine how accurately the INS algorithm can track the linear velocity, position of a vehicle movement.

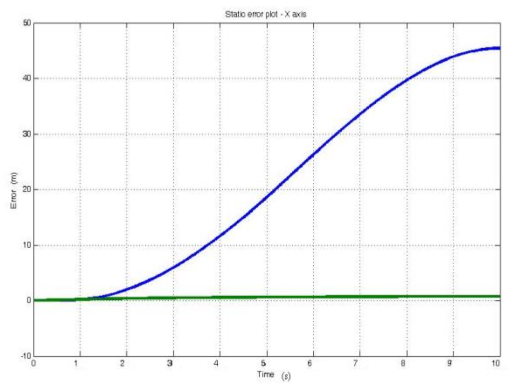
The land vehicle test path was set up on indoor flat environment. Because of the Indoor environments are typically very structured and flat with few obstructions. Which dose means that vehicle essentially navigating along a single planar surface that is also level with gravity, A square test path was chosen so that the vehicle could travel in a loop and finish at the same location that it started at. This loop path is a useful metric to have because after one complete loop of the test path, the vehicle stops almost at the exact same location that it started at. To help us compare the results each other's in same experiment course.

III. RESULTS AND DISCUSSION

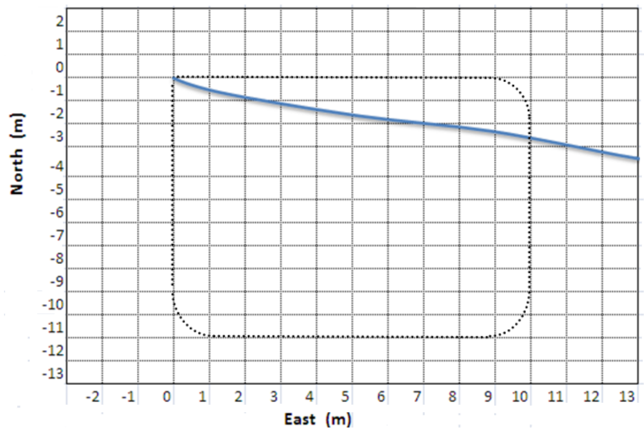
The results presented here illustrate how the INS-based on Low cost IMU perform. Figure 11 shows the error plot of INS in static mode at different time intervals, Even being stationary the IMU gave readings that accumulated to error growth very quickly where error reached to 45 meter at the time interval of 10 seconds, as can be seen from the graph of static error plot (Fig.9- blue curve). The static error was found to much less than the error using ZUPT method with same time interval (Fig. 9- green curve). The error reduced to 1 meter at the time interval of 10 seconds, but these errors are not standard and varied each time the INS started and called called stochastic errors, unlike deterministic errors, which are inherently stable and repeatable.

The result of the experiment at test filed, was found that when system limited to using only IMU data without Aided navigation information or sensor. With no aided addition information to help compensate for the inaccuracies and drifts in the inertial data, the errors in the true linear velocity, position of the vehicle grows unbounded over time data (Fig. 10 - blue path). If left unchecked these errors became very large very quickly, which is why accurately compensating for the drifts and other defects using with external information is important.

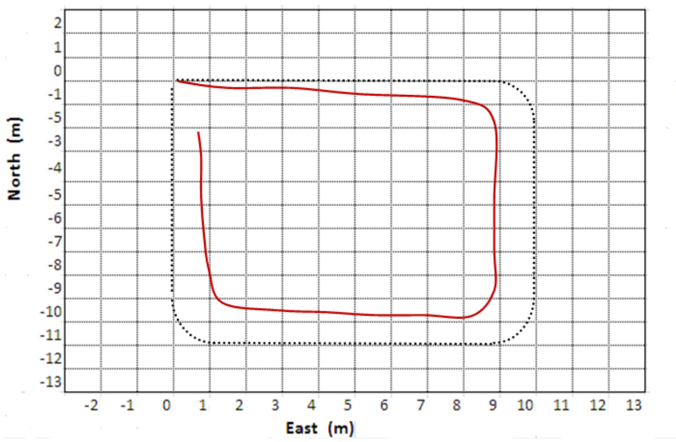
The (Fig.13- red path) clearly shows the performing of ZUPT helps to significantly limit the errors in the true linear position and orientation of the vehicle over time. The idea of ZUPT allowed to rest the accumulated errors due the velocity integration to the zero each period of time and could improve the position performance dramatically.



(Fig. 11) Static Error Plot
(blue curve shows how the error of INS standalone growth very large unlike when using ZUPT to aide INS - green curve)

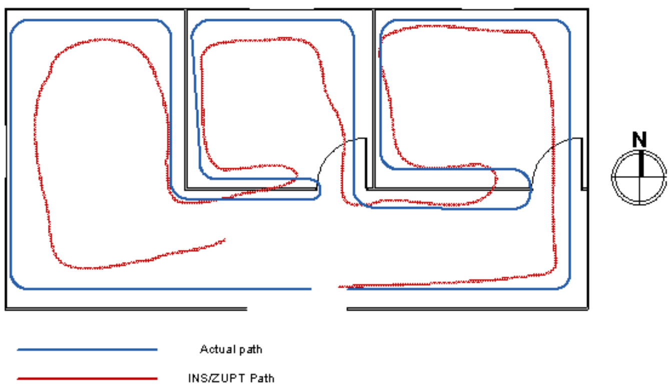


(Fig. 10) The path of INS using only IMU data



(Fig. 13) The path of INS using ZUPT method

In (Fig. 14) we can see the true trajectory of inertial navigation system ZUPT aided used in following experiment. The navigation unit is travelled at normal human speed (5~6m/s) for almost five minutes, and zero velocity updated affected in each period of time (0.3s of 1s) matching with walking cycle. The results path shown in the (Fig. 12) are calculated with IMU/mpu6050 applied in real time mode. We may notice that the shape of the path is followed by INS, where prominent improvements are achieved with aided INS using ZUPT method.



(Fig. 14) this figure shows how the INS/ZUPT Path (red) followed the actual path (blue) at indoor environment

IV. CONCLUSION

The major objectives of this paper were to construct and develop an INS model based on low cost IMU in the real time mode, and test the one of methods to improve the navigation accuracy of low cost inertial measurement unit.

The results showed the gradual error growth in the INS data. Two different techniques showed different results. zero velocity update showed better performance over distances while free INS was found worse . Inertial data from the INS only is still not as high-quality as the inertial data from the INS/ZUPT is. The inertial data from the INS/ZUPT is still much better overall

Low cost IMU sensors are still considered relatively poor devices in accuracy for land surveying applications despite its popular growth and low cost but can give reasonable support if used integrated with an aiding information such as (ZUPT) that can support the INS drift by giving update of accurate measurement.

The conclusion to take away from previous results is that the analysis and modeling of typical MEMS IMU error sources did make the inertial data from the INS/ZUPT better overall, and the performance gap of the MPU6050 did decrease, but the inertial data from the INS only is still not as high-quality as the inertial data from the INS/ZUPT is. The inertial data from the INS/ZUPT is still much better overall, due largely in part to how the internal mechanisms of MPU6050 are set up. While the MPU6050 and is constructed using MEMS technology, it's has several sophisticated internal mechanisms (temperature calibration, low-pass filtering, etc.) that operate on the inertial data before it is received by the us.

V. REFERENCES

[1]. Noureldin, Aboelmagd, Karamat, Tashfeen B., Georgy, Jacques "Fundamentals of Inertial Navigation, Satellite-based Positioning and their Integration "2013, http://www.springer.com/gp/book/ 9783642304651

[2]. David H. Titterton and John L. Weston "Strapdown Inertial Navigation Technology"- 2nd Edition 2004 The Institution of Electrical Engineer

[3]. Cai, Guowei, Chen, Ben M., Lee, Tong Heng "Unmanned Rotorcraft Systems "2011 http://www.springer.com/978-0-85729-634-4

[4]. VectorNavTechnologies,LLC privately owned company headquartered in Dallas, Texas, USA. http://www.vectornav.com/support/library/imu-and-ins

[5]. Inertial Navigation System, Master project, Control Rolf Christensen Nikolaj Fogh,4th of June 2008 http://www.control.aau.dk/

[6]. Khairi Abdulrahim Terry Moore Chris Hideand Chris Hill "Understanding the Performance of Zero Velocity Updates in MEMS- based Pedestrian Navigation"International Journal of Advancements in Technology March 2014 ISSN 0976-4860

[7]. wikipedia.org https://en.wikipedia.org/wiki/Inertial_ navigation_system

[8]. iMAR Navigation GmbH Solutions in Inertial Navigation http://www.imar-navigation.de

[9]. Saurabh Godha "Performance Evaluation of Low Cost MEMS-Based IMU Integrated With GPS for Land Vehicle Navigation Application "2006 UCGE Reports Number 20239 www.geomatics.ucalgary.ca/research/publications/ GradTheses.html

[10]. Oliver J. Woodman "An introduction to inertial navigation"August 2007 Technical reports published by the University of Cambridge Computer Laboratory are freely available via the Internet:

[11]. Mr. Rohan North - Dominion Plaza 2014 markets and markets, http://www.marketsandmarkets.com/ ResearchInsight/inertial-navigation-system.asp

[12]. John L. Weston "Strapdown Inertial Navigation Technology", 2004 2nd Edition The Institution of Electrical Engineers

[13]. Justin michael barrett "analyzing and modeling low-cost mems imus for use in an Inertial navigation system"2014, A thesis Submitted to the faculty Of the Worcester polytechnic institute

[14]. "Basic Guide to Advanced Navigation"2010 rto publication set-114/rtg-65 NATO

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