FPGA BASED REAL TIME SYSTEMS FOR POSITION TRACKING

N V S SAI KRISHNA KANTH[#[1]], S SANDEEP KUMAR[#[2]], R RAVI KUMAR[*[3]]

[#]Student, Department of Electronics and Communication Engineering, k.L.University Greenfields, Guntur, Andhra Pradesh, India

[*] Assoc.Proffesor, Department of Electronics and Computers Engineering, k.L.University Greenfields, Guntur, Andhra Pradesh, India

Abstract*— Position tracking systems supported with RISS and gyroscopes are found to be better solutions in the places where GPS is unemployable or in the places where GPS cannot work. Generally systems that are based on GPS for position tracking, face a lot of problems in the areas where line of sight is hard to achieve i.e. GPS denied environment, like dense terrestrial areas, subways, tunnels and hidden places. This system provides continuous and highly reliable position tracking by synchronising real time stimulus obtained from the sensors and the actual GPS values. The core processor of the system is built on an FPGA which is used in the system kernel. The key factor for using FPGA in the system is its customisable core and its flexibility to interface with the sensors. The core employees the Hybrid Kalman filter for estimating the displacement and position. In this system we integrate the 3D-RISS with GPS to achieve a Reliable and uninterrupted Position Tracking. In these systems the processor estimates the position of the object based on the four inputs taken from the RISS and the Odometer, they are Velocity, acceleration, orientation and position. Here the system integrates the offline Inertial data (i.e. while the GPS is unavailable) with that of actual GPS data. The system starts to compute the position and velocity using the initial data provided by the GPS at the instant it was lost. This kind of position tracking systems used in various kinds of moving objects like Aircrafts, Guided missiles, Land Rovers, and Marine navigations.

***Keywords*— Position Tracking, FPGA, Inertial Navigation System, IP-Core, RISS, Hybrid Kalman Filter.**

I. Introduction:

1.1 Inertial Navigation System

This is a navigation system is used to compute the position and velocity and orientation of the object. The computations are done with the aid of sensors like gyroscope, motion sensors, and some computing algorithms. All these are integrated through an ASIC or a processor and this whole system acts as an Inertial Navigation System. Stimulus from the sensors is correlated in time with the help of a Hybrid Kalman filter. Once the INS is provided with the initial data, it further doesn't need any external references, and it updates the position and orientation by integrating and computing the responses from its sensors. INS systems are used trace the trajectory followed by an object in relation to time. The bias in accelerometer and gyroscope contribute to an considerable error in the position to an order proportional to t^2 and t^3 respectively. Since in many applications cost and weight are the key concerns in the navigational systems, there lies trade of between accuracy and cost. Since the existing MEMS based INS are much prone to noise and Drift errors. Contemporary research is being done on implementation of INS based on MEMS with low noise and bias factors.

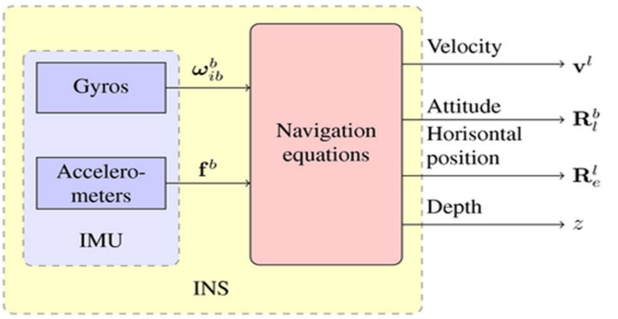

Figure 1. Basic block diagram of an INS

1.2 Real Time Embedded Systems using FPGA

Real time embedded systems are those which are designed to perform some dedicated functions .These systems collect required data from surroundings through the network and sensors. And manipulate data according to algorithms. These are designed to process data in large amounts also these systems can be integrated to a complex system feasibly. Also these embedded systems when hosted on a target system which employees a general purpose processor, should have its method of software development known as cross platform development. The embedded systems can be developed on different platforms such as Digital Signal Processors s, ASIC s and FPGAs. The selection of platform depends on many factors such as cost of production, power consumption and performance besides availability of developing tools and the cost and time of project. Here the objective is to realise the position tracking algorithm on an embedded system through which stimulus from various sensors are acquired and synchronised. By this we can track the position of an object in time based measure. There is no restrictions to develop the system on a particular platform so we choose the methodology based on the platform we prefer, for example embedded software's for DSPs , processor based cores such as microcontrollers.

The main vision of this paper is to implement an Real time embedded system for position tracking based on 3D RISS/GPS.

1.3 Integrated 3D - RISS/GPS Position tracking systems:

The integrated position tracking system uses an integrated algorithm that integrates the RISS with that of GPS. In a general GPS based positioning systems, at times of blockage or absence of line of site the system gets interrupted, and that leads absence of information or multipath which degrades the system performance. On the other hand the dedicated INS based tracking systems are a failure due to the errors that arise in the sensors in it, once if these errors are not corrected the error in positioning grow unbounded. In this integrated system the GPS helps to calibrate the error in the sensors and thus the system becomes adaptive in order make self-corrections and at the time the GPS outages the positioning goes uninterrupted by handing over the process to RISS. The advantage of 3D- RISS over traditional integrated systems is (i) In this system we eliminate the accelerometer to derive the velocity instead we use an odometer, (ii) By the use of 3D-RISS the position can be done even in the Air and marine navigations also. The first advantage that we pointed in this system is using the vehicle velocity reading directly instead of deriving it from accelerometer/ sensors. If the velocity is calculated using sensor that which involves an integration operation, the sensors will have bias error, and so the integration causes a deviation proportional to square of the outage time.

Another drawback in a traditional INS/GPS based navigation system is due to the uncompensated bias drifts in the gyroscope the positioning deviation which is cube times the GPS outage time , the error causes worst deviations in the values. So we overcome those errors by neglecting the Horizontally aligned gyroscopes, since in case of land navigation the positioning can be treated as almost 2 dimensional, and any motion in the spatial direction is extremely low and hence negligible. So these errors are totally eliminated from the system. Since we eliminated the integration errors the system yield better performance than the existing solutions either in terms of deviation from actual values or the accuracy in proportional to outage time.

1.4 RISS Mechanisation:

This is the process of transforming stimulus produced from the components of RISS system into parameters like position, velocity and posture. RISS mechanism works with reference to initial measurements, previous outputs. For the actual position tracking, RISS involves 5 navigation states for a system i.e. latitude (ϕ) and longitude (λ) for position, V_{east} and V_{North} for velocity and orientation parameter (A).

$$A_{k+1} = A_k - (\omega_{z(k+1)}.T_S - \omega^e.SIN(\phi_k)T_S - \frac{V_{east(k)}.\tan(\phi_k)}{R+h}.T_S)$$

Where:

Y=Yaw angle (radians)

A=Azimuthal angle (radians)

ω_z =Angular velocity measured by the gyroscope (radians/sec)

ω^e =Earths angular velocity (radians/sec)

ϕ =Vehicle's Latitude

V_{east} =Vehicle's east component of velocity (meters/sec)

R_N =Normal Radius of curvature of earth's ellipsoid (meters)

h=Vehicle's altitude (meters)

$$\begin{pmatrix}\phi_{k+1}\\ \lambda_{k+1}\end{pmatrix} = \begin{pmatrix}\phi_k\\ \lambda_k\end{pmatrix} + \begin{pmatrix} 0 & \dfrac{1}{R_M+h} \\ \dfrac{1}{(R_N+h).\cos(\phi_{k+1})} & 0 \end{pmatrix} \begin{pmatrix} V_{East(k+1)} \\ V_{North(k+1)}\end{pmatrix} T_s$$

λ = Vehicle's Longitude (radians)

R_M = Meridian radius of curvature of earth's ellipsoid (meters)

V_{North} = Vehicle's north component of velocity

$V_{forward}$ = Vehicle's speed derived from odometer.

II. INTEGRATION of RISS/GPS DATA USING HYBRID KF:

In conventional KF method the initial parameter from the GPS is fused with RISS computed parameters in a closed loop for position tracking. In order to estimate the state, KF integrates measurement data considering the measurements have errors that have small effect on state estimation. Since the errors in dynamic system are variable in time, error models are required for analysis and estimation of various error sources.

Making use of these governing models the KF estimates the state of a discrete time process

a) State equation (System model):

$$\mathbf{X}_{k+1} = F_{k+1,k}.\mathbf{x}_k + G_k \mathbf{w}_k$$

where

$\mathbf{x}$ = Error state vector

F = State transition matrix

G= Noise coupling matrix

$\mathbf{w}$ = System/process noise

b) Observation model(Process model):

$$\mathbf{Z}_{k+1} = H_{k+1}.\mathbf{x}_{k+1} + V_{k+1}$$

Where

Z= Observation vector

H= Measurement design matrix

V=Measurement noise

III. MEASUREMENT SYNCHRONIZATION:

While implementing a synchronised system the main concern is synchronisation between GPS, IMU and odometer measurements. The clock difference and data transmission latency could cause data alignment discrepancies during the data fusion stage. In multimobile sensor systems the GPS time is taken as time reference. The alignment of PPS signal edge to the standard GPS is +/- 50ns the width of the PPS signal is 1millisecond. The PPS signal is connected to a general purpose IO core which is linked to an interrupt controller. Since PPS is the key signal in our system it was given the highest priority within the system.

While the navigation algorithm is processing the synchronised measurements, the processor is forced to switch context to the IMU interrupt handlers in order to obtain almost all the measurements of the gyroscope which would be around at a rate 200 Hz.

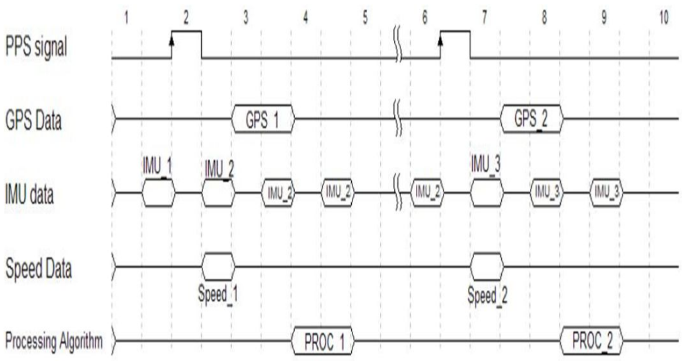

Figure 2. Timing diagram showing the PPS signal with respect to GPS, IMU and odometer output.

IV. HARDWARE RESOURCES UTILIZED:

In the FPGA we used only around 19% of the available logic cells an 35% of the BRRAM available. This implicates that even a low density FPGA suits for this application or we can include few more peripherals and coprocessors.

Resource	Used	Total Available	Utilization %
Hardware Resources			
Logic	5,935	30,720	19
Input/output	36	450	8.0
Block RAM	67	192	35
DSP	7	192	3.6
Software Memory Profiling			
Instruction Memory	117.3 KB	128 KB	91.6

Figure 3. Hardware Resources and Memory Profiling

I. *References:*

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