GINS: Dynamic Emissive Location-Based for Underwater Sensor Networks

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Abstract

Due to collect and monitor exploration of natural location resources which was difficult to acquire the location without Global Position System (GPS) in the underwater. However, there are something research was used Inertial Navigation System (INS) to location, but the INS accuracy degrades over time that the issue will be occurred, like as have uncompensated rate gyro, accelerometer errors, suffer from the drifts and biases and non-linear disturbances. This paper put forward a plan for improving the accuracy of position in INS. We devise an accuracy of position based on the Global Position System Inertial Navigation System (GINS), which the GINS derived filter is more accurate than Extended Kalman filter (EKF) for underwater sensor network. The GINS will get their position from GPS while floating above the water, and next step, they dive into water. In addition, we revised the location data from reference to oceanography profiles of fluid forces, which forces involved in underwater motion is included the buoyant force, the current force, and the fluid resistance force to correct the EKF error. And then the underwater of Cartesian coordinates (X, Y, Z) were an object with a predict-correct algorithm for solving the nonlinear dynamic systems at EKF. Finally, we present an adaptive GINS which can reduce costs of optimum position trade-offs in wide coverage of the location-based network.

Keywords: *UWSN, GPS, Oceanography, INS, Location Kalman filter*

1. Introduction

The underwater world holds climate and resources that will have incentive to the next generation of science and business. However, compared with terrestrial operations, underwater operations are fraught with difficulty due to the absence of an easy way to collect and monitor data [10].

As now, for the above purposes equipped with underwater sensors has become a promising operational technology, which includes the fast development of sensors floats and Multiple Unmanned or Autonomous Underwater Vehicles (UUVs, AUVs) for observation underwater environment. Both technologies will find application in exploration of natural undersea resources and not only gathering of scientific data in collaborative monitoring missions but also must be able to coordinate their operation by exchanging configuration, and utilizing underwater sensors to exchange data through acoustic waves for location and movement information [11], lastly step to relay monitored data to an onshore station. Underwater wireless communications can enable many scientific, environmental, commercial, safety, and military applications.

In the underwater [2], as very limited resources that include, high propagation delays, distance-dependent bandwidth, fading require considered, time varying multipath efficient and reliable communication protocols to network multiple devices. Especially the high-power medium absorption at high frequencies (greater than 50 kHz) [18]; and the available acoustic bandwidth depends on the transmission distance due to high environmental noise at low frequencies (lower than 1 kHz). So that available acoustic bandwidth may be available at tens of kilometers. Caused by multipath will result with high bit error rates, fading, and the inter symbol interference (ISI). As now underwater solutions can be addressed at the medium access control (MAC) layer by designing receivers that are capable of dealing with multipath which solutions are mainly focused on carrier-sense multiple access (CSMA), code division multiple access (CDMA), Aloha with carrier sense (Aloha-CS), and time-division multiple access (TDMA) [12].

As shown in Fig. 1 Underwater Sensor Network Communication Architecture [1].Each of these scatter sensor nodes has the capabilities to collect oceanography data (water temperature, salinity, pressure) and route data back to the sink. Data are routed back to the sink by multi-hop infrastructure architecture through the sink and let user to analyses the collect data via internet. Also, most of the existing positions for underwater wire communications do not consider infrastructures build issuer. In this paper which play a crucial role in the design of wireless positions especially in underwater environments.

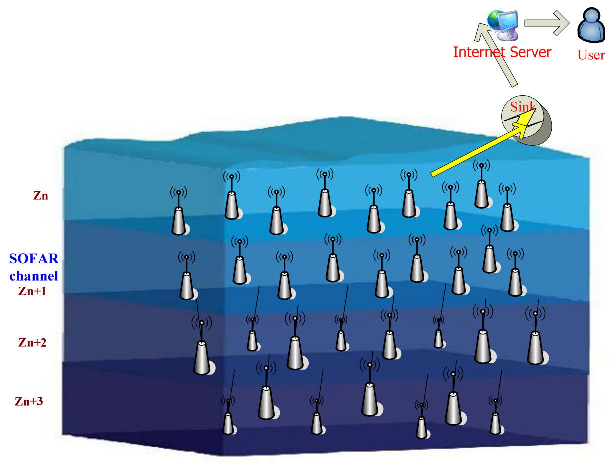

Figure 1.Underwater sensor network communication architecture

In this work, we propose a method inspired from implement the location based for sensor devices towards ubiquitous system integrating technologies. According to the target GPS position and then setting dynamic INS position. The rest of this paper is organized as follows: In Section I, we describes our application context and provides a state of the art on sensor location issue. The location is researched in Section II. How the INS and GPS are both combined in Section III. Results are then exhibited and analysed in Section IV. Finally Section V concludes this paper and gives our future working directions.

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2. Related Works

While location issues of sensor networks have become very popular on land, but the underwater environment still poses some difficult problems [14][15][16]. It utilize position-based strategy will be able to take this decision based on the available node position information and therefore enabling exchange of information within the underwater acoustic sensor network. There are something research for terrestrial sensor networks which the signal positioning algorithm to estimate the position of the sensor nodes, including the angle of arrival (AOA), received signal strength indicator (RSSI), time difference of arrival (TDoA) [4]. The distance estimation is computing that sensor nodes are aware of their position in a common coordinate system. This purpose is able to establishing a communication between a sender and a receiver that determined the position of a given node under having a request.

In the literature, Melike Erol, Luiz F. M. Vieira, Mario Gerla, [3] also address in the issue of underwater sensor location. The authors propose a reservation-based GPS architecture to obtain their position from GPS while floating above the water, and next step, they dive into water. This way will be useful to compute the location, but it was difficult to be measured position when sink to underwater, which limits the use of GPS to only above or near sea surface. In spite of fluid algorism was used to estimate of position in the absence of GPS signaling in the underwater from this literature; however the UWSN will be drifted by current so that utilizing fluid to compute the location was not accurate. Therefore, it may be necessary to introduce an alternative approach, like as GINS, which is much easier to comprehend and utilize to obtain the optimal location in this paper. Clearly, the GINS can maximize successful accurate position and minimize average end-to-end routing path in UWSN. All of buoy-based observatory has needed to acquire long-duration time series measurements of a variety of processes, and can be trapped effectively in the narrow SOFAR channel. Also requiring a large number of anchor nodes whose locations are known a priori are prohibitive to UWSN, and allowing the waves to propagate over distances in excess of 15,500 miles [13].

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3. GINS: Global Position System Navigation System

The UWSN will get their position from GPS while floating above the water, and next step, they dive into water [3]. The Cartesian coordinate (x, y, z) at time for an object with initial position is given by equation (1~2) and position of z is come from UWSN of sensor data. Also consider with the forces involved in underwater motion is included the weight force, the buoyant force, the current force, and the fluid resistance force which depends on the object shape.

$$\Delta x(n)=\sum_{t=1}^{n}\left(x(t)+(\mathrm{V}_{\mathrm{t}}^{\mathrm{cx}}-\mathrm{V}_{\mathrm{t-1}}^{\mathrm{cx}})+\frac{\mathrm{V}_{\mathrm{t}}^{\mathrm{x}}-\mathrm{V}_{cx}}{F/m}\left[1-e^{-\frac{F}{m}(t-t_{-1})}\right]\right) \tag{1}$$

$$\Delta y(n)=\sum_{t=1}^{n}\left(y(t)+(\mathrm{V}_{\mathrm{t}}^{\mathrm{cy}}-\mathrm{V}_{\mathrm{t-1}}^{\mathrm{cy}})+\frac{\mathrm{V}_{\mathrm{t}}^{\mathrm{y}}-\mathrm{V}_{cy}}{F/m}\left[1-e^{-\frac{F}{m}(t-t_{-1})}\right]\right) \tag{2}$$

The mass of an object is given by m = ρv, where ρ is the water density and v is volume. The current force of an object is given by $F=C\sigma A_{xy}$. Where σ is the water shape, C is constants, and the A_{xy} is the parameter related with the cross sections of the object subject to current. The UWSN was floated between time t and n. The initial position (x(t_1), y(t_1)) were came from GPS and Δ(x(t_1), y(t_1)) are position at present. The initial velocity were ($v_x(t_1), v_y(t_1)$) and the V_{cx}, V_{cy} are the water current velocity in x and y. Hence, we use EKF equation to calculate distance which is instead of the current velocity.

a. Inertial Navigation System

The integrated Inertial Navigation System (INS) solution has appeared in the literature [6]. Hence, accurate location is heavily needed for UWSN system in order to increase the routing of probability. We proposed a GPS position to initially INS position. And then the adaptive Kalman filter, which combined the Extended Kalman filter (EKF) [5] and input estimation algorithm is proposed in this paper with equation (2,3). The purpose of the EKF is to predict the state vector of a system from a set of nonlinear quantities which is based on pre-calibration of measurement vectors. Also it is applied to location of data measurements instead of using it to directly obtain the target location estimate. That is, we estimate:

$$\hat{F}_{k+1} = \alpha + \beta' x_k + \delta_k, \qquad (3)$$

where $\hat{F}_k$ is the Kalman filter estimated ratio, $\wedge$ denotes the estimated value by INS, α is attitude matrix (transition matrix), β' propagated input vector, x_k is the state vector with the measurement position vector at step k and δ_k is the noise. In the general case, it is assumed that the state vector is changing over the discrete time k as

$$\mathbf{x_k} = \mathbf{f}(\mathbf{x_{k-1}}, \mathbf{w_{k-1}}), \qquad (4)$$

where **f** is the state transition function which can be used to compute the predicted state between the previous estimate and similarly, and **w** is the white Gaussian random sequence having zero mean and covariance matrix $\mathbf{Q}_k$. Thus that the measurement model has the following form:

$$\mathbf{z_k} = \mathbf{h}(\mathbf{x_k}, \mathbf{v_k}) \qquad (5)$$

where **h** is the observation location function which can be used to compute the predicted measurement from the predicted state, and **v** is a white Gaussian measurement noise having zero mean and covariance matrix δ_k. Assumed that the functions **f**, **h** is nonlinear; the solution to the filtering problem is provided by EKF.

b. EKF of Corrections

Both EKF and Radio Signal Strength Indication (RSSI) are pre-calibration of measurement mechanisms which process have been applied on the proposed localization system [7]. In all above-mentioned mechanisms seems to be suitable tool for mobile tracking, but the achieved accuracy RSSI value is difficult from underwater. Because the RSSI of velocity was vary with reference to oceanography profiles of water temperature, and salinity. In this paper, we referenced fluid velocity measurements can reduce the long-term error by INS when GPS is unavailable. As shown in Fig. 2, the algorithm of flowchart was included to using oceanography profiles and the structure of a classical error state Kalman filter. Due to the INS accuracy degrades over time that the issue will be occurred, like as have uncompensated rate gyro, accelerometer errors and non-linear disturbances. The structure of a classical was determined by the statistical optimum value of the errors in the navigation states (position, velocity, attitude/heading), also included sensor error parameters (scale factors, biases) [8]. Because both noise and bias are dynamically compensated by the EKF that estimates heading, position, attitude, velocity and bias compensation error. These estimates are filters were successfully with in achieved accuracy of position applied as corrections to the INS computations, as indicated by the dotted lines. The INS unit was provided self-contained passive means for the computation of position, attitude estimates and feedback is particularly important when low cost inertial sensors are used, with excellent short-term accuracy.

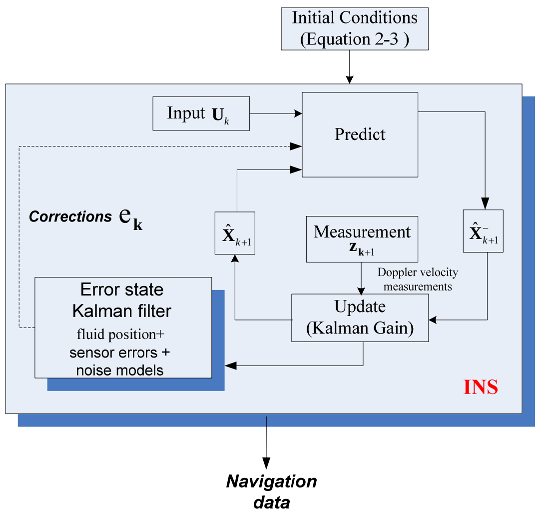

Figure 2. algorithm of flowchart

Estimates current position using the new measurement information, which equation as below shown.

$$\mathrm{x}_{\mathbf{k+1}} = \mathbf{x_k} + \mathrm{n}_{\mathbf{k}} + e_{\mathbf{k}}, \qquad (6)$$

Where x is 3D position of UWSN device, n is noise, and k is error state EKF. The equation that relates measurements to state variable is

$$\mathbf{z_k} = \Delta\mathbf{h}(\mathbf{x_k}) + \mathrm{w_k} + \sigma_\mathbf{k}, \tag{7}$$

$$\sigma_k = f(\Delta R_k, \Delta V_k), \tag{8}$$

$$\Delta\mathbf{h}(k) = \sum_{j=1}^{k} \{(eq_j(1,2) + INS_j(position))/2\}, \tag{9}$$

Where z is measurement function, w is measurement noise, and σ is measurement correct error [9] with variance k. The σ is included by R is rotation vector, and V is linear velocity. Thus the elements of the vector $\Delta\mathbf{h}(k)$ are the position relative which is considered to be equation (1-2) and INS position.

$$\hat{x}_{k+1} = x_k + k_{k+1} + z_{k+1}, \tag{10}$$

Where the $\hat{x}_{k+1}$ is effected distance measurement. Not only the measurement update was evaluated iteratively, but also the predetermined convergence criterion will be waited for met. Thus the distance measurements are predicted to the EKF, in addition these measurements were evaluated iteratively the previous estimates the EKF gives the next position estimate. Finally the output navigation data will be resulted in this paper.

4. Simulations

In the configuration depicted in Fig. 3, the performance of the GPS navigation system (Real signal) and GINS was assessed in simulation, that all of UWSNS were located on the water. Because this paper was addressed in accurately position. So that we assumer that oceanography profiles are the same between underwater and on the water. From the simulation results it became clear that as the GINS provides a very flexible framework for location systems. Simulation results also evidenced the equation (1, 2) and equation (10) could be accurately enhancement in position estimates. The sampling characteristics of the GINS sensors are as shown in Table 1. We have run simulations with the MATLAB to building sensor position. To investigate the performance of our proposed approach, Utilizing the algorithm concurred to bring about the location for underwater sensor networks. Our scenario consists of 625 mobile UWSN nodes that communicate with a sink. Normally, the UWSN have a communication range of 250m in which the data rate is 50 kbit/s [15], cone angle is 60, bandwidth is 10.89, TransmitPower is 250.00, ReceivePower is -30.00, ListenPower is -30.00, DataPacketLength is 9600.00 bits. And we use a random walk mobility model with a speed of 1.5m/s. For UWSN routing in SOFAR channel , the speed is changed to 1.48m/s, and range of 10km with data rate 10 kbit/s. The underwater sensor nodes are uniformly dispersed into a field with dimensions in a volume of 100 m× 100 m× 10000 m depth. The periodic transmit packets is 240 s for observe the number of collisions. In order to study the scalability of the UWSN, we have run simulations 3600 times and compared the performance.

Table 1 CHARATERISTICS OF SENSORS

	Bias	Noise
Gyros	1 deg/min	0.5 deg/min
Compass	1 deg	1 deg
Depth	0 m	0 m

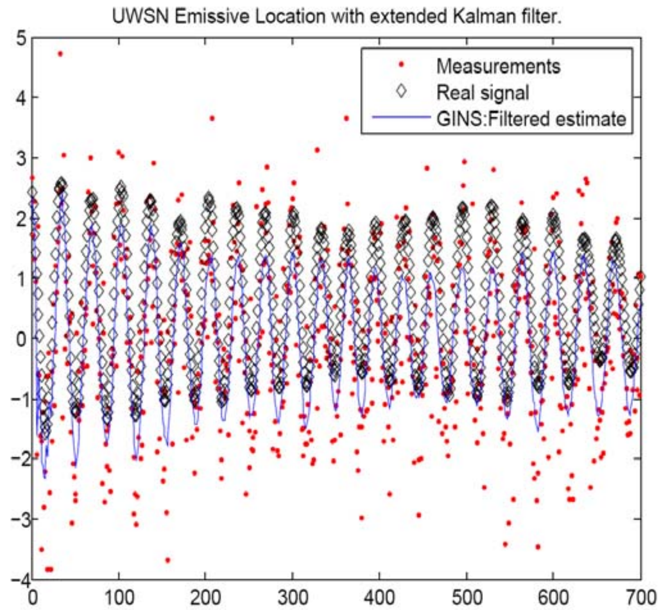

Figure 3. Difference between Real signal position estimate and GINS reference position

5. Conclusions

In this paper demonstrates that it is possible to achieve very similar between UWSN of robust location estimation. A new approach for the position estimation for underwater navigation systems is described and more robust against with the EKF filter. From a new angle of multi-object decision making, the GINS include the GPS coordinates and a novel fusion method based on EKF measurement is proposed for location. That is EKF subject to more complex correction than considered here. So we find more efficient ways of utilizing location thus it results in effective detection and identification capabilities for underwater sources.

In the future, we will utilize motion sensor by MEMS sensors. The micro-machined electromechanical systems (MEMS) sensor not only has enabled the construction of low-cost, but also has provided continuous state information to estimate current position in underwater. However, the sound waves bend with high error rata. Also we will utilize a more realistic mobility UWSN model to analyze the performance of underwater positioning.

Acknowledgments

Part of this work was support by Tatung University, Taipei, Taiwan under grant B103-I01-031.

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