Using AI in Integrated Navigation*

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Abstract—In this paper, we present an AI method which improve integrated navigation system performance. We use a deep neural network to estimate the error of the inertial navigation system. The network is trained by a LSTM network. The results show that the proposed method can improve the performance of the integrated navigation system. Three methods are proposed to train the network. The first method is to train the network by measurement update. The second method is to train the network by propagation and measurement to predict the attitude. The third one is used to predict attitude and heading in the absent of magnetometer or GPS. The results show that the proposed method can improve the performance of the navigation in absent of magnetometer or GPS.

Index Terms—Integrated Navigation, Deep Learning, LSTM, AI, Kalman Filter, AHRS

Algorithm 1 AHRS EKF Formulas with Euler Angles

1: **procedure** PREDICTIONSTEP
2:   **Input: $\boldsymbol{\theta}$, $\boldsymbol{\omega}$, Δt, P, Q**
3:   $\boldsymbol{\theta} \leftarrow$ EulerUpdate($\boldsymbol{\theta}, \boldsymbol{\omega}, \Delta t$)
4:   $\mathbf{F} \leftarrow$ ComputeStateTransitionMatrix($\boldsymbol{\theta}, \boldsymbol{\omega}, \Delta t$)
5:   $\mathbf{P} \leftarrow \mathbf{F} \cdot \mathbf{P} \cdot \mathbf{F}^T + \mathbf{Q}$
6: **procedure** CORRECTIONSTEP
7:   **Input: $\boldsymbol{\theta}$, P, H, R, K, z, h**
8:   $\mathbf{K} \leftarrow \mathbf{P} \cdot \mathbf{H}^T \cdot (\mathbf{H} \cdot \mathbf{P} \cdot \mathbf{H}^T + \mathbf{R})^{-1}$
9:   $\boldsymbol{\theta} \leftarrow$ EulerCorrection($\boldsymbol{\theta}, \mathbf{K}, \mathbf{z} - \mathbf{h}$)
10:   $\mathbf{P} \leftarrow (\mathbf{I} - \mathbf{K} \cdot \mathbf{H}) \cdot \mathbf{P}$

I. INTRODUCTION

Integrated navigation is a method to improve the performance of navigation system by using different sensors. In this method, the navigation system uses the information of different sensors to estimate the state of the system. The most common sensors used in integrated navigation are inertial measurement unit (IMU), magnetometer, GPS, and barometer. The IMU is used to estimate the attitude and position of the system. The magnetometer is used to estimate the heading of the system. The GPS is used to estimate the position of the system. The barometer is used to estimate the altitude of the system. The integrated navigation system uses the information of different sensors to estimate the state of the system. The most common method to estimate the state of the system is Kalman filter. The Kalman filter is a recursive filter which uses the information of different sensors to estimate the state of the system.

II. ATTITUDE HEADING REFERENCE SYSTEM (AHRS)

The Attitude Heading Reference System (AHRS) employing an Extended Kalman Filter (EKF) is a sophisticated method for accurate orientation estimation. This system integrates sensor measurements, such as accelerometers, gyroscopes, and optionally, magnetometer or GPS data, to provide robust attitude and heading information.

III. NETWORK FILTERING MEASUREMENTS

In this section, we present a method to improve the performance of the integrated navigation system. In this method, we use a deep neural network to filter the measurements of the sensors. In this scenario gyroscope had time-variant bias. Here is the results and comparison of the performance of the integrated navigation system with and without the proposed method. The results show that the proposed method can improve the performance of the integrated navigation system. Here is the structure of the network. The network is trained by a LSTM network.
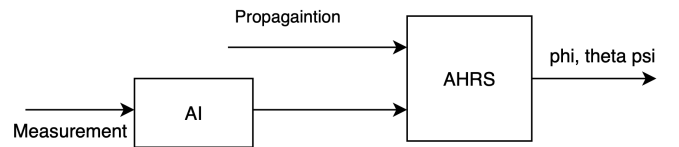

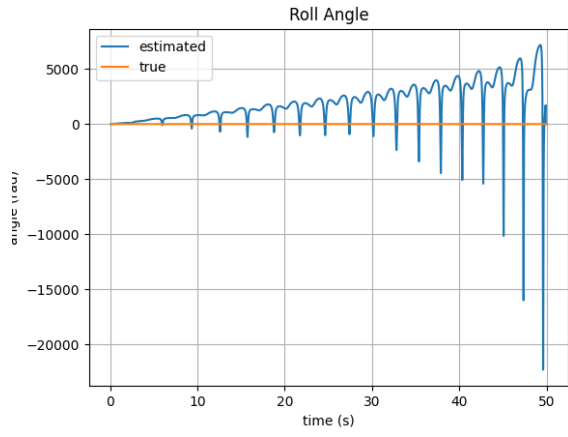Fig. 1. Structure of the network method I.
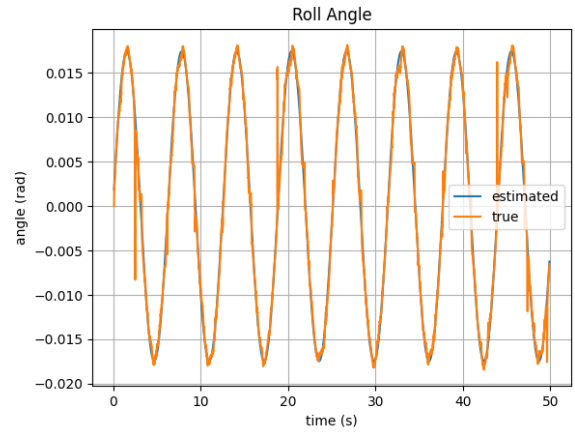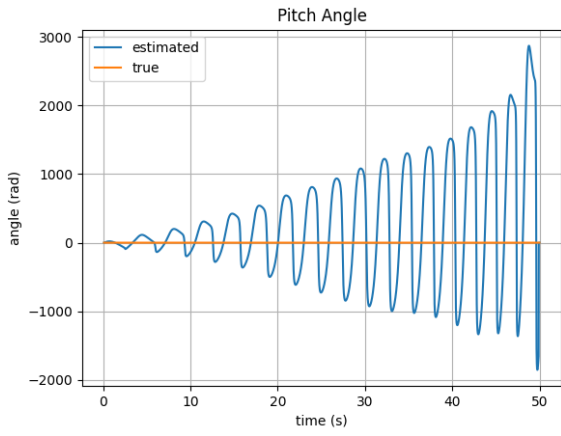
Fig. 2. Roll angle without AI.

Fig. 3. Pitch angle without AI.

Fig. 4. Yaw angle without AI.

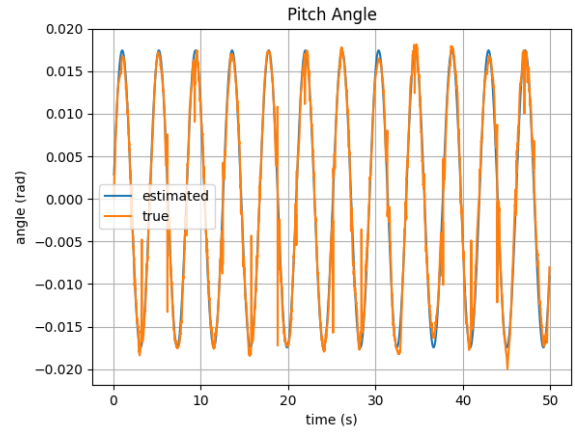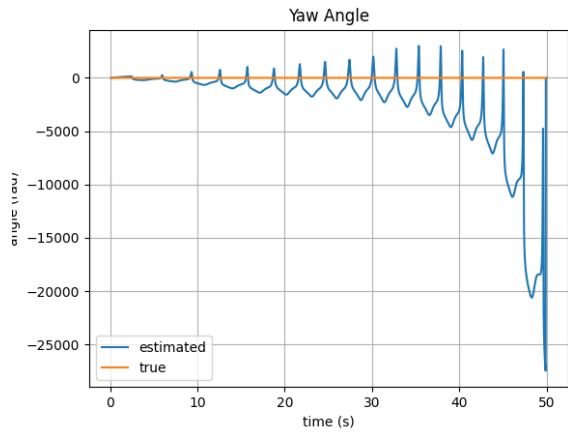Fig. 5. Roll angle with AI.

Fig. 6. Pitch angle with AI.

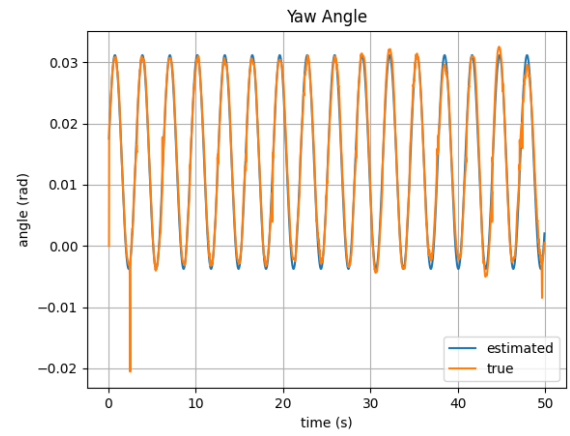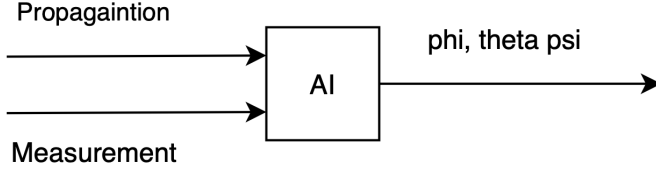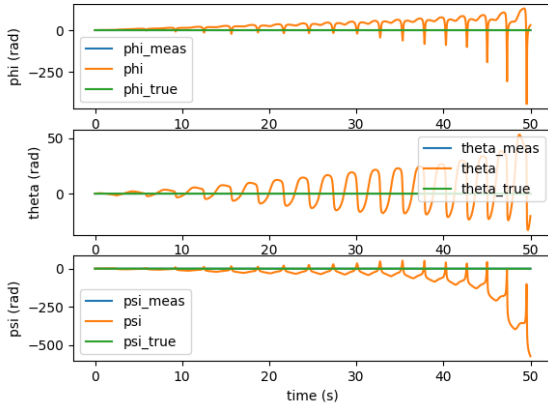Fig. 7. Yaw angle with AI.

IV. NETWORK CALCULATING ATTITUDE

In this section, we present a method to improve the performance of the integrated navigation system. In this method,

we use a deep neural network to calculate the attitude of the system. In this scenario gyroscope had time-variant bias. Here is the results and comparison of the performance of the integrated navigation system with and without the proposed method. The results show that the proposed method can improve the performance of the integrated navigation system. Here is the structure of the network. The network is trained by a LSTM network.
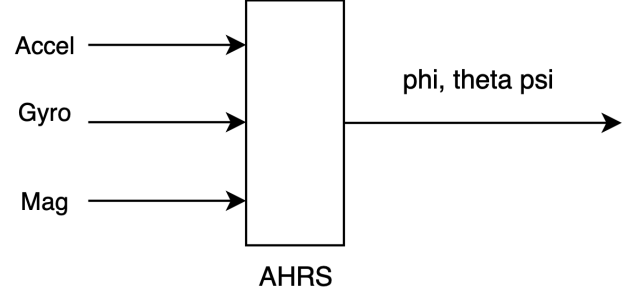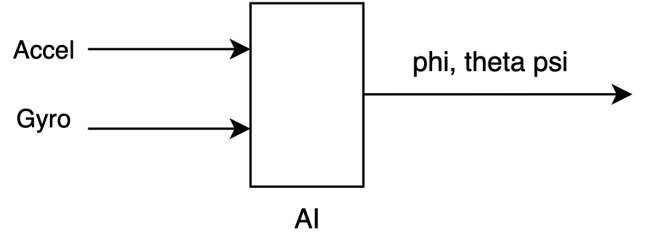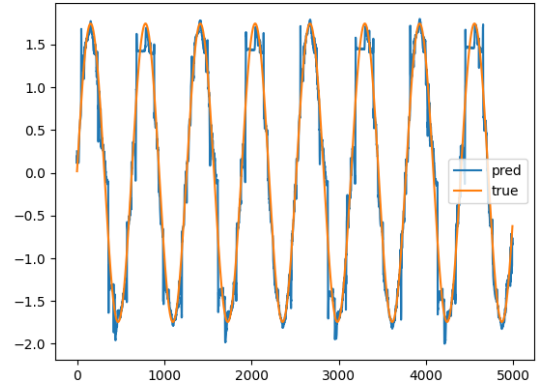

Fig. 8. Structure of the network method II.

Fig. 10. Structure of the network in training method III with magnetometer

Fig. 9. Results with AI.

Fig. 11. Structure of the network in predict method III.

V. NETWORK CALCULATING ATTITUDE WITHOUT MAGNETOMETER

In this section, we present a method to improve the performance of the integrated navigation system. In this method, we use a deep neural network to calculate the attitude of the system. In this scenario gyroscope had time-variant bias. Here is the results and shows the AHRS has a good performance in the absent of magnetometer. The results show that the proposed method can improve the performance of the integrated navigation system. Here is the structure of the network. The network is trained by a LSTM network.

Fig. 12. Roll angle with AI.

Fig. 13. Pitch angle with AI.

Fig. 15. Structure of the network in training method III with GPS

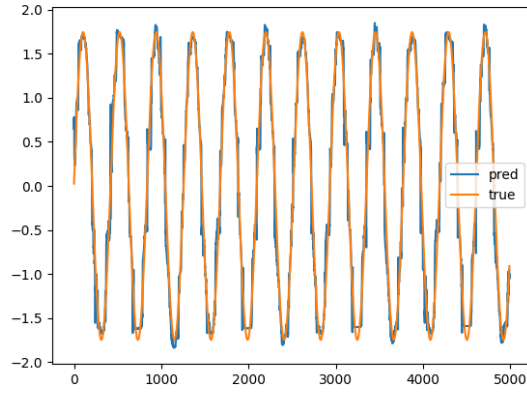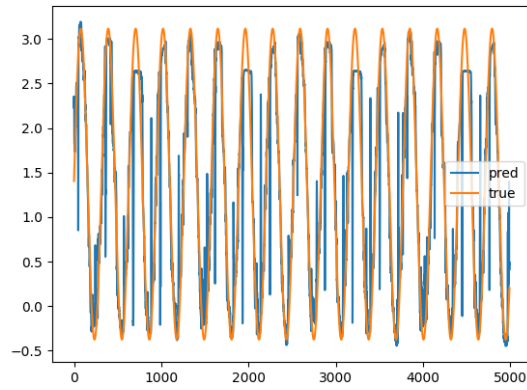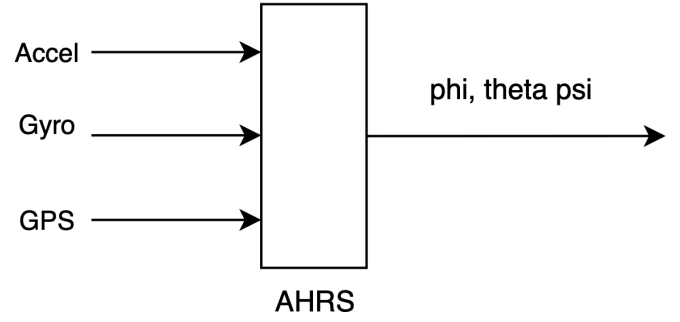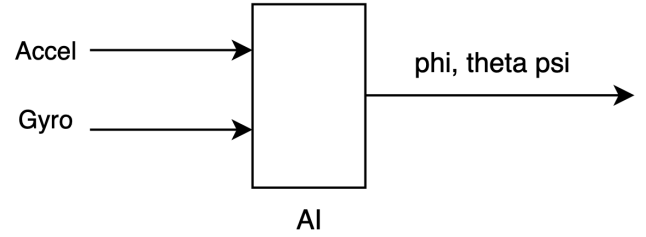Fig. 16. Structure of the network in predict method III.

Fig. 14. Yaw angle with AI.

VI. NETWORK CALCULATING ATTITUDE WITHOUT GPS

In this section, we present a method to improve the performance of the integrated navigation system. In this method, we use a deep neural network to calculate the attitude of the system. In this scenario gyroscope had time-variant bias. Here is the results and shows the AHRS has a good performance in the absent of GPS. The results show that the proposed method can improve the performance of the integrated navigation system. Here is the structure of the network. The network is trained by a LSTM network.