Measurement Time-Delay Error Compensation For Transfer Alignment

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Abstract

This paper is concerned with a transfer alignment method for the SDINS(StrapDown Inertial Navigation System) under ship motions. Major error sources of transfer alignment are data transfer time-delay, lever-arm velocity and ship body flexure. Specifically, to reduce alignment errors induced by measurement time-delay effects, the error compensation method through delay state augmentation is suggested. A linearized error model for the velocity and attitude matching transfer alignment system is first derived by linearizing the nonlinear measurement equation with respect to its time delay and augmenting the delay state into the conventional linear state equations. And then it is shown via observability analysis and computer simulations that the delay state can be estimated and compensated during ship motions resulting in considerably less alignment errors.

1. Introduction

The transfer alignment provides a way how slave inertial navigation system(SINS) mounted on the vehicle is aligned by using the accurate information of master inertial navigation system(MINS) for aircrafts or ships navigation. The transfer alignment techniques are methodologically divided into angular rate, acceleration, velocity and attitude matching methods[1].

The Kalman filter estimates attitude errors of the SDINS or mounted misalign between MINS and SINS in the transfer alignment. As the Kalman filter acts like an observer, attitude error estimation is closely related to the observability of the transfer alignment systems. The acceleration or velocity matching method can achieve its alignment goal in the horizontal linear accelerated motion, and the angular rate or attitude matching method can do in the horizontal angular motion.

The transfer alignment systems of combined matching method make the Kalman filter do the best performance in arbitrary motions. The best combined matching method is known to be the velocity and attitude, or angular rate and acceleration method in the observability aspect[1].

This paper presents a transfer alignment algorithm as an initial alignment method of the SDINS under some roll and pitch motions of the ship. It has been investigated that the structure using the EM.log and the Gyrocompass information has better transfer alignment performance, and that major error sources of the transfer alignment are data transfer time-delay, lever-arm velocity and ship body flexure[2]. To be specific, in this study, to reduce alignment errors induced by measurement time-delay effects, an error compensation scheme based on delay state augmentation is suggested and described as follows.

2. Structure of Transfer Alignment System

2.1 Velocity and Attitude matching Transfer Alignment

Fig. 1 shows the block diagram of the transfer alignment system constructed by combining EM.log velocity matching and Gyrocompass attitude matching.

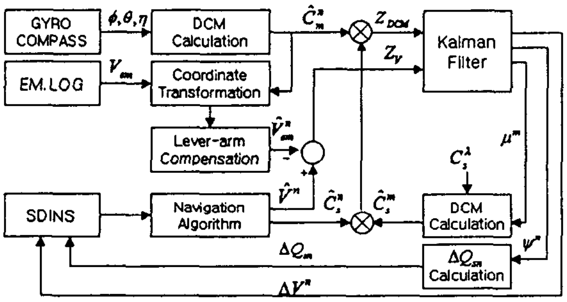

Fig. 1. Transfer Alignment System based on EM.log Velocity and Gyrocompass Attitude Matching.

The velocity information measured from EM.log v_{em} is transformed into the navigation frame using the DCM(Drection Cosine Matrix) $\widehat{C_m^n}$, and is subtracted from the estimated velocity of SDINS, $\widehat{v^n}$. And then the velocity difference $Z_v = \widehat{v^n} - \widehat{C_m^n} v_{em}$ is fed into the Kalman filter as a measurement input. On the other hand, the attitude information measured from Gyrocompass, that is, the Euler angle (ϕ, θ, η) is converted into the DCM $\widehat{C_m^n}$ and postmultiplied by the product of DCM's, $\widehat{C_s^m}\widehat{C_n^s}$, where $\widehat{C_s^n}$ is the DCM of SDINS, and $\widehat{C_s^m}$ corresponds to mounted misalign between MINS and SINS. Also, the attitude error vector Z_{dcm} , or the skew-symmetric matrix of Z_{dcm} ,