A PRECISE STATE TRANSITION MODEL FOR AIRCRAFT NAVIGATION

Abhijit Sinha[1], Svetlana Stolpner[1], Abir Mukherjee[1], and Simon Monckton[2]
[1]AUG Signals Ltd., Toronto, Canada
[2]DRDC, Suffield, Canada

This article considers the problem of accurately modeling the kinematic state transition of an Unmanned Aerial Vehicle (UAV). The full 3D range of motion is accurately captured using compact equations for position update derived in this work. This derivation makes use of the independence of the rotation and translation components of a 3D rigid motion. The proposed motion model is transparent to the sensors used in the system; it is particularly useful in GPS-denied environments and can contribute to different aspects of robust navigation, such as accurate state estimation, sensor fault tolerance and sensor bias estimation. Experimental results comparing the performance of the proposed kinematic model with those typically used demonstrate its superiority.

Cet article examine le problème de la modélisation exacte de la transition de l'état cinématique d'un véhicule aérien sans pilote (UAV). L'ensemble des mouvements en trois dimensions est capté avec précision en utilisant des équations compactes pour la mise à jour de position dérivées dans le présent article. Ce calcul utilise l'indépendance des composantes de rotation et de translation d'un mouvement rigide en trois dimensions. Le modèle de mouvement proposé est indépendant des capteurs utilisés dans le système; il est particulièrement utile dans des environnements sans accès au service GPS et peut contribuer aux différents aspects d'une navigation vigoureuse, par exemple une estimation d'état précise, la tolérance aux anomalies du capteur et l'estimation du biais du capteur. Les résultats expérimentaux de la comparaison de la performance du modèle cinématique proposé avec ceux qui sont habituellement utilisés démontrent sa supériorité.

Abhijit Sinha
abhijit@augsignals.com

Svetlana Stolpner

Abir Mukherjee

Simon Monckton

1. Introduction

Unmanned Aerial Vehicles (UAVs) have received a high degree of attention in civilian and military applications, primarily due to their ability to provide a critical vantage point to the operators. UAVs are gaining popularity as a cheaper and safer alternative to manned aircraft for remote sensing geomatics data collection. In the absence—or limited participation—of human operators, precision navigation is a critical aspect to ensure safety of the craft and its surroundings, and it reduces the possibility of UAVs crashing. The navigation system needs to be tolerant of sensor faults and have the ability to degrade gracefully if one or more sensors drop out. For example, GPS—a key sensor used for navigation of small UAVs—may be denied, impaired or otherwise unavailable. Other commonly used sensors, such as gyroscope, accelerometer and visual odometry sensor, do not have the ability to estimate absolute pose of an aircraft; rather, these sensors provide information that can be used to estimate the change in pose. Navigation based on these sensors requires accurate filtering of the data in order to minimize the rate of error accumulation. In turn, accurate filtering requires a precise kinematic state prediction (or motion) model. Other than minimizing error accumulation, such a kinematic model can improve a navigation filter's consistency and its ability to accurately incorporate measurement information in the estimated kinematic state. Hence, an accurate kinematic state prediction model is a key requirement for precision navigation, particularly when one or more critical sensors fail.

This paper presents an accurate model for kinematic state transition (motion) in three-dimensional (3D) coordinates, which is particularly useful for UAV navigation in GPS-denied environments. The proposed motion model is transparent to the sensors used in the system. UAV applications, such as geomatics data collection, can use a navigation system built on the proposed motion model by incorporating measurements from different sensors