Ph.D. Thesis Abstract

Method of estimation of navigation elements of unmanned aerial vehicle in radar terrain imaging system

Author:	**mgr inż. Michał Łabowski**
Supervisor:	**płk dr hab. inż. Piotr Kaniewski, prof. WAT**
Auxiliary supervisor:	**mjr dr inż. Piotr Serafin**

This dissertation describes the development of a new method of estimation of navigation elements for an Unmanned Aerial Vehicle (UAV), used in a navigation subsystem dedicated for supporting an airborne Synthetic Aperture Radar (SAR). The aim of this method is to estimate the UAV attitude, velocity and position which are used to correct the distortions of initial phases of the received echo signals, caused by UAV motion instability. These distortions, when uncompensated, decrease the quality of radar image (especially its focus). Thus, in this work three alternative navigation methods were introduced and examined using real-flight data.

The experiments show that navigation corrections obtained using the Inertial Navigation System (INS) improve the contrast and entropy of the whole image as well as the Peak-Sidelobe Ratio (PSLR) and Integrated-Sidelobe Ratio (ISLR) of point-like target images. Thanks to this method the geometric distortions of the image caused by nonlinearity of flight trajectory are significantly reduced, but additional distortions are introduced due to the growing INS errors. This drawback was limited by integration of the INS and Global Positioning System (GPS) data within the Kalman filter, which is the second navigation method presented in the dissertation. The radar terrain image obtained using this method has reduced geometric distortions in comparison to the INS method, while remaining parameters are deteriorated. The reason for this are GPS random errors, which are not completely eliminated by the Kalman filter and cause random changes of the estimated navigation corrections. These noise-like changes propagate in the system and additionally modulate the phase of echo signal.

In order to achieve the highest possible image quality a new method of estimation of the UAV flight parameters was introduced. This method uses a multi-instance INS system, which combines the individual advantages of INS and INS/GPS systems. In this approach, the corrections are calculated using data coming from a currently running INS instance, which ensures the "smoothness" of the corrections. Exceeding the allowable threshold by INS instance position error (the difference between INS and INS/GPS data) initiates another INS instance (based on navigation data obtained from INS/GPS system running in background), which keeps the INS errors at a bounded low level. Both instances operate simultaneously for a defined period of time to ensure, that at the moment of instance switching, the number of corrections estimated using data from the new instance allows for synthesis of a single aperture without using data from the previous one. The obtained radar image is characterized by a significant reduction of the geometric distortions (like in INS/GPS method), while remaining image quality parameters maintain good values (similar to the INS and contrary to the INS/GPS method).

The presented method can be an alternative to iterative autofocusing methods, as it allows for obtaining a radar terrain images of satisfactory quality and maintains a low computational effort because the determination of the corrections is performed simultaneously and independently with respect to the image synthesis procedure.

In the course of the study a thesis was confirmed that it is possible to determine the navigation elements of UAV using multi-instance INS system, in a way that improves the quality of terrain images obtained from the SAR system, compared to the methods using a classic INS or integrated INS/GPS system.