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МЕТРОЛОГІЧНІ ЗАВДАННЯ АЕРОФОТОЗЙОМКИ ЗА ДОПОМОГОЮ БЕЗПІЛОТНИХ ЛІТАЛЬНИХ АПАРАТІВ

Розглянуто використання безпілотних літальних апаратів для потреб аерофотозйомки місцевості. Встановлено, що використання поширених навігаційних систем може спричиняти похибки в умовах з певними перешкодами, зокрема в містах з густою забудовою. Саме тому запропоновано визначати координати безпілотних літальних апаратів з урахуванням похибок системи глобального позиціонування. Позиціонування безпілотників розглянуто з урахуванням розташування наземних об’єктів та розробленої моделі навколишнього середовища.

Розглянуто оцінку координат безпілотників з використанням додаткової інформації з бортової системи нагляду. В цьому контексті важливою є автоматизована обробка аерофотознімків. Використано методику чотирипроцесорного векторного обчислення. Для обробки даних, що відповідають за позиціонування, використано коефіцієнт Калмана–Бьюсі.

Ключові слова: безпілотний літальний апарат, аерофотознімання, позиціонування безпілотних літальних апаратів, зшивання зображень, локальна навігація, зовнішні і внутрішні сенсори.

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METROLOGY TASKS OF AIRPHOTOSHOOTING BY REMOTE-PILOTED VEHICLE

This paper dwells upon the use of remote-piloted vehicles in the airphotoshooting of different areas. There is a need to process images automatically, for example, by searching the overlapping areas for stitching of the images. Air monitoring by using images can make qualitative changes in monitoring of the terrain, help prevent late decisions due to insufficient information base or data collection for expert analysis.

In this context, it is highlighted that the positioning of remote-piloted vehicles plays vital role. Nowadays GNSS (Global Satellite Navigation System) and GPS (Global Positioning System) systems are widely used by using additional information from on-board system.

It is highlighted to make positioning of remote-piloted vehicle based on the analysis of the location of the ground objects and the previously developed model of the environment. For this purpose, it is necessary to develop method of airphotoshooting by using of on-board 4-processor vector calculator that provides processing of photographs.

This computational core also provides automatic flight in the absence of reception of GNSS data, being guided by the indications of the inertial block, which includes a combination of accelerometers and gyroscopes. To process data from sensors responsible for positioning, the iterative formula was used, so called, Kalman-Bucy coefficient.

Key words: remote-piloted vehicle, airphotoshooting, remote-piloted vehicle positioning, image stitching, local navigation, external and internal sensors.

Introduction

Nowadays the remote-piloted vehicles are widely used in different spheres of life. As a result, there is the need for automated processing of the results of airphotoshooting. One of the common tasks of processing is the automatic detection of the overlapping area and the combination of individual images, so called image stitching.

The resulting information about the overlapping area and the relative location of the photographs can be used to construct accurate and up-to-date terrain plans, to analyze any events or changes in the terrain.

Main part

The remote-piloted vehicle takes off and makes a landing in semi-automatic mode along the previously loaded route and flies along a previously planned route in the GIS, performs a digital shooting of the terrain resulting in high resolution images at the programmed points on global geographical coordinates.

After completion the aerial photo shooting route, the remote-piloted vehicle lands at the take-off point and transmits the received data during the aerial photo shooting to the ground station. For each picture there is a full set of digital information, geographic coordinates of the central point of the picture, the height of the shooting, a complete set of telemetry data for transferring and use in common GIS systems such as ArcView and MapInfo. So, all photos are geolocated using single or dual-frequency global navigation satellite systems (GNSS) receiver and the possibility of stitching photos into a single orthophoto of the area. Stitching of the images is one of the commonly used forms of mounting of aerial photos, especially it is applicable for creating panoramic images [1].

A panorama is an image created by combining a series of pictures into one wide format picture. At the first step to create such image it is necessary to determine the place and obtain image, pre-determining the image of what kind should be obtained. Depending on this, is choosen one of the methods of obtaining images. Before further processing all the distortions are needed to be corrected caused by the camera lens, and therefore to the obtained images, it is sometimes necessary to apply certain corrective procedures. In the field of image processing there is no generally accepted term for key points that have non-zero area. As mentioned above, the position and orientation of the remote-piloted vehicle is usually measured by the GNSS receiver and the IMU unit.

So, the accuracy of the positioning depends on the type of GNSS receiver and external environment conditions (atmospheric phenomena, the location of the object position). On the other hand, the error in determining the angle is strongly dependent on the IMU unit because the accelerometers give a margin of error of the measurements. The effectiveness of the target tasks is significantly influenced by the accuracy of the positioning of the remote-piloted vehicle.

The global satellite navigation system (GNSS) is the basis of the majority of the navigation systems of the remote-piloted vehicle. The GNSS is distinguished by high accuracy of location in the conditions of the open sky, provided by relatively inexpensive single-frequency receivers of navigation signals. Nevertheless, the conditions of dense urban areas impose significant restrictions on the location accuracy of GPS, which are not overcome by the use of even expensive two-frequency GNSS receivers. The reasons for this is the shading of signals, their reflection and multipath propagation [1].

Therefore, in real conditions of dense urban environment there is the great probability of false determination of coordinates for the GNSS signal. Thus, the problem of estimation the coordinates of an remote-piloted vehicle in the absence or distortion of the GNSS signal is actual and practically important. The estimation of the coordinates of remote-piloted vehicle in similar conditions can be performed using:

- additional onboard and / or ground equipment;
- regular equipment of the remote-piloted vehicle.

The use of additional equipment leads to a decrease in mobility of remote-piloted vehicle in general and the increase in cost and weight and size indices. The latter significantly affects the range and time of flight of the remote-piloted vehicle. Use of standard equipment is without such shortcomings, but is currently underdeveloped. The composition of the standard equipment of the remote-piloted vehicle includes integrated sensors for angular speeds, accelerometers, GNSS receivers, computers, magnetometers, altimeters, and a surveillance system that includes sight devices, computers, drives, etc.

The high speed of errors accumulation in inertial systems of positioning is caused by error of measurements of the used integrated accelerometers and the need to calculate the integral, leads to the multiplication of errors and does not allow to obtain positioning accuracy comparable with the accuracy of GNSS.

The positioning of remote-piloted vehicle is made on the basis of the analysis of the location of ground objects and pre-designed models of environments. The diagram presents the block “Flying task and control” which is responsible for the collection and processing of the 2D images obtained through the onboard camera, and solves three important tasks:

- adjustment of coordinates of an inertial positioning system;
- stabilization with respect to a predetermined position;
- safe landing of remote-piloted vehicle.

Functional block “Local navigation” is responsible for self-positioning and 3D modeling of environment relative to the local coordinate system. At this stage there is a formation of 3D information based on a set of flat images, thus forming a 3D map of the studied surface. In close connection with this block is the “Global navigation”, which presents the positioning of the remote-piloted vehicle by using the constructed 3D model of the external environment. This technique allows to solve the problem of positioning in the condition of absence of GNSS signals. Local positioning system takes into consideration the onboard sensors indices, external sensors and position change data from the camera, which after processing by the filter of Kalman-Bucy solve the problem of orientation in space of dense urban development [2, 3].

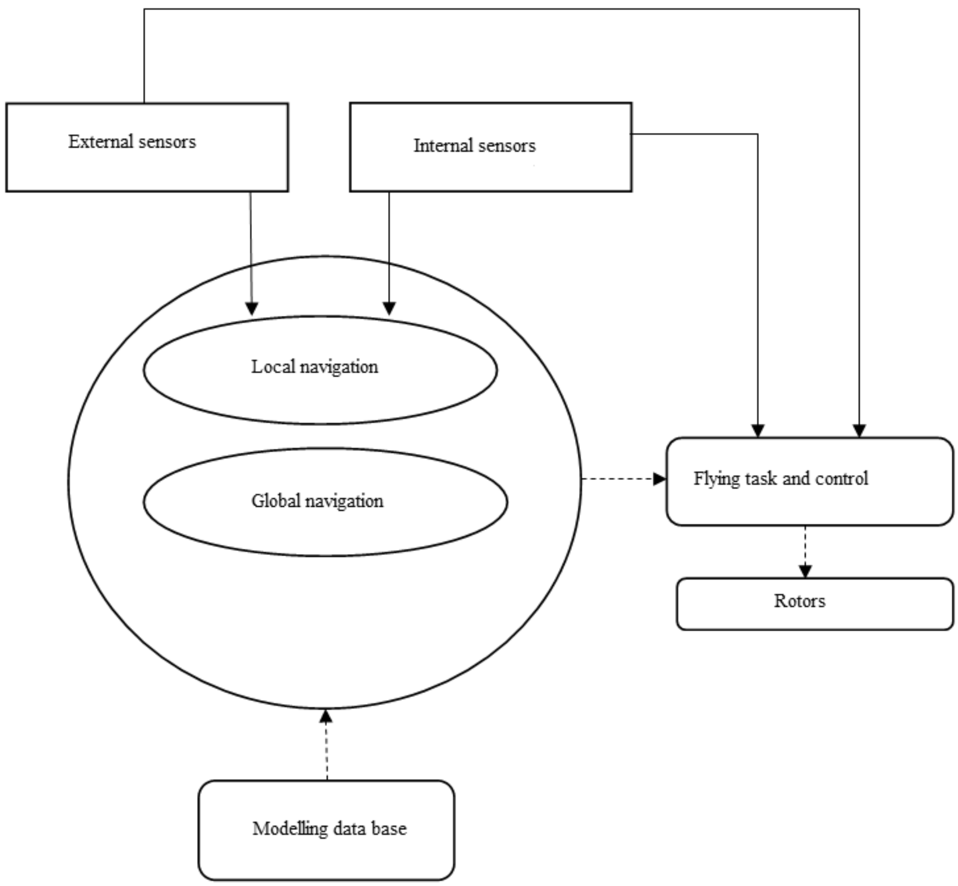

Diagram of the remote-piloted vehicle positioning in the absence of GNSS signals based on the target onboard equipement

For the practical implementation of the proposed algorithm of the selection of a preferred profile of detection is necessary to ensure the adequacy of the technological process of production of photographs using the remote-piloted vehicle. For this purpose it was necessary to develop the methodology. Significant differences of this method consist in the use of on-Board 4-processor vector computer capable of processing images. The compute engine also provides automatic flight of the remote-piloted vehicle in the absence of GNSS data reception, focusing on the testimony(показання) of the inertial block, which includes a combination of accelerometers and gyroscopes. For processing data from the sensors responsible for the positioning, was used an iterative formula to calculate the Kalman-Bucy coefficient [2]:

$$E(e_{n+1}^2) = \frac{s\frac{2}{k}(Ee_n^2 + s\,_m^2)}{Ee_n^2 + s\,_m^2 + s\,_k^2}, \tag{9}$$

де e_n^2 і e_{n+1}^2 – square of failures in n і n+1 moment of time accordingly; Ee_n^2 і $E(e_{n+1}^2)$ – expected value square of failures in n і n+1 moment of time accordingly; $s\,_m^2 + s\,_k^2$ – dispersion of positioning inertia block values and receiver of GNSS signals respectively.

By storing in the automated system of retrospective spatial data it is possible to set the flight mission, specifying only the name of the study area. By applying to the obtained areas data filter of Kalman-Bucy, it is possible significantly to improve the accuracy of the inertial navigation system due to the complete independence of measurement errors by these methods. Equation of Kalman-Bucy filter can be solved in parallel by using OpenCL capabilities of the ARM Cortex FS 6. In the space of possible measurements are included the GPS coordinate transmitted from MultiWii, which allows to compensate long term drift of the coordinates of the inertial navigation system. External sensor allows local to identify obstacles and by knowing updated in the previous step coordinate to make changes in the environment model, adjusting the flight task with the new data [1,2].

The use of the two-level scheme for the implementation of the prototype has allowed to implement a secure debug mode, because MultiWii allows the remote-piloted vehicle to hover or return to the starting point by the elementary route in the case of a failure in the block of “Remote-piloted vehicle navigation”. The application in this mode of ultrasonic sensor allows to avoid collision with an obstacle by the elementary route. Operational adjustment of parameters takes place via radio or GPS in flight. At the time of the remote-piloted vehicle positioning on the landing pad are loaded the initial flight assignments and uploaded the collected information on the ground station via WiFi network.

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