Abstract

In recent years, unmanned aerial vehicles (UAVs) have become increasingly popular in various industries. The primary source of data for UAVs comes from global satellite systems (GPS), which are integrated with a set of inertial actuators. The presence of GNSS signals is crucial for the operation of UAVs and to achieve the desired objectives. However, problems with the satellite navigation system can result in an inability to accurately determine the UAV’s position and orientation, which can cause deviations from the desired path. In this paper, we review the navigation system of UAVs to identify the best solution for various environmental conditions. We aim to find solutions that improve the accuracy and reliability of UAV navigation, enabling them to perform their intended tasks with precision.

Keywords: direction finding, global satellite navigation systems, inertial systems, Kalman filter, unmanned aerial vehicles, video navigation

1. Introduction

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Since the mid-1990s, thanks to the appearance and the beginning of operation of the Global Navigation Satellite System GPS, unmanned aerial vehicles (UAVs) have been rapidly developing in the USA. Modern unmanned vehicles are designed to fly in the airspace (atmosphere) and perform various tasks. A distinctive feature of this type of aircraft is the absence of a person, crew on board (Kartashov et al., 2018).

Unmanned aerial vehicles (UAVs) are increasingly being widely used in various industries such as agriculture, production system, military and environment protection (Amelin, 2014; Buyval, 2015; Makushin, 2017; Panov, 2015; Yakovlev, 2020; Yakovlev and Mikhaylov, 2020). Localization of a mobile robot and in particular a UAV is often a critical function, as it allows the work to plan the route more accurately and make decisions. For a number of UAVs and mobile robots operating outdoors, the main source of data about their own location is usually a GPS/GLONASS receiver. For robots operating indoors, as is known, the use of this sensor is almost impossible. As a rule, inertial sensors and laser rangefinders are very often used for localization indoors, which in turn also have disadvantages. In particular, laser rangefinders are quite expensive today, have a limited range and are sensitive to the reflectivity of the environment. The use of inertial sensors is associated with the accumulation of localization errors and sensitivity to vibrations.

2. Method

Now the main positioning method not only for UAVs, but also in other areas is the global navigation system. The receiver is installed on board the UAV and receives data from satellites. To increase the accuracy of data readings from the global system, networks of ground-based stationary towers have now been actively used. Such towers are reference points for the UAV navigation system, they determine the errors of the global navigation system readings and send corrections via radio channel to the UAV receivers. One of the most common, at the moment, systems of this type is DGPS (differential global positioning system). There are works in which it is proposed to use stationary towers not only as correctors, but also as the main source for obtaining location data. The paper (Kartashov et al., 2018) describes a system and algorithm for clarifying the location of a light UAV based on Kalman filtering of direction-finding type measurements. A UAV positioning system is proposed based on the distances to the units of the tower network. Also, to obtain information about the position of the UAV in space, a complex of inertial systems is installed on board the UAV, in addition to GPS receivers. It includes a set of sensors, according to which the autopilot receives information about airspeed, rolls, accelerations, barometric altitude, etc. The inertial system complex may include (Panov, 2015; Yakovlev, 2021):

- A barometer with which it is possible to determine the height relative to the specified zero level. The height calculation is based on the use of a regular measurement of atmospheric pressure, depending on the height of movement, relative to a certain level. The disadvantage of such a sensor is a relatively large measurement error (about 10-15 m).
- A radio-technical sensor is based on measuring the time interval between sending and receiving electromagnetic waves reflected from the surface to which the height is measured (the surface of the earth or water). Suitable for light mobile robots, the sensor has a large power consumption and at the same time works at distances up to 20-30 m, which is not enough for flying robots.
- Sonar is a means of sound detection of underwater objects using acoustic radiation. Suitable for light mobile robots, sonar works at distances up to 10 m, which is not enough for flying robots.
- LIDAR (light detection and range determination) have high power consumption and high weight, which excludes the use of such sensors in ultralight mobile robots.
- A complex of a three-axis gyroscope and accelerometer, which allows you to determine the angles of inclination of the UAV relative to the horizon and the acceleration of rotation.
• Thermal sensors in six directions, according to which the UAV microcomputer evaluates the temperature difference in different directions and draws conclusions about the angles of inclination of the UAV relative to the horizon (Semenova, 2018).

3. Results

In order to the development of inertial systems for positioning UAVs, the direction of visual positioning of UAVs in space has been developing recently. Such methods use onboard sensors, photo-video recorders or a complex of such recorders and sensors, as well as software tools for processing the received data. The positioning of UAVs according to the built-in sensors was first used for automatic orientation of cruise missiles in the XX century. During the flight, the rocket microcomputer receives information from the onboard altimeter in the form of a sequence of differences in distances to the surface at a given time and in previous ones. This sequence is compared with the relief map recorded on the ground, and it is the sequences of relative heights that are compared, and not the absolute values of heights.

As soon as the microcomputer detects coincidences, the control system receives the coordinates of the route, calculates the amount of accumulated error and makes corrections to the course of movement. Such a system requires high accuracy of height measurement, has a large weight (more than 20 kg) and high energy consumption, which does not allow using such a method in ultralight UAVs. The paper (Buyanov and Islamov, 2017) describes an algorithm for determining the three-dimensional coordinates and orientation angles of a UAV without using satellite navigation signals. This approach consists in using a computer vision system to generate and process a stream of photographs of the underlying terrain, as well as further comparing the data obtained with existing maps in order to search for marker points (at least three). Due to the requirement of a large computing power resource, such a system involves processing the received data at the base station and, consequently, constant communication with the UAV. To increase the accuracy of following a given route in conditions of rare location updates (for example, flying in mountainous terrain), it becomes necessary to introduce flight optimization algorithms into the program code of the UAV microcomputer by evaluating unknown external processes operating on the UAV (Makushin, 2017).

3.1. Adapting to climate change using agricultural drones

Unusual weather conditions are an unfortunate occurrence for many agricultural operations. Climate change is creating a growing list of productivity barriers, including droughts, floods, and storm damage. As a result, farmers are looking for new solutions to improve production and increase its efficiency. By using agricultural drone technology, farmers have been able to successfully stabilize farm conditions. Irrigation is the biggest concern of farmers who are facing long and severe droughts. Agricultural drones equipped with appropriate sensors can identify parts of the farm that need more water. Farmers can use this information in time to adjust the conditions of their agricultural land and use their resources optimally without wasting. In addition, information collected by agricultural drones can help farmers adjust the amount of water available in the field to create the best growing conditions for specific crops.

When crops are damaged by storms and other unpredictable weather conditions, agricultural drones equipped with imaging equipment can be used to determine the amount of lost crops. This simultaneously helps to clean up the lost products and improve the condition of the remaining products; It also reduces risk and farm maintenance costs for the farmer.

3.2. Reducing pollution using agricultural drones

Agricultural wastewater - which contains industrial fertilizers and pesticides - is one of the health concerns. By checking the health of plants and identifying the affected areas, agricultural
drones provide valuable information that, by using this information, farmers can reduce the use of chemical fertilizers by targeting plants.

Also, agricultural drones can be equipped with equipment that allows them to scan the ground and spray the exact amount of chemicals at the right and required height. This dramatically reduces the amount of chemicals used and virtually eliminates chemical overspray. The ability of agricultural drones to make adjustments at the right time has greatly increased the efficiency of this method compared to old and unprincipled dusting methods.

4. Conclusions

The binding of the sign to external objects and processes is carried out due to the fact that the input signs of the recognizing automata of the lower level of the hierarchy are data coming from sensors. The formation of automaton states in the process of agent observation occurs using a special HTM learning algorithm. HTM uses neurophysiological data on the structure of certain areas of the cerebral cortex to form a biologically plausible scheme on formal neurons, or using Markov chains and hierarchical clustering algorithms. The basic principles of HTM include: the use of a hierarchy of computing nodes with ascending and descending connections, the use of Hebbian learning rules, the separation of spatial and temporal groupings, suppression of activation to form a sparse representation.

The connections formed as a result of the HTM algorithm between the components of a computing node within the framework of two nodes connected by a hierarchical connection set a prediction matrix for some output feature in the model of recognizing automata.

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