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Modern Unmanned Aerial Vehicle Control Systems

Рассмотрены современные системы автоматического управления беспилотными летательными аппаратами, их функции и недостатки. Описаны факторы, которые могут негативно повлиять на работу автопилота и их устранение.

Ключевые слова: Автопилот, БПЛА, *GPS*-спуфинг, перехват, резервирование.

Розглянуто сучасні системи автоматичного керування безпілотними літальними апаратами, їх функції та недоліки. Висвітлено фактори, які можуть негативно вплинути на роботу автопілоту та їх усунення.

Ключові слова: Автопілот, БПЛА, *GPS*-спуфинг, перехоплення, резервування.

The automatic control systems of the modern unmanned aerial vehicles are considered. The description of the negative factors and their influence on UAV autopilot and ways of their correction are considered.

Keywords: Autopilot, UAV, GPS-spoofing, interception, reservation.

Introduction. For the last 40 years unmanned aviation evolved from the cumbrous military flying camera to multifunction device that could be used in, almost, each everyday life sphere. Aviation is regularly used not only for the military purposes implementation, but in the security, agriculture sectors, journalism, etc. But the systems of such airborne vehicles are still demanding modernization for its usage in the great variety of domains. The most profound problems of modern unmanned aviation and some current researched data that would help to solve these problems are shown below.

Set of problem

To derive of the most actual problems of the automatic control systems of the world's unmanned aviation by 2017, to develop the ways of its solving and also to systematize the problems with the examples of attempts of their solving in one single list.

Aim of the work

To characterise of disservices that could be done by the modern UAV problems and to propose the ways of correction of the UAV autopilot deficiencies.

Main part of the work

Autopilot of the unmanned aerial vehicle is an onboard control system, other words – unmanned aerial vehicle (UAV) automatic control device. Autopilot provides the automatic take-off and landing, holding of preset course, speed and latitude of flight, facilitates the mass centre stabilisation of the aircraft on the preset trajectory, accomplishes the piloting evolutions («coordinated» turn, evasive and other tactical combat manoeuvres) by some programme. Autopilot consists of the several sensitive gyroscope elements that are connected with the tracking systems. Modern autopilot of unmanned aerial vehicle is a complicated complex of mechanisms, connected to the radio-astronavigation instruments, gyroinertial seeker and other aeronavigation devices.

The majority of UAV autopilots have just 20–30 gramms weight, but it is a very complex invention. In autopilot, besides of powerful processor, plenty of sensors are installed – three-dimetional gyroscope and accelerometer (and sometimes magnetometer), GLONASS/GPS-receiver, pressure sensor, airspeed measuring sensor. With all these devices unmanned aerial vehicle would fly by preset course directly.

Basic factors that could have a negative impact for unmanned aerial vehicle autopilot includes:

1) Vulnerability to external noises (inconvenience of UAV exploitation at increasing magnetic and nuclear radiation activity zones).

The influence of magnetic and nuclear radiation activity on electronic equipment is one of the biggest problems that prohibit usage of robotized and unmanned vehicles at working zones of powerful electronic devices, magnetic field and radiation pollution. Even with better radiation safety tools, electronic plates are not designed for exploitation in such aggressive conditions. The result of an UAV longtime usage at zones with such radiation could variate from some parts of electronic equipment malfunctions to full losing of UAV with minimal work process efficiency. At such case, UAV usage fits just for radiation level measurements without bad impact for people's health.

On February 2017, Japanese firm TEPCO, that provide service operations on nuclear power station Fukusima-1, presented quadrocopter, that gather measurements data at turbine islands and across the territory of third power plant unit of damaged power station. Quadrocopter RISER (Fig. 1) is equipped with GPS navigational system, survey high-resolution video cameras and γ-rays detector «N-Visage», that sends colourful three-dimentional image of the received data. The radiation level visualization technology was developed by British company Createc and it already has been used for the second power plant unit and other areas of damaged nuclear power station inspection.

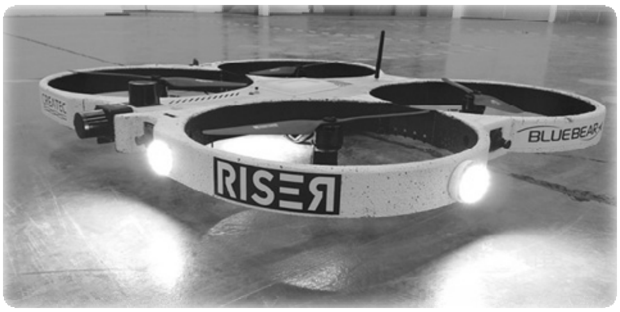

Fig. 1. Quadrocopter RISER (Remote Intelligent Survey Equipment for Radiation)

RISER has a resistance to radiation level that is not more than 10 mS/h, so it is not required to work at more dangerous zones of Fukusima-1 nuclear power station. Such UAV have limited working time at zones with less radiation level as well. Such fact makes the process of radiation level measurement at the nuclear power station area much more difficult and setting apart the beginning of station-repearing works. Also, it complicates the estimation of harm that was done to environment [1].

For military purpose the sensibility of the UAV electonic equipment to VHF-radiation is used. SHF-attack could destroy all onboard electronic devices physically, that has been proved on numerous military operations on Middle East, Iraq and Iran. By the year of 2017, the efficiency of such system usage was rised to 70%.

2) Absence of traffic alert and collision avoidance system and ground collision avoidance system.

Rising of different civil and military UAV production and exploitation tempo, rising of modern UAV sizes and inability of total air traffic control of such aircrafts are making a condition for UAV autopilot equipping by such systems and realization of special algorithms, that would help to avoid collisions with other aircrafts, birds and different objects, that have no stable location in space.

By available characteristics that were developed by Denver university members, business jet on 2 km height with the cruise speed around 850 km/h could hold a crash with only 3.6 kg object. Large amount of small class UAV can't be limited by requested dimentions and they are meant to be a real danger for big aircrafts(planes and helicopters) at heights around 5–7 km. [4]. During the incurrence of such air-approaching situations, onboard systems just ignores appearing of such small object, like mini- or micro-UAV, that could cause a fatal consequences without aircraft collision-avoidance system. Analogically, EGPWS system (for remote controlled UAV), should be implemented and that would provide safety landing on the underlying surface or on water.

For today (2017) such system of dangerous approaching alert and crash with another aircraft warning exists as the project and patent. Basic development works of such systems were made at 2003–2006 in France, Japan, USA and other countries. The result of this work is registration of the patent on the piloting airborne collision avoidance system on the basis of TCAS II system that is included into the list of standard devices of more than 90% piloting airborne vehicles and permits implementation of such system on unmanned aerial vehicles. However, testing of the such system has finished unsuccessfully. In 2013 General Atomics, manufacturer of multipurpose unmanned aerial vehicles Reaper and Predator made a successful system check test, based on Predator-B UAV (fig. 2) using of ADS-B system [3]. But nevertheless, dimensions of the vast majority of commercial UAVs that are produced in the world by 2017 (comprised more than 95% of total number of UAVs that were produced) was not taken into account.

3) Absence of environment flight data parameters (direction, windspeed, weather conditions, etc.)

Due to less mass-dimensional characteristics mini-, micro-, small and medium UAVs are much more influenced by wind and weather conditions (for example, by the rain) then handled aircrafts. Special sensors that allows to calculate the wind speed and its direction could be installed on large aircrafts as against to UAVs.

Fig. 2. General Atomics Predator-B. Similar UAV was used for traffic alert and collision avoidance system testing in 2013

Mini- and micro-UAVs as low-powered and light aircrafts are having fundamental exploitation limits during bad weather conditions and wind. Even light wind flows have a serious influence on flight process of such aircraft, due to what data about airspeed and its direction is one of the basic characteristics of the flight accomplishing. On the large airborne vehicles, sensors that allows calculating of speed and wind direction could be installed. But autopilots of the vast majority of mini-UAVs are not took into account wind parameters during the exploitation that is impermissible [4].

02.2017 – partly modified version of the weather data capturing system TAMDAR (Tropospheric Airborne Meteorological Data Reporting) was installed on UAV. This system was installed on «Ikhana» UAV (fig. 3) – special version of striking aircraft MQ-9 «Reaper» that was prepared for exploitation as a sonde. During the flight, system gathering data about the air temperature, pressure, power and direction of wind on the latitude, relative humidity, frosting and turbulence conditions. These data has a matching to time and GPS coordinates.

During the development of the system NASA airplanes were accomplished 213 flights in 2013–2016. These airplanes were equipped by the radiation calculation systems in the real time mode.

In the vast majority of flights, increasing of the radiation level during the ascending was in the normal limits – in comparison to the surface of the earth, the radiation is doubling every two kilometers. However, in six flights airplanes of NASA has registered essential increasing of the radiation that was, sometimes, two times higher than a normal background for this latitude.

Fig. 3. «Ikhana» UAV that was used for TAMDAR system testing for unmanned aviation

In NASA esteeming that in the future airplanes, perhaps, should have to avoid not only ordinary weather conditions, like thunderstorm fronts or turbulence zones but also «radiation clouds», that could be dangerous for the health of passengers.

But, nevertheless, implementation of the weather data systems gathering by the unmanned aerial vehicles of another speciality and, moreover, including of such systems to the UAV autopilot is currently impossible [5].

4) In qualitative assembling of the autopilot and assortment of the materials and components of the autopilot.

During the manufacturing and assembling of high quality equipment for the autopilot of UAV quality of welding, isolation operations and quality of materials and components is very important. Reducing of cost of UAV is often leading to essential loss of quality, even to impossibility of UAV using for the main purposes. By the statistics of manufacturers, almost 5–7% of UAVs, that are manufactured annually has a defect, which is relate to the low quality assembling, welding or bad quality of the selected materials. The vast majority of them are returning on the manufacturing plant for reconstruction or, in particular case, for utilisation and replacement by another airplane. Such operation has a bad influence on the economic effect of the manufacturers and users of such devices as well. Particularly, quantity of defected parts of the UAVs depends on its dimensions – the smaller is aircraft, than higher quantity of defect parts could be at the aircraft. On the contrary – manufacturing of big size UAVs allows to prevent the defects during the process of manufacturing absolutely.

5) Absence of reservation on the small unmanned aerial vehicles.

Usage of the reservation methods allows establishing of the fault-tolerant property of the system during the stage of design that allows saving of full or particular working capacity in the status of failure due to hardware or information overload. Implementation of reservation methods is limited by common deficiencies: the most effective is reservation of the simple, high reliable devices; during the enhancement of the reservation degree, an average time of fail-safe working of the UAV autopilot is decreasing; low effectiveness of reservation over the simultaneous negative factors influence that results to appearing of the connecting failures, errors and, furthermore, to avalanche-growing quantity of failures in working process of the system; increasing of weight-and-dimensional characteristics that would lead to rising of energy consumption and increasing of price indexes of its production and exploitation. As shown at the analyze of reservation methods, not a single can be used during the enhancement of the autopilot fail-safe level, because their implementation leads to device redundancy, increasing of the mass of construction and rising of price indexes. That is why essential and perspective way of the UAV autopilot fail-safe work assurance is its intellectualization, which consists of clothing a system with ability of self-diagnostics and after, by the results of diagnosis, ability of renovation of the working capacity [6].

Absence of reservation on the UAV autopilots is an essential disadvantage that does not allow the usage of such aircrafts in this moment as a portable monitoring unit of current situation in the city (traffic jams, public transport schedule control, long durable monitoring of extraordinary and dangerous situations), unit of permanent reproduction of wireless signal, durable sounding for monitoring of weather/nuclear situation in the environment, etc.

6) Human factor during the creation and updating of the UAV software.

Analogically to above-described problems with low-quality assembling and materials, low quality of software creation and installation exists. Errors in programme code, irrelevant files and low-quality software could be a reason of UAV autopilot disabling and, consequently, a reason of its waste. Such problem is not so serious, as material assortment, but about 2–3% of UAVs are wasting by the reasons of low-quality software annually. Also, around 5% are passing second software installation or updating procedure during the premarket period.

7) Drawback of the publicly-accessible software platforms usage for UAVs that performs socially useful work. Usage of GPS-spoofing for UAVs interception. (fig. 4).

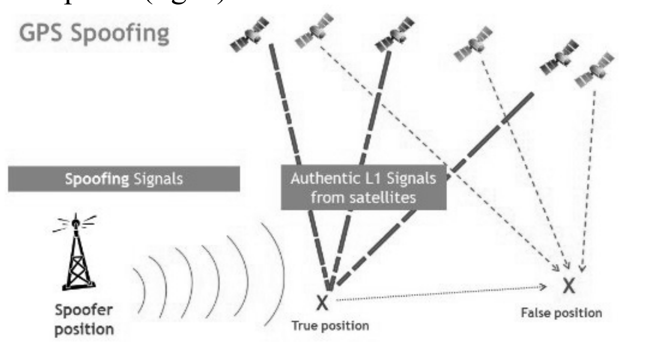

Fig. 4. GPS-spoofing working principle

The second drawback of the modern UAVs with the perspective of transformation to global problem is mainstream use of Android and Dronecode platforms to the vast majority of commercial mini- and micro-UAVs that even though extends functionality and abilities of UAV and facilitates development of the software for third manufacturers of UAVs, simultaneously, simplifies interception/deterioration of UAVs on the programme level. Also, during the usage of general accessible operating systems, the risk of particular or, even, global incapacitation of the UAV-fleet that works on the same operating system appears due to the connection to the same server from which software update performs in the automatic mode. Even now such systems are the worthwhile goal for massive cyber attacks and in the nearest future such attacks could cause essential economy and social consequences (fig. 5).

It is worth noting that interception of UAV is possible by other methods too, for example, by method of sending more powerful signal to the UAV GPS-receiver that causes the wrong situation calculation and further deviation from prescribed course. Such method is known as GPS-spoofing. Existence of such method was experimentally discovered by the students of Austin university (Texas, USA) in 2013. There were committed a few accidents of similar interception of the American and Israel UAVs in 2011–2012, but their losses (without any proofs of real ability of such attack) were explained by the software drawbacks and environmental phenomenons. By 2017, technological development caused creation of similar GPS-spoofing systems for protection of some civil and military objects all around the world.

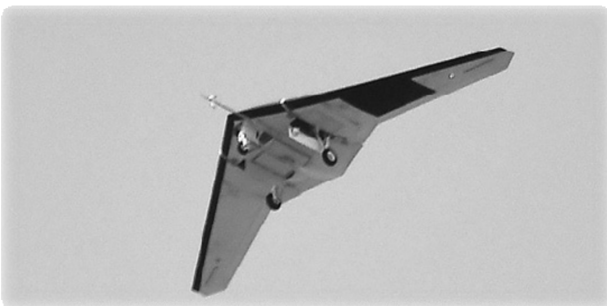

Fig. 5. Lockheed-Martin RQ-170 «Sentinel», analogical UAV was intercepted in 2011 in the Iran flight area by the help of GPS-spoofing

Conclusions

The autopilot of unmanned aerial vehicle – is a complicated complex of mechanisms that is connected to the radio-navigation equipment, gyroenertial orientator and other aeronavagation devices, but sensitivity to external barriers, absence of traffic alert and collision avoidance system and ground collision avoidance system, environmental flight data deficiency, low quality of the autopilot assembling and bad quality of the materials for autopilot system components, absence of reservartion on the small unmanned aircrafts and human factor during the creation and updating of the UAV software could have a negative influence on the work of autopilot. Currently, availability of described disadvantages create a problem in development of UAVs and their implementation in different domains that are related to the situation of UAV under the influence of unfavourable weather conditions, nuclear and magnetic radiation, etc. Additionally, usage of standard platforms would increase the probability of cyberattacks and damage that could bring such attacks as well. Present disadvantages have an essential negative economic effect during the using of the UAVs and correction of it would dramatically accelerate and improve economically using of UAVs in our everyday life and for accomplishment of different military search and rescue problems as well.

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