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CURRENT ASPECTS OF USING UNMANNED AERIAL VEHICLES IN ENVIRONMENTAL MONITORING

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Abstract. In environmental monitoring, human presence is necessary in order to monitor, record and control the evolution of environmental parameters, but, at the same time, is to be avoided, because it is a disturbing and possibly intrusive element. A solution to this challenging dilemma is to use autonomous or remote controlled mobile sensors, which, in its turn, leads to the use of unmanned aerial vehicles (UAVs), similar to those already developed and used in the military field. UAVs have unmatched qualities that make them the only effective solution in specialised tasks where human presence either is not necessary, or is not allowed. Although the civil applications of the UAVs were developed later than military ones, there is already a wide range of civil UAVs. Nowadays, they are used in scientific, emergency, governmental or commercial missions. The environmental monitoring missions are already performed by some UAVs meant for scientific or emergency missions. This work presents some current aspects of designing UAV built specifically for environmental monitoring and other scientific missions in civil area. The particular project presented will be entirely developed by an academic consortium. The environmental monitoring project described in this paper was focused – more than others – on the interaction with the environment, because the authors gave careful consideration to its environmentally-friendly dimension. Consequently, the design specifications imposed that the vehicle should have the smallest possible impact onto environment. The assigned design goal was to realise an environmental monitoring system/vehicle according to some criteria, prioritised on an environmental preservation basis (the choice of the main characteristics, the propulsion method and the onboard energy resource management). The resulting design is able to carry out multiple missions. The operation mode was therefore determined depending on the number and on the type of sensors that would be installed as a payload in each particular mission.

Keywords: environmental monitoring, vehicle-mounted sensors, unmanned aerial vehicles (UAV), the Coanda effect.

AIMS AND BACKGROUND

WHY UNMANNED AERIAL VEHICLES IN ENVIRONMENTAL MONITORING?

Romania, due to its geographical position, is a country with high biological biodiversity, expressed both at the level of ecosystem and at the level of species. The natural ecosystems have a large spatial distribution and also a vast temporal variability, which makes monitoring them a difficult task.

Because the ecological systems are functional systems, with complex organisation, generally, the structural modifications can be observed from year to year

only in case of ecological accidents and on short term. The protected areas are necessary to be prevented against the loss of various species due to structural and functional changes in ecosystems.

Up to now there are almost no monitoring devices or systems for the biological diversity. By using this self-sustaining vehicle we could monitor vast areas without the intervention of the anthropic factor in the equilibrium of the ecosystem.

The purpose of the monitoring system is the identification and measuring of the state variables which characterise the structure and functions of the ecosystems and of the factors that endanger the ecological integrity, in order to prevent their effects.

The first tasks of the experimental model to be achieved within the project will be either photo- or video-recordings with scientific purpose or real-time monitoring of the nature reserves and of the areas found within the range of the remote control.

In environmental monitoring, human presence is necessary in order to monitor, record and control the evolution of environmental parameters, but at the same time, is to be avoided because it is a disturbing and possibly intrusive element. A solution to this challenging dilemma is to use autonomous or remote-controlled mobile sensors or, to be more accurate, vehicle-mounted sensors. The very specific solution to this, as our collective thought to be, is to use unmanned aerial vehicles (UAVs), similar to those already developed and used in the military field. Consequently, the UAVs design specifications impose mainly that the vehicle should have the smallest possible impact onto environment.

WHAT IS AN UAV?

The idea and the first test to use unpiloted aircrafts appeared since World War I. The military applications of such a kind of weapons continued to be developed by all military powers, during the World War II, as in the years after. After the late 1970's, the remotely-piloted aerial vehicles were being called unmanned air vehicles (UAVs), so now, UAV stands for unmanned aerial vehicle, i.e. an unpiloted aircraft or airship.

UAVs have unmatched qualities that make them the only effective solution in specialised tasks where human presence is not necessary or is not allowed. So, UAVs are often preferred for missions considered to be too 'dull, dirty or dangerous' for manned aerial vehicles. Moreover, in certain types of operations, unmanned aerial vehicles are less expensive and more flexible to operate than manned aerial systems and the steady progress in the field is increasing their operational capabilities as well as the variety of available sensors for data collection.

Although the civil applications of the UAVs were developed later than military ones, there is already a wide range of unmanned civil aerial vehicles and systems

(UAV/UAS), used nowadays in scientific, emergency, governmental or commercial missions.

The need in the civil domain of the UAVs for more and more diversified vehicles is increasing constantly* (Ref. 1). Some of the various civil applications for the UAVs are: Border and Costal Patrol and Monitoring, Homeland Security, Law Enforcement and Disaster Operations, Precision Agricultural – Wildlife and Land Management, Digital Mapping and Planning/Land Management, Search and Rescue Missions.

Some existing environmental monitoring applications comprise:

- Natural disasters monitoring (water flows, avalanches, oil spill tracking);
- Forest and crops disease management;
- Forest and crops fire detection and wildfire fighting management;
- Forestry or fishery inspection;
- Natural reservation monitoring, as wildlife inventory and species conservation, especially in mountains or in wet areas, etc.

DISCUSSION

MEDIAS – A PROJECT FOR AERIAL SURVEILLANCE OF THE ENVIRONMENT

The environmental monitoring project we have started called 'Self-sustaining Vehicle for Aerial Surveillance of the Environment', in short MEDIAS, was focused, more than others, on the interaction of the observer with the environment. In designing it, the authors gave careful consideration to the environmentally-friendly dimension of the device used to observe and monitor the environment.

This work presents some current aspects of designing an aerial vehicle, from the class of unmanned vehicles/systems, meant specifically for carrying the necessary sensors in environmental monitoring and, eventually, for other scientific missions in civil area.

The assigned design goal is to realise an environmental monitoring system/vehicle according to some criteria (e. g. the choice of the main characteristics, the propulsion method and the onboard energy resource management), prioritised on an environmental preservation basis.

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* The present state of UAVs development in Europe is, according to some 2007 documents, surpassed by the one registered in USA and Israel. Achievements over the European average have only a few countries characterised by a great military strength, such as France, Great Britain, Germany and Italy. And also the countries around the Mediterranean Sea, including Spain and Greece, already developed unmanned aerial vehicles, for missions in the forest fire-fighting. At the same time, in the countries that recently adhered to the European Union, countries as the Czech Republic, Poland, Romania, there is an increased interest for this market of the civilian applications of the UAVs, market which is developing rapidly. The interest in these countries is doubled by the need to increase the experience in designing and use of UAVs for the civilian uses. A good example is Hungary, with notable achievements in the field of fire-fighting using UAVs.

The resulting design has to be able to carry out multiple missions. The operation mode will be, therefore, determined for each particular mission, having as a result the choice of the number and of the type of mobile sensors and tracking devices that will be mounted as a payload.

Considerations regarding the choice of the UAVs characteristics. There is a wide variety of UAV shapes, sizes, configurations, and characteristics, but all the UAVs should be capable of a controlled, sustained level flight. Nowadays, the missions of the UAVs are piloted mainly in two ways: the simpler ones are controlled by a human operator, from a remote location, others fly autonomously based on preprogrammed flight plans, using more complex dynamic automation systems. For propulsion, an UAV uses either a jet motor or a piston engine driving a propeller (a helicopter screw or a pusher airscrew).

Vehicle-mounted sensors can be utilised to air temperature and parameters, as also atmospheric conditions. Mobile data provide quick, real-time information for those involved in monitoring the areas, and it supplements fixed information sites with additional details. The quality of the data gathered and – implicitly – the success of the missions is ensured by the sensors and the equipments (devices) installed onboard. UAV remote sensing functions that should be covered by the sensors installed onboard include electromagnetic spectrum sensors, biological sensors, and chemical sensors.

Such a monitoring system will prove its utility both by monitoring the evolution of the natural capital of ecosystems and by supporting the preservation of the biologic diversity.

What kind of UAV is more suitable for the aerial surveillance of the environment? Starting from the non-involvement in the environment of the monitoring device or system, arose the necessity of an aerial vehicle using an alternative propulsion system which must not alter the monitored environmental parameters. The specific solution we found solves also the problem of non-invasive and non-pollutant surveillance of the protected areas.

A first limitative requirement was not to be propelled by an internal combustion engine, as planes, helicopters, moto-gliders, etc., because these solutions are known to be pollutant and noisy.

Supplemental, but having the same importance, the vehicle had to satisfy a few other conditions considered to be normal for a traditional ‘observer’. Such a request for the vehicle was to be able to keep effectively a fixed position, including the altitude, relative to an area of interest. Beside this, it was required for the vehicle, that in exceptional situations, to have a reserve of sustentation, in order to be able to transport an increased payload.

The solution chosen within the MEDIAS project. The environmental monitoring missions are already being performed by some UAVs meant for scientific or emer-

gency missions. The present work illustrates current aspects of UAV designing, specially built for environmental monitoring and other scientific missions in the civil area.

A primary planning condition for the self-sustentation vehicle for aerial surveillance of the environment must be its environmental-friendly feature. Therefore, not only must it not trigger changes in the researched environment but it must not generate noxa as well. The chosen propulsion method consists in using air jets, the environmental air being induced into a vertical movement by a propeller coupled to an electric engine.

The electric engine main advantage is the fact that it can use alternative energy sources in order to generate electric power, by using eventually photovoltaic cells. These are concentrically placed on the upper surface of the semispherical cap of the vehicle. In this way the aerial vehicle is held up into the air and moves using air propulsion. Propulsion uses air only as a working agent without transforming it or generating any kind of noxa which could affect the surrounding monitored environment.

The solution, which combines all these advantages and which answers best, almost 'naturally' the mentioned requirements, is a vehicle which simultaneously uses the well-known Coanda effect, not only for sustentation, but also for propulsion and vehicle steering.

The Coanda effect is a classic phenomenon in fluid mechanics and one of the fundamental discoveries of the Romanian inventor H.-M. Coanda[2–4]. The Coanda effect increases lift up to 300% on wings and wind turbine blades by blowing a sheet of high speed air from a narrow slot above the bluff trailing edge and in some cases near the leading edge[5]. The sheet of fluid follows the curved surface up to 180 degrees.

In contrast to other UAV models, the authors of the present work propose as a means of compensation for a significant part of the required ascending force, the additional use of an enclosure filled with inert gas. This must be built /mounted inside the profiled cap, thus reducing the necessary energetic consumption for the sustentation process and increasing the air buoyancy.

It is preferable to use helium rather than other gases lighter than air, even if the permeability degree and the losses of helium through the walls of the enclosure are greater as compared to other light gases. That choice is motivated because in this way there is no more risk in setting the vehicle on fire as a consequence of charging the external surface of the cap with static electricity, for He is a non-burning gas.

How does MEDIAS project looks? The vehicle is presented in Fig. 1. Its main component parts (as one may see in a partial view/sectioned view) are: 1 – profiled upper cap, 2 – the steering flaps, 3 – toroidal helium chamber, 4 – counter-rotating

(anti-torque) rudders, 5 – inner exhaust profiled cap, 6 – propeller shaft, 7 – brushless electrical motor and battery, 8 – propeller, and 9 – propeller duct.

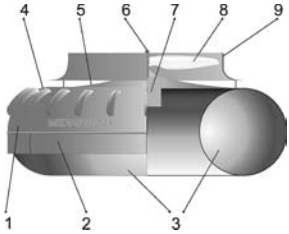

Fig. 1. Main components of the MEDIAS aerial vehicle (partially sectioned view)

The vehicle is relatively small (1 ... 1.5 m in diameter). However, the physical phenomenon used for its movement and sustentation should be able to allow it to lift and carry a significant weight compared to its estimated energetic consumption.

In this way, the vehicle will have an innovative design being a hybrid between the following three devices: I. An air vehicle – propelled by air jets; II. An air platform – which ensures its sustentation by using a propeller; III. An aerostat – which contributes to the improvement of some of the flight parameters. The specific contribution of each device to the propulsion and sustentation of MEDIAS aerial vehicle is shown in Fig. 2.

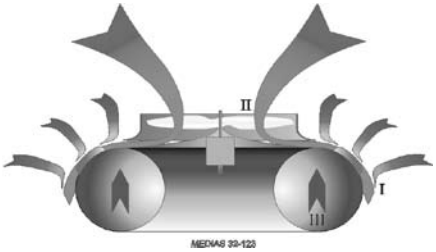

Fig. 2. Speciic contribution of each device to the propulsion and sustentation of the MEDIAS aerial vehicle (the Coanda type)

The operation mode will be, therefore, determined depending on the number and on the type of sensors to be mounted as a payload in each particular mission.

The present MEDIAS project, described in Ref. 6 will be entirely developed by an academic consortium*, involving researchers of Mechanical Engineering

* The project, named MEDIAS, has taken part in the Romanian national project contest financed by PROGRAMUL 4 PN II 'Parteneriate in domeniile prioritare' (translator note: 'Partnerships in priority areas'), 2008 ed. and has become one of the winners in the Field 3. 'Environment', for the Research Direction 3.3 'Ecological protection and reconstruction of critical areas and conservation of protected areas', at Research Theme 3.3.2 'Monitoring systems for the biological and ecological diversity dynamics at structural and functional level'.

Faculty of Braila, of 'Dunarea de Jos' University of Galati, of 'Gheorghe Asachi' Technical University of Iasi and of the University of Bacau.

CONCLUSIONS

1. MEDIAS project approach is an interdisciplinary one, uniting together environmental sciences and engineering sciences specialists.

2. The project will use the well-known, yet not so much studied, Coanda effect in order to sustain, propel and steer the vehicle. This effect seems to be more promising than those used nowadays, regarding the energetic efficiency supplied.

3. The vehicle resulted from the final design is able to carry out multiple missions. So, through developing a civil application of UAV and supplying it with required remote sensors, we will be able to fulfill the monitoring missions of the environment at a superior level.

The MEDIAS project aims to:

- create a modern, nonpolluting aerial vehicle, meant specially for environment monitoring;
- design an aerial vehicle with superior propulsion efficiency;
- elaborate the design principles and the calculus method for aerodynamic propulsion platforms using the Coanda effect;
- although for the initial stage of the project one shall use remote operated vehicle method, in the following stages is necessary to create a semi-autonomous control and guiding system of the flight.

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