Methods of Spatial Modeling for Evaluation of Air Quality based on UAV

FLORIN MINGIREANU  
Romanian Space Agency  
ROMANIA  
florin.mingireanu@rosa.ro

SORIN DAN GRIGORESCU  
Politehnica University of Bucharest  
ROMANIA  
sorin.grigorescu@upb.ro

COSTIN CEPISCA  
Politehnica University of Bucharest  
ROMANIA  
costin.cepisca@upb.ro

CATALIN STEFAN  
SC InSoft Development&Consulting SRL  
ROMANIA  
Catalin.Stefan@insoft-dc.ro

IONUT MOCANU  
SC Reev River Aerospace SRL  
ROMANIA  
i.mocanu@reevriver.ro

LUCIAN P. GEORGESCU  
University Lower Danube Galati,  
ROMANIA  
lucian.georgescu@ugal.ro

Abstract: - The major objective of this paper is to present the optimum methods of spatial modeling for evaluation of air quality and the achievement of a measuring system based on UAV (Unmanned Aerial Vehicle). The presented research combine monitoring and modeling and spatial assessment of air pollution into a specialized platform based on the use of a UAV, measurement system with specialized sensors and remote communications systems and specialized software developed for spatial analysis of air pollution.

Key-Words: - Air pollution, Cube of pollution, Unmanned Aerial Vehicle, Flight Control Computer System

1 Introduction
Biological and ecological diversity are related to air pollution, and the dynamics of the pollution is a factor to be watched carefully and unalterable [1, 5, 6]. Nowadays, the release of critical gases is an acute threat and mainly responsible for a multitude of immense dangers and problems – both global (ozone hole, global warming, climate change) and local (smog, pollution, poisoning danger in an accident or terrorist attack). EU, UNESCO, NATO and other decision bodies have been releasing directives on how to conserve and improve the environment for the current and future generations [2]. Hence, a necessary measure is to be able monitoring pollution agents such that to allow correct decisions to be taken in order to bring...
pollution agents levels back to normal accepted levels.
The gas release can take place in many different ways with different backgrounds: as exhaust from traffic or industry, as flue gas from volitional or unintentional fires, as a consequence of a chemical or dangerous goods accident, or as the result of a terrorist attack [3].
Recent accomplishments in the field of modeling of atmosphere pollution processes and of measurement systems refers only to getting the data at the level of surface soil (stations, satellites) or a vertical line (balloons) [4].
Use of UAV allows the development of the pollutants measurements in the space of three dimensions, for getting “the cube of pollution”, much clearer picture of the influence of local pollution. Mathematical models to be developed will allow not only getting concentrations of pollutant in soil surface (Fig.1) but also the realization of an image in the volume of the pollutant distribution, with heights up to several thousand meters.

Fig. 1 Mathematical model of pollutant [9]

The proposed measurement platform for the pollution monitoring is based on the use of the UAV (Unmanned Aerial Vehicle) – Fig. 2.

Fig. 2 Platform UAV

These unmanned aircrafts are designed to fly for several hours and to carry the measuring system of pollutants, the communication system and the fuzzy systems for the flight trajectory optimization.

2 UAV system structure
The measurement of gas pollutants at the surface level provides partial information for pollution studies. Information on the vertical distribution is essential for properly answering questions concerning such issues as transport and hazards to human health.
The proposed methods for evaluation of air quality introduce and develop a new concept, defined as advanced hardware/software system for 3D dimensional determination of pollution produced by various noxious agents (measurement, modeling, optimization, etc.), with the aim of preservation of biological and ecological diversity in the area studied.

Fig. 4 The structure of the proposed system

The basic elements are the computing platform that provides three-dimensional modeling of pollution and measurement platform based on an UAV.
The dedicated software/hardware main components, shown in Fig. 4, are:

a) UAV avionic modules:
FCCS - Flight Control Computer System performs flight control function;
ADAHRS - Air Data and Attitude Heading Reference System combine tri-axial angular rates, tri-axial linear accelerations, tri-axial magnetic field measurements, air data and GPS;
SACS - Servo Actuator Control System ensures drive servo commands and supplies deriving from the onboard batteries and PV modules [7].
GDLS - Ground Data Link System provides the communications link between on board electronics devices and the ground station
MS - Measurement system for the pollutants: sensors, transducers, acquisition board, and memory card for results. The gas detector can detect many combustible gases and vapours e.g. O₂, CO, H₂S, NH₃, CO₂, SO₂, PH₃, HCN, NO₂, Cl₂. The gas transport to the sensors can be passively (without
auxiliary device) or actively (using an additional equipment).

b) **Ground control system functions**

![Fig.5 Proposed trajectory](image)

UAV trajectory determined according to information received from modeling to obtain 3D dimensional results about pollution (fig.4). Virtual instruments will be installed for remote control (fig.5) and optimization will use fuzzy techniques. The results will be simulated, evaluated and validated by field tests.

![Fig. 6 The ground radio control station](image)

The UAV system can be operated using a manual remote control-ground-station (Fig.6), able to cover an action radius up to 50 km. As an alternative, the system has an auto-pilot configurable structure, based on the use of two differential GPS. The auto-pilot system is based on data acquisition cards and a specific type of DSP processing units. The autopilot allows the UAV to perform an extended range of missions at an increased safety index. It offers the UAV the capability to fly autonomously certain maps (trajectories), return to home upon command or when the battery/fuel has reached a critical level. It can also offer autonomous take-off and landing with precision higher than the one usually reached by an average human operator. A useful feature of the autonomous flight is that it can have pre-programmed trajectories along main pollution gradients previously predicted through a mathematical model or detected during flights. This way the system can refine the pollution data-space and at the same time can provide restraints and refinement for the mathematical model in order to achieve an unmatchable level of precision and robustness.

### 3 Basic System Operation

A usual operation involves the deployment of UAV and ground station at a specific location in space related to the pollution agent. The range of the UAV ensures more than enough coverage and possibility to maintain a safe distance from the pollution agent. Next a flight map determined either through a mathematical model or through a combination of a mathematical model and previous measurements is loaded in UAV’s autopilot. Sensor package is chosen according to the pollution agent intended to be detected.

Next step is setting up the ground station and autonomous UAV launch. Minimum human operator intervention is needed at this step since the UAV is designed to take-off, fly and land autonomously. In flight the UAV transmits video and sensor data automatically and also stores the data onboard for post flight retrieval in the unlikely event that some of the radio becomes corrupted. The ground station stores a copy of video and sensor information while the data aggregator packages the video/sensor data and sends it via dedicated link to the portal repository system.

The data is then extracted through the portal and presented to various users according to their permission levels and device compatibility. For example, automatic video reformatting is done such that this content can be presented real time both on PC/laptops as well as on limited mobile platforms such as PDAs, IPADS, tablet PCs. At a minimum, the portal offers the user the capability to view the data and order it according to specific requirements.

At maximum, the portal offers the user the capability to compare various datasets, perform specific mathematical operation on sensor datasets and even send new flight maps to the ground station in order to be executed. Various operations that a user can perform will be determined by users’ permissions/level of access.

A key frame of the entire portal is the capability to offer integrated voice/video communication with the human operator at the ground station making the entire system self-consistent without relying on traditional third party communications capabilities (e.g.: mobile phones).

### 5 Modeling and Simulation Station

Air pollution dispersion modeling is a computer simulation that predicts the concentrations of emission sources. It considers the emission rate,
One of the innovations of this research is 3D modeling of atmospheric pollution in a given area. Currently methods of pollution modeling refer to the soil surface. Most widely used models are:
- Gaussian model;
- Lagrangian model;
- Eulerian model – the significant difference between Lagrangian model and Eulerian model is that uses a fixed three-dimensional Cartesian grid.

Development of a computer program allowed us to obtain cumulative concentration at a point due to all sources – Fig. 7.

Fig. 7 Results of OML modelling for all sources

Computations are organized so the user can conveniently manage the files: mapping, graphics, data import and flexible output.

4 Conclusion

The environmental problems for biodiversity include air pollution, climate change, water and thermal pollution. The emission of air pollutants from fossil fuel combustion is the significant cause of urban air pollution.

The system proposed in this paper ensures rapid identification of different types of pollution sources and spread in the area studied, both horizontally and vertically as.

The proposed modular concept allows the ad hoc exchange of sensors in the gas detector, which enables users to customize it for their specific application. Will follow the measurement accuracy compared to those obtained in specialized laboratory. This new monitoring system provides the gathering of atmospheric data through the use of UAVs that enable researchers to form dimensional profiles of pollutants and other atmospheric masses at relatively low cost. Design of sensor modules for specific applications will make the cost will be lower.

Acknowledgments

Authors want to thank Romanian Space Agency for support regarding data referencing and aerodynamic modeling. They also acknowledge the support of SC InSoft Development & Consulting SRL in generating a specialized software framework for data interpolation and communication.

At the same time, they are grateful to SC Reev River Aerospace SRL for proving UAV and ground station information and relevant UAV flight and operation information.

References: