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Atmospheric Boundary Layer Dynamics Evaluation Using Piezo-Resistive Technology for Unpowered Areal Vehicles

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ABSTRACT

The paper presents a method for real-time observing of the convectional processes in the atmosphere boundary layer. The essence of the method is in providing real-time measurement of temperature, humidity, and pressure during the flight of a glider (soaring flight). Based on these measurements, a real-time evaluation of the atmosphere dynamics is presented. Measurements are taken during soaring flight of the glider and during the flight of a remotely controlled quadrocopter. Additionally, a method for atmosphere thermal identification by the measured parameters is introduced. The main application areas of this work are in unpowered flights, as well as in extending the flight time and distance of powered aerial vehicles. Moreover, the paper can be useful in research and observation of the lowest portion of the atmosphere and micro-scaled atmosphere dynamics evaluation.

KEYWORDS

Atmosphere Thermals, Convective Lift, Digital Sensors, Gliders, Laps Rate, Micro-Scaled Atmosphere Dynamics, Real-Time Evaluation, Soaring

1. INTRODUCTION

Measuring pressure, temperature and relative humidity *fast enough* in order to provide real-time information of the momentum state of the atmosphere plays an important role in navigation and instrumentation applications for soaring gliders and in UAV

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(Unmanned aerial vehicles) (Akhtar, Whidborne, & Cooke, 2012). This is achieved via suitable electronics for providing online information to the pilot inside the UAV cockpit (Reddy, Celani, Sejnowski, & Vergassola, 2016). However, as we are aware, appropriate *light-weight multy-sensory systems* for paragliders, for example, have not been designed yet, and the pilot relies on intuitive decisions most of the time of the soaring flight.

Sensors with low power consumption, digital interfaces, miniature and light-weight packing, based on piezo-resistive technology such as Bosch Sensortec BME280, for example, are available at a low-cost price today and can be implemented in the multi-sensory system (MSS) for assessment of the momentum state of the atmosphere. At the same time, mathematical processing of the data is necessary in order to accomplish the micro-scaled dynamics evaluation in order for the multi-sensory system to implement intelligence solutions to provide better cognitive support to the pilot rather than just displaying raw data. One promising approach is based on ornithology studies (Laurenza, 2007), since the soaring of a glider and a bird share many commonalities like – being lightweight, motor-less, relying on current atmospheric dynamics at low altitude of flight.

Numerous accounts of birds soaring without flapping their wings, ranging from observations by Leonardo da Vinci to Octave Chanute can be found in the literature (Laurenza, 2007). Birds circling in thermals are typical examples for the advantageous use of the atmospheric energy to preserve one's position in the air (Ákos, Nagy, Leven, & Vicsek., 2010). For instance, nowadays different types of gliders are soaring thermals and reaching hundreds of kilometers and dozens of hours in the air in a single unpowered flight (Pagenan, 1992).

It is well known that there are different forms of energy in the atmosphere boundary layer (Ákos, Nagy, Leven, & Vicsek., 2010). Some of them are stronger, but less predictable than others. Dynamical forms of energy can be found in:

1. Ridges (orographic lift, where the slopes of hills and mountains deflect wind);
2. Atmospheric thermals (uneven heating of the ground, which produces buoyant instabilities);
3. Waves (long period oscillations of the atmosphere, which occur in the lee of large mountain ranges). These waves were used in the altitude flight record by Airbus Perlan Project, for example, (https://www.airbus.com/newsroom/press-releases/en/2018/09/airbus-perlan-mission-ii-glider-soars-to-76-000-feet-to-break-ow.html). In recent years also theoretical and experimental investigations of energy extraction from atmospheric turbulence are performed with main application large aircrafts (Patel & Kroo, 2008). With UAV, however, the forms of energy, influencing the flight, differ in scale and dynamics, which needs further investigation and modeling.

The *atmospheric thermals* are the most commonly used forms of energy for soaring flights. Although they occur frequently and over various types of terrains, in both

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