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Cloud Height Estimation with a Single Digital Camera and Artificial Neural Networks

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Clouds influence the local weather, the global climate and are an important parameter in the weather prediction models. Clouds are also an essential component of airplane safety when visual flight rules (VFR) are enforced, such as in most small aerodromes where it is not economically viable to install instruments for assisted flying. Therefore it is important to develop low cost and robust systems that can be easily deployed in the field, enabling large scale acquisition of cloud parameters.

Recently, the authors developed a low-cost system for the measurement of cloud base height using stereo-vision and digital photography. However, due to the stereo nature of the system, some challenges were presented. In particular, the relative camera orientation requires calibration and the two cameras need to be synchronized so that the photos from both cameras are acquired simultaneously.

In this work we present a new system that estimates the cloud height between 1000 and 5000 meters. This prototype is composed by one digital camera controlled by a Raspberry Pi and is installed at Centro de Geofísica de Évora (CGE) in Évora, Portugal. The camera is periodically triggered to acquire images of the overhead sky and the photos are downloaded to the Raspberry Pi which forwards them to a central computer that processes the images and estimates the cloud height in real time.

To estimate the cloud height using just one image requires a computer model that is able to learn from previous experiences and execute pattern recognition. The model proposed in this work is an Artificial Neural Network (ANN) that was previously trained with cloud features at different heights. The chosen Artificial Neural Network is a three-layer network, with six parameters in the input layer, 12 neurons in the hidden intermediate layer, and an output layer with only one output. The six input parameters are the average intensity values and the intensity standard deviation of each RGB channel. The output parameter in the output layer is the cloud height estimated by the ANN. The training procedure was performed, using the back-propagation method, in a set of 260 different clouds with heights in the range [1000, 5000] m. The training of the ANN has resulted in a correlation ratio of 0.74. This trained ANN can therefore be used to estimate the cloud height.

The previously described system can also measure the wind speed and direction at cloud height by measuring the displacement, in pixels, of a cloud feature between consecutively acquired photos. Also, the geographical north direction can be estimated using this setup through sequential night images with high exposure times. A further advantage of this single camera system is that no camera calibration or synchronization is needed. This significantly reduces the cost and complexity of field deployment of cloud height measurement systems based on digital photography.