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A novel approach for automatic snow depth estimation using UAV-taken images without ground control points

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Recent developments in snow depth reconstruction based on remote sensing techniques include the use of photographs of snow-covered terrain taken by unmanned aerial vehicles (UAVs). There are several approaches that utilize visible-light photos (RGB) or near infrared images (NIR). The majority of the methods in question are based on reconstructing the digital surface model (DSM) of the snow-covered area with the use of the Structure-from-Motion (SfM) algorithm and the stereo-vision software. Having reconstructed the above-mentioned DSM it is straightforward to calculate the snow depth map which may be produced as a difference between the DSM of snow-covered terrain and the snow-free DSM, known as the reference surface. In order to use the aforementioned procedure, the high spatial accuracy of the two DSMs must be ensured. Traditionally, this is done using the ground control points (GCPs), either artificial or natural terrain features that are visible on aerial images, the coordinates of which are measured in the field using the Global Navigation Satellite System (GNSS) receiver by qualified personnel. The field measurements may be time-taking (GCPs must be well distributed in the study area, therefore the field experts should travel over long distances) and dangerous (the field experts may be exposed to avalanche risk or cold). Thus, there is a need to elaborate methods that enable the above-mentioned automatic snow depth map production without the use of GCPs. One of such attempts is shown in this paper which aims to present the novel method which is based on real-time processing of snow-covered and snow-free dense point clouds produced by SfM. The two stage georeferencing is proposed. The initial (low accuracy) one assigns true geographic, and subsequently projected, coordinates to the two dense point clouds, while the said initially-registered dense point clouds are matched using the iterative closest point (ICP) algorithm in the final (high accuracy) stage. The stable reference is offered by specially-selected trees which are located in the vicinity of the terrain of interest. The method has already been implemented and along with the presentation of its concept, a few case studies from the Izerskie Mountains (southwestern Poland) are discussed. Although the method reveals several constraints, it may serve the purpose of generating the snow depth maps with reasonable accuracy, in particular in the absence of GCPs. The snow depth estimation algorithm has been elaborated in frame of the research grant no. LIDER/012/223/L-5/13/NCBR/2014 financed by the National Centre for Research and Development of Poland.