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The potential of Unmanned Aerial Systems: A tool towards precision classification of hard-to-distinguish vegetation types?

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ABSTRACT

Detail plant species classification using very high spatial resolution data is a challenging task. Exploring the potential of imagery acquired by Unmanned Aerial Vehicle (UAV) to identify individual species of plants and assessing values of additional inputs such as height and thermal information into classification process are hot research topics. Our study uses a fusion of visible, multispectral and thermal imagery acquired through the low altitude aerial survey for detail classification of land cover and vegetation types. The study area is located in the central part of the Czech Republic and situated in an environmentally specific area – an arboretum of 2.45 ha. Visible (i.e. RGB), multispectral, and thermal sensors were mounted on a flying fixed-wing Unmanned Aerial System. The imagery was acquired at a very detailed scale with Ground Sampling Distance of 3–18 cm. Besides three mosaics (one from each sensor), normalized Digital Surface Models were built from visible and multispectral sensors. Eight classification models were created – each mosaic (visible/multispectral) was enriched with height data, thermal data, and combined height and thermal information. A classification into a three level system was performed through Geographic Object-based Image Analysis using Support Vector Machine algorithm. In general, Overall Accuracy grew with the amount of information entering the classification process. Accuracy reached 77 – 91 % depending on the level of generalization for the best model based on multispectral data and 67 – 80 % for data from the visible sensor. Both thermal data and height information improved the accuracy; however, the statistical evaluation did not reveal any significant difference between the contribution of height and thermal data. Results also indicate that increasing spectral resolution leads to a significantly better performance of the models than higher spatial resolution. UAVs equipped with a proper sensor provide a convenient technology for detail land cover classification even in areas with many similar plant species.

1. Introduction

Nowadays, it is relatively easy to acquire one´s own image data with a detailed spatial, sufficient spectral and variable temporal resolution. Unmanned Aerial Vehicles (UAVs) and their use are among the most dynamically developing fields of remote sensing (RS), being a suitable source of data for environmental analyses focused e.g. on classification of vegetation (Gini et al., 2014; Husson et al., 2017; Laliberte et al., 2011; Lisein et al., 2015; Michez et al., 2016; Weil et al., 2017), invasive plant detection (Müllerová et al., 2017), pests (Näsi et al., 2015), plant diseases and water stress detection (Baluja et al., 2012; Berni et al., 2009; Calderón et al., 2013; Nishar et al., 2016; Zarco-Tejada et al., 2012), modelling of individual treetops (Díaz-Varela et al., 2015), in agriculture (Moravec et al., 2017; Pérez-Ortiz et al., 2015), or for monitoring animal species (Chrétien et al., 2016).

One of the major UAV challenges lies in a detail classification of the land cover (Ahmed et al., 2017), which may support decision-making mechanisms and operations. Besides low altitude UAV surveys, other technologies are used for precision classification, e.g., for species classification of trees (Ali et al., 2004; Holmgren et al., 2008), of vegetation specific for various environment types (Alonzo et al., 2014; Bork and Su, 2007; Feng et al., 2015; Hartfield et al., 2011; Husson et al., 2017; Rampi et al., 2014; Reese et al., 2015; Sankey et al., 2017), or a complex land cover classification (Kuria et al., 2014; Szostak et al., 2014; Teo and Huang, 2016; Zhou and Qiu, 2015).

Classification accuracy can be affected by the properties and quality of both the spectral information and height data from (a) digital terrain models (DTMs); (b) digital surface models (DSMs) or (c) normalized digital surface models (nDSM). For land cover classification, a fusion approach combines multi(hyper)-spectral satellite data (Reese et al., 2015; Zhou and Qiu, 2015), airborne (Alonzo et al., 2014; Bork and Su, 2007; Teo and Huang, 2016) and UAV-borne (Sankey et al., 2017) with

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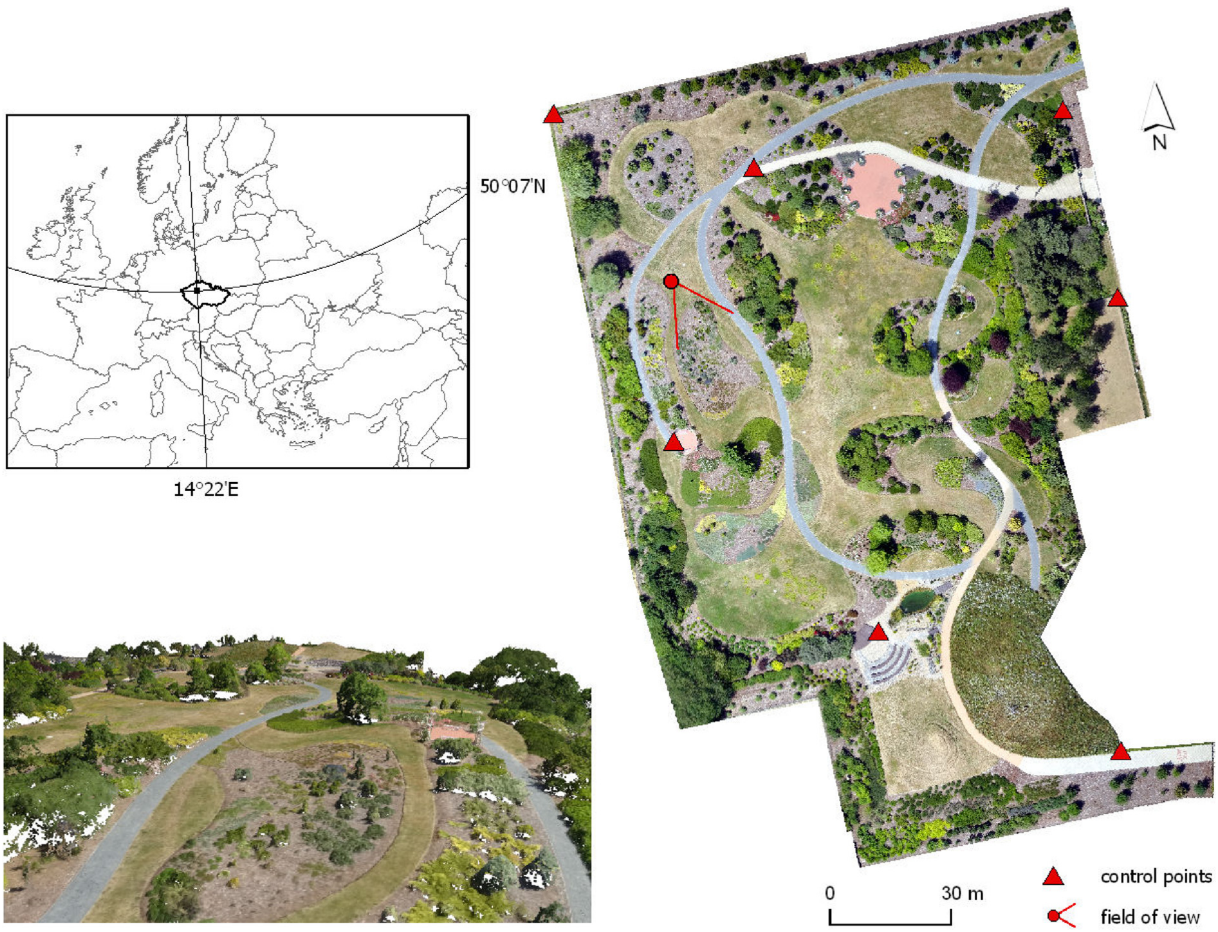

Fig. 1. (Above left) Location of the study area. (Right) The study area, a part of the Libosad arboretum (2.45 ha). Seven ground control points were used to facilitate further data processing. (Bottom left) Oblique view of the coloured densified Point Cloud from the point indicated on the orthophotomap. The map corresponds to ETRS 1898 LAEA projection (EPSG 3035).

Airborne Laser Scanning (Alonzo et al., 2014; Bork and Su, 2007; Holmgren et al., 2008; Zhou and Qiu, 2015) or with airborne images processed through photogrammetric image matching (Reese et al., 2015). The height data (point clouds) can be also derived from UAV-borne imagery by a photogrammetric Structure from Motion (SfM) method. However, the height data are frequently inappropriately neglected during classification utilizing UAV imagery (Feng et al., 2015) despite the fact that they can be instrumental in achieving better results (Husson et al., 2017).

The accuracy of resulting classification is also affected by the classification approach. If processing very high resolution data (e.g. UAV-borne data), classifications based on Geographic Object-based Image Analysis approach (GEOBIA; Blaschke, 2010; Liu et al., 2015) tend to provide better results than the traditional pixel-based approach (Yu et al., 2006). The benefit of GEOBIA has been repeatedly shown in multiple studies utilizing predominantly satellite or airborne high spatial resolution data (Addink et al., 2007; Alonzo et al., 2014; An et al., 2007; Diaz-Varela et al., 2014; Hartfield et al., 2011; Peña et al., 2013).

UAV sensors are typically RGB cameras recording images in visible (Feng et al., 2015; Gini et al., 2014; Husson et al., 2017; Müllerová et al., 2017) or in near infrared spectrum (Ahmed et al., 2017; Weil et al., 2017). RGB cameras are used on a mass scale due to their availability, their classification accuracy is however substantially lower (Ahmed et al., 2017). On the other hand, the higher spatial resolution may act as a substitution for additional spectral bands in specific RS studies. Other sensors, e.g. hyper-spectral cameras or UAV LiDAR (Sankey et al., 2017) are also available, however, their costs are high.

Due to current restrictions and regulations, use of UAV is limited by country-specific legislation. Applicability is also limited by a higher price of miniaturized sensors or a relatively high UAV susceptibility to failures (Freeman and Balas, 2014; Zuiev et al., 2015). UAV is still a novel technology, therefore use is still facing challenges and problems that need to be identified and overcome than the traditional remote sensing methods (Ahmed et al., 2017). The analysis of imagery obtained through other (non-UAV) methods have led to the development of many more or less standardized approaches over the years. It is likely, although not properly verified yet, that for various environment-related analyses, these approaches will be also applicable very high resolution data (magnitude of a few cm). Recent general reviews of UAV applications have been published (Marris, 2013; Pajares, 2015), more studies using different types of UAV imaging sensors are however needed to increase the potential of the utilization of such new platforms in vegetation inventorying and other environmental applications. Despite the fact that UAVs have been a hot research topic in the recent years, only a few studies focused on their usability for precise classification using a set of sensors have been published.

The aim of our study is to evaluate the potential of UAV acquired data (namely of images acquired using visible, multispectral and thermal sensors, and height models – nDSMs – derived from such data) for classification of land cover, particularly on the level of individual plant species. Following research questions are presented: (i) Is it possible to classify individual plant species with a sufficient accuracy based on UAV imagery? (ii) Is it possible to substitute additional spectral data by an RGB sensor with a higher spatial resolution for classification of plant species? (iii) Do the height data contribute to improving the