SMALL WOOD

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REPORT

Unmanned aerial vehicle photography and photogrammetry in the Smallwood project

A drone was acquired for the Smallwood project. Apart from the ability for the researchers to visually convey methods and stand characteristics in the study areas, the potential of remote sensing using unmanned aerial vehicle (UAV) photogrammetry for complimentary analysis was investigated. Aerial survey imagery was processed into dense point clouds, digital elevation models and orthophotos, enabling comparisons of stand attributes before and after thinning and between work methods. The study showed that there is great potential for using photogrammetric remote sensing to augment field study results such as thinning intensity estimation, biomass concentration analysis, strip road terrain profiling, and more.

Introduction

Smallwood is a research project co-funded by the European Union where partners from the Swedish University of Agricultural Sciences (SLU), Technical University of Madrid (UPM), Slovenian Forestry Institute (SFI), Faculty of Economics and Business of the University of Maribor (FEB), University of Eastern Finland (UEF) and Bracke Forest collaborate to develop and evaluate new technology and operational models that can support a sustainable management and utilization of different types of small diameter wood [1].

Picture 1. Photo from the demo event in Bräcke, Sweden. Photo: Christian Höök

Within the project, trials to date have been conducted in Sweden (Picture 1), Finland, and Slovenia, where an upgraded version of the accumulating felling head Bracke C16.c has been tested with two thinning methods: a conventional, selective thinning and a novel, boom-corridor thinning (BCT). BCT has been proposed as a cost-effective harvesting operation method for use in young dense stands that increases productivity while maintaining similar stand structure as in selective thinning [2].

To document and analyse complementary results from different treatments within the stands at the study sites, a small consumer-grade UAV was used (Picture 2).

Picture 2. DJI Mavic 2 Pro with its controller. Photo: Urban Žitko.

UAV, more commonly known as a drone, is an aircraft without a pilot on board. The earliest use of an UAV was recorded in 1849 when Austrian forces launched incendiary balloons in an effort to besiege Venice [3]. Though initially used in military applications, the drone market is rapidly expanding in scientific, recreational, and commercial use due to its modularity and inexpensiveness. Commercially available consumer and "prosumer" drones are typically designed as a small device carried by several propellers in a helicopter-like fashion and generally come equipped with an onboard camera. Other attachments available from different manufacturers and models include lights, speakers, infrared cameras, multispectral cameras, LiDAR units, and more. Using a camera-equipped drone to capture a birds-eye-view of a landmark or landscape enables researchers and others to, via photogrammetry, generate spatial data in three dimensions.

Photogrammetry is the science of transforming 2D imagery into reliable information about physical objects and the environment. Photogrammetry has been around for almost as long as photography itself, where the first use cases were to manually create topographic maps from photographs in the mid-19th century [4]. With the recent development in computer processing power, photogrammetry software can process large numbers of photographs, accurately representing big objects and environments in three-dimensional space to be used for further processing. The use of this powerful technique enables measurements of distances and volumes in industry applications, aerial surveying, digital reproduction of objects for historic documentation or use in a digital environment such as videogames, and so on. UAV photogrammetry has also been used to measure forwarder wheel rut depth with great accuracy [5].

Within the Smallwood project, aside from presentational and promotional material such as photos and videos, the drone was used as an experimental tool to explore technologies related to photogrammetry.

Materials and Methods

The decision as to which drone to acquire for the project was based on economy, utility, and portability. The chosen drone, a DJI Mavic 2 Pro, fulfilled the specifications needed since it was: a consumer-grade drone; small enough to go in hand luggage on an airplane; and having a good-enough camera system for videography, photography, and further photogrammetry. The drone itself had a weight of 0.9 kg, a flying time of about 30 minutes on one battery, and a theoretic range of 8 km from the remote controller. The drone's camera had a 1" CMOS sensor of 20 MP, a rolling shutter, and was able to record 4K video in 30 frames per second. An iOS or Android device with special software, or apps, needed to be plugged in to the remote controller as the device's screen would act as viewfinder and route planner.

To capture video clips and photographs for use in promotional material using the drone, the iOS application DJI GO 4 [6] was used. This application is a free tool for flight and capture control and works in tandem with the physical controller to pilot the drone, as well as acting as a viewfinder for the onboard camera. Using the DJI GO 4 app, photos and videos for documentation and presentation in mind were taken ad hoc and without regard to any continuity in between captures.

For the capture of survey images to be used in photogrammetry software, the iOS application DJI GS PRO [7] was used. DJI GS PRO focuses on planning and executing "missions" of autonomous flight and automatic capture - ideal for photogrammetry and mapping surveys. DJI GS PRO allows for flight route and camera configuration, including settings for drone route, drone speed, shutter speed, focus, ISO, aperture, image overlap, and more.

Missions planned using DJI GS PRO was typically set to a flying height of 80 metres and an image overlap of 85% both horizontally and vertically. To reduce motion blur in images, they were taken in shutter priority mode (shortest shutter time the ambient light could support without an ISO above 200) while the drone speed was adapted to be as low as possible for each specific mission in regard to available flying time (dictated by the battery power).

Images and videos captured for documentation were post-processed using tools in the Adobe Creative Cloud software suite (Photoshop, Premiere Pro and After Effects). The survey images were processed and analysed using Agisoft Metashape Professional [8]. All tools were used on a laptop PC with a 6th generation two-core, four thread Intel i7 processor, 32GB RAM and integrated Intel HD graphics.

Results

Aside from pictures for promotional material and internal documentation, a short video introducing the project was edited and published on the Smallwood project website [1].

Using Agisoft Metashape, the survey images taken autonomously with the DJI GS Pro application were processed into dense point clouds (Picture 3), digital elevation models (DEMs) and orthophotos.

Picture 3. Point cloud reconstruction of the study site post-harvesting in Bräcke, Sweden.

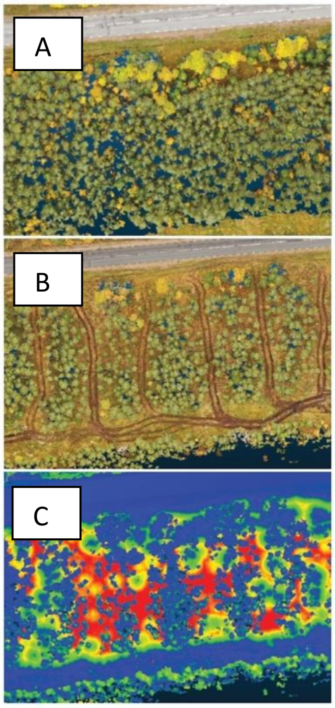
Using orthophotos from the sites after thinning work (before forwarding), the number of bunches of felled trees per study unit were quantified. This helped in analysing differences in biomass concentration between conventional and boom-corridor thinning (Picture 4).

Picture 4. Orthophoto generated from UAV photography showing part of a strip road post harvesting in Finland. Points were manually placed on bunches of trees for quantification of bunch variation between treatments in the study.

Discussion

The motivation for using a drone in the Smallwood project was primarily for documentation. Smallwood is an ambitious project that would be presented both in conferences and academic journals, and aerial photographs and videos could visually help convey methods used in the trials and site characteristics. Images and videos captured by the drone were generally of high quality and perfectly fine for use in promotional material and the intended documentation. The video edited in-house was of good enough quality to front the project website.

In addition to the images and videos captured as a way of presenting the field studies, a few interesting thoughts on how to incorporate the potential of photogrammetry analysis emerged along the way.
Photogrammetric reconstructions of a site before and after treatment could be compared on a point-cloud level, computing distances between points to, for example, identify the intensity of a thinning management in a certain area. To realize this potential, the point clouds must be aligned to a high degree of accuracy to facilitate a good enough point distance computation. This analysis was conceptualized after field work resulting in inaccurate results as aerial surveying was not adapted for this method. The process was, however, tested and results visually inspected (Picture 5).



Picture 5. Point clouds of the same study area. A: Before harvesting B: After harvesting C: Point cloud distance computation of A and B. Blue areas are unaffected by harvesting, green slightly affected and red heavily affected.

For future evaluation of this concept, the use of ground control points (GCPs) that defines absolute georeferenced points in the study area (along with higher resolution, overlap and quality of survey images) would increase "cross-cloud" accuracy. The open-source Cloud Compare software was used for comparative analysis of point clouds [9].

Instead of using Cloud Compare to analyse difference in stand characteristics before and after treatment, digital elevation models (DEMs) could be used as input data for further analysis. As a comparison to the point cloud distance computation a DEM was generated from the point cloud with interpolation of points in no-data "holes". DEMs are raster-based and therefore compatible with all raster tools in any typical geographic information system (GIS). One example of the use of a DEM would be to extract profiles of the strip roads to analyse and present differences in terrain between or along study plots.

The drone used (DJI Mavic 2 Pro) proved to be very reliable regarding flight. The controls were intuitive and its safety features and advanced autonomy made it easy to pilot, even for beginners. The portability of the drone was satisfactory, there were no problems travelling with it in a regular airplane luggage. The flight time on a single battery, 30 minutes, was generally enough for our use. In hindsight, increasing image overlap when surveying for a photogrammetric workflow would increase flight time and could become an issue when surveying areas larger than a few hectares. The DJI GS Pro app, however, supports multi-battery missions where the drone would pause a survey and fly back to its starting point for a battery swap, and then resuming the mission. Though a helpful feature, this could potentially introduce inconsistencies in the series of images and their metadata, resulting in a lower quality reconstruction.

The images and videos produced by the on-board camera were satisfactory in quality for documentation. However, the camera uses an electronic rolling shutter which introduces an image defect sometimes referred to as the "jello-effect" [10]. The rolling shutter captures an image over a short amount of time from the top row of pixels down to the bottom. As this "scanning line" moves down the sensor, the image is recorded and gradually created. This happens at very fast speed, but when capturing moving objects, it can produce a very slight distortion of the image frame. When using images captured by a rolling shutter camera for photogrammetry, the distortion can introduce noise in the point cloud reconstruction. This was not a big problem for the coarse reconstructive work in the Smallwood project, but using a drone with a mechanical shutter for further projects where accuracy is a priority would improve accuracy in the photogrammetric workflow.

The Agisoft Metashape Photogrammetry software was satisfactory for the needs. It supports the creation of dense point clouds, DEMs and orthophotos. There are other similar softwares, including some open-source ones, but only Metashape was evaluated and used.

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