DRONEMAPPER - CLOUD BASED SOLUTION FOR AUTOMATIC IMAGE MOSAICKING AND GEOREFERENCING

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Abstract: Unmanned air vehicles (UAVs) are used increasingly often to collect images for precision agriculture. Since drones fly at low altitudes, the camera has a limited field of vision. To cover an area of interest, taking even up to a thousand photos is necessary. To provide a complete view of the area, the photos need to be merged into a single composite image. Here we describe a DroneMapper - cloud application for automatic mosaicking and georeferencing. DroneMapper uses numerous open source tools for image processing and mapping. Thanks to the powerful computing resources of the server on which the application is hosted, DroneMapper performs a multiple times faster map processing in comparison to desktop solutions.

1. INTRODUCTION

The acquisition of precise and timely information about crop condition during the season is of crucial importance for precision agriculture crop management applications, [1, 2]. Aerial RGB and spectral images give a series of spatial and spectral terrain parameters which could be used for various applications: vegetation classification and mapping, crop forecasting and yield prediction [3-4], nitrogen stress and water stress detection [5-6], soil erosion detection [7], crop status and condition monitoring, estimating leaf chlorophyll concentration [8], etc.

Satellite images have limited application in agriculture due to a small spatial and spectral resolution, as well as a big time interval between two consecutive image capturing. Due to the fact that precision agriculture requires detailed information about the terrain parameters, oftentimes a spatial resolution of several meters is required, while for certain specific application greater resolutions need to be achieved [8]. The images taken from the plane are detailed enough, but data acquisition in this manner is too expensive and impractical.

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Usually, the planes are equipped with high-resolution cameras, which are quite expensive, compared to other types of imagery [8].

Because of previously stated reasons, unmanned aircrafts (drones) are used increasingly often. The drones are relatively cheap, they can be used to scan an area of interest more frequently, and due to the fact that they fly low enough, a spatial resolution of up to 2cm/pixel can be achieved [8].

As drones usually fly on altitudes below 100m, the camera has a limited field of vision. To cover an area of interest, taking even up to 1000 photos is necessary. To provide a complete view of an area, the photos need to be merged into a single composite image. This process of joining two or more independent images into single image is called mosaicking, and the resulting image is called a mosaic [9]. Apart from this, the image needs to be georeferenced, i.e. match every pixel with real geographical coordinates [9-11].

There are a number of commercial desktop photogrammetry tools that are designed for mapping applications in precision agriculture [12, 13]. However, desktop photogrammetry software is quite expensive and usually require significant storage and processor resources. In recent years cloud computing gained attraction and many applications are migrated to the Cloud [14, 15]. For the ordinary user, the cloud-based applications are cheaper, simpler to use, and also can provide all the necessary information to make timely decisions [16, 17]. It frees them from buying expensive photogrammetry software and computing resources.

In this paper, a DroneMapper - cloud application for automatic image mosaicking and georeferencing is described. DroneMapper allows users to upload aerial photos, stitch the images and host created maps [14]. DroneMapper uses available open source tools for image and digital terrain model (DTM) processing. It has been shown that maps generated by DroneMapper have very good quality. Also, the DroneMapper has shorter image processing times, compared to the some popular commercial and desktop mapping software.

The rest of paper is organized as follows. An overview of existing desktop and cloud software tools for image mosaicking is given in Section II. In Section III, DroneMapper design and features are presented. At the end, some image processing results and conclusion are given.

2. OVERVIEW OF PHOTOGRAMMETRY SOFTWARE

The main purpose of auto-mosaicking software is to facilitate the construction of a single composite image from multiple images with overlapping segments [13, 18]. In UAV imagery, the altitude of UAVs strongly impacts the quality of the photo maps produces by auto-mosaicking software. Lower-altitude imagery results in higher resolution, i.e. allows capturing more details in the landscape. If the number of the taken images is sufficiently large, this increases probability of correctly matching common points on a photo map. On the other side, higher-altitude imagery could significantly reduce the time required to photograph large areas, as well as the processing time of the auto-mosaicking software [13]. In addition, the quality of the photo mapping is less prone to distortions found in the individual images of building and other objects on the ground. Therefore, the altitude of UAVs should be carefully chosen based on the specific use-case. The configuration of the flying routes is another relevant issue to be considered. For good mosaicking results, the UAVs should be routed such to ensure photo overlapping by minimum 20% [11].

There are many commercial software products for professional aerial mapping applications. Pix4D [19] and Agisoft PhotoScan [20] are the two most widely used today. Pix4D enables auto-construction of high-quality 3D textured models, digital surface models (DSM) and NDVI maps. It also offers set of tools customized for precision agriculture (Pix4D AG [19]), that could be used for aerial crop analysis, generating index maps and/or to facilitate configuration of different processing functions. Agisoft PhotoScan provides a set of similar general-purpose functionalities, including: photogrammetric triangulation, 3D model generation and texturing, dense point cloud generation, etc. Also, it has built-in tools for measuring distance, area and volume of objects [20].

The processing of high-definition images is computationally intensive, and could require abundant processing and storage resources. For this reasons, a large number of conventional mapping applications have been migrated to the Cloud [14]. Maps Made Easy (MME) is a cloud application which allows users to upload UAVs photos, create photo maps online, and store the created maps on Cloud resources. MME uses standard methods to produce georeferenced images that are compatible with existing GIS solutions [21]. It also supports processing of NDVI images and provides some advanced tools, such as a measuring of the object area or volume.

There are also several open-source projected dealing with aerial imagery processing [22]. MapKnitter is free open source tool for manual stitching images in geographic space into a one composite map [23]. On the other side, OpenDroneMap uses GPS data to automatically create orthorectified maps and 3D models from drone imagery [24]. Visual Software from Motion (VisualSFM) is a GUI application for 3D reconstruction using structure from motion (SFM) [25].

3. DRONEMAPPER DESIGN

A global outline of the DroneMapper application is shown in Figure 1. The DroneMapper is designed to support several users, whereby each user is able to upload a set of captured images via a web interface, begin their processing and make an overview of already created maps. Drone images are uploaded to cloud storage, where they are stored one week. The uploaded images are processed by different open source image processing tools in order to get a mosaicked and georeferenced map.

All information about users and generated maps are stored in the MySQL database, which consists of two tables. The relational database represents a reasonable choice since the DroneMapper is not intended to a large number of users. The user interface is mainly written in PHP, by using the Laravel framework, while some parts are written in Vue.js framework. Creating new maps is very simple - the user only needs to enter map name and its description, choose whether the map is public or private, and finally upload UAV images (Figure 2).

Once the map has been created and images uploaded, an image processing job is pushed into the queue. At the moment, DroneMapper has the ability to process one map in time. Since the number of images, map processing time, and number of processing cores are stored in the database, in next the version of DroneMapper, this information will be used to optimize the number of jobs served from the queues. After the processing, the user receives an e-mail notification. The user also has the ability to download the maps in standard GeoTiff format and use them in one of the existing GIS tools. The dashboard is divided into two parts: maps that are already created, and the maps that are currently being processed. To visualize maps we used Leaflet.js – open source JavaScript library.

Fig 1. A global outline of DroneMapper

DroneMapper uses numerous open source image processing tools. The most computationally demanding among them is OpenDroneMap (ODM) which is able to perform multi-core parallel processing [23]. ODM is a command line open source tool for processing drone, balloon or kite imagery, [23]. ODM uses open source image processing libraries, such as OpenSfM, PMVS, bundler tools, to generate Point Clouds, Digital Surface Models (DSM), Textured Digital Surface Models (TDSM) and Orthorectified Imagery. ODM consists of five modules: georeferencing, meshing, orthophoto, slam, and texturing. Since the ODM can be run from the command line, one can to write automated scripts which can be called on user demand, via the web interface. OpenDroneMap has many input parameters that should be optimized in order to make the best compromise between the map quality and processing time.

Figure 2. Image uploading interface

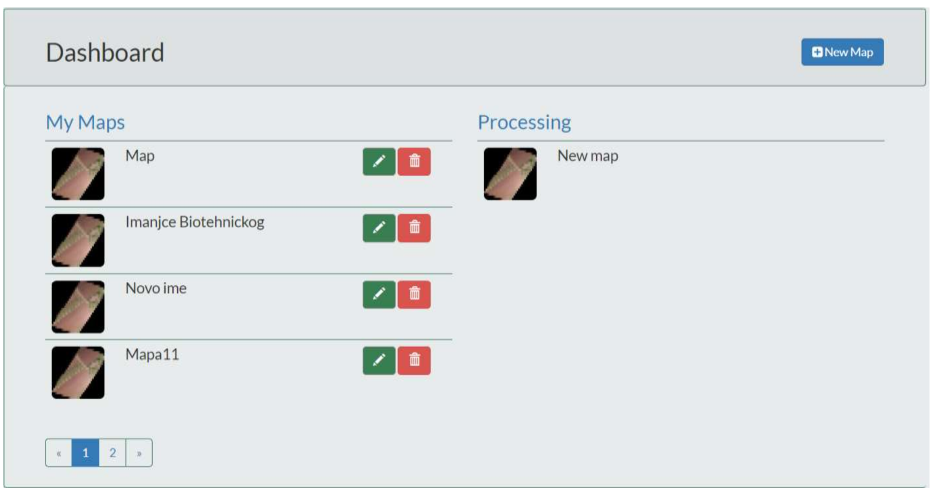

Figure 3. DroneMapper dashboard

Basically, ODM takes images as input and produces a georeferenced assets as output, such as maps and 3D models. Finally, when georeferenced map is generated, a *gdal* library is used to create map tiles [26]. Gdal generates a directory with small tiles and metadata, following the OSGeo Tile Map Service Specification [26]. At the moment, web server and image processing tools are hosted on the same virtual machine. In the next version DroneMapper separate installation of the web server and image processing tools will be considered. To keep server from overloading, a process control system (supervisor) is installed [27]. Supervisor controls the number of processing jobs pushed from the queue. DroneMapper can found application in precision agriculture. For, example, it can be integrated with some already developed services [28, 29].

4. RESULTS AND DISCUSSION

DJI Phantom 4 drone, equipped with a 12.6Mpx camera, is used to capture the images. Two image datasets are collected: one that consists of 180 images taken at altitude 50m, and the second one that consists of 65 images taken at altitude 100m. DroneMapper processing time is compared with Agisoft PhotoScan and MapsMadeEasy. Agisoft PhotoScan was installed on Windows 10 PC, with quad-core CPU and 8GB of memory, while the DroneMapper was installed on the cloud server with 24 cores and 6GB of RAM.

In the first example, the dataset that consists of 180 images is used. The resulting map, obtained by DroneMapper, is shown in Figure 4. The map is rendered at resolution 5 cm per pixel, and it is shown overlaid a Google Earth. It can be seen that accurate georeferencing is achieved. Also, it can be seen that map has a good overlap with Google Earth. One can observe that map quality is on a very good level, so DroneMapper should be considered as an alternative to expensive professional mapping software.

TABLE I. COMPARISON OF PROCESSING TIMES

Tool	DroneMapper	MapsMadeEasy	Agisoft
Number of images	180	180	180
Processing time	25min	5h 20min	9h 45 min

Table I shows the processing time of the considered mapping tools. It can be seen, that the DroneMapper has the shortest processing time – 25min, while the MapsMadeEasy and PhotoScan need 5h 20min and 9h 45min to finish map processing, respectively.

Fig 4. The resulting map at zoom level 12 (180 images)

Fig 5. The resulting map at zoom level 12 (65 images)

Fig 6. The resulting map at zoom level 4 (65 images)

In the second example, the dataset that consists of 65 images is used. The resulting map was rendered at resolution 10 cm per pixel and it is shown overlaid a Google Earth (Figure 5). Figure 6 shows the resulting mosaic at zoom level 4. It can be seen that also in this example the precise georeferencing is achieved. The resulting map also has a good overlap with Google Earth.

The processing times of considered mapping tools are compared in Table II. It can be seen that also in this example the DroneMapper has shorter processing time compared to the MapsMadeEasy and PhotoScan software.

TABLE I. COMPARISON OF PROCESSING TIMES

Tool	DroneMapper	MapsMadeEasy	Agisoft
Number of images	65	65	65
Processing time	11min	1h 10min	3h 50min

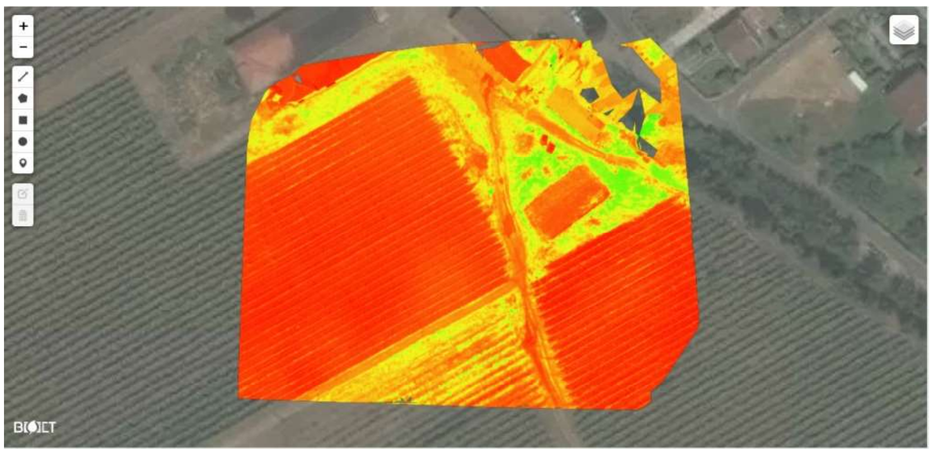

Fig 7. The resulting VARI map

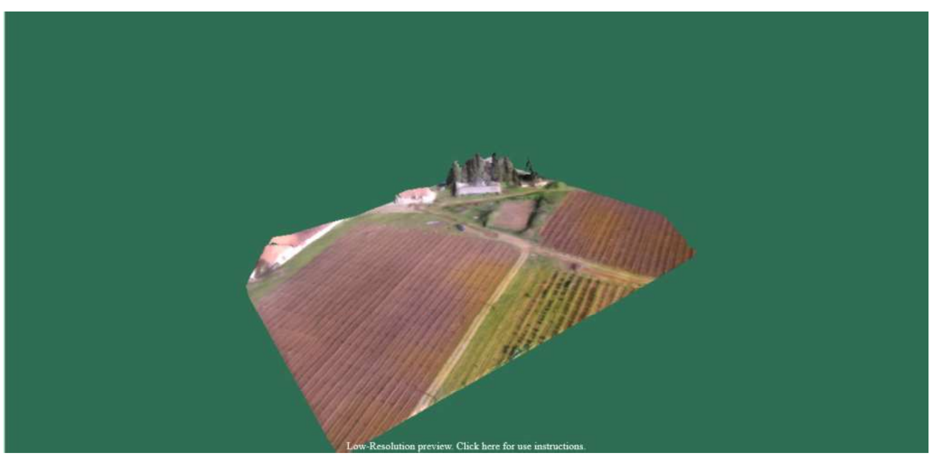

Fig 8. Reconstructed 3D model

Maps generated by ODM can be further post-processed depending on specific application. For example, Figure 7 shows map filtered by VARI filter. VARI index is a measure of "how green" an image is. In absence of NDVI camera, VARI maps can be useful in estimation of the fraction of vegetation. The DroneMapper has also the possibility to reconstruct the 3D models from UAV imagery. These models can find application in cultural heritage and digitalization. For example, Figure 8 shows the reconstructed 3D model. Note that 3D model quality highly depends on a number of images, as well as the viewing angle of the camera.

5. CONCLUSION

DroneMapper - a cloud application for automatic image mosaicking and georeferencing is described. DroneMapper uses numerous open source image processing tools, while the most computationally demanding among them are able to perform multi-core parallel processing, which provides a better usage of the cloud resources. Also, some post-processing tools are designed. The DroneMapper generates high-quality maps of the scanned area with accurately assigned geographic coordinates. Thanks to the powerful computing resources of the server on which the application is hosted, DroneMapper performs a multiple times faster map processing in comparison to desktop solutions, as well as several other existing cloud tools.

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