Developing UAV image acquisition system and processing steps for quantitative use of the data in precision agriculture

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Abstract. Mapping natural variability of crops and land is first step of the management cycle in terms of crop production. Several methods have been developed and engaged for data recording and analyzing that generate prescription maps such as yield monitoring, soil mapping, remote sensing etc. Although conventional remote sensing by capturing images via satellites has been very popular tool to monitor the earth surface, it has several drawbacks such as orbital period, unattended capture, investment cost. On the contrary, unmanned air vehicle (UAV) is more flexible in terms of deploying, monitoring small area and easy to acquire at low cost.

In this aspect, the objective of this study was to develop a low-cost and easy to implement technical solution to map spatial variability, and to explore its relationship with crop conditions. The idea was to build a close loop process starting from a standardized UAV based image shooting till an easy but reasonable production of NDVI and derived/prescription maps especially for vineyards.

The main components of this image acquisition system are Unmanned Air Vehicle (UAV) and modified commercial digital camera. Within the study, 3 different UAV (2 fixed wings and one flying wing) have been built, based on commercial airplanes models fitting the purpose and used open source autopilot. As sensors, 2 small format digital cameras (1 Nikon and 1 Canon) have been tested, part of them modified in order to be able to acquire also NIR radiations.

Laboratory tests were conducted in order to calibrate the cameras. After all, UAV based image acquisition system was developed. Future tests were planned for the assessment of practical usage in situ.

Keywords. *UAV, sensor, precision agriculture*

Introduction

For last few decades, precision agriculture and its technologies have been considered being the most significant development in agricultural sector targeting management of natural heterogeneity to improve farm profitability, to minimize negative load on environment and to comply agronomic requirements (Tekin and Yalçın, 2014).

The new approach utilizes detailed records of whole farm operations that require technological tools in order to save automatically generated data. Moreover, the improvement of natural heterogeneity management is a primary mission of precision agriculture by processing the data. The philosophy of precision agriculture is “applying the right thing, at the right time, on the right location, with right methods and with the minimum negative load on the environment”.

In order to comply with the philosophy, the sensing and gathering data is a key element since it is the first step of determination of variability (Fig 1). Several methods and tools such as remote sensing, spectral and hyperspectral camera have been developed for 30 years.

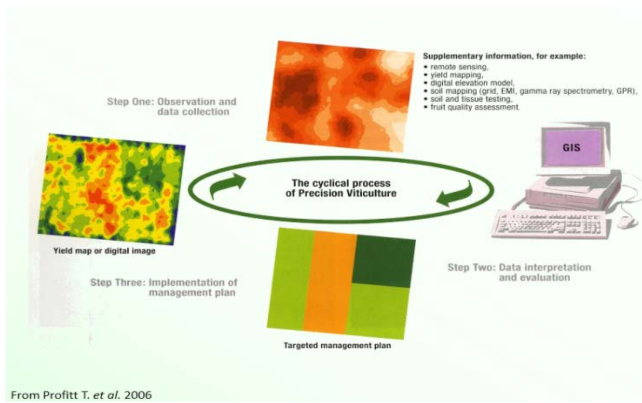

Fig 1- The cyclical process of precision viticulture

Remote Sensing

Objects reflect off light coming from the sun or artificial sources. Light is consists of electromagnetic spectrum those certain wavelengths (380- 700 nm) of it can be seen with human eye. However, large scale of electromagnetic spectrum is not visible for naked eye. Previous researches revealed that each objet has unique spectral signature which is the difference in the reflectance/emittance characteristics with respect to wavelengths (i.e., reflectance/emittance as a function of wavelength). Spectral characteristics of objects, in this case crops, soil and etc. are an information source for determination of variability.

Satellite and airborne imaging systems capture the sunlight reflecting from ground objects by their sensors. This type of tools allow user to capture the images on demand and to cover large area. However, several drawbacks still exist and prevent to obtain clear images such as cloud and atmospheric haze.

Recently, unmanned air vehicle has been promise in civil use although it was developed for military purpose. The platform has been used in civil life; Surveying mapping, civil infrastructure, mine exploration, precision agriculture and etc. Due to many advantages and closing the gap arising from conventional remote sensing, unmanned air vehicle is getting attractive.

Several commercial UAV platforms and sensing tools have been on the market with quite expensive cost. On the other hand, it is well known that farmers cannot generate sufficient cash easily and invest new technologies that limit the penetration of them. Therefore, the cheapest and affordable tools are required.

The stated objectives of the project are;

- to develop a low-cost and easy to implement technical solution to map spatial variability, and to explore its relationship with crop conditions
- to build a close loop process starting from a standardized UAV based image shooting till an easy but reasonable production of NDVI and derived/prescription maps
- finally to have a tool for PF giving good quality result without investing enormous amount of money

Material and Method

The main components of the proposed image acquisition system were Unmanned Air Vehicle (UAV) and modified commercial digital cameras.

UAV Platforms:

Within the study, 3 different UAV (2 fixed wings and one flying wing) have been built, based on commercial airplanes models fitting the purpose and used open source autopilot (Fig 2). The models are equipped with APM 2.5, APM 2.6 and APM 2 model ardupilot (open source autopilot, based on Arduino and equipped with Arduplane firmware) respectively supplied from 3D Robotics (USA).

(a) Phantom Fx-61

(b) EPP-FPV HK

(c) SkyWalker 1900

Fig 2- The UAV platforms

Cameras for image capturing:

Typically most chlorophyll-containing vegetative surfaces reflect strongly in the green side of the spectrum (≈ 530 nm) while have low reflectance (associated with strong chlorophyll absorption) in the blue and red side. Therefore, photosynthesizing objects appear green when viewed in visible portion only. On the other hand, a higher proportion of the sunlight is reflected in the near infrared band of the electromagnetic spectrum (Campbell, 1996).

Measurement of near infrared reflectance is an important method of delineating relative amounts of plant biomass. It has been also revealed that the near infrared reflectance of vegetation is more sensitive to changes in plant health than in the visible portion of the spectrum (Campbell 1996). In this case, the influence of vine diseases, pests, nutrition and available moisture will affect vine biomass therefore leaf spectral characteristics.

Spectral vegetation indices (NDVI, VI, GNDVI, LAI and etc.) which utilize the significant differences in reflectance of vegetation at green, red and near infrared wavelengths allow monitoring health and development of vineyards.

Therefore, within the project, 2 small format digital cameras (1 Nikon and 1 Canon) have been tested and part of them modified in order to be able to acquire also NIR radiations (Fig 3). The spectral sensitivity of the cameras without hot-mirror filter was measured using monospectral calibrated light source from Specord 50 MonoChromator (400 – 1060 nm step 20 nm) (Fig 4)

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(a) Nikon Coolpix P6000 **(b)** Canon IXUS 132

Fig 3- The Cameras for image capturing

Fig 4- Measuring spectral response of CCD Camera

When the internal hot-mirror filter is removed and a blue-blocking filter is placed in front of the lens, Bobbe et al. (1995) found that the blue channel records the NIR light reflected from vegetation. In calibration process, the contributions of NIR light to the digital numbers of the green and red channels were subtracted based on the value from the blue channel. Therefore, with extensive post-processing, the raw digital camera image has been converted into a red, green and NIR false-color image.

The image acquisition on the cameras was done using external triggers (infrared or autopilot driven contact) and can be activated through the operator remote control on the ground or programmed to be automatically done using either a dedicated feature of the autopilot board (based on GPS or regular interval) or intervallometer scripts at camera's firmware level.

At an altitude of 150-200 m, this system acquires images with a ground resolution of 6 cm for the visible and near infrared bands. Unmanned Aerial Vehicle common altitude stretches over several tenths of meters up to 500 m and is adapted to the survey of fields of several hectares with very high spatial resolution.

Geometric and radiometric processing is necessary on images for quantitative use of the data. Therefore, all images were taken in raw format for both camera types. The images were preprocessed and corrected especially for vignetting effect present on the modified cameras and particularly visible in NIR band. Classical photogrammetric calibration was used in order to measure lens geometry of each camera and evaluate as precisely as possible the coefficients of the lens polynom needed by commercial photogrammetric software. Several sets of images were acquired over experimental fields. These images were radio metrically and geometrically corrected used the above elements and are stored as georeferenced images in Agisoft Photoscan software (Russia). The images were compensated for different atmospheric and illumination conditions in the image time series by using invariant targets on the field.

Results

Development of technical solution:

Within the project it was aimed to develop a low-cost and easy to implement technical solution to map spatial variability. Therefore, it was proposed to build UAV platform for carrying the image capturing tools at low cost. After receiving parts of the UAV from several suppliers, the platforms have been built in laboratory condition (Fig 5). The platforms can be controlled either by remote control unit or autopilot. After assembling parts such as wing, tail to build UAV body, electronic parts (control unit, battery, radio link, servo controllers and etc.) were installed. The body parts made of EPO foam structure that allow in case of crash to fix the damaged parts in less than 30 minutes and continue shooting the pictures. EPO foam airplanes are light, less dangerous and easy to repair in the most cases. The communication link was established with RC and flied in outdoor successfully.

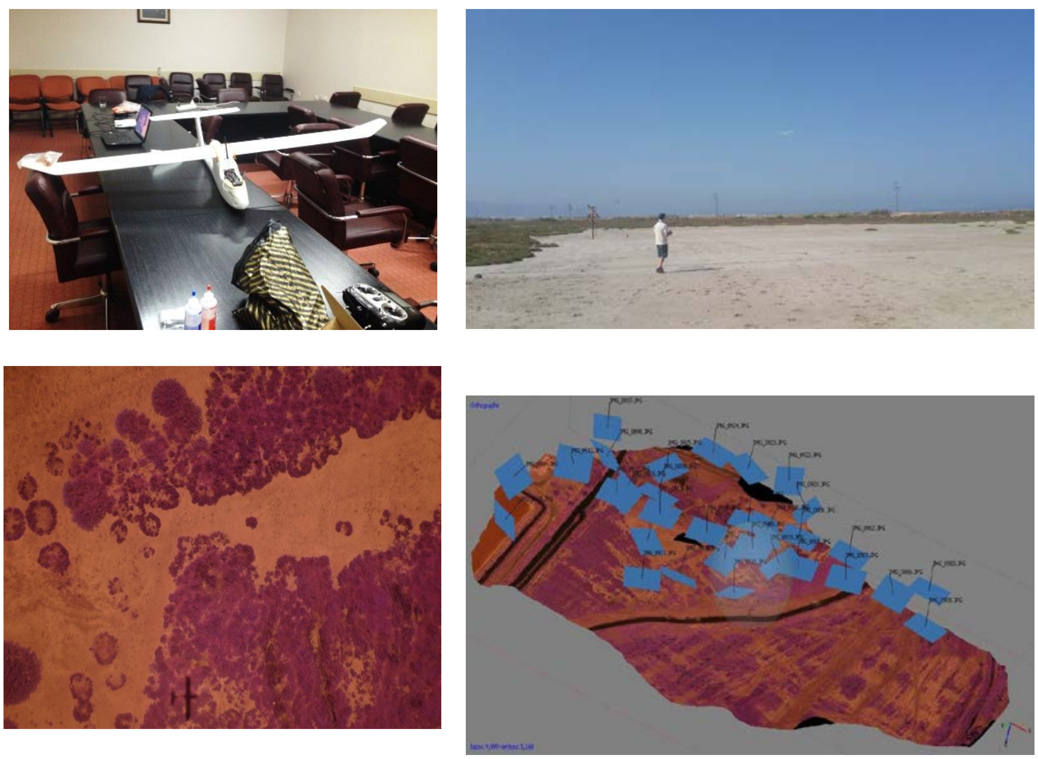

Fig 5- Assembled structure of Skywalker 1900 and initial outdoor test

After teaching the flying ability of UAV to autopilot, simple mission was completed successfully in open area. All tests were done in order to optimize the sensor settings and training the UAV autopilot.

In order to have cheap solution for capturing image, digital cameras were modified. It was tested if the camera could capture invisible portion of the spectrum. After measurement, the data was processed in excel and graphed in order to obtain the performance. The modified camera is a capable of sensing the wavelengths in a range of 380 – 1060 nm. That allows capturing NIR band (Fig 6).

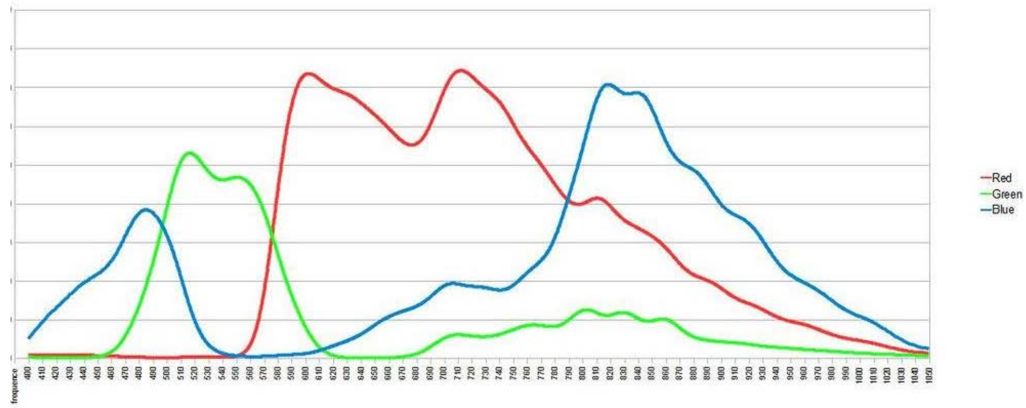

Fig 6- Spectral response of CCD Camera

NDVI calculation was based on previous research (Volker Dworak ,2012) and adapted to the spectral response of the selected camera:

NDVI = ((1.4*b3-b1)/b1)*((1.4*b3)/2)

Where b3= Blue Channel, b1 = Red Channel – please note that in case of single chip camera without hot mirror, b1 = NIR+Red

Development of NDVI maps:

In order to reveal the ability of proposed technological solution, all field tests was carried out in viticulture parcels in Denizli, Turkey (Fig 7) managed by Sevilen Group who carried out also basic ground truthing survey.

Fig 7- Mission flight on viticulture parcels in Denizli, Turkey

The images were captured during the mission flight and processed to obtain ortophoto and overlapped over google earth (Fig 8).

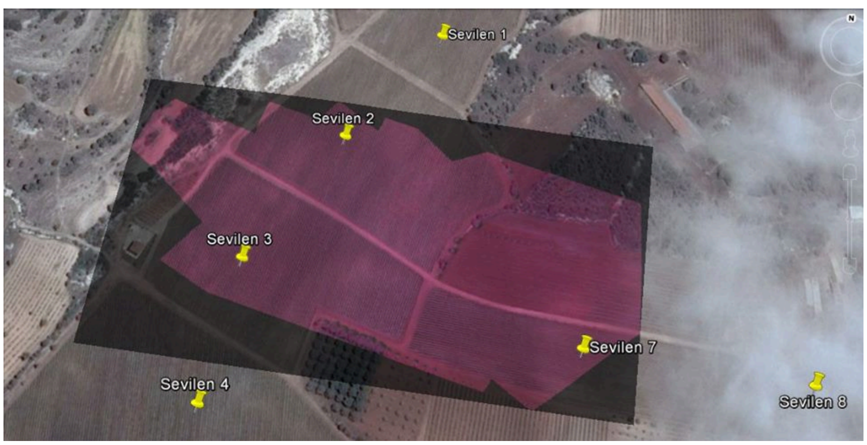

Fig 8- Ortophoto and overlapping on google earth map

In order to have clear vision from the map, several post processing and false colors palette were applied. The blue on the processed map resemble low vigour, red resemble high vigour of the vegetation (Fig 9). Although, the result was not used in field, but gave an idea of the problematic parts. From the analisys of these maps it is understood that higher number of pictures have to be combined together in order to smooth indirect sun light reflectance. Hovewer, this first study is fundamental for having the chance to meet with target.

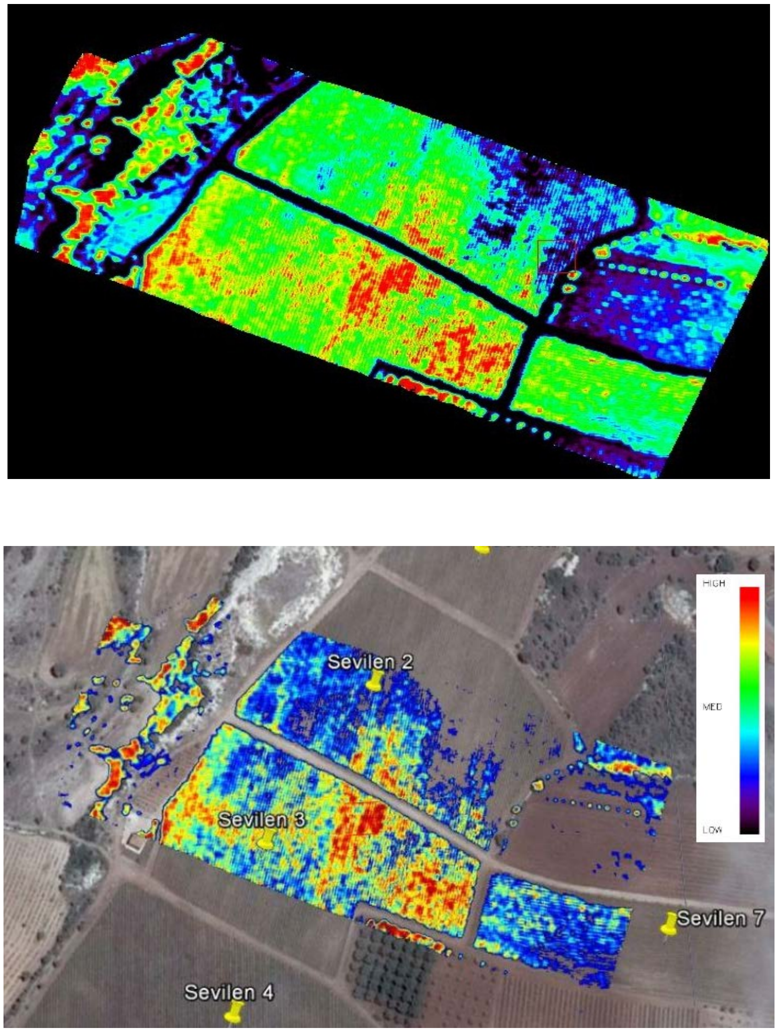

Fig 9- NDVI map of viticulture parcels

Cost of the solution:

Total system cost was aprroxiamlety $ 1600 that includes UAV (SkyWalker 1900 in use at University) and modified camera (Canon Ixus 132), is easliy affordable. To have a clear idea, the cost could be compared with the price of a basic spectral camera for UAV only, that is around $3500.

Conclusions

Within the study, low-cost and easy to implement technical solution to map spatial variability was developed. The system was tested to explore relationship with crop conditions by using NDVI indices for viticulture. It was revealed that the solution is capable of generating prescription maps for precision viticulture more generally for precision agriculture. Further studies will be carried out to verify actual results with agronomist support.

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