CONSTRUCTION OF A 3D VINEYARD MODEL USING VERY HIGH RESOLUTION AIRBORNE IMAGES

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Abstract

In recent years there has been a growth in interest and number of research studies regarding the application of remote optical and thermal sensing by unmanned aerial vehicle (UAV) in agriculture and viticulture. Many papers report on the use of images to map or estimate the growth and water status of plants, or the heterogeneity of different parcels. Most often, NDVI or other similar indices are used. However, analysis of this type of image is difficult in vineyards covered with grass, because contrast between the green of the grass and the green of the vine is low and difficult to classify. This paper presents the acquisition methodology of very high-resolution (5 [cm]) images and their processing to construct a three-dimensional surface model for the creation of precise digital surface and terrain models in order to separate different strata of a vineyard.
The images were acquired with a Sensefly Swinglet CAM unmanned aerial vehicle at an altitude of 110 [m], allowing for a resolution of 5 [cm]. The images were combined using Pix4D software, with a lateral overlap of 75% and a longitudinal overlap of 60%. The produced digital terrain and surface model was subtracted and an extraction mask containing only vine pixel was created. The results show the importance of using a precise digital terrain model. The raster file obtained by subtracting the DSM and the DTM showed values between -0.1 and + 2 m. in good accordance with the average value of the vine. The great majority of pixels fell between the threshold (0.5 [m]) and the topping values 1.6[m]). Using this procedure and parameters, an extremely precise surface model is obtained, as well as the pattern of the vineyard rows and, to some extent, the location of different plants stocks. This mask could be used to analyse images of the same plot taken at different times. The extraction of only vine pixels will facilitate subsequent analyses, for example, a supervised classification of these pixels.

Keywords: UAV, vineyard, green cover, 3D-models, precision viticulture

1 INTRODUCTION

In recent years there has been a growing interest and number of research studies regarding the application of remote optical and thermal sensing by unmanned aerial vehicle (UAV) in agricultural applications (Lee et al. 2010; Usha and Singh 2013), notably viticulture (D’Oleire-Oltmanns et al. 2012; Mathews and Jensen 2013; Torres-Sanchez et al. 2013; Lucieer et al. 2013). The use of images to map or estimate the growth and water status of plants, or the heterogeneity of different parcels, have been reported in many papers (Hall et al. 2003; Zarco-Tejada et al. 2003; Fiorillo et al. 2012). Most often, indices like NDVI or other, similar combinations of spectral bands are used with different pixel resolution (Fiorillo et al. 2012; Santesteban et al. 2013). The apparition of a platform adapted to very high resolution imagery (lower than 25 cm) offers the possibility to observe very small details of the plants (Hall et al. 2003). The height of trees can also be estimated using 3D surface modelling (Zarco-Tejada et al. 2014).

Unfortunately, high resolution is linked to an exponential size of images and the analyses procedures to extract the information need to be automated. However, analysis of this type of image is difficult in vineyards covered with grass, which are very common in Switzerland. With high resolution, a majority of pixels represent green cover. Furthermore, the low contrast between the green of the grass and the green of the vine is very difficult to

manage with conventional supervised or unsupervised classification. The green color does not correspond to the same intervals among the different spectral bands (RGB or NIR) on all parts of the picture because of differences in reflectance. Thus, thresholds defined to extract a given level of green are not valid on the whole image and reduce the possibilities of vineyard vigor status calculation, for example.
This paper presents the acquisition methodology of for very high-resolution (from centimeter up to half-meter resolution) images and the processing to construct a three-dimensional surface model for the creation of precise digital surface and terrain models in order to extract the pixels belonging to the vine.

2 MATERIALS AND METHODS

The images were acquired with a Sensefly Swinglet CAM unmanned aerial vehicle (Sensefly, Cheseaux, Switzerland) at an altitude of 110 [m], allowing for a resolution of 5 [cm]. The distance between the rows was 1.2 [m], the distance between plants was 0.8 [m], the slope was 8% and the topping height given by the viticulturist was 1.6 [m]. The pruning system was a single Guyot.
The images were automatically combined using Pix4D software (Ecublens, Switzerland). A lateral overlap of 75% and a longitudinal overlap of 60% were used. A mosaic combining 100 images was created. The software Pix4D allowed simultaneously the production of an extremely precise surface model, as well as the pattern of the vineyard rows and to some extent also the location of the different plants stocks. The images presented here were taken in autumn to facilitate the view of the rows.

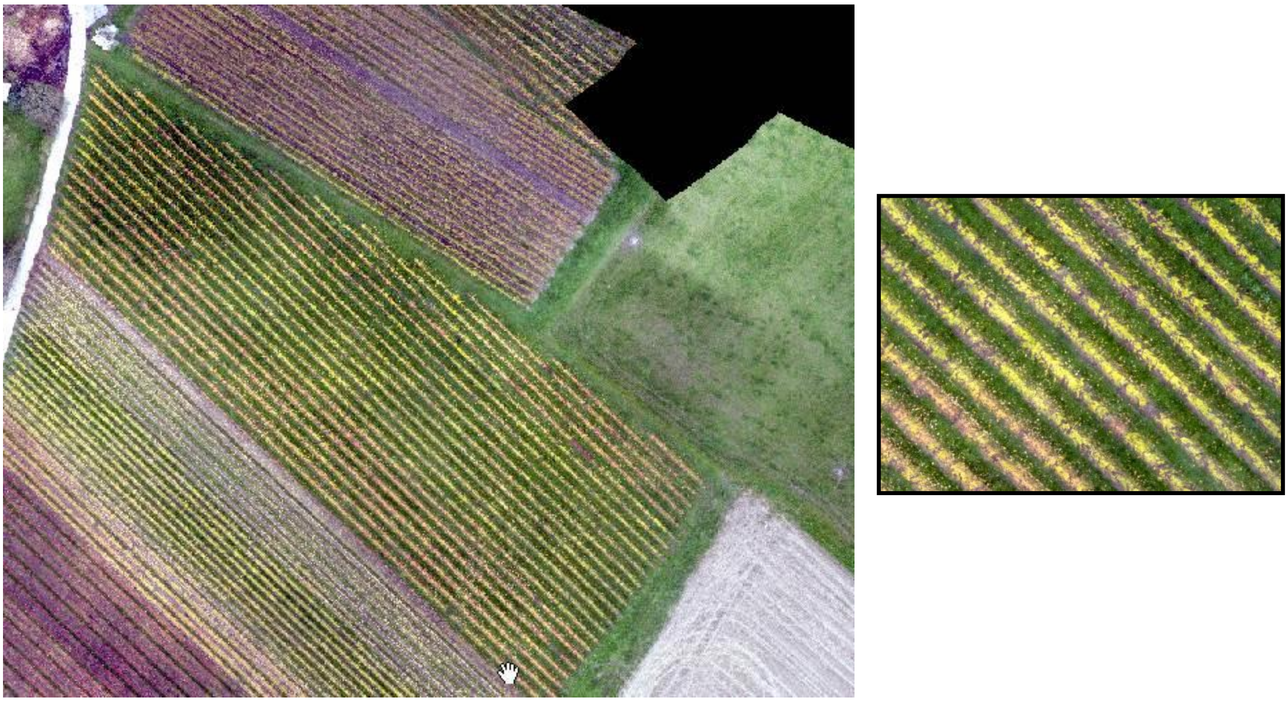

Figure 1 Orthomosaic image obtained by the combination of 100 images obtained in autumn with a Sensefly swinglet cam and assembled by the Pix4D software (Ecublens, Switzerland).

To allow extraction of the rows by altitude differential, a 1m resolution digital terrain model (DTM) was vectorized to single points and then extrapolated to 5 cm resolution DTM using a two-dimensional minimum curvature spline technique (Spline function, ArcMap 10.2).

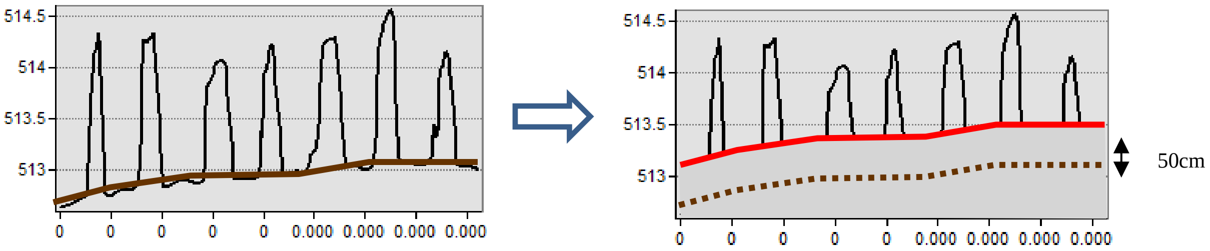

Figure 2 process of row extraction using difference between the digital surface model (DSM, brown) and the digital terrain model (DTM, black). The red curve represents the 50 [cm] threshold.

The DTM was then subtracted from the DSM using the raster calculator function (Spatial analyst, ArcMap 10.2). The points with a value greater than 0.5 m were considered to belong to the vine rows (Figure 2) and were reclassified as 1 for rows and 0 for the rest using the function Reclassify (Spatial analyst, ArcMap 10.2). This raster file then contains pixels which belong, with a high probability, to the plants. These pixels were then used as mask to extract only the pixels of the vines on the mosaic image or on the DSM (Extract by mask, Spatial analyst, ArcMap 10.2).

3 RESULTS AND DISCUSSION

The figure 3 a) shows the digital surface model of the plot. Dark green color indicates a higher elevation class. The rows can now be well distinguished. This model can be represented in a 3D image by draping the mosaic orthorectified image onto the DSM (Figure 3b).

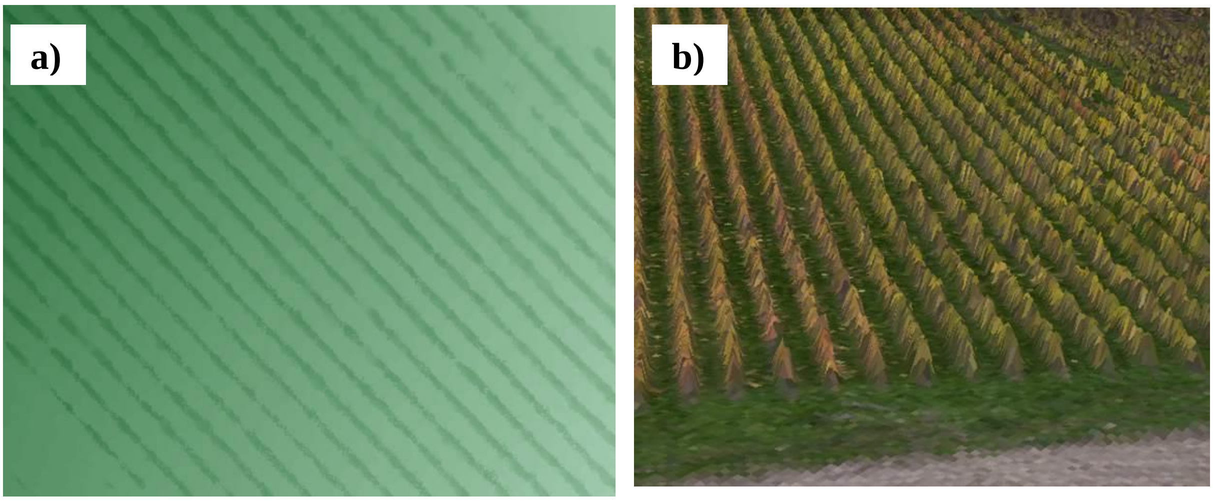

Figure 3 a) Digital surface model and b) reconstructed 3D image issued from the combination of 100 images obtained with a Sensefly swinglet cam and processed by the Pix4D software.

Figure 4 shows a transversal cut of the vineyard. The different points represent the altitude calculated by the automatized procedure. Each point is present on several images, and the combination allows for a precise 3D representation. The overlapping of the images allows the production of the 3D model.

Figure 4 Frontal representation of a part of a vineyard obtained by automatized 3D pixel generation with the software pix4D.

Figure 5a shows the results of the calculated difference between the DES and the DSM. In the first image (a), the light and dark colors represent pixels with a positive and a negative difference obtained by subtracting the DTM (soil surface) from the DSM. The reclassification of this raster layer with a threshold of 0.5 m gave the value of 1 for values higher than 0.5 m and no value for the rest. These pixels are shown in red in figure 5 b).

Figure 5 c) shows the last step of the extraction of the mosaic image. Only pixels with a value of 1 were extracted. Therefore, only the pixels belonging to the vine rows are visible. The ground’s green color was excluded, and thus the noise issued from the grass is eliminated. Only the pixels of the vine can be used for further analyses in order to compare the intensity of green, for example.

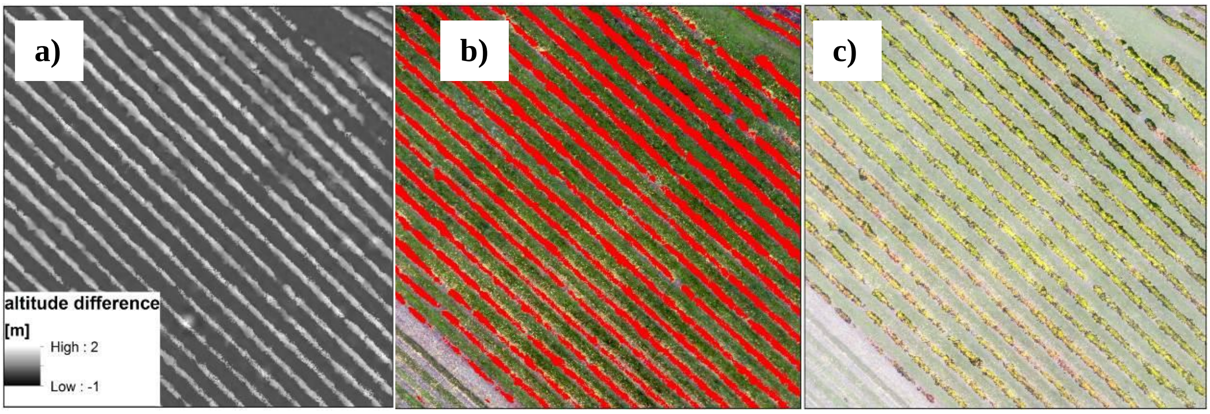

Figure 5 a) Difference between the DTM and DSM in [m] b) extraction of pixel (in red) with a difference higher than 0.5 [m] above the DTM, c) extracted pixels from the mosaic image respectively.

Once the extraction mask is created, it is possible to use it for leaf color analyses for the assessment of plot heterogeneity or for plant height determination. Figure 6a) shows the cumulative curve of 224’054 points extracted from the altitude difference layer in the visible zone of figure 5. The curve shows that 99 % of the values fall between the threshold value of 0.5 and the height of topping (1.6 [m]) given by the viticulturist. Only few are above. Thus the precision of the elevation is very good. The same analysis done with the 697’634 points corresponding to the ground (< 0.5[m]) shows that90 % of the points fall within the interval -0.11 to 0.16 [m] (Figure 6b)). We can deduce that there is a good correlation with the different strata of the vineyard. Therefore, the results are coherent with the row height and correspond to the precision we can reach with such an automatized procedure (Zarco-Tejada et al. 2014)..

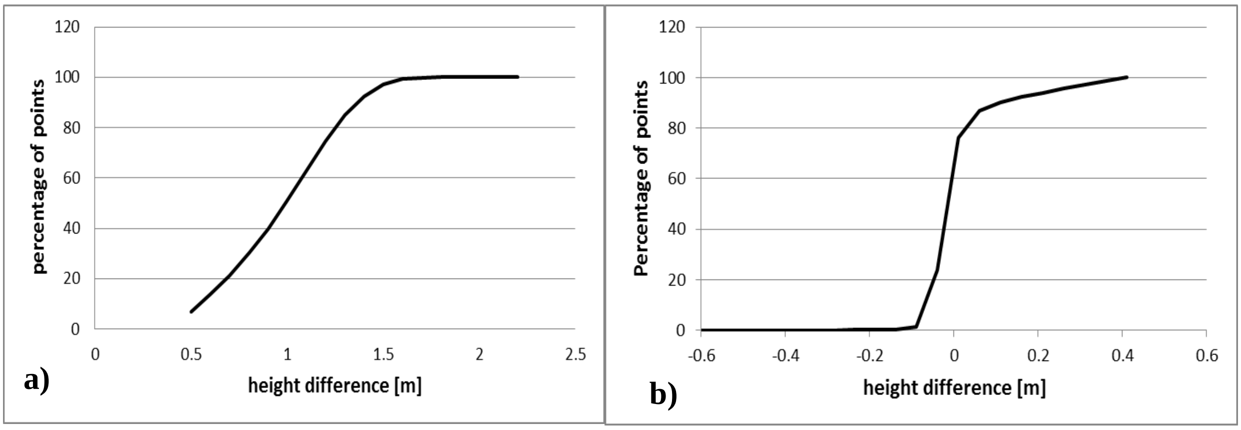

Figure 6 Cumulative curve of the height values extracted from the difference between DSM and DTM, a) at row position (> 0.5[m]), b) on the ground (< 0.5[m])

This procedure thus was able to discriminate with good precision the origin of diverse pixels in a very high-resolution image. The extraction of the rows through a DSM reduced the noise present due to other factors, particularly the green cover, shadows and bare soil. The analysis can be done with the raster layer or the vectorial layer derived from this mask. An extraction of the value of the different pixels associated to a zonal statistic can be performed to compare different zones of a plot or plots. This procedure facilitates the calculation and simplifies the processing and analyses of images taken during other periods of the year, which is very important considering the large size of the generated images.

4 CONCLUSIONS

The extraction of the vine pixels is often difficult because it depends on combining information from different spectral bands. If the whole image is not represented under the same light, due to differences in landscape position with different reflectance or management technique, then the risk exists to delineate zones that do not correspond to differences in vine growth.

The possibility to create a 3D model of a cultivated plant (in our case, a vine), allows for the analysis of different layers in the canopy or the variation on the surface relief. This could be used to analyse erosion patterns or even highlight a single plant. The extraction of the value of altitude difference between the DSM, the DTM, and the effective height of the vine canopy showed that the pixels effectively belong to the vine. This procedure could be used, for example, for counting missing plants. This differentiation is useful for pixel extraction in order to facilitate subsequent analysis. It reduces the noise caused by other plants present in the field and number of pixels to classify, and could increase the efficiency of clustering procedures.

The use of airborne, very high-resolution images allows the possibility to see a lot of detail. However, these technologies are linked to a very high requirement in storage capacity, image treatment processes, and precautions to produce high quality images (calibration). Particular attention has to be paid to image distortion and white-balance correction in order to reduce noise. The added value for the productivity of this kind of measurement needs further evaluation.

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