Optimizing channel weights for digital surface models with snow coverage

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Highlights: The generation of timely well defined digital surface models with UAV's in alpine environments with snow coverage is important for the analysis of natural hazards like dynamic and static inundations, debris flows or snow hydrology for power generation. The role for DSM quality of near infrared from different redefined cameras will be investigated with user-defined channel weighting during processing.

Key words: *snow, DSM, surface reconstruction, camera sensor, near infrared*

Introduction

Alpine environments are snow covered over long periods during the year. Natural hazards like dynamic and static inundations, debris flows or snow hydrology for power generation happen in areas which are often partially snow covered and therefore the assessment of different snow types is a requirement for further numerical analysis. Unmanned aerial vehicles (UAV) allow the acquisition of remote sensing data shortly after an event or with a higher interval than with expensive airborne campaigns. The timely well defined acquisition of snow coverage data is essential to derive appropriate results, specially during melting periods.

The generation of digital surface models (DSM) is a well established processing step in remote sensing and depends on the accuracy of many spatial constraints like image position,sharpness and overlap but also heavily on the spectral characteristic of the image data. The analysis of remote sensing data from airborne aerial images relies on well defined cameras and sensors and results in a tight integration of sensor characteristic and the following processing chain, often realized within the same software environment.

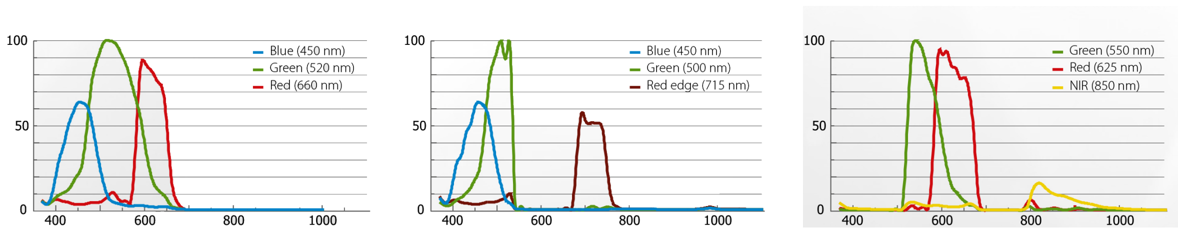
In contrast to this, the image acquisition of UAV data and the following processing is not very strict defined. Image characteristic is based on EXIF-tags and the camera calibration geometry can be configured. But spectral channel information is typically not propagated properly or only with proprietary hint data for a specifically recommended software package.

Therefore we hypothesize, that an appropriate processing of spectral information with special focus on snow and near infrared results in a distinct improvement of digital surface models.

UAV cameras and snow

Sensor data from UAV is acquired with a wide variety of digital consumer cameras (DSLR), but in contrast to airborne flights the camera is typically not properly calibrated to compensate for geometric and spectral variation. Using optical sensors to map snow depth requires further refinement of the color processing, mainly because snow absorbs more solar radiation in the near infrared (NIR, wavelength 780-1400 nm) than in the visible bands (RGB, wavelength 400-700 nm). Therefore image data acquired in NIR should reveal more surface variation than RGB imagery and reduces sensor saturation over bright, snow-covered areas [1,2,3]. Due to our specific interest in snow we focus in the following analysis on the influence of the spectral characteristic of modified cameras and custom filters.

Redefining DSLR cameras by removing the low pass filter (cut-off for infrared wavelengths) inside the camera has become quite common among photo and scientific professionals for different applications [7,8]. Most cameras used in UAV applications use a Bayer filter mosaic for the photo sensor, the FOVEON sensor from Sigma [9] is still a rare exception. This modification applies always to the whole sensor area, therefore also the following redefinition of the camera with a narrow band spectral filter, either inside the camera on the sensor



Canon S110 RGB Canon S110 RE(Red Edge) Canon S110 NIR

Figure 1: Unmodified (RGB) and modified cameras (RE,NIR) from Sensefly [11]

or as a screw filter, has a strong influence on all channels [10]. The resulting sensor response varies among cameras, but some significant spectral overlap remains (Figure 1).

Mainly due to cost and weight issues, real multi-spectral sensors are rarely used or suffer from low spatial resolution. Several commercial system exist like the MultiSpec 4C (Sensefly [11]) or Tetracam Mini-MCA [12]. To achieve a high resolution digital surface model, at least 12 MPixels are required and therefore these better suited spectral sensors are not sufficient concerning resolution requirements.

Weighting spectral channels

The spectral response of a consumer camera is not precisely known (Figure 2)[4], but influences the processing chain, mainly the tie point and feature extraction during dense matching. All variations of matching algorithms, e.g. feature- or intensity-based approaches use color-independent grey values as input values. Therefore a color conversion from the sensor color space to gray levels is always in use. In contrast to airborne image data, color processing within photogrammetric software environments typically depends on the information from EXIF-metadata, which contains no tags concerning effective wavelengths of channels. Hence the traditional assumption of wavelengths with red=channel1,green=channel2 and blue=channel3 is used.

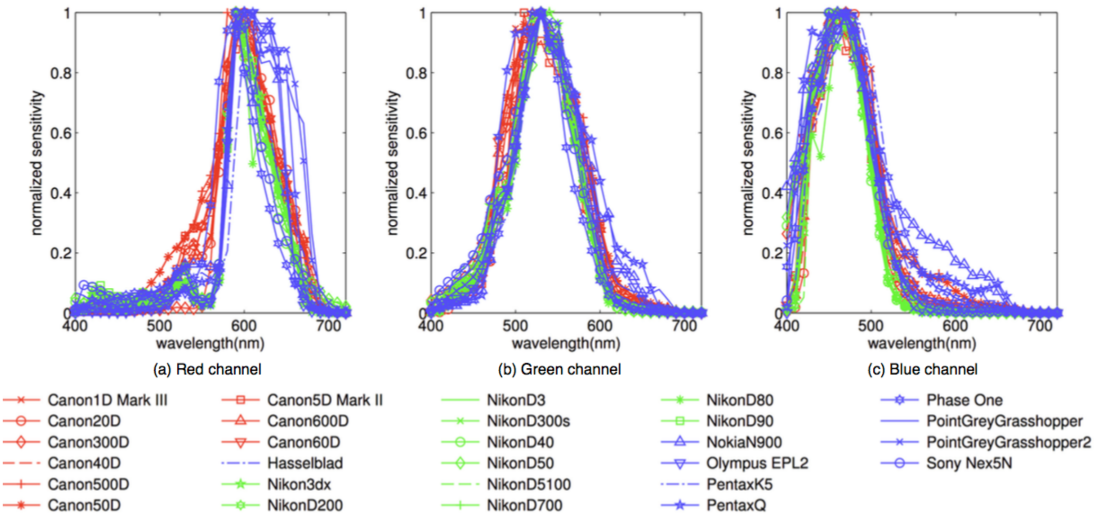


Figure 2: Normalized RGB sensitivities of 28 DSLRs, point-and-shoot, industrial and mobile cameras, from [4]

The following incomplete list of image processing packages to generate a DSM reveal the large variety of commercial or free software packages, e.g. Agisoft Photoscan, Inpho Match-AT, Pix4D PostflightTerra, PhotoModeler, Micmac, nframes SURE Aerial, VisualSFM. Many of these software packages use (often undocumented) equal weights of the given channels or use a luminance-based approach [5] where the resulting grey level is equal to

luminance = 0.21 * Red + 0.71 * Green + 0.07 * Blue

In the presented investigation the conversion from RGB/NIR to a single grey channel with user-defined weights for each input channel has been implemented and only single channel data (as 32bit-float) has been used during image processing. To compare only the effect of camera redefinitions with optical filters on the processing chain Agisoft Photoscan Pro v1.1,build 2016 has been used. The same set of ground control points for orientation have been selected to avoid side effects from the bundle adjustment as much as possible.

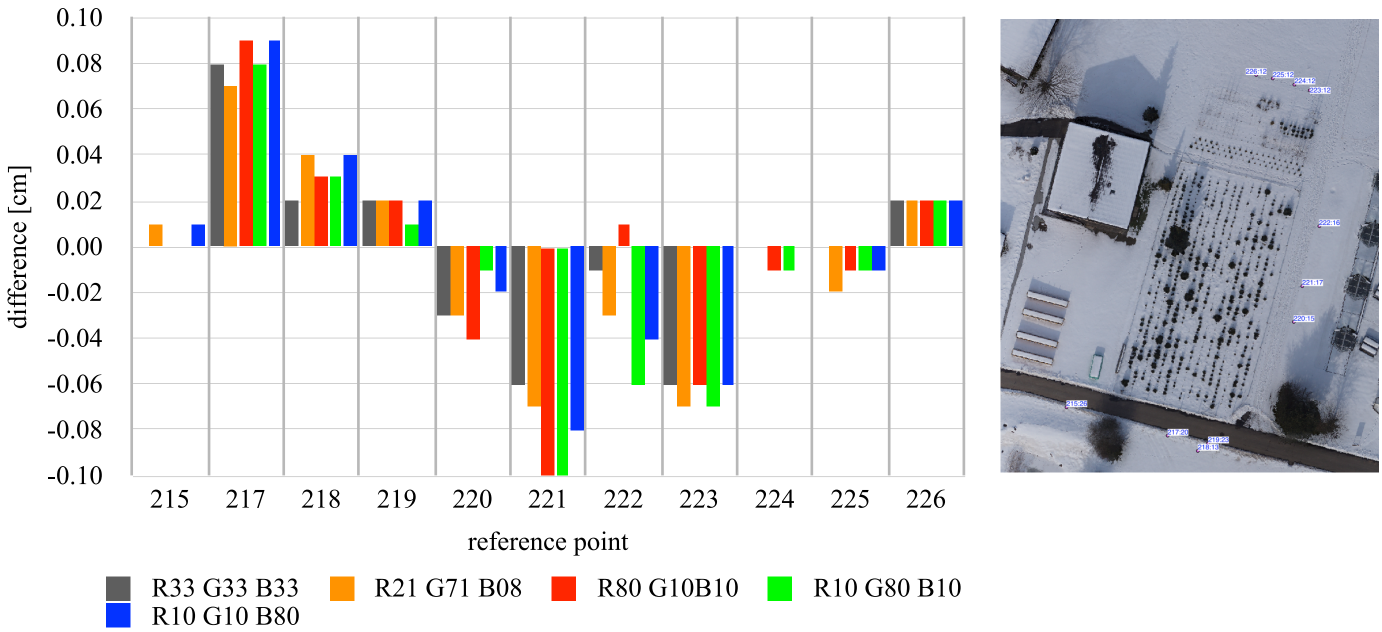


Figure 3: Sony NEX-7 unmodified "dry snow" 13.Feb 2015

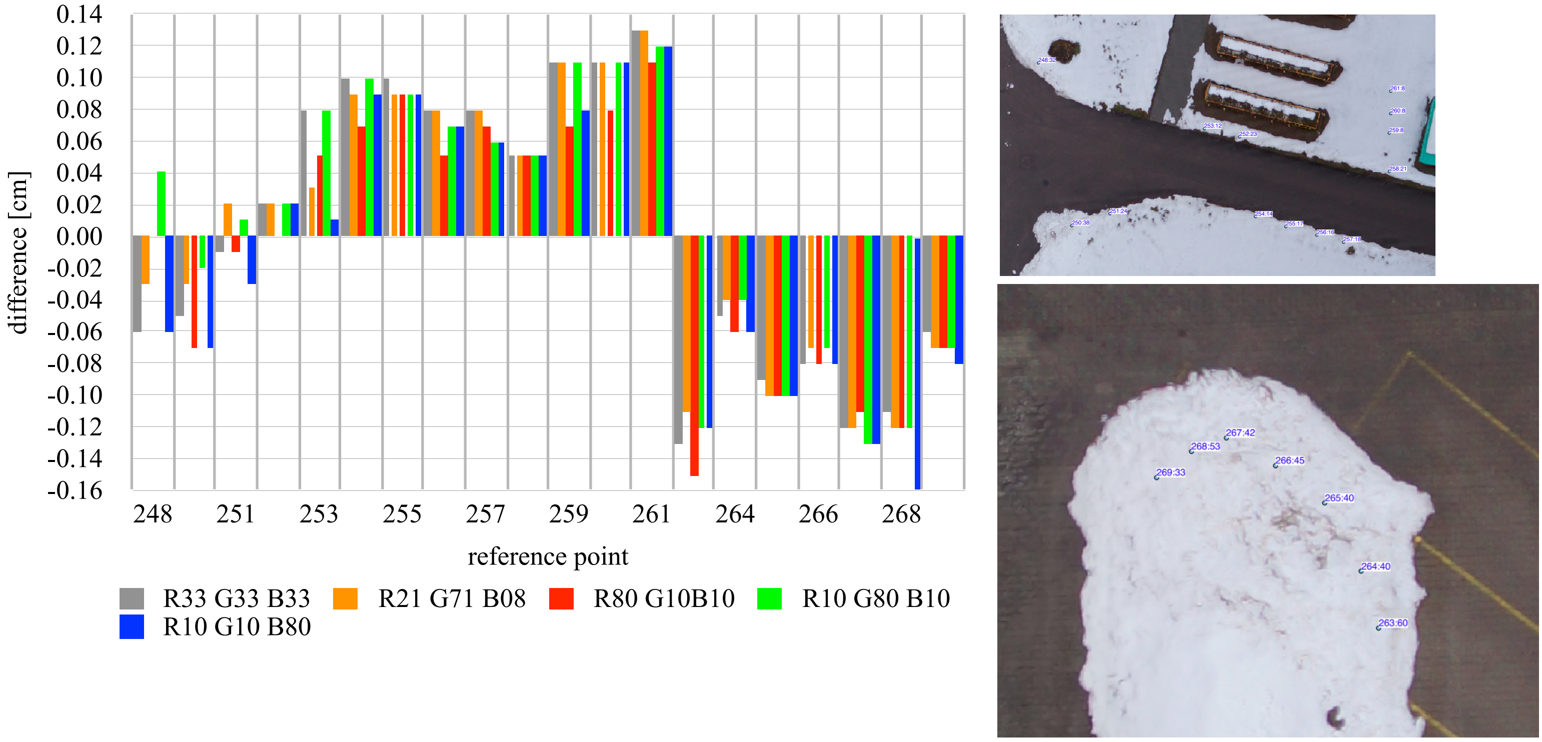


Figure 4: Sony NEX-7 unmodified "wet snow" 24.Feb 2015

In Figures 3 and 4, an unmodified Sony NEX-7 mounted on an UAV "AscTec Falcon 8"[13] has been used to acquire snow coverage in a homogenous flat area. Reference heights have been measured with a Leica GPS 1200 and a horizontal and vertical accuracy of ±2cm has been achieved. 11 points have been measured on dry snow, 20 points on melted/wet snow.

Flight Date	13. Feb 2015	24. Feb 2015
Flight Height [m]	100	100
Images	46	47
Overlap [m]	70	70
GSD [cm]	3.39	3.39
Temperature [ºC]	+1	+9
Weather	sunny,calm	covered,calm
Snow	dry	wet

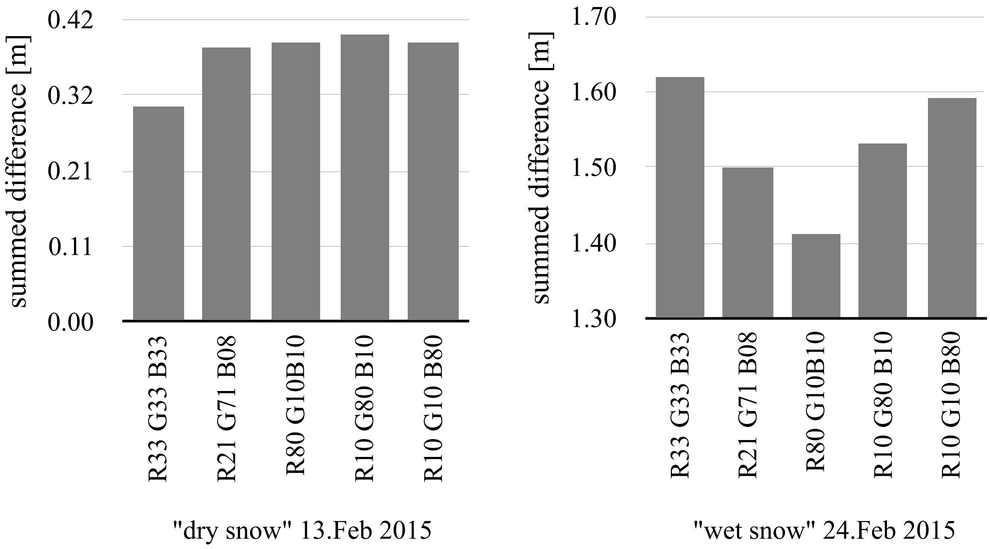


Table 1: summed snow height differences between DSM and reference heights

Preliminary results:

The difference evaluation "dry snow 13.Feb 2015" for an unmodified DSLR reveals only a minor improvement with equal channel weights (Table 1). The situation "wet snow 24.Feb 2015" shows a slight advantage when emphasizing the red channel (R80G10B10). The increased snow grain size seems to improve image matching.
Between January and April 2015 several UAV flights over snow with undefined cameras and optical filters with 550, 700, 830nm have been made. In June/July 2015 we will the DSM of redefined cameras with the unmodified model. In comparison with the measurements of the unmodified off-the-shelf Sony NEX-7, we expect more distinct difference measurements when a weighting R80G10B10 is used compared to the other weighting schemes. This would confirm the hypothesis inherited from airborne cameras, that appropriate processing of NIR channel data yields more accurate digital surface models.

References

[1] Y. Bühler, L. Meier, and C. Ginzler, “Potential of Operational High Spatial Resolution Near-Infrared Remote Sensing Instruments for Snow Surface Type Mapping” IEEE Geoscience And Remote Sensing Letters, Vol. 12, no. 4, pp. 821–825, 2015.

[2] A. Dietz, C. Kuenzer, U. Gessner, and S. Dech, “Remote sensing of snow—A review of available methods” Int. J. Remote Sens., vol. 33, no. 13, pp. 4094–4134, 2012.

[3] T. H. Painter, J. Dozier, D. A. Roberts, R. E. Davis, and R. O. Green, “Retrieval of subpixel snow-covered area and grain size from imaging spectrometer data,” Remote Sens. Environ., vol. 85, pp. 64–77, 2003.

[4] J.Jiang, D. Liu, J. Gu and S. Susstrunk, “What is the Space of Spectral Sensitivity Functions for Digital Color Cameras?” IEEE Workshop on the Applications of Computer Vision (WACV), 2013.

[5] ITU, "Parameter values for the HDTV standards for production and international programme exchange", Recommendation ITU-R BT.709, International Telecommunication Union, 2004.

[6] P.M. Dare, “Small format digital sensors for aerial imaging applications“ XXIst ISPRS Congress, Beijing, China, 2008.
[7] C. Mauer, "Measurement of the spectral response of digital cameras", VDM Verlag Dr. Müller, 2010.
[8] V. Lebourgeois et al., "Can Commercial Digital Cameras Be Used as Multispectral Sensors? A Crop Monitoring Test.", Sensors, vol 8, no. 11, pp. 7300–7322, 2008.
[9] Hubel, P.M., Liu, J. & Guttosch, R.J., "Spatial Frequency Response of Color Image Sensors: Bayer Color Filters and Foveon X3", Proceedings of SPIE, vol. 5301, Electronic Imaging, pp. 402-407, 2004.
[10] Nebiker S., S.Läderach and E. Matti, "Neue leichtgewichtige Multispektralsensoren für Micro-UAVs – Sensorvergleiche und Leistungsuntersuchungen in der Agronomie",35. Wissenschaftlich-TechnischeJahrestagung der DGPF und Workshop on Laser Scanning Applications, Köln, pp. 35-44, 2015.
[11] Sensefly, https://www.sensefly.com
[12] Tetracam, http://www.tetracam.com
[13] AscTec, http://www.asctec.de