A Hand Goniometer For Ads Spectroradiometer: Application To Brdf Sentinel 2 Bands Over Urban Surfaces

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KEYWORDS: goniometer; Sentinel-2; urban cover; spectroradiometer

ABSTRACT

A new hand goniometer based on open hardware and freeware has been developed in order to attach it to the ASD fiber optic and record the attitude of each measurement. The aim of the device is to support ASD measurements as a quality test and new, and fast, angle capability.

Identify urban land cover is an important task for many purposes like vegetation planning, urban growth, illegal buildings and development plans. The Sentinel-2 spectral, spatial and temporal resolution makes it a powerful tool to distinguish between different land covers.

This study tries to measure the reflectance of the main urban covers, and simulate the reflectance at Sentinel-2 level using a ASD spectroradiometer together with our goniometer. This information will be valuable to develop algorithms for monitoring urban land cover with the imagery that Sentinel-2 will provide. Reflectance measurements have been taken by means of an ASD spectroradiometer under different illumination and view angles measured by the developed goniometer. These angular measurements provide the information needed to calculate the Bidirectional Reflectance Distribution Function (BRDF) by means of kriging methodology.

INTRODUCTION

The ASD FieldSpec3 spectroradiometer is a powerful tool to measure spectral signatures from the different covers. For this study a new electronic device has been developed in order to attach an angle measurement of the ASD sensor. This measurement of the positional behavior of the ASD has been carried out with a goniometer based on the Arduino platform and several commercial sensors. This capability added to the ASD has been included to improve quality of the urban measurements and include the angle dependence of the spectral signature of the urban covers.

The history of urban growth indicates that urban areas are one of most dynamic places on the Earth‘s surface. Despite its regional economic importance, urban growth has a considerable impact on the surrounding ecosystem (Yuan et al., 2005). The spatial information from the remote sensing satellites provides effective solution for sustainable environment and urban development. There is a general consensus that the development of spatial data infrastructure is a key to sustainable land management with economic and urban development (Mohan, 2005).

Effective analysis and monitoring of land cover changes require a substantial amount of data about the Earth‘s surface; most of the times the task of identify urban land covers is performed by aerial photography or ground observations that result expensive. Satellite high spatial resolution imagery can be used for that purpose. Usually this kind of data has very low temporal resolution especially for large areas.

In this sense the Sentinel-2 spectral, spatial and temporal resolution makes it a powerful tool to distinguish between different urban land covers. Inside the urban land covers we identify asphalt roads, pavers, artificial turf, grass, trees, industrial roofs, tiled roofs, water bodies, parking and others.

In order to optimize the pattern recognition techniques, previous image segmentation process has to be performed. At this stage, the knowledge of cited spectral signatures could be very helpful. The traditional segmentation techniques are focused on partitioning imagery into image-objects (with well-defined boundaries) to apply the urban land-use pattern recognition methods based on morphological properties of different categories (Bamsley and Barr, 1997). The fuzzy image segmentation works with image-regions, expressing degrees of membership of different target classes (Lizarazo and Elsner, 2009). Both, the traditional segmentation techniques, as the newer ones, based on fuzzy image segmentation could take advantage of this accessible data.

Commonly, the spectral signature is only known in nadir configuration geometry and the Bidirectional Reflectance Distribution Function (BRDF) is not described. The BDRF was defined by Nicodemus et al. (1977) as the intrinsic property of a surface that describes the angular distribution of radiation reflected by the surface under any given illumination geometry. Most surfaces are non-lambertian, this means that spectral reflectance depends on illumination and view angles (Deering et al. 1992). For these surfaces BRDF is an important distinguishing attribute in surface feature and pattern recognition (Combal et al. 2002; Coburn and Peddle, 2006).

This work tries to perform a database with, irradiances at Top of Atmosphere Sentinel-2 level, which can be useful to identify different urban covers from Sentinel-2 data. This information will be accessible for the community online.

SENTINEL 2 CAPABILITIES

Sentinel-2 is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring and is planned for launching in 2013. It is being developed as a part of the Global Monitoring for Environment and Security (GMES) program (Aschbacher and Milagro-Pérez, 2012). Sentinel-2 will carry an optical payload MultiSpectral instrument (MSI), filter based push broom imager (290KG, 1 m3) with 3 mirrors silicon carbide telescope, with dichroic beam-splitter (Drusch et al, 2012).

The spectral channels will be distributed in the visible, near infrared and shortwave infrared part of the spectrum (13 channels in total). Four of these channels will be of 10 m, six of 20 m and three of 60 m spatial resolution. The mission will orbit at a mean altitude of approximately 800 km and, with the pair of satellites in operation, will have a revisit time of five days at the equator (under cloud-free conditions) and 2–3 days at mid-latitudes (Segel et al. 2006). The spectral bands of the Sentinel-2 are distributed between 443 and 2190 nm.

The system of two satellites will provide enhanced continuity to the French SPOT and US Landsat missions. The mission is dedicated to the full and systematic coverage of all land surfaces (including major islands) globally from −56° (Southern America) to +83° (Northern Greenland) latitude, with a swath width of 290 km. The acquired data will be distributed in tiles of 100*100 km2 (Aschbacher and Milagro-Pérez, 2012).

Figure 1 shows the spectral response function of the Sentinel-2 multispectral instrument for the 13 channels. These functions are used to complete the radiative transfer calculations.

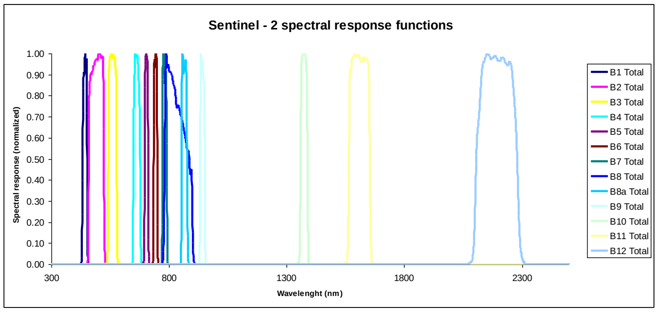

Figure 1: Sentinel-2 multispectral instrument spectral response functions

URBAN COVERS AND FIELD MEASUREMENTS

Cities show a great diversity of urban covers. High resolution remote sensing focus on identify those covers, in order to perform maps or identify urban components. Usually the sensors used to this kind of tasks have very high spatial resolution, but do not have bands in the near infrared and shortwave infrared and its temporal resolution are, usually, too low. In this sense Sentinel-2 has enough spatial resolution and several channels in these regions. This study tries to obtain the behaviour of different urban covers in the domain of the electromagnetic spectrum cover by Sentinel-2 bands by means of a spectroradiometer and a radiative transfer code.

The reflectance spectrums of the urban covers mentioned before were taken with an ASD SpectralField 3 spectroradiometer in the range 250 to 2500 nm. The measurements have been taken under clear sky conditions and in absence of shadows.

Several electronics components as gyroscope (ITG-3200 manufactured by InvenSense Inc.), magnetometer (HMC5883L manufactured by Honeywell International Inc), accelerometer (BMA180 manufactured by Bosch Sensortec GmbH), GPS (D2523T manufactured by ADH Technology Co. Ltd), Secure Digital (SD) card storage and timer clock has been assembled and synchronized with the ASD in order to control the ASD attitude. The different components mentioned are controlled by a free hardware platform named as Arduino (Arduino, 2013). Figure 2 shows the device inside; once it is closed, it is coupled to the ASD optical fiber pointer in order to align both instruments. This device has two main functions: by one hand the attitude recorder discriminates the nadir measurements that not satisfy the maximum angle of deviation from the vertical which is set to 1 degree. By the other hand the electronic device has the possibility of measure the BRDF of the different surfaces by collect the measurement angles (yaw and pitch) to acquire the function and evaluate the impact of the orientation of the different urban surfaces in different planes. Figure 2 shows the ASD FielSpec3, it is ported with a backpack and the optic fiber is coupled to the pointer.

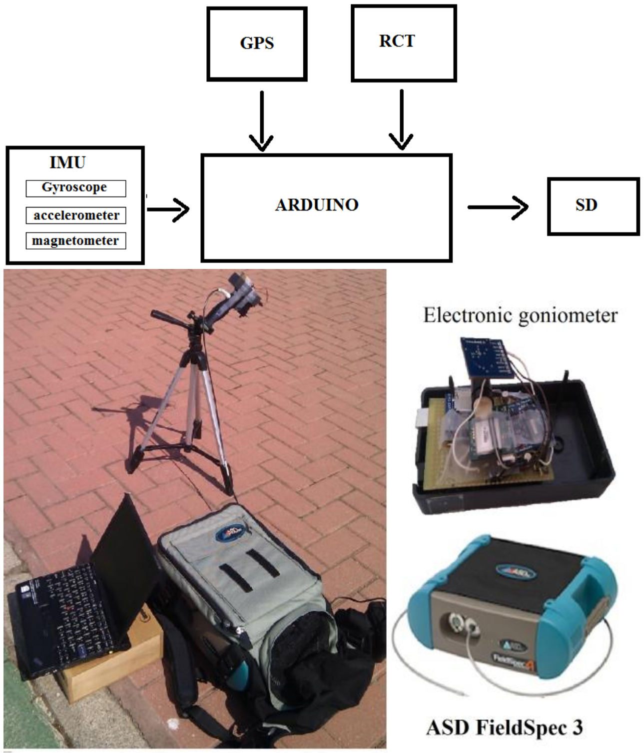

Figure 2: Electronic equipment to perform field measurements

In the measurement process of the BRDF a tripod is used. First, the yaw angle is fixed, and the pitch angle is set to 0 degrees, this means pointing horizontal to the ground. Under this geometry the magnetometer signal to noise is maximized and the yaw angle is recorder to the next measurements that are performed by changing the pitch angle without changing the yaw angle. This way we perform measurements with the yaw angle set to one value and the pitch angle varying between 0 and 90 degrees, this is form horizontal to nadir values. In the next step the yaw angle is set to another value and the measurement process is repeated again, until the yaw angle has take all desired values between 0 and 360 degrees. At the end of the measurements a set of reflectance values between 250 and 2500 nm has been measured in yaw and pitch angles varying between 0 and 90 and between 0 and 360 respectively. This measurement angles are not equispaced in general, and a kriging process (Brooker, 1979) is applied to every wavelength in order to obtain the BRDF in the desired angular resolution. Some combinations of yaw and pitch angles are not possible because of shadows of the tripod, these measurements are not taken, and the reflectance is calculated by the kriging process.

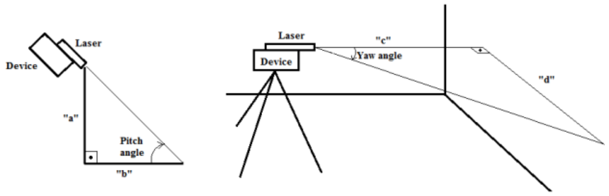

Figure 3: Angular validation measurements

The accuracy of the measured yaw and pitch angles has been analyzed. The pitch angle has been measured with the attitude recorder and calculated by measuring the height perpendicular to the ground of a laser coupled to the device "a" and the distance between the laser point in the ground and the point just beneath the laser "b" as is shown in figure 3. This way, the measured pitch angle equals to arcTan(a/b). In the case of the yaw angle the laser coupled to the device is pointing to the wall. The distance between the laser and the wall "c" (perpendicular to the wall) and distance between the point in the wall perpendicular to the laser and the pointing laser in the wall "d" as is shown in figure 3 are measured. This way, yaw angle equals arcTan(d/c).

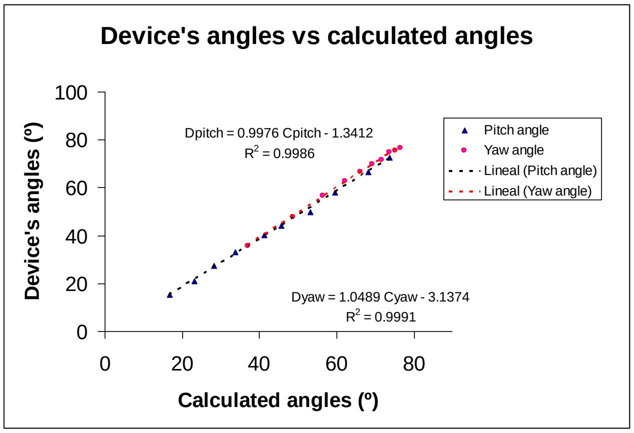

Figure 4: Comparison between measured and calculated angles

The angles pitch and yaw, measured by the device and calculated by measuring "a, b, c and d" distances have been compared in order to find the device sensibility to both angles. Angles between 0 and 90º has been measured following the detailed process, results between calculated and device's angles are summarized in Figure 4. The sensibility of the yaw angle with the pitch angle has been analyzed and the result is shown in Figure 5. Note the yaw angle has been measured under different pitch angles to reinforced the measurement protocol, in witch the yaw angle that correspond to the horizontal pitch angle is applied to the rest of the pitch angles measured without varying the yaw angle.

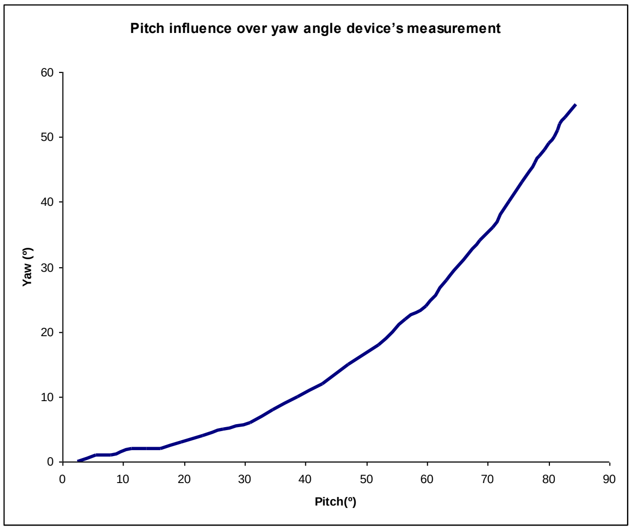

Figure 5: Pitch influence over yaw angle device's measurement

The reflectance spectra have been used as inputs in the frame of the radiative transfer code LibRadTran (Mayer and Kylling, 2005) in order to calculate the radiation that will reach the Sentinel–2 sensors for every urban cover, for different atmospheric conditions.

For this calculation different standard atmospheres has been used (Anderson et al. 1986). The aerosols properties of the atmosphere have been selected as aerosols urban type with visibility of 50 km (Shettle, 1989). By this operation the measured spectrums for different urban covers at ground height (without atmosphere disturbance) have been transported to the reflectance at the top of atmosphere for different Sun-Earth geometries and different atmospheric conditions.

These spectrums at Sentinel-2 level have been used to generate the irradiance for each band (taking into account the spectral response function of each Sentinel-2 spectral band) for each urban cover and for each standard atmospheric condition. Different geometries, atmospheric compounds configuration and surfaces can be taking into account by repeating the process with the new radiative transfer calculations. Also the spectral response function can be replaced with the definitive ones in order to adapt the process to the real ones.

That way, the process is established to generate BDRF between 250 and 2500 nm of different covers at surface and sentinel-2 level. Also Sentinel-2 bands values can be estimated under different geometry and atmospheric configurations.

RESULTS

The results are grouped in reflectances measured by the ASD Fieldspec3 together with our goniometer, reflectances atmospherically modified by LibRadTran at Top of Atmosphere Sentinel-2 level, irradiance at Sentinel-2 level for each band and BRDF of different urban covers. Figure 6 shows the different products generated for white pavers and green grass urban covers: reflectance spectrum (a), reflectance at Sentinel-2 level in each band (b and c). The radiative transfer calculations have been perform for the Sun-Earth geometry during the 22 of march the 2012 at solar noon and for different standard atmospheric configurations.

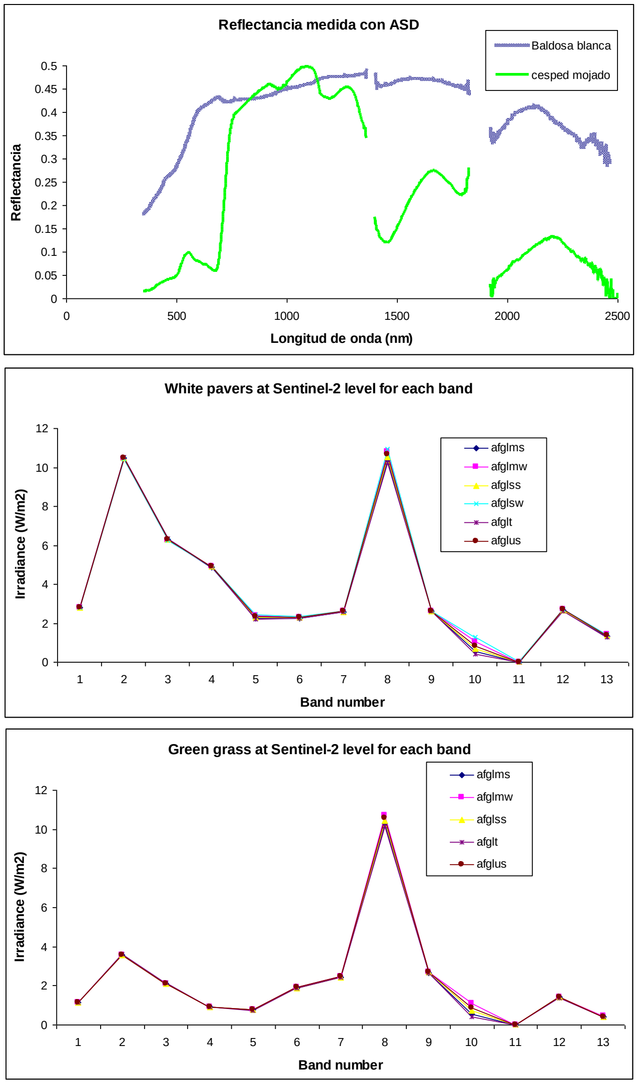

Figure 6: (a) Measured reflectance for green grass and white pavers at nadir. (b) and (c) irradiance for each channel and different standard atmospheres for white pavers and vegetation calculated at Sentinel-2 level

It can be seen how reflectance of white paves and vegetation show different behavior along the spectrum which implies different irradiance values for each channel at Sentinel-2 level, specially, in the visible part of the spectrum. The atmospheric standard configurations do not varies the result of the irradiances at Sentinel-2 level, but for the channel 10, centered in the 1375 nm part of the spectrum, which coincides with the water vapor absorption.

Figure 7 shows the BRDF of white and red pavers measured the 22 and the 30 of March 2012 respectively. The measured spectrums have been integrated in the channel 5 of the Sentinel-2 sensor (Drusch et al. 2012). Both color pavers present a maximum value of reflectance in the specular direction.

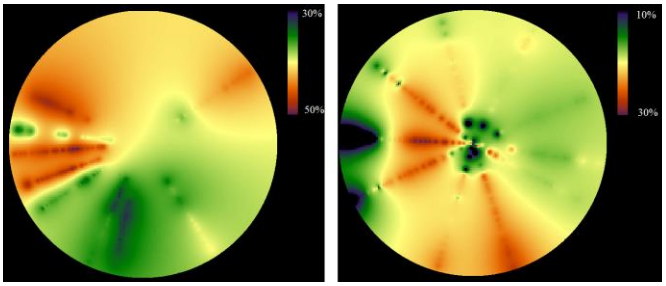

Figure 7: Measured BDRF, integrated over channel 5 of the Sentinel-2 sensor, of white (left) and red (right) pavers measured the 22 and the 30 of March 2012 respectively

CONCLUSIONS

A data base has been generated with expected values of reflectance for each Sentinel-2 bands of several urban covers
Different standard atmospheres have been used to perform the calculus of irradiance at Sentinel-2 level.

BRDF of different urban covers have been measured in order to show the angular dependence of the reflectance in the urban covers. To do that we have used a goniometer pasted to the ASD espectroradiometer. This goniometer allows us to perform very quickly many radiance measurements under different angles and with high accuracy.

This data base will be helpful to generate urban products based on Sentinel-2 mission. Specially, as a previous step in the recognize pattern algorithms like the segmentation process.

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