SIMULATION OF URBAN OPTICAL IMAGES FROM SPECTRAL AND SPATIAL RESOLUTION MULTI-ANGULAR AIRBORNE ACQUISITIONS

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1. INTRODUCTION

The specification of the coming earth observation sensors requires the simulation of acquired signal. Two existing methods allow the simulation of radiance images. The first one consists in the application of the radiative transfer equation over a synthetic scene. Some parameters like sun and sensor position, scene reflectances or atmosphere composition are chosen by the operator. But such method conducts to non-realistic results as the spatial variability is not taken into account. Another method is based on airborne acquisitions which are radiatively transfered at satellite level. Its main drawbacks are the viewing, illumination conditions and atmosphere composition of the airborne image which can not be changed.

This paper presents a new method avoiding the drawbacks of the previous ones. That is to say, this new method allows the simulation of a realistic image in any acquisition conditions. Instead of the first method, the reflectance comes from airborne images after an atmosphere compensation process. As the output image may be simulated in any viewing condition, the reflectances of the entire scene have to be known. So, it is essential to have several multi-angular acquisitions to access to the walls. One of the key points of the method is the inversion step. Most of studies about reflectance retrieval in urban high spatial resolution image make the assumption of a flat ground [1][4]. It implies, for instance, artefacts in shaded areas or estimation bias on roof slope. These defaults are avoided if the geometry of the scene is considered. A reflectance retrieving method for urban image acquired at nadir position, Icare [5], an algorithm designed at Onera, takes into account the 3D background. But for now on, a brand new multi-angular method, Icare v2 is able to estimate the wall optical properties. After a brief description of the urban radiative signal, this abstract presents the method and analyses the application on real data.

2. RADIATIVE TRANSFER MODELING IN URBAN AREA

The radiance received by a sensor from a point P of the scene is the sum of three separate radiances.

$$R_{sensor}(P) = R_{scene}(P) + R_{environment}(P) + R_{atmosphere}(P) \tag{1}$$

$R_{environment}(P)$ is the signal coming from the neighbourhood of the P point and received by the sensor because of the scattering of the atmosphere. $R_{atmosphere}(P)$ is the light scattered by the atmosphere directly toward the sensor without interaction with the ground. The main contributor, $R_{scene}(P)$ results from all irradiances incident on P and after reflection directly transmitted to the sensor in its instantaneous field of view. Assuming the reflectances of the scene are isotropic (i.e. lambertian or constant in any direction), $R_{scene}(P)$ coming from the point P toward the sensor is written as:

$$R_{scene}(P) = \frac{\rho}{\pi}\left(I_{total}(P)\right)T^{\uparrow} \tag{2}$$

Where ρ is the reflectance of the point P, $T^{\uparrow}$ is the direct transmission of the atmosphere from P to the sensor. I_{total} is the sum of the irradiance incident to P. As R_{sensor}, I_{total} can be decomposed following.

$$I_{total}(P) = I_{direct}(P) + I_{scattered}(P) + I_{environment}(P) \tag{3}$$

$I_{direct}(P)$ is the irradiance directly coming from the sun and $I_{scattered}(P)$ the downwelling atmosphere irradiance. $I_{environment}(P)$ results from reflections on the walls and also from the multiple reflections occurring between the ground and the atmosphere.

3. METHOD DESCRIPTION

As it is said in introduction the input data are a set of angular airborne acquisitions. The first step consists in retrieving reflectance of the entire scene thanks to the images. The second step is the simulation of a new image.

3.1. First step, the reflectance retrieval

According to the Equations 2 and 3, the reflectance ρ of a point P is

$$\rho(P) = \frac{\pi(R_{sensor}(P) - R_{atmospheric}(P) - R_{environment}(P))}{(I_{direct}(P) + I_{scattered}(P) + I_{environement}(P))T^{\uparrow}} \tag{4}$$

As the atmosphere composition and the geometry conditions are supposed to be known, it is possible to estimate the following radiative terms: $T^{\uparrow}$, $I_{direct,}$ $I_{scattered}$, $R_{atmosphere}$. In regard to the environment terms, $I_{environment}$ and $R_{environment}$ depend on the reflectance of the scene. Therefore, this equation is solved by iterating ρ.

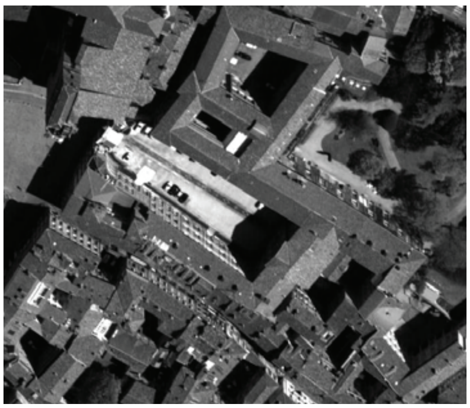
The Equation 4 assumes the reflectance is lambertian, although, many urban materials have a directional behaviour. For instance slate is very specular and gravel, because of its roughness, presents a back-scattering behaviour. The experiment results will allow a discussion about the relevance of this assumption.

3.2. Second step: simulation of a new image

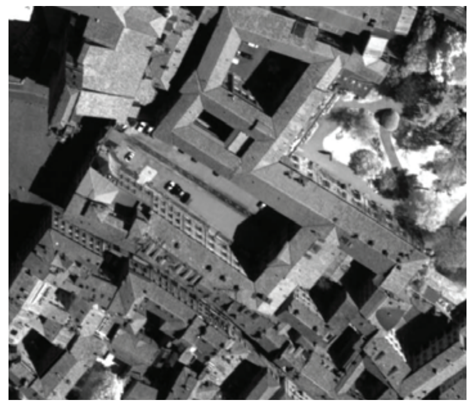
At the end of the inversion step, we gather a model of directional reflectance for each part of the scene corresponding to the ground pixel size. Using the 3D radiative transfer code called Amartis v2 [3][6] developed at Onera, we are able to simulate a new image choosing an arbitrary sun and sensor position and atmosphere composition.

4. EXPERIMENT

The paper presents the application of our method on real data acquired during the airborne campaign which occurred on March 2009 over Toulouse, France. Two systems equipped with four cameras each (485nm, 550nm, 670nm, 870nm) were used: one at nadir position, and the other one at 23 degrees. The airplane flied along several azimuth directions from the North: 0°, 63°, 148°,180°,243°, 328°. So, the gathered data are a set of multi-angular acquisitions. The ground pixel size is 20cm. Figure 2 presents some extracts from these acquisitions. Below each pictures, the position of the sensor and the wavelength are specified.



$\theta = 23°, \varphi = 63°, \lambda = 550nm$



$\theta = 23°, \varphi = 63°, \lambda = 870nm$

Figure 2: Extracts of airborne acquisitions over Toulouse

During the data processing, each step of our method will be analysed. An intermediate step of validation will be presented because we will compare the retrieved reflectance during the inversion step with the ground reflectance measured simultaneously. At the end of the experiment, the feasibility, the advantages and the drawbacks of our method will appear clearly.

5. CONCLUSION

Because of the geometric et radiative complexity of this environment, urban remote sensing papers are numerous [1][4]. This paper combine progresses we made in the field of simulation and inversion above urban areas. This method takes into account reflections, shadows, and directional behaviours of urban materials reflectances. It therefore allows the simulation of realistic image in any condition.

6. REFERENCES

[1] E. Ben-Dor, N. Levin, and H. Saaroni, “A spectral based recognition of the urban environment using the visible and near-infrared spectral region (0.4–1.1 m). A case study over Tel-Aviv,” *Int. J. Remote Sens.*, vol. 22,no. 11, pp. 2193–2218, 2001.

[2] P. M. Dare, "Shadow Analysis in High-Resolution Satellite Imagery of Urban Areas",Photogrammetric Engineering & Remote Sensing Vol.71, No2, February 2005, pp. 169-177

[3] S. Doz et al., "Simulation over urban area: two case study", proceedings Joint Urban Remote sensing Event, Shanghai, mai 2009.

[4] M. Herold, M.E. Gardner, D.A. Roberts, "Spectral resolution requirements for mapping urban areas",*GeoRS(41)*, No.9, pp.1907-1919

[5] S. Lachérade, C. Miesch, D. Boldo, X. Briottet, C. Valorge, H. Le Men "ICARE : A physically-based model to correct atmospheric and geometric effects from high spatial and spectral remote sensing images over 3D urban areas", *Meteorology and Atmospheric Physics*, Vol 102, pp. 209-222, octobre 2008.

[6] C. Miesch, X. Briottet, Y. H. Kerr, and F. Cabot, "Radiative Transfer Solution for Rugged and Heterogeneous Scene Observations", Appl. Opt. 39, pp 6830-6846 (2000).