Synthetic Images Simulation (SImS): A Tool in Development

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Keywords: Synthetic Image, Remote Sensing, Simulation, Blender.

Abstract: Images from remote sensing are presented as the main and most relevant data produced by this technology due to the numerous applications in the most diverse areas of knowledge. In this context, simulating these products can mean a significant reduction in costs, time, as well as assisting in the design stages of future sensors in the laboratory. One of the challenges of simulation is to reduce as much as possible the gap between it and the reality one wishes to study. In this context, the purpose of this work is, from a brief review of the methods of simulation of passive sensor images, present a proposal to classify them, to cite some examples of each, to present the conceptual model that is being developed, to mention aspects which provide versatility and functionality as well as some results.

1 INTRODUCTION

Synthetic Images (SI) are those created by using of computational resources and/or Virtual Reality (VR) with specific modelling software or methods to make it possible to explore and suggest different situations to visualization, immersion and interaction as facilitator in complex works of learning, through the creation an environment in which the data generation conditions are reproduced.

The evolution of computational resources in hardware and software has allowed advances in visualization and manipulation of information due to the growing need to represent the reality and many real-world information. Thus, simulation and modelling tools represent one way to support a number of the design, implantation and operational studies (Schott et al., 2010).

On the other hand, Remote Sensing (RS) images from optical satellites allow to allow to acquire information about the surface of the Earth by means of capture energy reflected or emitted energy without physical contact between the system sensor and the object or sensed area. These images are used by professionals from numerous and different areas. In this sense, simulation of RS images, even previous to have a physical device, would permit to determine usability and the capabilities of and existing or planned RS system.

Following the previous ideas, simulation and modelling tools represent one way to support a number of the design, implementation and operational studies, being more common:

- Meteorology – weather forecasting, monitoring of atmospheric changes, pollutant control, measurement of greenhouse effect and hole in the ozone layer
- Civil Defence – prediction of natural disasters that allow preventive measures to be taken
- Planning and monitoring of agricultural crops
- Planning and monitoring of urban growth
- Monitoring of forest areas to detect fires and other forms of deforestation
- Military uses – espionage, tracking of enemy movements and strategic planning ot troop positioning
- Sensors development
- General users

Compared to other areas of RS, the few works published on simulated images usually are focused on specific applications. For example, an existing web-based hyper-spectral image generator for cotton crop (Alarcon and Sassenrath, 2004; Sassenrath *et al.*, 2003) was enhanced to output averaged continuum-removed reflectance curves for synthetically

Stelle, C., Ariza-López, F. and Ureña-Cámara, M.
Synthetic Images Simulation (SImS): A Tool in Development.
DOI: 10.5220/0006807903130318
In *Proceedings of the 4th International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2018)*, pages 313-318
ISBN: 978-989-758-294-3

generated images. Another application can be seen in Marcal et al. (2010) in the use of Synthetic Image TEsting Framework (SITEF) as a tool to evaluate and compare image segmentation results.

An efficient way to produce a simulated image is to create an environment in which the data generation conditions are reproduced. Ientilucci and Brown (2003) emphasizes that the image simulation surrogate must ideally match real world scenes in both spatial and spectral complexity for one to have faith in algorithm performance. Thus, radiometrically, as well as geometrically, correct synthetic imagery offers algorithm developers a surrogate to potentially unattainable field campaigns. To this end, the NASA, through the Rochester Institute of Technology (RIT), has initiated a program to build a synthetic scene-sensor model called Digital Imaging and Remote Sensing Image Generation (DIRSIG) model is designed to produce end-to-end image simulations incorporating all the relevant characteristics of images (Schott et al., 2012).

This paper presents the current stage of tool Synthetic Image Simulation (SImS) that aims to create passive remote sensing images from a 3-D model with real-world features.

2 IMAGE SIMULATION METHODS

An important issue about images simulation is the quality or fidelity of the models. Some applications need only change the pixel size of the image, others need reproducing the radiation levels into the scene. Thus, it is concluded that the methods must be adjusted for each problem and it is necessary to understand them in a brief review.

Considering that the satellite images are generated according to four resolutions (spatial, temporal, radiometric and spectral) and that to simulate is to try to reproduce a data under controlled conditions, then it is reasonable to say that the efforts of the simulation should be directed to the spatial and spectral questions, which are the characteristics most evidenced in the applications. Simulating the temporal question can be obtained from the ephemeris of a sensor and in this way, use a model to estimate the data at a desired time. Simulating the data with the least amount of bits is also relatively easy, as it is enough to compress a range of gray levels to a single value, which is no longer so trivial in the inverse process. Usually the increase of bits in the quantization after the produced image is achieved by the addition of noise. Thus, at this moment, this work will focus on the spatial and spectral issues and the components that affect them.

Although there are many simulation methods, there is no one that consolidates them. Therefore, in this paper we propose that we can classify them in two main categories: Computational Based (Based on Existing Images and Totally Synthetic) and Analogue Based.

Table 1: Proposed classification of methods.

Analogue Based	Models / Dioramas	Francis et al. (1993) Maver and Scarff (1993)
Computational Based	Based on Exiting Images	Justice et al. (1989) Esposito et al. (1998) Boggione et al. (2003) Chen et al. (2008) Yang et al. (2009) Nelson et al. (2009) Maeda et al. (2008)
	Totally Synthetic	Ientilucci and Brown (2003) Schott (1997) Latorre et al. (2002)

2.1 Analogue based

Physical models may include terrain, ground cover, structures and vehicles, with scene detailing depending on the resolution of the sensor to be simulated. This approach is described by Francis et al. (1993). The scene is illuminated with a collimated beam to simulate the sun and many diffuse sources to simulate the sky as shown in Figure 1. The sensors are located above the model and the optics is adjusted to simulate the desired field of view. The image in this case is designed to represent the radiance field in the sensor. It is also easy to change the camera and the sun angles to generate multiple images of the same scene. This methodology has the disadvantage that it is necessary to ensure that high reflectance and reflectance variation are included in this scenario. This problem becomes severe when this approach is used to simulate multispectral scenes. Maver and Scarff (1993) describe a hybrid approach to simulate

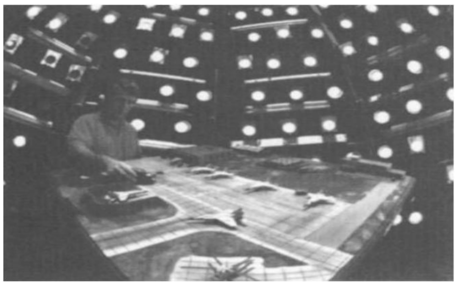

Figure 1: Simulation using physical model (Schott, 1997).

multispectral scenes where physical models and lighting are used to generate scenarios that are then processed through computer vision.

The advantage of this approach is that some of the spatial variations and interactions of certain materials can be included in the design of the model. The disadvantage is that generating complex scenes can become difficult, requiring in many cases considerable manual editing.

2.2 Computational based

This approach involves simulation techniques that propose methods in which the simulated images are generated from other images or a synthetic scene. These techniques typically address the degradation of a better-resolution image to generate images at worse resolutions, although there are reverse cases. These techniques allow to simulate scenes close to reality.

2.2.1 Based on Existing Images

Justice et al. (1989) present aspects of spatial degradation generating simulated images in six grids of different resolutions in a range of 79 m to 4000 m from the Multispectral Scanner / Landsat (MSS) sensor.

Esposito et al. (1998) present the simulation of the images of the CBERS cameras, which at the time of this work had not yet been released, using AVIRIS (Airborne Visible / Infrared Imaging Spectrometer) images. It was necessary to extrapolate the spectral radiance measured by AVIRIS at 20 km altitude to the altitude of the CBERS orbit at 778 km and the MODTRAN 3.0 program was used for this calculation, providing the transmittance values at each wavelength. For the difference in time taken for the images (CBERS programmed to pass over the equator at 10:30 a.m., and the AVIRIS images of the study were collected between 1:30 p.m. and 4:30 p.m.), and knowing the lighting conditions of the scene, the solar zenith angle was calculated for both the AVIRIS transit time and the CBERS transit time, obtaining a correction factor that was applied throughout the scene.

Boggione et al. (2003) present the possibility of simulating a panchromatic band for Landsat 5 from its spectral bands. In this work the restoration technique combined with interpolation is used to generate images in smaller grids. The spectral question is solved using the relation between areas of the spectral curves of the bands of Landsat 7 and its panchromatic.

Chen et al. (2008) propose a simulation method to acquire simulated hyperspectral images using spectral low resolution images. The proposed method uses the idea of pixel mixing to understand the relation between the spectral values of a pixel of the image and to simulate the processes of radiation transmission.

Yang et al. (2009) presents the simulation of high resolution images in the mid-infrared spectral range using an analytical model of radiative transfer of the atmosphere. Unlike other spectral ranges, the average infrared is highly dependent on atmospheric dispersion and emissions.

Nelson et al. (2009) who used the simulation of images to study the effects of resolution in the estimation of forest areas, simulated images of 90 to 990 meters of resolution from images of 30 meters resolution of the Landsat system.

Maeda et al. (2008) using the ETM + / Landsat7 image degradation technique and nearest neighbour resampling simulated and evaluated the potential of WFI / CBERS-3 images for land use and land cover classification in two regions with distinct landscape characteristics.

2.2.2 Totally Synthetic

With DIRSIG model, Ientilucci and Brown (2003) produced imagery that can be used to test the performance of spatial and spectral image exploitation algorithms and concluded that synthetic data should be considered a powerful tool to assist in the testing of algorithms and potentially as a surrogate when real data is not available.

According to Schott (1997), an alternative to the use of analogue based models is a totally synthetic approach, where scene elements, radiation propagation, and sensor effects are simulated using computational modeling. This approach is more interesting because it allows infinite variations, essentially, in the processes of adjustment of scene elements and interaction. On the other hand, the computational complexities of this approach in terms of coding and run time are disadvantages. In practice, the idea is to accurately model the physical processes that occur in the process of imaging. The result is a hi-fidelity model that can provide information about the imaging process as well as the simulated image itself. Typically, a model is used to generate an estimate of the radiation from the target to the sensor. This model is often associated with a model of radiation propagation, such as MODTRAN (MODerate resolution atmospheric TRANsmission) used to calculate the level of surface radiation in the microwave, near infrared, visible, and ultraviolet (Latorre, 2002). It is a code that can be used to predict spectral radiance for various geometries and atmospheric conditions. Atmospheric propagation models often have a database of atmospheric conditions that are needed as input. Finally, a sensor model must be available to characterize the sensor location, acquisition geometry, field of view, resolution, spectral response and radiometric.

3 RESULTS

The development of this simulator (SImS) is centered in this last proposal (Schott, 1997) and it aims to generate, from free software and vector cartography, in an automated way satellite synthetic images. This simulator presents independence from analogue based, other images or commercial software which means that images can be generated from random scenarios and created according to input parameters of users, as well as pseudo-synthetic images from cadastral data for example.

Following this, we select the free software Blender 2.78 to create tools that generate images using its integrated Python 3 programming language.

Some strategic decisions are needed to be defined for the development of SImS and the main ones were:

- The indicated free software Blender 2.78 – is the free and open source 3D creation suite. It supports the entirety of the 3D pipeline — modelling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation. Also customize the interface layout and colours and combine 2D with 3D.
- Python programming language – Blender has a flexible Python controlled interface and layout, colours, size and even fonts can be adjusted as well as it is possible create own using Blender's accessible Python API.
- Geospatial Data Abstraction Library (GDAL) - is a translator library for raster and vector geospatial data formats and the gdal_edit.py script can be used to edit in place various information of an existing GDAL dataset (projection, geotransform, metadata).
- OpenCV - is the computational view in which we can use computational algorithms to describe and analyze the content of any image. It is free for academic use and it has Python interface and support Windows.
- Object format - the Wavefront .obj file is a simple data-format and it is considered a "universal format" for 3D object representation. It is represented in ASCII format and recognized by most 3D modelling/visualization software.

The conceptual model of the main modules can be seen in Figure 2.

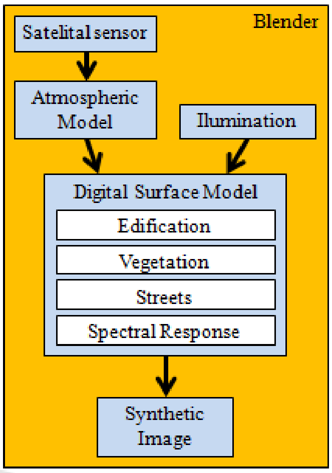

Figure 2: Conceptual model.

The main parameters to be inserted in the satellite sensor module should allow the definition of the program, platform and sensor from a library of satellite platforms. Their spatial position will be obtained from their own orbital parameters or ephemeris.

Currently, the parameters that the user can define are those shown in Figure 3. In this figure, Band 2 of the OLI sensor (Operational Land Imager), Landsat 8 is highlighted as spectral information to be simulated.

Figure 3: Simulator toolbar.

Information such as the geographical coordinates (latitude, longitude), date, time and types of roads can also be defined.

The Illumination module consists of simulating the behaviour of incident solar rays in a raytracing system compatible with reality.

The Atmospheric Model module, also comes from a library to be implemented, will aim to predict in a simple way only the dynamic state of the atmosphere. These simple model will be defined only for RS purpose and will not suitable for weather or climate forecasting.

With regards to the module Digital Surface Model (MDS), in development, automatically and according to a user's defined criteria, different layout of streets, blocks, vegetation and buildings are textured. Nowadays, this model allows to simulate static textures defined from the ASTER Spectral Library (Baldridge et al. 2009) like Construction Asphalt, Construction Concrete, Conifer and Aluminium Metal, respectively. Developing importers of MDS and spectral libraries are the future stage, mapping validity will ensure greater variability of 3D scenarios.

The synthetic image will also be associated with a synthesis metadata file. Nowadays, the export module allows to create a synthetic image and in its future version, it will create a text file with the creation parameters that corresponds to the end of the creation process.

Figure 4 and 5 show, respectively, a simulated scenario in its real appearance given the pre-defined geographical and lighting conditions, and the sensor display in nadir position (upper view). The parameters defined as follows:

- Latitude: 37.78º
- Longitude: 3.78º
- Day: 25
- Month: August
- Year: 2017
- Hour: 1000
- UTC: 2

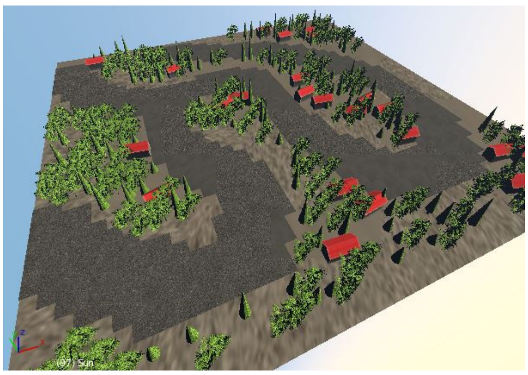

Figure 4: Simulated scenario (real appearance).

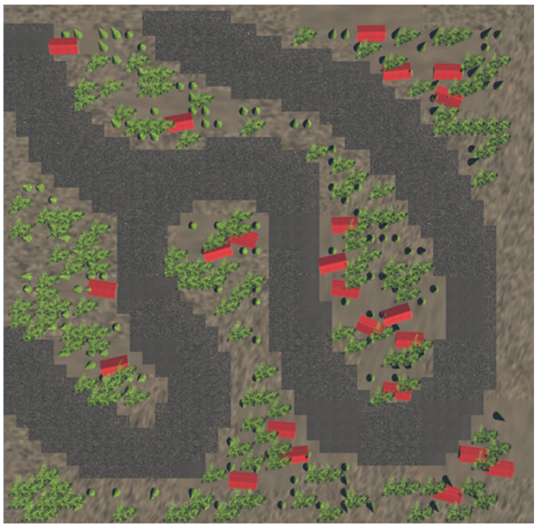

Figure 5: Simulated scenario (upper view).

Finally in order to show the versatility and potentiality of the simulator, Figure 6 shows the same image that corresponds to the OLI sensor, Landsat 8, Band 5 Near-Infrared (0.85 - 0.88 µm), but with a spatial resolution of approximately 1m and not 30m.

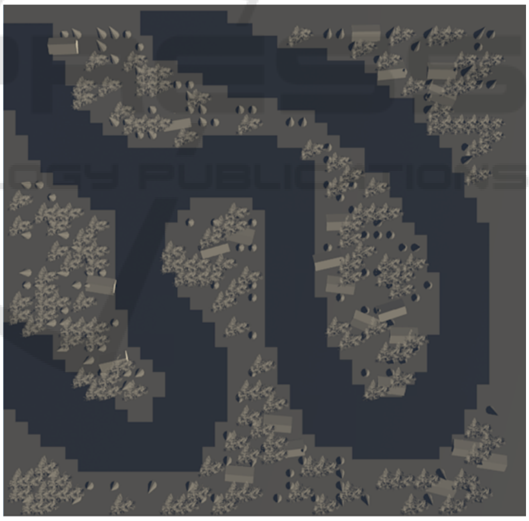

Figure 6: Simulated scenario (upper view).

4 CONCLUSIONS

In this paper we described the present state of a software and its model to create synthetic images from the simulation of a 3D scenario.

The development of this tool, based on free software and using independent sources of geographical information, allows the user to generate a scene in which it is able to control all the stages of creation and to obtain an image as similar as possible to what would obtain a real system. In this sense, the simulator tries to generalize its use to different disciplines.

Currently the user is allowed to define day, month, year, time, latitude, longitude, streets, structures and vegetation for the random creation of a scenario that, with probabilities or specific quantities of objects, can be exported in the respective spectral and spatial resolutions of interest.

Moreover, the present tool allows the user to define the desired spectral band and spatial resolution. This flexibility is fundamental to the make SImS a universal tool. For this reason, as an example, images corresponding to the OLI (Landsat 8) sensor spectral resolutions were presented in this paper.

Our future work will consist of integrating other elements of the territory, such as elevation models and different atmospheric models with different meteorological parameters. In this way it will be possible to parameterize sensors and platforms for the effective integration in the generation of synthetic images, considered by the countries strategic factor.

ACKNOWLEDGEMENTS

The authors acknowledge the Regional Government of Andalusia (Spain) for the financial support since 1997 for their research group (Ingeniería Cartográfica) with code PAIDE-TEP-164 and the Department of Science and Technology of the Brazilian Army.

REFERENCES

Alarcon, V. J. and Sassenrath, G. F. 2004. Cotton crop spectral imaging analysis: a web-based hyperspectral synthetic imagery simulation system. In: *Remote Sensing and Modeling of Ecosystems for Sustainability*, (Gao, W. and Shaw, D.R., Eds.). Proceedings of SPIE, Vol. 5544, 178-185.

Baldridge, A. M., S. J. Hook, C. I. Grove and G. Rivera, 2009.. *The ASTER Spectral Library Version 2.0. Remote Sensing of Environment*, vol 113, pp. 711-715.

Boggione, G. A.; Pires, E.G; Santos, P. A; Fonseca, L. M. G. *Simulation of Panchromatic band by spectral combination of multispectral ETM+ bands. International Symposium on Remote Sensing of Environment (ISRSE)*, Hawai, Nov. 2003.

Chen, F.; Niu, Z.; Sun, G.; Wang, C.; Tang, J. *Using low-spectral-resolution images to acquire simulated hyperspectral images. International Journal of Remote Sensing*, v. 29, p. 2963-2980, 2008.

Esposito, E. S. C. *Simulação das bandas espectrais das câmaras CCD e WFI do satélite CBERS, a partir de dados do sensor hiperespectral AVIRIS.* versão: 1970-01-01. Dissertação (Mestrado em Sensoriamento Remoto) - Instituto Nacional de Pesquisas Espaciais, São José dos Campos, 1998.

Francis, I; Maver, L.; Schott, J.R. *Comparison of physically and computer generated imagery.* Proceedings SPIE, v. 1904, p. 20-23, 1993.

Ientilucci, E.J.;Brown, S.D. Advances in Wide Area Hyperspectral Image Simulation. Proceedings of SPIE Vol. 5075 (2003).

Justice, C. O.; Markhan, B. L.; Townshend, J. R. G.; Kennard, R. L. *Spatial degradation of satellite data. International Journal of Remote Sensing*, v. 10, n. 9, p. 1539-1561, 1989.

Latorre, M.; Abílio, O.; Júnior R, D. C.; Paula, A.; Carvalho, F. D.; Shimabukuro, Y. E. *Correção Atmosférica: Conceitos e Fundamentos. Espaço & Geografia*, v.5, n. 1, p. 153-178, 2002.

Maeda, E. E.; Arcoverde, G. F. B.; Formaggio, A. R.; Shimabukuro,Y. E. *Evaluation of the potentiality of WFI/CBERS-3 Sensor data for land use and land cover classification. Revista Brasileira de Cartografia*, v. 1, n. 60, p. 79-87, 2008.

Marcal, A. R. S.; Rodrigues, A.; Cunha, M. "Evaluation of satellite image segmentation using synthetic images," *2010 IEEE International Geoscience and Remote Sensing Symposium*, Honolulu, HI, 2010, pp. 2210-2213.

Nelson, M. D.; McRoberts, R. E.; Holden, G. R; Bauer, M.E. *Effects of satellite image spatial aggregation and resolution on estimates of forest land area. International Journal of Remote Sensing*, v. 30, n. 8, p. 1913-1940, 2009.

Maver, L.; Scarff, L. *Multispectral image simulation. Proceedings SPIE*, v.1904, p. 144-160, 1993.

Sassenrath, G. F., Alarcon-Calderon, V. J., Pringle, H. C. 2003. "Synthetic imagery of cotton crops: Scaling from leaf to full canopy." *Digital Imaging and Spectral Techniques: Applications to Precision Agriculture and Crop Physiology.* T. van Taoi, ed.. pp. 111-133. Agronomy Society of America Special Publication Number 66, Madison, WI.

Schott, J. R. *Remote sensing the image chain approach*. New York, NY: Oxford University, 1997 394305169.

Schott, J.R.; Raqueno, R.V.; Raqueno, N.G.; Brown, S. D. *A Synthetic Sensor/Image Simulation Tool to Support the Landsat Data Continuity Mission (LDCM)*. In *Proceedings of ASPRS 2010 Annual Conference*, San Diego, CA, USA, 26–30 April 2010.

Schott, J.; Gerace, A.; Brown, S.; Gartley, M.; Montanaro, M.; Reuter, D.C. *Simulation of Image Performance Characteristics of the Landsat Data Continuity Mission (LDCM) Thermal Infrared Sensor (TIRS). Remote Sens.*2012, *4*, 2477-2491.

Yang, G.; Liu, Q.; Liu, Q.; Huang, W.; Wang, J. *Simulation of high-resolution mid-infrared (3–5 mm) images using an atmosphere radiative transfer analytic model. International Journal of Remote Sensing*, vl. 30, n. 22, p. 6003–6022, 2009.