An Evaluation of Knowledge-Based Interpretation Applied to Low-Resolution Satellite Images

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Abstract— **The present paper presents the preliminary results of a research aiming at evaluating the potential of knowledge-based approaches for the interpretation of low-resolution satellite images. This work applies a knowledge-based image interpretation system, so-called GEOAIDA, developed at the University of Hannover, Germany, which hires semantic networks and external operators to model the knowledge basis as well as takes advantage of additional data from Geographic Information Systems, GIS. Herein, GEOAIDA is used to perform automatically the post-editing, one of the steps of visual interpretation, aiming at mimicking the reasoning of a trained photo-interpreter when he refines the result of a pixel classification procedure. The results obtained hitherto show that the use of knowledge-based approaches for this purpose is promising and, in the future, can be used to automate the post-editing.**

Keywords: Knowledge-based image interpretation, semantic networks.

I. INTRODUCTION

Agenda 21, a document signed during the United Nations Conference on Environment and Development in Rio de Janeiro (Eco92) [1] and consolidated during the United Nations Conference on Environment and Sustainable Development in Johannesburg (Rio+10) [2], defined the concept of sustainable development as the most important paradigm to the societies of the new millennium. As a consequence, it increases the demand for technology to support the rational utilization of natural resources. In this context remote sensing plays a strategic role because it provides tools for monitoring the environmental degradation processes as well as the effects of preservationist measures.

Nonetheless, despite the fact that there are powerful software packages commercially available, which can be used as monitoring tools for environmental conditions all over the Earth, these packages have characteristics that hinder the full exploitation of such technology.

A proposal capable of simplifying the utilization of remote sensing technology is the exploitation of specific knowledge in order to automate the interpretation and analysis of the remote sensed images. Among the diverse approaches in the literature which make use of knowledge in order to automate the analysis, SPAM [3], ERNEST [4], SIGMA [5], MESSIE [6], AIDA [7] and GEOAIDA [8], [9] can be mentioned. Specifically, this work uses the GEOAIDA system which hires semantic networks and specific holistic operators to model the knowledge basis as well as takes advantage of external reference data from Geographic Information Systems, GIS. The present paper reports the results of its utilization to the interpretation of low-resolution satellite images. It is worth mentioning that, so far, such system has been successfully used to interpret aerial images, but on low-resolution images few was done. Therefore, the current essay is part of the first attempt of its utilization in order to analyze low-resolution satellite images. This work is part of an international cooperation project involving three Brazilian institutions, (Pontifical Catholic University of Rio de Janeiro, University of the State of Rio de Janeiro and EMBRAPA Soils Research Center) and two German Institutes from the Hannover University which developed GEOAIDA.

Little is reported in the literature about the use of knowledge-based approaches to the interpretation of low-resolution satellite images. Yun Zhang, in [10], describes a method which aims at detecting changes in the land use. The approach simultaneously employs SPOT and LANDSAT images to update the urban maps of Shangai, China, and discriminates vegetation, water and urban areas. As a result, the urban maps are updated highlighting the new constructions.

In [11], Kunz et al. employ ERNEST to update the maps in a GIS database. The approach derives a semantic network from the contents of the GIS database. Beside the spectral response, the compactness, the mean curvature, the texture standard deviation and homogeneity are evaluated, are compared with the contents of the GIS database. Discrepancies are corrected, being the GIS updated.

Largouet et al. [12] implement a land cover analysis for a sequence of images of different satellites with the use of a temporal model. The investigated scene corresponds to a rural area and the analysis of the images uses special agricultural knowledge, modeled in a formalism, so-called timed automata, as a priori knowledge about the scene.

Suzuki et al. [13] integrate structural knowledge to the image classification process. Basically, a fuzzy classifier generates a preliminary partition of the image and, then, the system tries to improve the initial classification.

This work aims at evaluating the potential of GEOAIDA as a tool to automate the interpretation of low-resolution satellite images. Specifically, herein, GEOAIDA is used to automate the post-editing step, of the interpretation of a LANDSAT-7 image from a region in Brazil undergoing a severe environmental degradation process.

The present document is organized as follows, section II presents a short overview of GEOAIDA, section III describes the performed experiments whose results are analyzed in section IV and the conclusion is presented in section V.

II. GEOAIDA

By and large, semantic networks consist of nodes and links, in the form of a graph. In GEOAIDA, nodes represent the objects expected in the scene, whilst links describe the relations between the objects. In this context, the general description of the scene contents, encompassing nodes and links, is called conceptual network which yields the framework of the scene.

GEOAIDA defines three different sorts of node, *generalization* which split up and branch into alternative scene interpretations, *compound* which represent objects composed of several parts, and *end* that are just linked to their respective parents.

On the other hand, links are merely bi-directional relations between two nodes and revel to each node only its parent and its offsprings. Thus, each node knows its "genealogy", contains information about the represented object and encloses attributes and methods dynamically administrated.

III. EXPERIMENTS DESCRIPTION

The experiments presented in this work aim at monitoring land use and land cover (LULC) of the Alcinópolis County, located in the State of Mato Grosso do Sul, in Brazil. It consists of a region predominantly used for extensive cattle-raising for meat production. However, improper managing of this activity results in environmental drawbacks. The most critical are severe soil erosion processes, resulting in gully formation, which augments regrettably the amount of sediments carried by the rain that get to the water-streams. Most of them go to the Pantanal region, one of the most important and delicate wetland ecosystems of the World, causing siltation, increased by flood events, and affecting the fragile economical and ecological balance of the region.

The LULC classes present in the studied region are *ancillary forest*, *dense savannah*, *water*, *pasture*, *regenerating fields* and *bare soil*. However, the fact that many of these classes have similar spectral appearances hinder that the pixel classification process by itself provides a reliable outcome. Thus, often, the image interpretation process also encompasses the visual post-editing of the supervised pixel classification result. In such procedure, a human photo-interpreter, taking into account expert knowledge as well as additional information about the region, correct the misclassifications.

In this experiment, GEOAIDA is used to represent explicitly the knowledge of the photo-interpreter aiming at mimicking its behavior while post-editing the outcome of the pixel classification procedure. In the region of interest, the pixel classification procedure tends to confuse ancillary forest, dense savannah and water. In the proposed experiments, the visual as well as the automatic approaches make use of information about the rivers of the region in order to solve such inconsistencies, being, by the automatic approach, the following rules employed:

1. Since shades and water have nearly the same spectral response, pixels classified as *water* situated farer than 5 pixels of the rivers are switched to the class *forest*. In that fragment, the mountains where occurs the shades are covered by forest.
2. Pixels originally classified as *ancillary forest* placed farer than 10 pixels of the rivers are reclassified as *dense forest*. Inasmuch as these classes have similar spectral responses; however, ancillary forest only occurs alongside rivers.
3. By the same reason fragments of *forest* having more than 80% of their area closer than 5 pixels to the rivers are switched to *ancillary forest*.

IV. RESULTS ANALYSIS

The input to the post-editing either visual or automatic is produced by a supervised pixel classifier. In order to evaluate the appraisal of its result, TABLE I. exhibits the error matrix whilst TABLE II. shows the measures of accuracy.

The pixel classification procedure provides a very poor result, from the 12464 pixels of the class ancillary forest 1046 are classified as dense savannah. On the other hand, from the 43099 pixels of dense savannah, 8368 are classified as ancillary forest while 1993 are improperly selected as water. Analyzing the omission and the commission errors, for the class ancillary forest it was obtained 8% of omission and 44% of commission. On the other hand, for the class dense savannah the pure pixel classification procedure reached 24% of omission and 3% of commission. Besides, for the class water it provided 0% of omission and 77% of commission.

In order to allow the evaluation of the potentiality of the knowledge-based approach, TABLE III. presents the error matrix whereas TABLE IV. presents the measures of accuracy.

Even though from the 12464 pixels of the class *ancillary forest* 1534 were classified as *dense savannah*, 488 more than the previous result, for the classes *dense savannah* and *water* the knowledge-based approach allowed a considerable improvement relative to the pixel classification result. After its application, from the 43099 of class *dense savannah* only 771 were considered as pertaining to the class *ancillary forest* and 0 were classified as *water*. Analyzing the omission and the commission errors, for the class ancillary forest it was obtained 12% of omission and 8% of commission. On the other hand, this procedure allowed 2% of omission and 5% for the class dense savannah. In addition, it provided 0% of both omission and commission for the class *water*.

Thus, despite the small rising of the omission error for the class *ancillary forest* and the commission error for the class *dense savannah*, the usage of knowledge allowed the significant reduction of the commission error for the class *ancillary forest* and the omission error for the class *dense* *savannah*; moreover, it had completely eliminated the commission error for the class *water*.

TABLE I.
ERROR MATRIX (PIXEL CLASSIFICATION)

Reference Data							
	Ancillary Forest	***Dense Savannah***	***Water***	***Pasture***	***Field***	***Bare soil***	***Row Total***
Ancillary Forest	11418	8368		693			20479
Dense Savannah	1046	32738		7			33791
Water		1993	6651			4	8648
Pasture				84207			84207
Field					6906		6906
Bare Soil						18449	18449
Column Total	12464	43099	6651	84907	6906	18453	172480

TABLE II.
OMISSION AND COMMISSION ERRORS (PIXEL CLASSIFICATION)

	Producer's Accuracy	***Omission error***	***User's Accuracy***	***Commission error***
Ancillary Forest	92%	8%	56%	44%
Dense Savannah	76%	24%	97%	3%
Water	100%	0%	77%	23%
Pasture	99%	1%	100%	0%
Field	100%	0%	100%	0%
Bare soil	100%	0%	100%	0%

TABLE III.
ERROR MATRIX (KNOWLEDGE-BASED APPROACH)

Reference Data							
	Ancillary Forest	***Dense Savannah***	***Water***	***Pasture***	***Field***	***Bare soil***	***Row Total***
Ancillary Forest	10930	771		113		4	11818
Dense Savannah	1534	42328		587			44449
Water			6651				6651
Pasture				84207			84207
Field					6906		6906
Bare Soil						18449	18449
Column Total	12464	43099	6651	84907	6906	18453	172480

TABLE IV.
OMISSION AND COMMISSION ERRORS (KNOWLEDGE-BASED APPROACH)

	Producer's Accuracy	***Omission error***	***User's Accuracy***	***Commission error***
Ancillary Forest	88%	12%	92%	8%
Dense Savannah	98%	2%	95%	5%
Water	100%	0%	100%	0%
Pasture	99%	1%	100%	0%
Field	100%	0%	100%	0%
Bare soil	100%	0%	100%	0%

V. CONCLUSION

This work presented the application of a knowledge-based approach to automate the post-editing which is one of the steps of the visual interpretation of low-resolution satellite images. The proposal applies GEOAIDA, a knowledge-based image interpretation system, which, herein, was used to model the information that a trained photo-interpreter employs to solve the inconsistencies during the analysis of a LANDSAT 7 image of a rural area of Brazil. Such misclassifications occur because of the similarity of the spectral appearance of the different classes involved.

The preliminary experiments reported herein, exploit only the bottom-up process of GEOAIDA inasmuch as the top-down process is performed by external operators prototyped using MATLAB. Even thus, the outcomes showed that the application of knowledge-based approaches to automate the post-editing is quite promising.

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