EVALUATION OF CAPABILITIES OF FUZZY LOGIC CLASSIFICATION OF DIFFERENT KIND OF DATA

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ABSTRACT:

In this paper, in order to evaluate the capability of several data, acquired by different sensors, some object-oriented classification tests have been carried out. In particular, the results obtained with two RGB ortophotos, acquired with traditional methodology, have been compared with the ones obtained with two QuickBird images and with the ones obtained by ADS40 pushbroom sensor.
The object classification is based on two next steps: The classification to objects is based on two next steps: the decomposition of the whole image in dimension objects bigger than the pixel, procedure called segmentation, and the next classification with Fuzzy logic. This approach provides more reliable results with respect to the classification based on the pixels as it associates homogeneous objects on the basis of the information contained both in the objects themselves and their mutual relations. At last, the results obtained in the three cases have been compared through statistical methods necessary to evaluate the quality of the produced classifications. The comparison has been carried out through the comparing of the confusion matrixes produced on the basis of some samples extracted from the origin images. The used methodology is very useful for the monitoring and identification of landscape changes; in particular, in order to individuate the changes due to the anthropic pressure, a orthophoto, produced in 1979 by traditional techniques and two QuickBird images, acquired in 2002 and 2006 respectively and relative to the very naturalistic area have been elaborated.

1. INTRODUCTION

In the last ten years, the geometric resolution of several digital sensors, both for satellite and airborne platform, is increased and the differences between the traditional photogrammetric applications and remote sensing ones have decreased. The traditional photo-interpretation has been deserted in favour of a more objective and automatic classification process. This passage is also justified by one more reason, in fact, most of the new digital sensors are able to acquire information in the near infrared wavelength (NIR) that just in special case is acquired by traditional analogic photogrammetric camera. The traditional classification methods exist from the remote sensing birth and they are integrated in the most of image processing software. This methods compare the spectral features of the single pixel. In this article a different kind of methodology, called object classification, has been used. This methodology has been developed in the last years and it is based on the information contained in groups of homogeneous pixel called objects.

The application has been carried out on two different areas (Fig. 1). The first area, “Parco D’Orleans”, is the seat of the Palermo University: it’s a flat area with several buildings and narrow streets. The second one is located in Scopello, a tourist area in the North West of Sicily. In this case the studying area is characterized by very high difference of levels and, except a little marine village and a residential area it is uncontaminated.
The described areas have been chosen for three reasons: the availability and the assortment of data acquired by different sensors and in different periods of time, for the possibility of to exert an objective checking of the classification results and to select the training sites correctly.

Regarding the Parco D’Orleans area the following images have been acquired:

1. A RGB Orthophoto from the “TerraItaly” project of CGR society of Parma with a 1:10000 nominal scale and 1 metre geometric resolution. The image has been acquired in 2000 by a traditional photogrammetric camera and digitalized by a photogrammetric geometric calibrated scanner later. The digital image has been orthorectified. The orthorectification has been carried out by CGR with traditional digital orthorectification methodology.

2. A RGBNir QuickBird image (Red, Green, Blue, Near Infrared) with a 2.4 metres geometric resolution acquired in 2002. The orthorectification has been carried out by Rational Function method.

3. A RGBNir ADS40 image also acquired by CGR in the 2005 (Red, Green, Blue, Near Infrared) The images, is a 0.6 metres resolution and has been orthorectified by an aerial triangulation carried out by ORIMA software. The ADS40 sensors is equipped with three series of CCD sensors. The three lines are one looking forward, one in. the nadir position and one looking backward with respect to the flight path. The infrared images is acquired by the forward CCD sensor; for this reason the image is characterized by a visible perspective error and in the classes of the classification there are two classes respectively for shadow and front of buildings.

Regarding Scopello area the following images have been acquired:

1. A RGB photogram acquired in 1979 by a traditional photogrammetric camera. Due to unavailability of stereoscopic model of the area an orthorectification by Rational Function method has been carried out.
2. Two RGBNir QuickBird images with 2.4 metres geometric resolution. They also have been orthorectified by Rational Function.

The Ground Control Points have been acquired during a GPS survey within a National Research Project (Cofin01).

Figure 1. Test areas

2. THEORETICAL BASIS AND RESULTS

In this paragraph the theoretical basis of the applied methodology is showed.

The object classification is based on two steps:

- Segmentation;
- Fuzzy logic classification.

2.1 Images Segmentation

The first step, changing some parameters chosen by the user, allows to decompose the original image in homogeneous objects; there are a lot of segmentation algorithmic based on 4 different methodologies:

- Based on borders extraction;
- Based on regions extraction;
- Based on cluster analyses;
- Based on models

In this paper, both for the segmentation and the classification, the software Definiens Developer has been adopted. The software uses a very powerful and really versatile algorithmic. The shape and the size of the objects depend by some input parameters:

- Weight of the bands. The segmented objects are influenced by the band with the highest weight. For example a vector file of buildings contour can be loaded and if a very high weight is attributed to the vector layer the segmentation procedure follows the buildings contours.
- The scale parameter is the most important. A scale factors higher correspond few objects constituted by a higher number of pixel. The scale factor allows to carry out the multi scale classification.
- Shape and colour. The algorithmic allows to choose how much the colour or the shape have to weight in the segmentation process.
- Compactness or smoothness. The algorithmic is able to provide a segmented image with size object more or less compact depending of the compactness value.

In the fig. 2 the segmentation result regarding the QuickBird image of Scopello is showed.

2.2 Fuzzy Logic Classification

Regarding the classification, the software supports different supervised classification methods. After the segmentation procedure, the fuzzy logic classification has been carried out.

Figure 2. Segmented Image (scale=15)

This procedure requests to define the membership functions. These functions calculate many parameters based both radiometric features and on the semantic relationships between the different objects and assign to each object a probabilistic value variable between 0 and 1. The classification process requests to define a class hierarchy. The hierarchy class contains the classification outline.

All membership functions can be composed using the most common *Boolean* operators (AND, OR, NOT, etc…). In order to highlight the capabilities of fuzzy logic classification the most common membership functions are showed:

Layer mean
In the pixel oriented classification the radiometric value of the single pixel assumes a main role. In the object classification the radiometric value of single pixel is replaced by the layer mean that it is defined how the arithmetic average of the *Digital Number* values of the pixels included into every object.

Ratio
For a generic band the Ratio function is the *layer mean* value of the examined band divided the sum of the layer means of all bands. For example, in the RGB image the vegetation can be classified using the ratio value for the green band.

Brightness
The brightness function represents the layer mean average of all bands. For example, the dark objects (sea, shadow, asphalt ecc..) are characterized by low value of brightness, instead the shining objects present a very high brightness value.

Nearest Neighbour (NN) e Standard Nearest Neighbour (SNN)
The nearest neighbour classifier allows to recognize similar objects. The used software is able to use another kind of nearest

neighbour, called Standard Nearest Neighbour. The SNN classifier is more flexible because it allows to define the parameters that the membership function has to use in order to evaluate the objects resemblance.

Relative Border to

It calculates for every object the shared perimeter percent with the surrounding objects and it assigns every object to the class with a value of shared border higher than a threshold value chosen by the user

In the fig. 3 an example of *layer mean* membership function is showed. This function is applied to the red band. In particular, in order to classify the red roofs of the RGB image acquired in 1979, this membership function has been used.

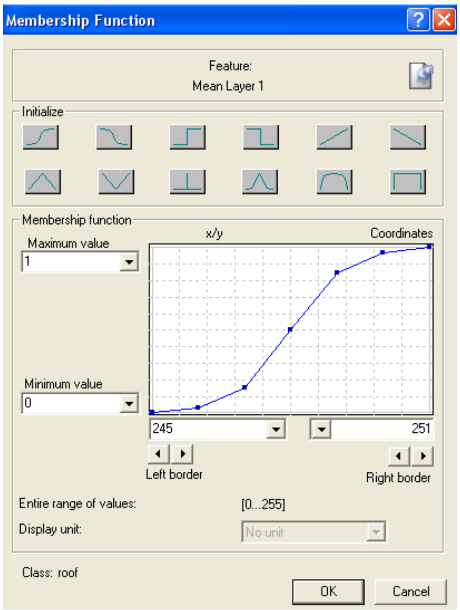


Figure 3. A membership function example

Due to the different geometric resolution of the six images, different segmentation scales have been adopted. The following table 1 and table 2 show the adopted parameters:

IMAGE	YEAR	Area	GSD [m]
Orthophoto	2000	Palermo	1
QuickBird	2002	Palermo	2.4
ADS40	2005	Palermo	0.6
Orthophoto	1979	Scopello	1
QuickBird	2002	Scopello	2.4
QuickBird	2006	Scopello	2.4

Table 1. GSD of the six images

IMAGE	WEIGHTS R/G/B/NIR	SCALE	SHAPE - COLOR	COMPACTNESS - SMOOTHNESS
Orthophoto	1/1/1/*	50	0.7 - 0.3	0.7 - 0.3
QuickBird	1/1/1/3	100	0.5 - 0.5	0.5 - 0.5
ADS40	*/1/1/2	40	0.5 - 0.5	0.7 - 0.3
Orthophoto	1/2/1/*	25	0.1 - 0.9	0.5 - 0.5
QuickBird	1/1/1/3	15	0.5 - 0.5	0.5 - 0.5
QuickBird	1/1/1/3	15	0.5 - 0.5	0.5 - 0.5

Table 2. Segmentation parameters

The class hierarchies and the membership functions have been defined in function of the type of image to analyse. For instance, the ortophoto and the photogram of '79 have not a near infrared layer, very useful for the vegetation classification. In this case, in order to individuate the vegetation, the ratio function on the green layer has been used.

The fig. 4 shows the class hierarchies regarding the classification carried out on the ADS40 image. This hierarchy class has been applied to obtain the classification of the ADS40 image showed in the fig. 5. Appling the ratio membership function on the red, green and blue layers the vegetation has been classified. In the second step of the classification, the vegetation has been distinguished in flourish and not flourish. In particular the layer mean of the NIR band is higher for the healthy vegetation. Using other membership functions like brightness, SNN and contest functions all image has been classified. In particular, for example, the shadow has been classified using the "*relative border to*" membership function. A membership value equal to one has been attributed to the not yet classified object with a percent of shared border with the building objects higher than 80 % .

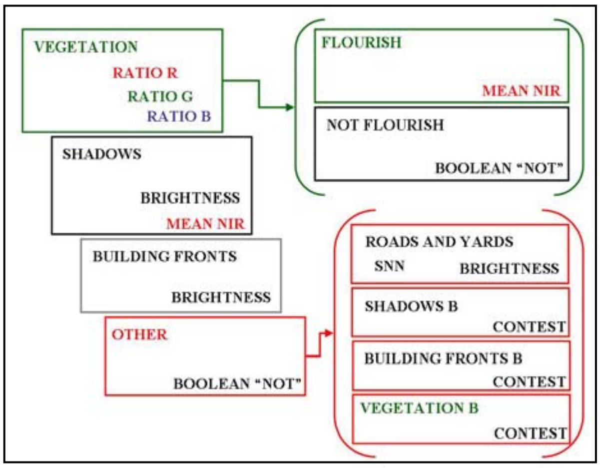


Figure 4. Class hierarchy (ADS40 image)

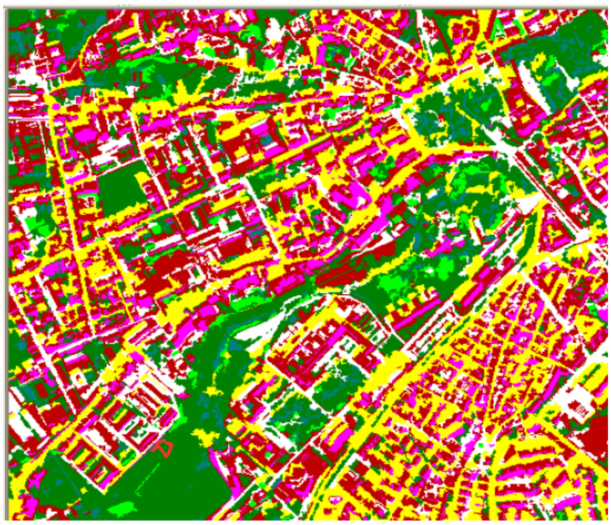


Figure 5. ADS40 Classification

2.3 Change detection experimentation

In order to estimate the increase of the constructed area from 1979 to 2006, the previous illustrated methodology has been applied to the Scopello area. The RGB and the QuickBird images, respectively acquired in 1979 and in 2006, have been georefered to the UTM WGS 84 cartography system.

An object classification, with the following class hierarchy, has been applied to the both images:

- Vegetation
- Bare soil
- Buildings
- Sea
- Shadows
- Roads and yards.

The following fig. 6 and 7 show the buildings class identified with the red colour.

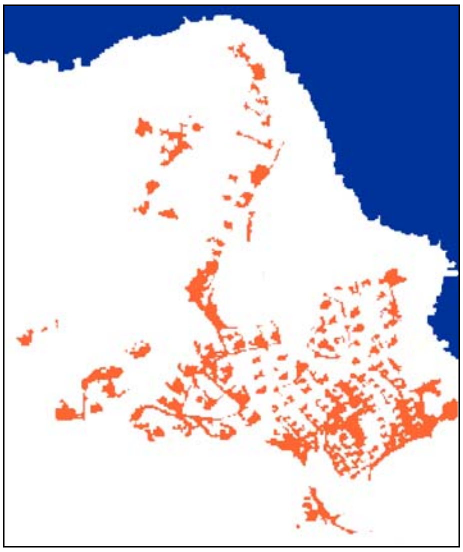


Figure 6. Buindings class in 1979 orthophoto

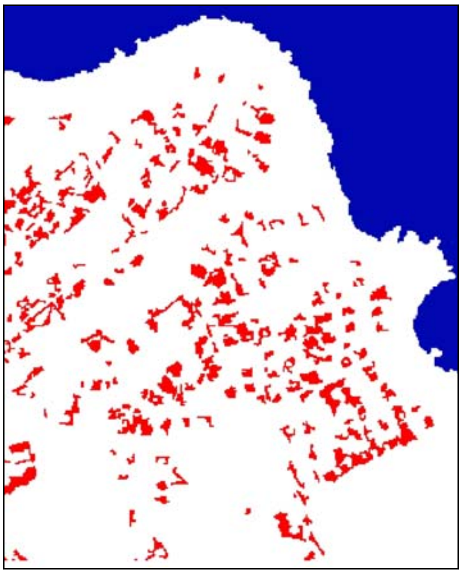


Figure 7. buildings class in 2006 QuickBird image

Both images (1979 and 2006), georefered to the same cartographic system, have been implemented in a GIS environment and for both images the same zone with the same surface has been examined. For both the images the percent of area classified like buildings, respect to the total area represented in the image, has been calculated. The results of this comparison have showed in the following table:

IMAGE	YEAR	BUILDINGS AREA/ TOTAL AREA * 100
ORTHOPHOTO	1979	7
QUICKBIRD	2006	10

Table 3. Change detection results

The table highlights an increment of 3 % of surface of the class building. This increment corresponds to about 10000 metres.
The building extraction is not precise because the methodology is not free of classification errors, but, how the User Accuracy shows (see chapter 3) , the classification accuracy for the “building” class is about 0.85. For this reason is reasonable to affirm that the increasing is precise in according with the User Accuracy value.

3. RESULTS VALIDATION

The software Definiens Developer allows to evaluate the accuracy of the produced classifications by a set of stability images and some tables of objective parameters. The fuzzy classification assigns a membership value to each object for different classes. The stability image of the classification represents the assignment ambiguity of the objects to the classes.

In order to evaluate the classification accuracy some samples have been identified and the confusion matrixes have been calculated for all the set of images.

It’s useful to describe some parameters that allows an objective valuation of the results.

The *Overall Accuracy* (OA) is a very important estimation parameter of the classification accuracy. It is the ratio between the number of the correct classified samples and the whole of the samples.

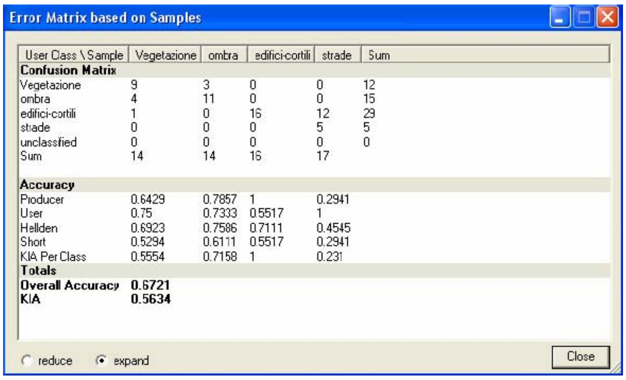
The *Producer Accuracy* (PA) estimates the correct assignment probability of the samples to the classes. It’s the ratio between the number of the identified samples and correctly assigned to a single class and the number of all samples assigned to the same class.

The *User Accuracy* is the ratio between the number of the correctly assigned samples and the number of the identified samples for the same classes

Another very interesting index is the *Hellden* (HA). This index is the harmonic medium between PA and UA indexes.

The just exposed analysis of the statistic data highlights that the best classification results are obtained from the images with a layer in the NIR wavelength (OA>0.8). In fact, in this case the extraction of vegetation class is easier because the vegetation has a very high reflectance value in the NIR.

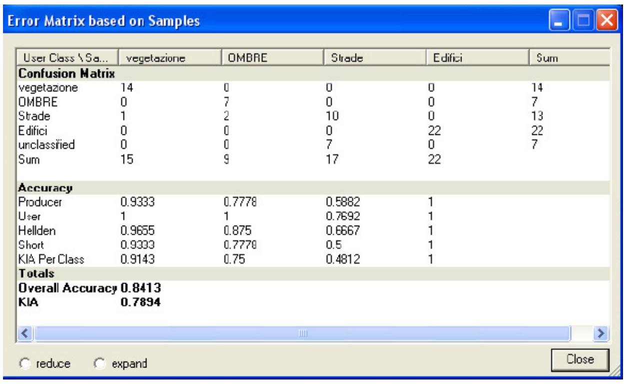
Regarding Palermo area, the following fig. 8, 9 e 10 show some examples of confusion matrix.


Error Matrix based on Samples

User Class \ Sample	Vegetazione	ombra	edifici-cortili	strade	Sum
Confusion Matrix					
Vegetazione	9	3	0	0	12
ombra	4	11	0	0	15
edifici-cortili	1	0	16	12	29
strade	0	0	0	5	5
unclassified	0	0	0	0	0
Sum	14	14	16	17	
Accuracy					
Producer	0.6429	0.7857	1	0.2941	
User	0.75	0.7333	0.5517	1	
Hellden	0.6923	0.7586	0.7111	0.4545	
Short	0.5294	0.6111	0.5517	0.2941	
KIA Per Class	0.5554	0.7158	1	0.231	
Totals					
Overall Accuracy	**0.6721**				
KIA	**0.5634**				

reduce expand Close

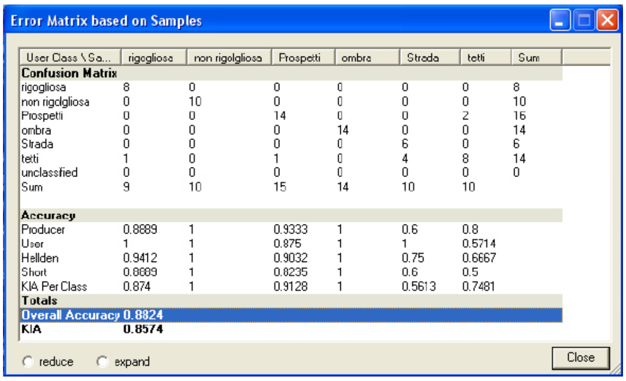
Figure 8. Confusion matrix – OA=0.67 (orthophoto Palermo)


Error Matrix based on Samples

User Class \ Sa...	vegetazione	OMBRE	Strade	Edifici	Sum
Confusion Matrix					
vegetazione	14	0	0	0	14
OMBRE	0	7	0	0	7
Strade	1	2	10	0	13
Edifici	0	0	0	22	22
unclassified	0	0	7	0	7
Sum	15	9	17	22	
Accuracy					
Producer	0.9333	0.7778	0.5882	1	
User	1	1	0.7692	1	
Hellden	0.9655	0.875	0.6667	1	
Short	0.9333	0.7778	0.5	1	
KIA Per Class	0.9143	0.75	0.4812	1	
Totals					
Overall Accuracy	**0.8413**				
KIA	**0.7894**				

reduce expand Close

Figure 9. Confusion matrix – OA=0.84 (QuickBird Palermo)


Error Matrix based on Samples

User Class \ Sa...	rigogliosa	non rigolgliosa	Prospetti	ombra	Strada	tetti	Sum
Confusion Matrix							
rigogliosa	8	0	0	0	0	0	8
non rigolgliosa	0	10	0	0	0	0	10
Prospetti	0	0	14	0	0	2	16
ombra	0	0	0	14	0	0	14
Strada	0	0	0	0	6	0	6
tetti	1	0	1	0	4	8	14
unclassified	0	0	0	0	0	0	0
Sum	9	10	15	14	10	10	
Accuracy							
Producer	0.8889	1	0.9333	1	0.6	0.8	
User	1	1	0.875	1	1	0.5714	
Hellden	0.9412	1	0.9032	1	0.75	0.6667	
Short	0.8889	1	0.8235	1	0.6	0.5	
KIA Per Class	0.874	1	0.9128	1	0.5613	0.7481	
Totals							
Overall Accuracy	**0.8824**						
KIA	**0.8574**						

reduce expand Close

Figure 10. Confusion matrix – OA=0.88 (ADS40)

4. REFERENCES

References from Journals:

Im. J., Jensen, J.R., Tullis, J.A.,2008. Object-based change detection using correlation image analysis and image segmentation. International Journal of Remote Sensing, Volume 29, Issue 2 January 2008 , pages 399 – 423.

Addink, E.A., De Jong, S.M. and Pebesma, E.J.,2007, The importance of scale in object-based mapping of vegetation parameters with hyperspectral imagery. Photogrammetric Engineering & Remote Sensing 73(8), pp.905-912.

Green, K., Lopez, C.,2007. Using Object-Oriented Classification of ADS40 Data to Map the Benthic Habitats of the State of Texas. Photogrammetric Engineering & Remote Sensing Journal of the American Society for Photogrammetry Engineering and Remote Sensing, Volume 73, no.8, August 2007, pages 861-865.

Lucas, R., Rowlands, A., Brown, A., Keyworth, S., Bunting, P:,2007. Rule-based classification of multi-temporal satellite imagery for habitat and agricultural land cover mapping. ISPRS Journal of Photogrammetry and Remote Sensing, Volume 62, Issue 3, August 2007, Pages 165-185.

References from Other Literature:

Forghani, A., Cechet, B., Nadimpalli, K.,2007. Object-based classification of multi-sensor optical imagery to generate terrain surface roughness information for input to wind risk simulation. Geoscience and Remote Sensing Symposium. IGARSS 2007. IEEE International. Barcelona, Spain.

Groom, G., Krag Petersen, I., Fox, A.D.,2007. Sea bird distribution data with object-based mapping of high spatial resolution image data. Challenges for earth observation - scientific, technical and commercial, Proceedings of the RSPsoc Annual Conference 2007, September 11-14, 2007, Newcastle University, Nottingham (UK), The Remote Sensing and Photogrammetry Society, paper 168.

Argialas, D., Tzotzos A.,2006. Automatic Extraction of Physiographic Features and Alluvial Fans in Nevada, USA from Digital Elevation Models and Satellite Imagery through Multiresolution Segmentation and Object-oriented Classification. Proceedings of ASPRS 2006 Annual Conference, Reno, Nevada; May 1-5, 2006.

Barlow, J., Franklin, S., Martin, Y.,2006. High Spatial Resolution Imagery, DEM Derivates, and Image Segmentation for the Detection of Mass Wasting Processes. Photogrammetric Engineering & Remote Sensing. Vol. 72, No. 6, June 2006, pp. 687-692.

Brooks, C.N., Schaub, D.L., Powell, R.B., French, N.H., Shuchman, R.,2006. Multi-temporal and multi-platform agricultural land cover classification in Southeastern Michigan. Proceedings of ASPRS 2006 Annual Conference, Reno, Nevada; May 1-5, 2006.

References from websites:

Definiens website. http://www.definiens.com/