An application of object-oriented analysis to very high resolution satellite data on small cities for change detection.

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Abstract: - The aim of this contribute is to examine an application of Object Oriented Image Analysis on very high resolution data, particularly on Ikonos images - multispectral and panchromatic – of Bagnara Calabra, in the province of Reggio Calabria. Our objectives are to show as an automatic analysis – with a minimal manual participation - can get a good classification also in presence of high and very high resolution data of small cities, where higher is an error possibility, and as is possible to find new constructions and eventual building abuses through the comparison of satellite data transformed in polygons, examining them through a procedure distinguishing in common and not common to the two photos.

Key-Words: - Object-Oriented Image Analysis - Morphological Based Segmentation – Fuzzy Classification - eCognition

1 Introduction

The pixel-oriented analysis of satellite data as main limit has the acknowledgment of semantic low level information, as the amount of energy emitted from the pixel, while the context does not assume any role. In the object oriented analysis the semantic level is raised: relation rules join space are added, topological information and statistics and so the context is defined. Recognition is based on concepts of Mathematical Morphology applied to the image analysis and elements of Fuzzy Logic for classification. In the explained example was used the software eCognition of Definiens Imaging GmbH, that operates a segmentation of the entire scene on more levels. The segmentation multiresolution obtains the automatic creation of vectorial polygons, directly extracted from the raster (with the remarkable advantage of having therefore a perfect coincidence in the superimposition on raster) and subsequently the final classification predisposing an adapted hierarchy of classes that hold account of the relations between the produced segmentation levels.

2 Multiresolution Segmentation

It is a bottom up region-merging technique starting with one-pixel objects. In subsequent steps, smaller image objects are merged into bigger ones. Throughout this clustering process, the underlying optimization procedure minimizes the weighted heterogeneity *nh* of resulting image objects, where *n* is the size of a segment and *h* an arbitrary definition of heterogeneity. In each step, that pair of adjacent image objects is merged which stands for the smallest growth of the defined heterogeneity. If the smallest growth exceeds the threshold defined by the scale parameter, the process stops. Doing so, multiresolution segmentation is a local optimization procedure.

Spectral or color heterogeneity is the sum of the standard deviations of spectral values in each layer weighted with the weights for each layer are used:

$$h_s = \sum_{c=1}^{q} w_c \sigma_c \quad (1)$$

where h_s is spectral heterogeneity; q = bands number; σ_c = standard deviation of *digital number* in c spectral band; w_c = weight assigned to c spectral band.

But the exclusive minimization of spectral heterogeneity leads to branched segments or to image objects with a fractally shaped borderline. This effect is even stronger in highly textured data, such as radar data.

For this reason it is useful in most cases to mix the criterion for spectral heterogeneity with a criterion for spatial heterogeneity, in order to reduce the deviation from a compact or smooth shape.

Heterogeneity as deviation from a compact shape is described by the ratio of the border length l and the square root of the number of pixels forming this image object.

$$h_{g\_smooth} = \frac{l}{\sqrt{n}} \quad (2)$$

where: h_{g_smooth} = fractal factor of spatial heterogeneity; l = border length; $\boldsymbol{n}$ = number of pixels of the image object..
The second is a compactness f*actor* ($h_{g\_compact}$) that depends from dimensional ratio of polygon axis:

$$h_{g\_compact} = \frac{l}{b} \quad (3)$$

where: $h_{g\_compact}$ = compactness factor; l = berder length; b = the shortest possible border length given by the bounding box of an image object parallel to the raster.

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The segmentation algorithm proceeds fusing adjacent polygons beginning from every pixel of the image until the change of observable heterogeneity between the two original polygons and the new generated polygon does not exceed the threshold defined from the customer (scale factor). If the change of heterogeneity already does not exceed the threshold defined the fusion is effectively realized, otherwise the two polygons remain separated. Heterogeneity difference (overall fusion value) between resultant object and the two original polygons is:

$$f = w_f \Delta h_s + (1 - w_f)\Delta h_g \quad (4)$$

where: f = *overall fusion value*; w_f = the user defined weight for color (against shape). For w can be chosen a value between 0 and 1, while 0 and 1 is also possible: for w_f =1 only the shape heterogeneity is valued, and for w_f = 0 only the color heterogeneity is valued.
The difference of spectral heterogeneity (Δh_s) between the resultant polygon and the two polygons before the merge is:

$$\Delta h_s = \sum_{c=1}^{q} w_c \left[n_{merge}\sigma_{merge_c} - \left(n_{obj1}\sigma_{obj1_c} + n_{obj2}\sigma_{obj2_c} \right) \right] \quad (5)$$

where: n_{merge} = resultant polygon pixel number; σ_{mergec} = standard deviation of *digital number* in c -spestral band of the resultant polygon; n_{obj1} = pixel number in the first of the two polygons before the merge; σ_{obj1c} = standard deviation of *digital number* in c -spestral band of the first of the polygons before the merge; n_{obj2} = pixel number in the second polygon before the merge; σ_{obj2c} = standard deviation of *digital number* in c -spestral band of the second polygon before the merge.

Again, the change in shape heterogeneity (Δh_g) caused by the merge is evaluated by calculating the difference between the situation after and before the merge. This results in the following methods of computation for smoothness and compactness:

$$\Delta h_g = w_g \Delta h_{g\_compact} + (1 - w_g)\Delta h_{g\_smooth} \quad (6)$$

w_g being the user defined weight for smoothness (against compactness). For w can be chosen a value between 0 and 1, while 0 and 1 is also possible: for w_f =1 only smoothness is valued, and for w_f = 0 only compactness is valued.

$$\Delta h_{g\_compact} = n_{merge}\frac{l_{merge}}{\sqrt{n_{merge}}} - \left\{ n_{obj1}\frac{l_{obj1}}{\sqrt{n_{obj1}}} + n_{obj2}\frac{l_{obj2}}{\sqrt{n_{obj2}}} \right\} \quad (7)$$

$$\Delta h_{g\_smooth} = n_{merge}\frac{l_{merge}}{b_{merge}} - \left\{ n_{obj1}\frac{l_{obj1}}{b_{obj1}} + n_{obj2}\frac{l_{obj2}}{b_{obj2}} \right\} \quad (8)$$

n being the object size, l the object perimeter and b the perimeter of the bounding box
The choice of the scale factor allows to calibrate the largeness of the resultant polygons, and its definition is tied to the cartographic scale reference that the customer must obtain. The segmentation process is multiresolution because, beginning from a same image, is possible to generate various hierarchical levels of polygons with various scale factors. Reducing the scale factor the polygons generated become more and more small because smaller it must turn out the spectral variability intra-polygons, and whereas increasing the scale factor. The particularity of the multiresolution consists in the existing connection between the polygons of the various hierarchical levels of the segmentation. When a first level of polygons is generated is possible to generate n new upper hierarchical levels if the scale factor is larger (greater polygons) or n inferior levels if the scale factor is smaller (smaller polygons). Polygons of inferior hierarchical level are always geometrically consisting with those of upper hierarchical level, so every polygon of inferior level only belongs to one polygon of upper level. All the polygons of the various levels of segmentation constitute an only database in which are all the existing connections between the polygons of the same or various hierarchical levels. For every polygon are therefore known the polygons in contact on the same hierarchical level, the polygons that constitute an eventual inferior hierarchical level and the polygon in which it is contained in the eventual upper hierarchical level
The procedure for the realization of a good

classification passes through a fine-resolution segmentation creating more segmentation levels, with the parameters indicated in the following table holding account of characteristics of the IKONOS dataset with availability of panchromatic:

Segmentation level	Bands					Scale	Criteri di omogeneità			
									Shape Settings	
	PAN	RED	GREEN	BLUE	NIR		Color	Shape	Smoothness	Compactness
Preliminar	Yes	No	No	No	No	4	0.8	0.2	0.9	0.1
Level I	No	Yes	Yes	Yes	Yes	4	0.8	0.2	0.9	0.1
Level II	No	Yes	Yes	Yes	Yes	10	0.8	0.2	0.9	0.1
Level III	No	Yes	Yes	Yes	Yes	1	0.8	0.2	0.9	0.1
Level IV	No	Yes	Yes	Yes	Yes	45	0.7	0.3	0.2	0.8

Table 1

3 Change detection

The aim of the application is to find new constructions and eventual building abuses through the comparison of satellite data of the same area in various periods. The buildings of the two photos are found and transformed in polygons, then examined by a procedure distinguishing them in common and not common to the two photos. Procedure for the comparison is made up substantially of two steps.

1, Production of ASCII data, readable by program COMPOL (reading polygons by READDXF. Program);

2, Comparison by COMPOL and production of a file containing all the polygons, distinguishing in common and not common to the two photos.

The programs developed for the comparison procedure are:

- WWDXF.EXE program that, beginning from or more files obtained by READDXF as in Fig. 1, produces one or more files containing polygons.

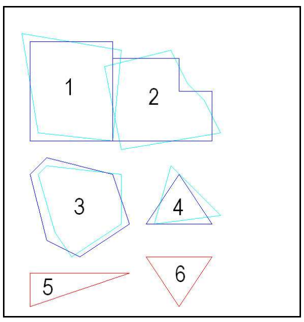


Fig.1:

The input data for the program must be contained in files ASCII produced with whichever text editor. These files must have the following structure:

- Name input vector file (i.e. BV13.DXF);
- Name output ASCII file (i.e. BV13.POL);
- .....

Name input vector file (i.e. BV44.DXF);

Name output ASCII file (i.e. BV44.POL);

- MODPO.EXE program that, beginning from one or more files obtained by READDXF as in Fig. 1, produces one or more files of the same type, eliminating some polygons in a percentage chosen from the customer (i.e. 10% in less) and varying every vertex coordinates position for the remaining polygons of an accidental value, until a threshold chosen from the customer, with the aim to simulate a situation of buildings "previous" to that available one. This, as better it will be described later on, has been made in the case in study. The data of input for the program must be contained in files ASCII that can be produced with whichever text editor. These files must have the following structure:

- Reduction percentage of the polygons for every file (i.e. 10, as 10% of reduction);
- The maximum polygons coordinates shifting in X and Y, in order to simulate imprecision in the survey of same polygons (i.e. 0,2, as 0,2 m of shifting);
- Name input ASCII file (i.e. BV13.POL);
- Name output ASCII file (i.e. BV13.POL);
- .....
- Name input ASCII file (i.e. BV44.POL);
- Name output ASCII file (i.e. BV44.POL);

- Program DATI.EXE that prepares the input data files for the comparison procedure. In fact the requested input data can be so much that the procedure could have to be repeated more times before reaching the wished result, it has been valued useful to develop this program that produces ASCII files containing the input data for READDXF and COMPOL. The produced files are DATDXF.INP for READDXF and DATCOM.INP for COMPOL.

- Program COMPOL for the comparison of the polygons of the two scenes. Input of the data of the polygons on rows ASCII produced from READDXF; The input data are supplied by files DATCOM.INP produced by DATI.EXE program.

It is necessary to specify that all the other programs have been realized in absence of the second photo, for simulating behaviour with the use of those programs.

The comparison of the polygons presupposes that the two photos must have the same scale and the same geographic reference, so the two polygons that refer to the same building in the two photo have the same coordinates. The method for the polygons

comparison in the two photos consists in considering a polygon at the time of the first photo and to compare it with everyone of the polygons of the second photo. The examined polygon in the first photo is comparable with that chosen one of the second photo if the vertexes number of the two polygons is the same one. In the case of equal number of vertexes, the comparison operates on the coordinates of the polygons' vertexes. For this purpose the sequence of the polygons vertexes must be covered in the same direction, i.e. in a clockwise direction. Therefore the program supplies to put all polygons vertexes of the two photos in a clockwise direction. The result of this order is registered on file, whose name is chosen from the customer.
Being POLI1 and POLI2 respectively a polygon of the first photo and that chosen one of the second photo for the comparison, both with vertexes ordered in the clockwise direction. Leaving from the first apex of POLI2 one looks at if a POLI1 apex exists that coincides with it within one equal or inferior distance to the tolerance demanded from the program and supplied from the customer. It must be considered the tolerance because, for several reasons, the survey of polygons vertexes can be slices from imprecision. Without the tolerance control the polygons could also not exceed the control of equality referring to the same perimeter in the two photos. If an apex coinciding within the tolerance exists, in sequence from that one is confronted every vertex of POLI1 and POLI2. If all vertexes coincide, always within the tolerance, polygons POLI1 and POLI2 are equal and are in this way "marked". Going to the next POLI2 the procedure is repeated, excluding from the comparison the polygons of the first photo already marked as equal. If a single apex does not coincide the polygon is not equal and it is passed to the next POLI1 for the comparison with POLI2. Exhausting all the polygons of the first photo without finding an equal one to POLI2, this is "marked" as not equal and it is passed to the successive polygon of the second photo. The procedure is repeated until to exhaustion of all the polygons. To the term of the procedure all the polygons of the two photos are marked as equal or not equal.
Figure 2 shows the complete result of the comparison between the two series of polygons. The colours attributed automatically from COMPOL program to the layers containing polygons are:
Layer SI1 (equal polygons photo 1) blue;
Layer NO1 (polygons not equal photo 1) red;
Layer SI2 (equal polygons photo 2) cyan;
Layer NO2 (polygons not equal photo 2) magenta;

In foreground (Fig. 2) are layer SI1 and NO2; therefore mostly are blue polygons (equal in the two photos) and magenta polygons (not equal in photo nr. 2, that is new regarding the 1 or with vertexes not coinciding).

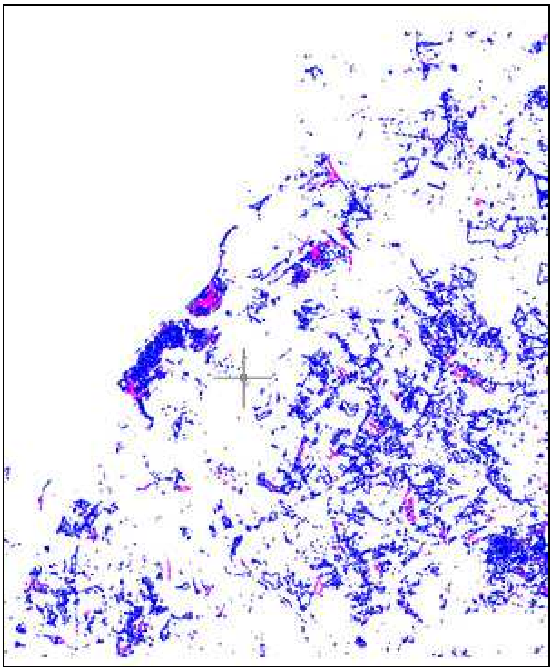


Fig.2: The results of the comparison.

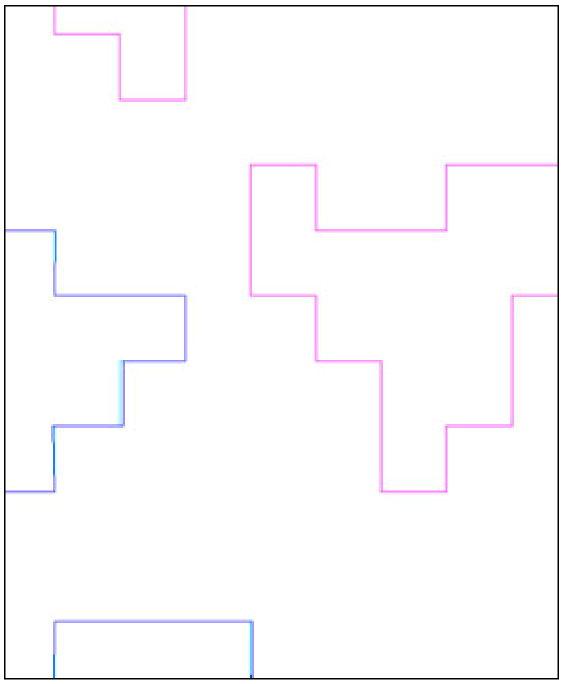
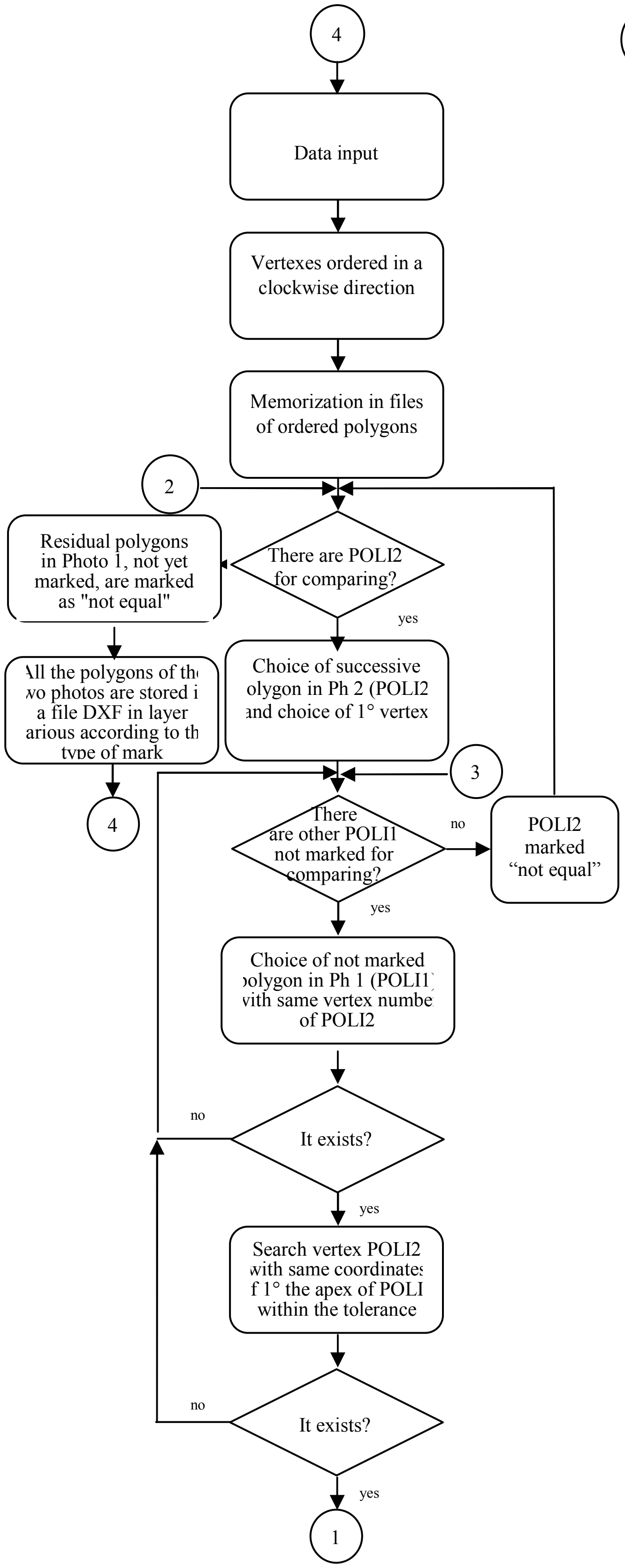
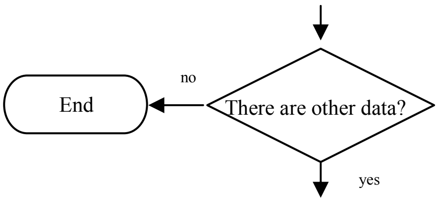


Fig.3: A particular of the comparison.

The figure 4 shows the Flow-chart of the COMPOL program.





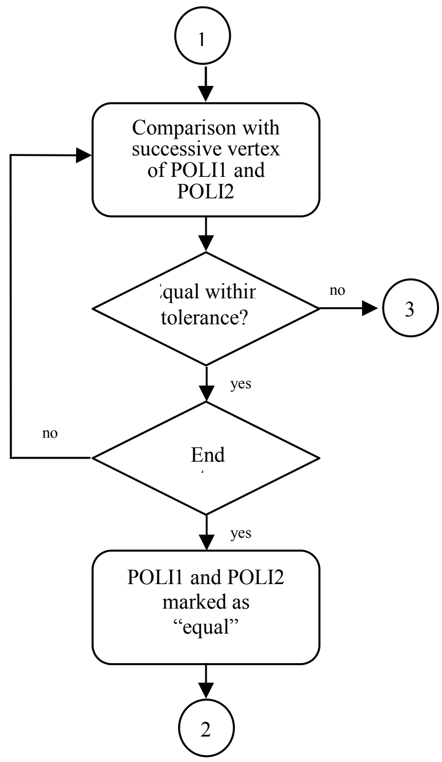


Fig.4: Flow-chart of the COMPOL program

4 Conclusion

Classification and multiresolution segmentation object-oriented techniques distinguish structural methodology from classic spectral analysis. The pixel-oriented analysis increases ambiguity in statistics definition of the land use classes increasing resolution in remote sensing images. With object-oriented analysis is instead possible to using better information from remote sensing data with an immediate integrability in the GIS allowing the direct realization of vectorial maps, the used software, eCognition of the Definiens Imaging, that it applies to concepts of Mathematical Morphology and principles of logic fuzzy, organizes the data hierarchically and it concurs to arrange of different typology, integrating also raster and vectorial data. The possibility to introduce rules for the location of the context and the relations between the objects meaningfully increases the acknowledgment possibility automatic rifle of the objects on the land surface. Also imitating therefore the approach followed in manual photo interpretation, such methodology exceeds the limits of a subjective classification, by making a process that can be reproduced and homogenous, and exceeds the problems of the traditional classification techniques.

After the segmentation, a procedure for change detection allows to find new constructions and eventual building abuses through the comparison of satellite data.

Moreover all the automated procedure can supply the comparison image polygons directly on GIS leaving from two remotely sensed images.

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