AUTOMATIC DETECTION OF MAN – MADE STRUCTURES IN BIG SIZE MOSAICS OF SPACEBORNE IMAGES.

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Abstract

This paper deals with a study carried out by Centro di Ricerca Progetto San Marco (CRPSM) in the mainframe of its involvement in the EU funded NoE GMOSS. The CRPSM has developed some techniques able to automatically extract potential made-man structures which could be present in a complex image, that's in a "mosaic of images". In particular, the considered satellite images mosaic has very big sizes (about 5 GB, in the considered cases, corresponding to 40 ASTER images) and the main goal of this research is to develop a technique that allows the automatic detection of given objects of interest.

The purpose described above is obtained by using an algorithm based on the theory of Mathematical Morphology. This algorithm has been developed exploiting the functions available in the Matlab Image Processing Toolbox. The mosaic is automatically subdivided in smaller frame, in order to increase the efficiency of the processing chain, then, using suitable structuring elements, any object of a given shape, size and orientation can be detected. At the end of the process the frames with the detected object are recombined in a mosaic. The removal of not interesting objects can be carried out exploiting the geometric characteristics of them (area, length, width, solidity, centre of gravity, etc), since these information are gathered during the object detection process.

The efficiency and robustness of the method is demonstrated reporting the results obtained in the processing of images mosaics of the Libya/Chad and Pakistan/India (Kashmir region) borders.

1. Introduction

One of the topics of the GMOSS (Global Monitoring for Stability and Security) project, in which the CRPSM is involved, regards the monitoring of borders. Since this project is mostly based on the exploitation of satellite images and a quasi-continuous border monitoring at suitable resolution (10 m) is presently unrealizable, using the observation system currently orbiting around the Earth, this monitoring consists in a change detection analysis based on time series of images acquired with a certain time step. In general, the border monitoring requires the processing of huge satellite image mosaics looking for new structures or "tracks" evidencing or allowing to foreseen particular events (immigration flux, troops concentration, etc). The problem of analyzing huge dimensions images looking for something with unknown size, position and spectral characteristics cannot be in general afforded by using manual process. Then, it fully complies with the Image Information Mining purposes. In fact, satellite images applications involving analysis like: change detection, global monitoring, disaster management support, etc. and the continuous increase of the amount of available images and of the EO sensors, require new techniques and tools for extracting and managing the required information. The difficulties in developing a technique as automatic as possible, requiring a reduced human participation to the image processing, mostly reside in the variety of applications dealing with the processing of huge amount of data. In general some applications like, for instance, the monitoring of a water body can be performed just exploiting the often distinctive spectral characteristics of water to detect the absence of clouds on the area of interest extracting, from the database, the images where the area of interest is present and observable. More complicate applications are those where the object or feature of interest is less spectrally well characterized and the detection has to rely mostly on its size and shape. In this case a combination of spectral and object-oriented techniques has to be used.

Typical examples of these cases are those with which the GMOSS project is dealing, like: monitoring large areas for treaty control, sensitive structure monitoring, particular feature detection. In fact, in these cases the monitoring imposes a continuous processing of a possible large images dataset. This problem is mostly experienced in the case of very high resolution satellite imagery that is characterized by a high number of pixels covering a relatively limited area of the earth (10x10 km for Ikonos), this means that to cover the ground area corresponding to a single Landsat image 340 Ikonos images are needed.

Notwithstanding the effort of aerospace agencies (like ESA, NASA, etc) to develop new information mining systems, today, earth observation data are retrieved from archives based on attributes such as geographical location, time of acquisition and type of sensor. An example of the new content-based remote sensing image information mining methods is represented by the KIM/KES project [1], [2]. This project, funded by ESA, has the objective of experimenting knowledge driven information mining for access to the Earth observation image archives (KIM, Knowledge-driven Information
 Mining) based on automatic identification and extraction of general and robust primitive features from images (e.g., texture, geometrical shapes, and spectral signature), together with methods for unsupervised clustering and summarisation of the information to be used as index in a database of images. A prototype was developed (KES, Knowledge Enabled Services). The KIM/KES prototype is based on two steps: a first one includes a computationally intensive algorithms for off-line data ingestion in the archive, image feature extraction, and indexing and a second one providing the user with a graphic interface that manages the information fusion for interactive interpretation and the image information mining functions [2]. Many new concepts have been developed and prototyped aiming to ease and to accelerate the access to the imagery also through their information content [3]. Since the images used in our studies, for the moment, are selected from the archive using the classical coordinates and time based retrieving methods we have to compensate the absence of further information on the image content developing ‘ad hoc’ algorithms able to extract, as automatically as possible, the features or object of interest. Thus, we don’t know if the methods hereafter presented can be implemented in an operational software devoted to efficiently manage extended archives of remotely sensed images, made available by aerospace agencies, but they represent our solution, as user, to the problem of processing large amount of satellite images.

In particular, in this study, in the mainframe of the GMOSS project we present some techniques developed at CRPSM able to extract automatically potential man-made structures, which could be present in a complex image, that’s in a “mosaic images”. In particular, since the mosaic has very big sizes (about 5 GB, in the considered case, corresponding to 40 ASTER images), the main goal of this research is to develop a technique that allows the automatic detection of interesting objects. The algorithms developed at CRPSM rely on Mathematical Morphology theory [4], [5], [6], [7], [8]. In the paper a couple of examples of the results obtainable by applying this technique, developed in a Matlab environment [9], [10], to similar problems but in different scenario are provided. In fact, the method has been applied to the problem of detecting man-made structures in a deserted area like the Libya/Chad border and in a rather developed area in Kashmir, at Pakistan/India border.

2. Images and methods

The methods herein described have been applied on ASTER sensor images. This sensor presents a good compromise between its spatial resolution and the size of the object we are looking for. In particular, we are interested in detecting man made structures like, roads, airports, etc. Only the first 3 VIS/NIR channels of this sensor, having a spatial resolution of 15 m are used. The sensor provides images in 14 spectral channels of these the 6 SWIR have a spatial resolution of 30 m and the 5 TIR channels have a spatial resolution of 90 m. The images have been downloaded by a NASA website. Two big mosaics of ASTER images have been

![Figure 1. Libya/Chad border considered as an example in this paper. The superimposed tracks pattern corresponds to that of SPOT 4 and 5.](image1)

![Figure 2. One of the ASTER images mosaics, covering the Libya/Chad border, on which the analysis has been carried out. It is made of 20 images.](image2)

considered, one is covering the Libya/Chad border and the other one refers to the Pakistan/India (Kashmir region) border. Fig. 1 shows the extent of the area of interest in Africa. The red square shows the part of mosaic reported in Fig. 2. To cover all the border about 40 ASTER images are needed. Fig. 3 shows a part of the mosaic covering the Kashmir area around the Pakistan/India border. The difference in the landscape characteristics, with respect to the previous case, can be clearly observed. The method proposed by CRPSM, to extract the object of interest, relies on an object-oriented approach that is based on a theory for the analysis of spatial structures called Mathematical Morphology (MM). It is called
morphology because it aims at analysing objects shape and size. It is mathematical in the sense that the analysis is based on the set theory, integral geometry, and lattice algebra.

Mathematical morphology has proven to be a powerful image analysis technique. In mathematical morphology, two-dimensional grey tone images are seen as three-dimensional sets by associating each image pixel with an elevation proportional to its intensity level. An object of known shape and size, called the structuring element, is then used to investigate the morphology of the input set. This is achieved by positioning the origin of the structuring element to every possible position of the space and testing, for each position, whether the structuring element either is included or has a non-empty intersection with the studied set. The shape and size of the structuring element must be selected according to the morphology of the searched structures. The basic idea of this study is to extract, in automatic way, information from big size images (like mosaics) exploiting not only the spectral characteristics, but also the morphological characteristics in order to simplify the images analysis by the users.

3. Automatic extraction of man-made objects.

The purpose described above is obtained by using an algorithm comprised of the following steps (see Fig. 4):

- the RGB image is converted to a grey image since, as we know MM (on which our algorithm is based) is only applied to grey tone or binary images. The grey tone image can be obtained selecting the more suitable band, or applying a transformation technique like PCA (Principal Component Analysis) or a dedicated function like the one available in Matlab Image toolbox called rgb2gray. This function converts a RGB image to greyscale image by eliminating the hue and saturation information while retaining the luminance. The result of this function is shown in Fig. 5. That image represents a mosaic of 10 ASTER scenes (covering part of the Libya-Chad border), it is 242 MB in size. The grey tone image is pre-processed in order to highlight the required objects (for example, tracks) with respect to the background.

![Figure 3. Part of ASTER images mosaic of the Pakistan/India border (Kashmir region) on which the analysis has been carried out.](image)

![Figure 4. Schematic diagram of the steps involved in the man-made structures detection procedure.](image)
an airport or similar objects, using a suitable structuring elements, a precise angular scansion of the image can be performed. The scene, can be analyzed by using a probe image (structuring element) having the expected characteristics (length, width, inclination) of the “human-structure” that we are seeking. The original shape and size of the interesting objects can be re-obtained by means of the morphological reconstruction process. This allows the reconstruction of these objects using the marker image (represented by the processed frame) on the mask image which is obtained by a binarization process of the marker. The most important think we have to emphasize is that these thresholds are computed in an entirely automatic way, by using image depending characteristics, eliminating the need of a human-operator.

- The previous process is repeated for every sector. Finally, all the processed sectors are reorganized in a single image equal, in size, to the original one.
- Generally, the processed image presents several objects: our objects of interest plus some unwanted objects. These latter can be removed by using a morphological filtering which, exploiting the characteristics of “sought objects”, allows to meet the final purpose.

4. Results

The technique above described has been applied to the following problems:
- detection of man-made structures in a deserted area (Libya/Chad border) when no information are available on the spectral characteristics of the target object;
- detection of airstrips in inhabited areas in the Kashmir region (Pakistan/India border).

In both cases, due to the size of the images covering the area of interest, made of a mosaic of ASTER scenes, and the limits in the size of images manageable by Matlab, the processing chain foresees the subdivision of the mosaic in a series of smaller images which can be consecutively handled by the Matlab based algorithm.

Figure 5. ASTER mosaic: grey image obtained as described in the text. The red square indicates the airport position.

Figure 6. Several objects found after processing.

Figure 7. Remaining objects after filtering.

Figure 8. Final image with superimposed the found objects.
The cases considered exhibit very different background conditions then they represent suitable test cases to verify the performances of the developed methods. In both cases, the objects of interest are detected correctly using, together with the Mathematical Morphology theory, some ancillary information regarding the expected shape and size characteristics of the target. Of course, in the Kashmir case these information are needed to discriminate the airstrips from roads, rivers, irrigation channels and so on.

Fig. 6 shows the binary image obtained after the fragmentation and processing of the original image, as the output of the processing chain. Not interesting objects are removed exploiting the geometric characteristics of them (area, length, width, solidity, centre of gravity, etc). These properties, used like filters, enable us to separate “good objects” from “false” (Fig. 7).

The final image, where only the required object is displayed, can be superimposed to original image. In this way, the structures of interest can be emphasized (Fig. 8). In general, we can state that the algorithm is simple and robust but, in order to increase its efficiency, when big mosaics are used, a considerably powerful hardware is required. Fig. 9 shows a detail of the mosaic of Fig. 2, covering the Kashmir region, corresponding to a selected sector, where one of the targets is located. As it can be observed the background is very different from the other test case. The detection procedure has been applied to the whole mosaic and all the existing airstrips have been detected.

Fig. 9C represents the result of the processing applied to the sector shown in Fig. 9A. It is evident as, at the end of the process, before of the application of the morphologic filters, the image exhibits besides the objects of interest several unwanted elements (Fig. 9C) with size and shape very different from the sought ones (airports). This phenomenon is due to the fact that the image probe (structuring element), used for each mosaic sector, can be contained in structures very different from the desired ones, and as a consequence, the object morphological reconstruction process highlights them. At this point, the addition of a further step, based on morphological filters exploiting the characteristics of the required objects (length, shape, etc.) can help in discriminating them. The morphological filters can be applied, exploiting the ancillary (a priori) information available on the object of interest, since each object detected in the image can be described in terms of characteristics parameters like shape, length, thickness, centre area, etc. Fig. 10 and 11 show the result obtained by applying the same procedure to other fractions of the mosaic.

5. Conclusions

In the mainframe of the EC funded GMOSS project the CRPSM is facing problems related to the national border monitoring based on satellite images. This topic drives the development of automatic techniques able to
detect man-made infrastructures analyzing big size mosaics of satellite images. In order to meet this requirement a technique based on the exploitation of Mathematical Morphology has been applied. In particular, this technique has been used to detect airports/airstrips on areas characterized by very different background/scenarios in order to verify its robustness. A minimum number of ancillary information (morphological characteristics) like the plausible size or shape of the required target are needed to avoid false detection. The technique has been applied on ASTER images of the Libya/Chad and Pakistan/India borders. The results show that a general procedure, applicable at both scenarios, notwithstanding they are very different, can be developed. In fact, in a case (Libya/Chad) the area under study presents only a single man-made structure. Whereas in the second case (Kashmir region) different structures, even similar like roads, channels etc., are present in the same image.

Further studies will regard the generalization of the method to other structures and the development of a software able to assist the user in the extraction of these object from large size images.

6. References


