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An algorithmic technique by using aerial image processing

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Abstract
The aim of this study is to use different image analysis and processing methods in order to extract information content needed to update large scale maps. Recently available high resolution satellite imagery attracted mapping communities to shift their focus from aerial photographs to satellite imagery. Digital aerial cameras, recently introduced to aerial photography, have much higher radiometric resolution than traditional film aerial cameras do. Thus, even though the spatial resolution is almost the same level, a digital aerial camera can capture much clearer images of the earth surface than a film camera does. This paper highlights the capability of digital aerial images in detecting various damages due to earthquakes. In the recent earthquakes in Japan, such as the 2004 Mid-Niigata earthquake and the 2007 Off-Mid-Niigata earthquake, the affected areas were captured by digital aerial cameras as well as by analog aerial cameras and high-resolution satellites. In this paper, the quality of digital aerial images is first compared with scanned analog photos. Then the digital aerial images taken before and after the 2007 Off-Mid-Niigata earthquake are used to detect building damage. Both the pixel-based classification and the object-based classification are conducted. Debris of collapsed buildings is extracted correctly from the digital image processing.

Keywords: aerial image processing, image fusion, digital aerial image

Introduction
The analysis and the interpretation of aerial or satellite images constitute an important field of scientific research and study. Constructing and updating topographic maps, cadastral plans updates, discovery of forest diseases, and the localization of pollution zones are some applications. But the processing complexity required means that some particular problems must be resolved [1, 2]. Among these problems are the roads extraction, road networks, forests, vegetation, habitation, etc., for updating maps [3]. Many techniques are applied separately depending on the problem particularity. We cite here techniques based on homogenous zones and those based on discontinuities. The flat shapes don't really have an importance in the recognition phase. The third-dimensional information can concern mountains, high rises, etc. Here the surrounding areas of the recognition are based on simple objects modeling: an object is represented by a set of sights generated in a learning phase. Various methods are described in [4, 5]. In this domain we use various and different methods for information extraction and especially objects classification and recognition [6–10]. To bene- fit from all techniques, we plan to combine them in an efficient way. The objective of our work is to implement internal object representations facilitating the task of images processing by cooperation. So, the purpose in this paper is to establish an effective organization making possible the coherence of several models inspired from the world model, which is constituted in categories naturally. We introduce the cooperation as a mechanism permitting to resolve the vision problem by using the contributions of tasks and their result fusion. Unlike the traditional procedure, which operates in cascade levels, tasks here can be completed in a parallel way at one level and use the information as soon as available.

Review of literature
Aerial photography has been used widely for aerial surveying and photogrammetry. Because of its very high spatial resolution, aerial photographs were employed to detect damages due to earthquakes (e.g., Ogawa and Yamazaki, 2000). Digital aerial cameras, recently developed and introduced for aerial photography, have much higher radiometric resolution than traditional film (analog) aerial cameras do. Thus, even though the spatial resolution is almost the same level, e.g. 0.1 m, a digital aerial camera can capture much clearer images of the earth surface than an analog camera does.
Another important feature of digital aerial cameras is that they have a near infrared (NIR) band as well as RGB visible bands. Using the NIR band, detection of vegetation becomes quite easy. Through the pan-sharpening procedure, very-high resolution pseudo-color images can be obtained by combining these 4 multi-spectral bands and the panchromatic band. Note that the spatial resolution of high-resolution satellites currently available is 0.6 m (Quick Bird) at the maximum, and thus the digital aerial images can be used for extraction of detailed damages of buildings and infrastructures.
Most object recognition theories use a geometrical aspect (3D objects shape) and we can actually consider two groups of theories, which diverge on the format of the representation. The first group considers the object representation as a set of object characteristics (invariants). One the most interesting approaches is Biederman's recognition by components (RBC) [11, 12]. The second group considers that the object representation is linked to specific object views and that any

other view can be deducted by means of these views. The recognition is expressed as a function of the images already seen. Several processing models used by Edelman and Poggio are based on experiments. The recognition problem in both models is conceived as cascade levels transforming the numeric entry (image) to semantic entities (objects). So a failure at one level can stop all processes. A lot of previous work shows some difficulty in discovering invariants from images. This recognition process is alimented by the detection of visual indices like interest points, borders, colors, textures, object parts, etc. Early processing is known as segmentation and classification techniques. The segmentation is low-level processing, which consists of dividing set pixels into related regions: homogeneous and different from its neighbors. Here, we do not try to determine what the regions represent. Generally, two approaches are used: border extraction and region growth. The classification tries to identify what represents each of the segmented regions. It groups together the various elements (pixels) in subjects corresponding to the ground truth. The result is naturally a segmented image. Several approaches are used on this topic, like stochastic approaches (Markov fields, Bayesian inference, Bays rules) and neuronal networks. The current work tries to combine and unify these various models for robust segmentation by cooperation. Objects recognition is a very active domain of computer vision. The recognition operation consists of matching objects characteristics and visual indices revealed in the image. Significant work in this area was presented by Ayache and Faugeras (SEEMORE system).

Pixel-based classification

First, a conventional pixel-based classification was carried out based on the maximum likelihood method, the most common supervised classification method. In the classification, 8-bit data value (0-255) of blue, green, red, and near-infrared bands were used. Eight classes: black-roof, gray-roof, red-roof, white-roof buildings, road, ground, tree, and grass, were assigned for the pre-event image as training data, as shown in Figure 1. Shadow was not classified as a class because its brightness is difficult to separate from that of black-roof.

The result of classification looks, in general, reasonable. Especially vegetation was correctly classified because NIR band was used in the classification. The buildings were classified into 4 classes based on their roof color, and hence some misclassifications are seen, especially for the roofs with dark color roof-tiles. As the characteristics of pixel-based classification and due to very-high spatial-resolution of the digital aerial image, salt-and-pepper noise is seen (Matsumoto *et al*., 2006) [7] in the classified result.

For the post-event digital image, 9 classes, which correspond to the 8 pre-event classes plus the debris class, were assigned as shown in Figure 2. The result of the supervised pixel-based classification is also shown in the figure.

The area classified as the debris class looks more than the actual debris, consisting of the mixture of woods, mud, and roof-tiles. Since debris does not have unique spectral characteristics, commission error might be occurred by pixel-based classification methods. Mitomi *et al*. introduced a sort of spatial filtering to reduce the salt-and-pepper noise classified as debris. In such approaches, the size of spatial window should be assigned properly, depending on the size of target objects.

Architecture for the aerial image processing systems

Our idea is not to develop a new method, but to provide a framework for efficient information management in a vision system that allows using the majority of approaches. We implemented an architecture based on the following concepts: using one level of treatment, cooperation of all tasks and categorization as predictor, and adopting a mixed strategy for the control. The recognition starts in the early steps of treatment. To extract the maximum amount of information at this stage, we opted for a segmentation multicriterion (borders, colors, textures, etc.). Easy access to the object models in a selective way is possible by categorization. Localization of a category permits one to reduce considerably the number of models for the matching afterward. Classically, a category is seen as a collection of instances that can be handled indifferently in the same way. By means of this classic method, the components of a category are determined by matching a definition: the components are defined by using a certain number of characteristics, which can be necessary (totally or partially). To model categories, two theories are considered. First, the prototype model: Rosch supposed that, from experiences with copies, a “central tendency” of a category is formed and that the judgment of membership in a category bases itself on this “central tendency” or “prototype.” The prototype is so defined as an abstracted representation possessing the average characteristics of exemplars. The second is the “exemplars” model. To solve the problems of the context influence and the variability, one stocks any category occurrence (called an exemplary). The determination of a category component is similarly made according to the rule of the closest neighbor. Several approaches use a hybrid model.

1. The model

In aerial image processing, it is necessary to enrich the internal representation by other aspects like color and texture, and to endow the system with inference mechanisms for landing the gaps of the prototypes model. We consider in our architecture a complete object representation according to the following aspects: color, texture, flat forms, volume, and decomposition of the object in its parts. These characteristics are deducted in a predefined structure of parameters from a learning phase or introduced (directly manually) into this structure. The modeling takes into account three abstraction levels: meta-category, basic-category and subcategory according to the scheme shown in Fig. 3a.

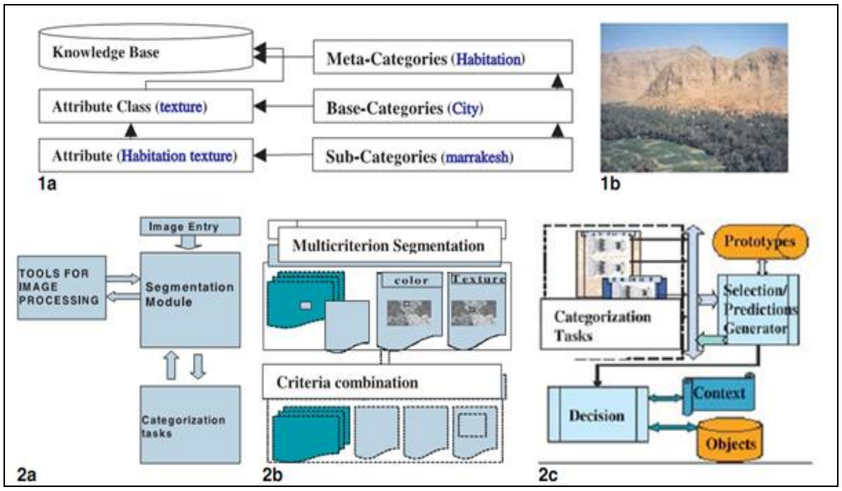

Fig 3a: Data organization, b Aerial image example (Dades Valley, Morocco)

Fig 4a: General architecture, b Segmentation multicriterion, c Categorization tasks

2. The general architecture

The architecture proposed uses three big modules (Fig. 4a): a library of treatment tools for images, segmentation multicriterion module (Fig. 4b), and a module for the categorization tasks (Fig. 4c). The recognition process in this architecture follows a simple procedure.

1. Activate the segmentation tasks by cooperation to extract the most visual indices (texture, shape, and color).
2. Select categories according to the visual indices discovered.
3. Elaborate segmentation by combination of criteria in order to satisfy the predicted categories.
4. Definitive decision: identification or categorization

Figure 4c suggests a functioning in two modes: learning and recognition. Learning is used to determine texture, color, and shape models. The object prototype is formed by these three models.

In these processes, we use the framework of the Bayesian theory. The allocation of an element x in one of the models $\{\omega_1, \omega_2, \ldots, \omega_k\}$ is based on the Bayes formula: $p(\omega_i|x) = p(\omega_i|x).\, p(\omega_i)/p(x)$ $p(\omega_i|x)$ is the a posteriori probability, $p(\omega_i)$ represents the probability that an element taken at random belongs to the model, p(x) is the law modeling the global histogram of the observed image, and $p(x|\omega_i)$ is the a priori probability.

Learning mode

The element x is a pixel; the process consists of finding models of textures, colors, and shape. The task is to determine various parameter-reserved characteristics (color, texture, and shape) by using images of objects. We then look for the parameters that maximize the law of a priori probability p (x|ωi).

Recognition mode

The element x is a zone that will be attributed to a model of a known object that maximizes the a posteriori probability p (ωi|x).

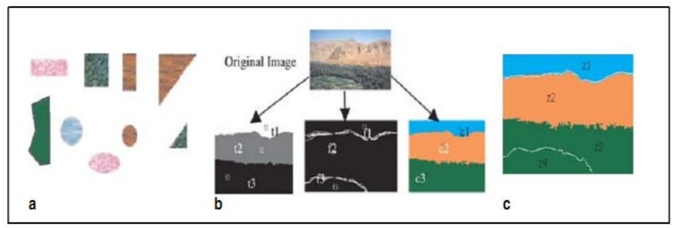

Fig 4a: Prototype bases b Segmented zones ti: textures, fi: shapes, ci: colors c Resulting zones

According to every criterion, the segmented image presents zones to the categorization process entry that selects one or several prototypes in the "bottom/up" control. Indeed, the visual indices resulting from segmented regions and originally arriving in the data stream allow one to find (by matching) a reduced number of compatible prototypes with these data. Then, the selected prototypes constitute initial hypotheses that must be verified by finding other visual indices in the image in "up/bottom" control. This process is gradual, since it begins by a set of possible categories, and tries to reduce this set with more detailed discoveries in the image. The "definitive decision" consists of proceeding by strictly matching the use of the context and certain hypotheses can be eliminated.

Geometric correction and image fusion

Map revision involves data sources from various entities including vector layers, scanned data, aerial photographs and satellite imagery. In order to establish maximum geometric compatibility, all of the mentioned data sources should be geocoded and projected in a common coordinate system. The old maps aimed to be updated had a good geometric accuracy and the maximum compatibility between different layers of the common areas and the adjacent sheets in the edges. Accordingly, we used these maps as reference vectors to rectify other data mentioned above. With the help of different geometric correction models, specifically polynomial and rational functions, aerial photographs and satellite imagery were geocoded and projected in UTM∗∗ coordinate system. Later on, corrected images made ready for further processing and analysis. In order to exploit the maximum capabilities of the images, we needed to extract pan-sharpened products. Results of multiplicative, IHS, PCA and wavelet image fusion methods were analyzed to obtain suitable pan-sharpened product according to specific needs of map revision. Quality of the results of different image fusion methods were assessed through visual interpretation. Multiplicative and wavelet methods keptspectral richness of the original multi-spectral images better than IHS and PCA methods, at the same time, the two last methods were better in keeping spatial precision of the panchromatic band. After that, smaller objects were extracted from the pan-sharpened image. From the visual point of view, pan-sharpened images acquired from PCA and IHS methods proved more useful for detection of boundaries of fine objects. Pan-sharpened images produced by multiplicative and wavelet fusion methods were exploited in automatic classification procedures.

Change detection and map revision

All of the results of the object extraction methods converted to vector layers. Images and aerial photographs together with extracted vector layers and old maps imported to a geodatabase in ArcGIS. Images saved in a raster catalog while vector layers saved in feature datasets. Both raster catalogs and feature datasets assigned the same coordinate system. All of the images and vector layers added in an ArcMap project to track changes. Two methods of change detection were used, comparison of the old and new extracted maps and comparison of the old maps with the recent images and aerial photographs. Images overlaid with aerial photographs and old digital maps. We examined those parts of the image where changes relative to the old maps had been occurred. Several kinds of changes were evident, some existing buildings had been vanished and some new ones had been constructed. In the city marginal areas, agricultural lands had been withdrawn in favor of man-made constructions. All of these changes manually digitized and saved in a dataset (named “Changes”) in the project geodatabase. In the second part of change detection process, the old maps overlaid with the new extracted maps. In this stage, different GIS methods were used to detect areas where changes had been occurred. Changed areas in the new maps were selected and exported as new layers and saved in the geodatabase (in the “Changes” dataset). At last, change layers merged together and converted to one layer. With the previous mentioned method, the change layer overlaid on the image to find those parts where editions were necessary. The final changes layer then overlaid on the old maps layer. Changed parts of the old maps and vanished features detected and newly constructed features added in an edition procedure. A new dataset called “Updated Layers” created and each of the revised layers of the old maps imported to it. Labels and attributes of the newly added features inserted to each layer’s attribute table. All of the revised layers then added to map sessions according to the old maps indices to create new updated maps of the project.

Conclusion

The introduction of categorization and gradual recognition permits one to constrain the vision problem. Here, we tried to incorporate other significant aspects in the geometry, notably in the field of aerial images. We advanced the interesting work of categorization, which suggests combining segmentation and recognition tasks into one level. The competition between several prototypes allows one to deliver quickly those that are considered relevant in the recognition process. The parallelism part is important, so we plan to introduce a mechanism allowing the organization of tasks in intelligent agents for more interaction and communication.In this study, we utilized different image fusion and object extraction methods to derive maximum information from high resolution satellite images and explained the process of using the extracted information for map revision. Comparison of the image fusion methods discussed in this study, multiplicative and wavelet methods were better in keeping spectral information, hence were good in terms of preserving color properties of the objects.Image classification was carried out by pixel-based and object-based methods for the pre-event and post-event images. Because salt-and-pepper noises were seen in the pixel-based classification result, the object-based classification is considered to be more suitable to classify very high-resolution aerial images of dense town areas. To establish a general damage detection method in future, however, more parametric studies must be necessary for environments.

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