REMOTE SENSING OBJECT-ORIENTED IMAGE ANALYSIS APPLIED TO HALF-TIMBERED HOUSES

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ABSTRACT:

Remote sensing image analysis techniques are particularly effective when they are based on multispectral images. When very high resolution satellite sensors entered into the civil market, conventional image analysis techniques such as classification by maximum likelihood did not any more fulfil the requirements due to higher spatial and poorer spectral dimensions. In this context we decided to apply different techniques of image analysis to terrestrial photographs which present a small spectral resolution, often limited to three bands.

Part of the experiments were carried out on photographs taken in the old part of Strasbourg city. Object of interest is the Alsatian house, built during the 18th century. Unfortunately, they might disappear since a lot of them are demolished or in a state of neglect without any buyer to renovate them. Recording and documentation of Alsatian half-timbered houses with their sloping roofs become essential to conserve a trace of our traditions and carpenter's special knowledge. As expected, a first experiment using traditional techniques of supervised classification produced poor results because of low spectral depth available. On the other hand, a segmentation of the image followed by a classification based on fuzzy logic provided interesting results. Indeed, the object oriented approach as conceived in eCognition (Definiens GmbH) allows to extract objects according to their shape, their texture and their context.

When applying this technique to Alsatian façades, it is necessary to formalise the knowledge through rules with help of heritage specialists. Therefore, it should be possible to automate façade detection in a semantic way and to complete architectural information systems. We hope that these examinations will enlarge the range of image analysis applications for the recording of Alsatian architectural heritage.

RESUME:

Les techniques d'analyses d'images de télédétection sont particulièrement efficaces lorsqu'elles sont basées sur des images multispectrales. Lorsque les images à très haute résolution spatiale ont fait leur apparition sur le marché civil, ces techniques d'analyses d'images ne répondaient plus aux exigences liées à une dimension spatiale plus élevée et une dimension spectrale plus faible. Dans ce contexte nous avons décidé d'appliquer plusieurs techniques d'analyse d'images à des photographies terrestres qui présentent une faible résolution spatiale, souvent limitée à 3 bandes.

Une partie des expérimentations a été réalisée sur des photographies dans le vieux quartier de Strasbourg ainsi que dans les villages aux alentours. L'objet de notre étude est la maison alsacienne, dont la construction date pour certaines du 18^{e} siècle. Malheureusement, ces résidences tendent à disparaître étant donné qu'une grande partie est démolie ou délaissée. Le recueil et la documentation de maisons alsaciennes à colombages deviennent essentielles pour la conservation de nos traditions et des connaissances de nos charpentiers. Une première expérience utilisant les techniques traditionnelles de classification a produit des résultats décevants en raison de la faible profondeur spectrale disponible. Par contre, une segmentation de l'image accompagnée d'une classification suivant le principe de la logique floue a fourni des résultats intéressants. En effet, l'approche orientée objet telle que conçue dans eCognition (Definiens) permet des extractions d'objets basées non seulement sur leur signature spectrale, mais aussi sur leur forme, leur texture et leur contexte.

Pour appliquer cette technique à des façades alsaciennes, il est nécessaire de formaliser nos connaissances par le biais de règles de discrimination avec l'aide éventuelle des spécialistes du patrimoine alsacien. Ainsi, il devrait être possible d'automatiser une détection de façade dans un sens sémantique et de compléter les systèmes d'informations architecturaux. Nous espérons que ces expérimentations vont alimenter le champ d'application des analyses d'images dans un esprit de conservation du patrimoine architectural alsacien.

1. CONTEXT OF THE STUDY

High resolution (HR) satellite imagery has today almost the same spatial and spectral characteristics as photographic digital images. In remote sensing, conventional image analysis techniques do not fulfil the requirements due to higher spatial and poorer spectral dimensions of HR imagery any more. To improve the results it is necessary to take into account not only spectral values but also various attributes, relational and contextual information.

To illustrate these requirements, we choose to apply conventional techniques as well as an object oriented approach conceived for HR satellite imagery on several terrestrial photographs of Alsatian façades. These images present also a small spectral resolution for a very high spatial resolution.

The aim of this analysis is to extract the elements composing the half-timbered façades by developing specific rules, which should be reliable to each typical Alsatian façade.

2. OBJECT OF INTEREST

Object of interest is the Alsatian house, built in the 18th century. These typical residences can still be found in little villages of Alsace or in the old part of Strasbourg city.
Only a few number of today's carpenters are able to master the technique and knowledge allowing the construction of Alsatian half-timbered houses in the way our ancestors worked (Fig.1).

Figure 1. First stage in the construction of an Alsatian half-timbered house

Several digital photographs have been taken with a conventional camera. We used one of them – a typical (renovated) Alsatian house – for all experiments and the others for assessing the quality of the semantic rules.

3. EXPERIMENTS USING CONVENTIONAL METHODS

Façades of Alsatian half-timbered houses are composed of large and dark oak beams which constitute the structure of the house at the beginning of its construction. Between these beams, brickwork with facing replaces today the cob used by our ancestors. Whatever it is, the last coat is a light colour. So, in a first level of our experiment, we use for discrimination only the spectral signature of the pixels.

3.1. Supervised classifications

The choice of training samples is limited to six main classes of interest : sky, oak wood beams, freestone (sand stone), tiled roof, shutter, and facing (over masonry). A minimum distance as well as a maximum likelihood classification are performed. The first one uses a geometrical algorithm simply based on the Euclidian distance separating the pixel from the sample clusters in the spectral space, whereas the second one is more sophisticated since it is based on the probability (calculated according to sample statistics) for a pixel to belong to a class. It is certainly the most used classifier for remote sensing purposes. The main difference between both classifications is the tiled roof which appears more homogeneous in the maximum likelihood (see Fig.3 b) and c)).

The other misclassifications are also mirrored by 2D scatterplots (Fig.2). Indeed, some classes like freestone, facing and also tiled roof present considerable spectral signature overlaps.

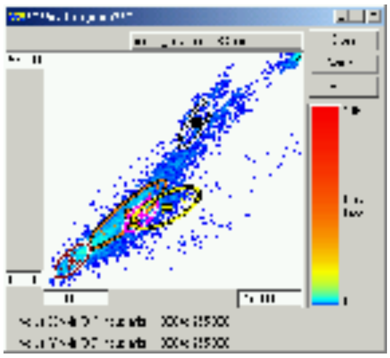

Figure 2. 2D scatterplot of the image (B1=red; B3= blue) with the 6 samples chosen for the experiment

3.2. Unsupervised classification

In order to test the presence of spectral classes, we start an unsupervised classification (isodata scheme). It is performed after imposing a maximum number of 6 classes. Nevertheless, only 5 clusters appeared (not tiled roof class) as shown in Fig.3a). This emphasises the main problem we are confronted with, i.e. attempt to define semantic classes on the basis of spectral classes.

Quantitatively, in order to assess accuracy, we perform a confusion matrix using a reference classification and achieve: 77% overall accuracy for the classification with minimum distance, 81% with maximum likelihood and 17% with unsupervised classification. Results are not really satisfying and above all they depend strongly on the samples.

Qualitatively, it becomes clear that conventional classification methods are not efficient with HR imagery. Indeed, a lot of isolated single classified pixels are dispersed over the image (Fig.3 a) to c)). Although a majority filter could lessen this effect, the main problem remains: a spectral analysis alone is not powerful to discriminate classes with similar responses and different meanings.

4. EXPERIMENTS USING OBJECT ORIENTED METHODS

4.1. Supervised classification

The object oriented image analysis system eCognition2.1 (Definiens) follows the concept that semantic information necessary to interpret an image is not represented in individual pixels, but in meaningful image objects and their mutual relations. That's why image objects are generated through multivariate segmentation where simultaneously spectral and shape heterogeneity criterions can be weighted. A scale parameter also influences the final object size by stopping the merging process.

In a first step we decided to use the same training samples as in the previous experiment in order to assess the influence of objects instead of pixels. The sample-based classifier used is a fuzzy approach of nearest neighbour clustering. When activating only spectral feature as discriminating criterion, this classifier is nearly comparable to minimum distance. Thus the results are similar except for the homogeneity aspect (Fig.3 d)).

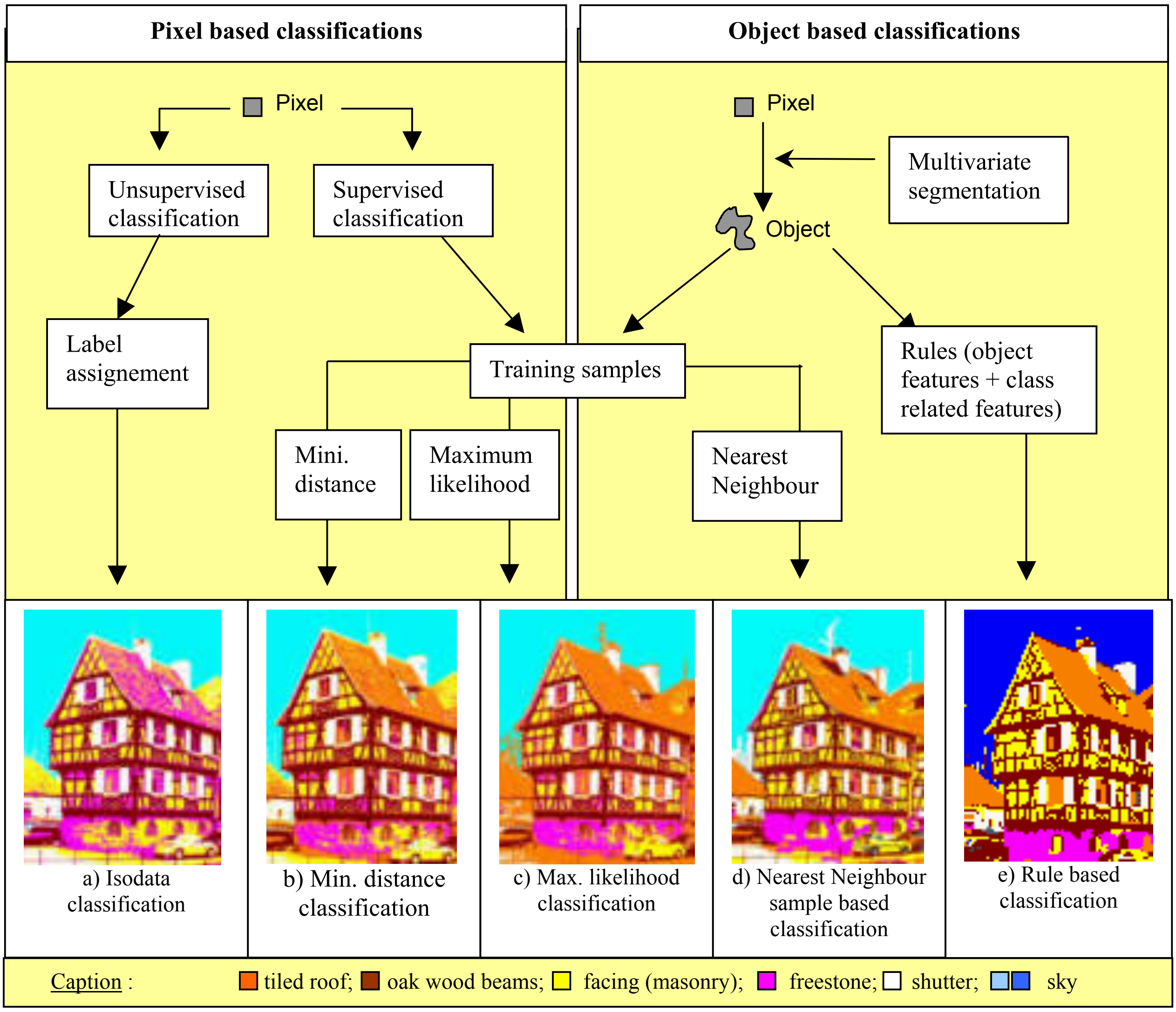

Figure 3. Flow chart of all experiments and results achieved

4.2. Rule-based classification

In this part, a higher degree of image analysis is applied. The most delicate and also interesting work consists in developing rules describing and formalising the knowledge on characteristics of Alsatian façades. These rules can integrate various object features (spectral values, shape, texture, hierarchy, etc.) or class related features (relation to neighbour objects, sub-objects, etc.) which are furthermore defined by membership functions. In these membership functions one can introduce fuzzy logic by particularly weighting that feature and combining it through logical operators with other features.

For instance, to discriminate sky from the rest of the image, one use the particularity that sky brightness is stronger than the brightness of the rest of the image. Another characteristic is that the standard deviation of the sky is especially small. Result is shown in Fig.4.

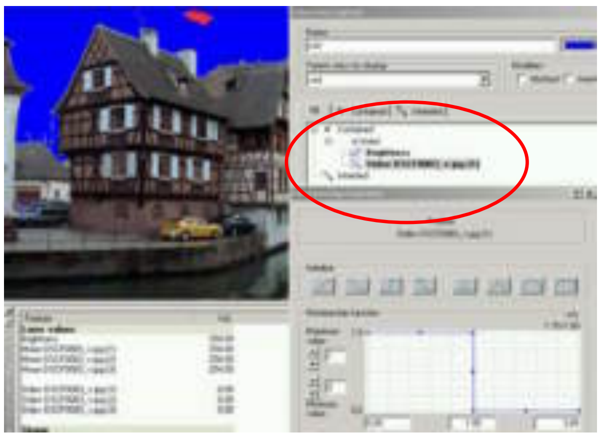

Figure 4. Rules established for the discrimination of the class “sky” (blue)

To dissect the façade elements, we use the knowledge that facing is always surrounded by oak beams which are much darker spectrally. This is reflected by an important mean difference to darker neighbours.

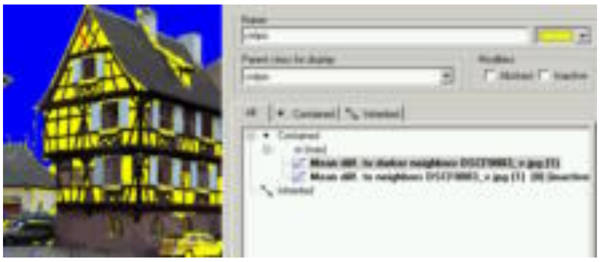

Figure 5. Rule established for the discrimination of the class “facing” (yellow).

Nevertheless, the rule is not sufficient (Fig.5). So another feature is introduced according to the mean difference to general neighbours. The reasoning continues with the beams : beams, but not only beams, are characterised by dark colours. Thus we introduce a second criterion according to the distance separating them from previously classified objects. Indeed, one beam is always in direct contact to facing, so that distance is placed to zero.

Each class of interest is analysed in this way. Tiled roof and freestones (composing the foundations of that house) are elements of the same parent class and, in addition to their own feature, inherit the area criterion from their parent class. After rule development, a classification based on fuzzy logic is performed over the entire image, without any training sample. Fig.6 illustrates the resulting classification.

Figure 6. First result of the rule based classification

Fig.3 sums up all experiments and results. Obviously, although the last classification provides the best results, it needs to be improved by refining the membership rules.

Considering the last set of rules, other photographs are used for testing the reliability of the formalisation. Fig 7 shows a lot of correspondences, but also raises new problems which will help us to refine the initial set of rules by further investigations.

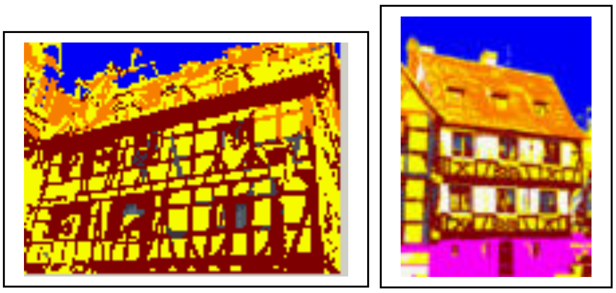

Figure 7. Same set of rules directly applied on other datasets.

4. CONCLUSION AND OUTLOOK

Conventional classification techniques are not anymore accurate for high resolution imagery. Trying to extract information automatically from these images, one is confronted to the difficulty to formalise human knowledge. Nevertheless, interpretation of this knowledge allows to sustain a set of rules describing different elements of interest. Thereby, once the rules are established, they might enable further automatic classifications of other half-timbered Alsatian façades and help supplying architectural information systems.

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