THEMATIC MAPPING BY CLASSIFYING SATELLITE IMAGERY

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TEMATIKUS TÉRKÉPEZÉS ŰRFELVÉTELEK OSZTÁLYOZÁSÁVAL

Összefoglalás

A Föld körül keringő mesterséges holdak igen jelentős információtartalommal bírnak. Számos felhasználási lehetőségük közül a szerző a tematikus térképkészítés lehetőségeit ismerteti. A műholdfelvételek feldolgozásánál hagyományos és modern, a mesterséges intelligencia eszközeit felhasználó megoldásokat egyaránt megtaláljuk. A módszereket három fontos kategóriába soroltuk, majd e kategorizálást követve ismertetjük a főbb módszereket. A felügyelt osztályozási módszernél közvetlenül az osztályok kialakításánál vesszük figyelembe a terepi információkat. A nem-felügyelt módszereknél elsőként klasztereket képzünk, majd ezeket rendeljük tematikus osztályokhoz. Az objektum-orientált megoldás szerint pedig a kép feldolgozásának első lépésében szegmenseket képzünk, majd a szegmensek jellemzőinek felhasználásával rendeljük azokhoz valamely tematika kódját. A cikk a lényegesebb módszerekre példát is mutat.

Summary

Around the Earth orbiting satellites have huge information content. Among their application fields the possibilities of thematic mapping are shown. In the satellite image processing workflow both traditional and modern, artificial intelligence solutions can be found. The methods are grouped into three categories; then the main algorithms are introduced following this categorization. The supervised classification takes into consideration the field information directly in the class creation. The unsupervised methods build clusters firstly, and then they are ordered to the thematic classes. In the object-oriented solution the first image processing step is a segmentation, then the segment features are derived and used to order thematic label to them. The paper shows examples for every main methodology.

Introduction

Remote sensing (RS) has basically three types of collecting information about the Earth's surface. The first case (passive RS) uses the Sun as light source, which illuminates the surface, then this ray interacts with the content of the surface (vegetation, soil, buildings, etc.) and is partly backscattered. The sensors being on a satellite platform get these signals, store and transfer them for being processed. The second way (active RS) is the case of active light or electromagnetic (EM) source (e.g. RADAR), which sends out impulses and receives them after the mentioned surface interaction. The third possible option (indirect RS) is when the Sun illuminates the surface, but instead of the backscattering, a smaller part of the EM waves are absorbed. This energy indicates some procedures in the object, which starts to radiate other type of waves. The man-made sensors are targeted to capture these signals (indirect RS) (CAMPBELL, 1996).

All of the three techniques have a common feature, namely they collect radiometric data about our globe. People working in design, monitoring, or in political decision making need information about different progressions in interpretable way. Therefore the raw radiometrics (or intensities of the radiation) must be converted into this form. Thematic maps are one of the best such efforts.

Thematic mapping – general overview

The thematic maps are derived from different information sources. This paper focuses on the direct thematic mapping techniques based on processing satellite images. This type of thematic mapping can use three main algorithms (*Figure 1*).

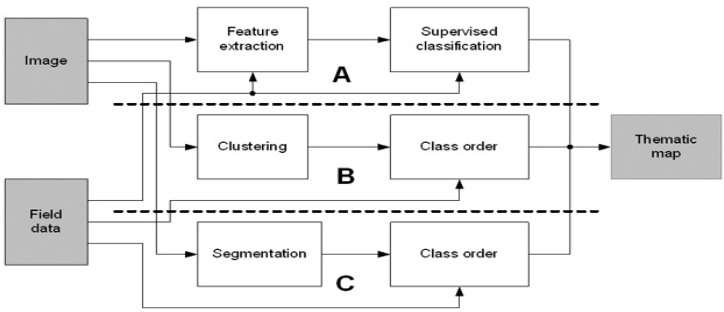

Figure 1. Thematic mapping technologies using satellite imagery

The first processing group is the supervised classification. This technology requires a sophisticated decision technique to order every image pixel to any thematic category. This is done during the classification. In order to execute this task with the highest accuracy, adequate features must be derived, which make the differentiation between the categories possible. The necessary features are derived by reliable feature extraction techniques

The second way contains an automatic pixel grouping, called clustering. The method takes some input settings into consideration and labels all pixels with an identifier. The result of the clustering is analysed and a class order step finishes the procedure. In the class order phase, field data are put into the system: in this phase a correct ranking is performed.

The third method splits the input image into homogenous compartments taking different information (like colour, texture, shape, etc.) into consideration. The segments as units built in this way are to be ordered to any thematic class in the order step.

Supervised classification

The feature extraction will produce a so-called feature vector for every image pixel. This vector contains all the important descriptive data of the pixel: intensities in all imaging channels, texture measures derived from the pixel's neighbourhood, different indices using remote sensing algorithms etc. The feature vector is a result of an iterative task: it gets its last layout only after several tests; it is created during an approximation refinement. The feature vectors can be analysed by nice statistical probes and techniques: they check whether all the elements of the vector are really required or any of them is redundant. The tests check also the separability of the thematic classes based on the actual feature vectors.

The core of the technique is the decision making, where the pixels get their thematic categories. This decision making can base on the theory of remote sensing: the thematic classes have good descriptive features and therefore location in the feature space. The classification is nothing more than a right differentiation between these locations and every image pixel must be ordered to the right group.

In this sense, differentiation can be done by using simple geometric measures like (Euclidean or Mahalanobis) distances, they can use class probabilities (like in the maximum likelihood method or in Bayes decision) (DUDA, 2001). We can differentiate the classes using decision rules: a simple rule set describes the borders of the classes, more sophisticated rule sets try to consider the extension of the classes, too.

Very important classification tools are the artificial neural network (ANN) based techniques. Feed-forward neural networks, radial basis neural networks or probabilistic neural networks can decide the pixel membership in a proper way. All the neural techniques require deep knowledge about computational intelligence. The neural classifier behaves as a black box: the system is trained by field data and image information; it gets flexibility thanks to the network structure, but in several cases the output is inestimable. Although these disadvantages belong to the neural techniques, they are widely used, because the advantages are „stronger": such systems have better classification accuracy, they can differ more complicated cases, they can order pixels to classes being represented separately in the intensity or feature space (subclass detection possibility) (BARSI, 1998).

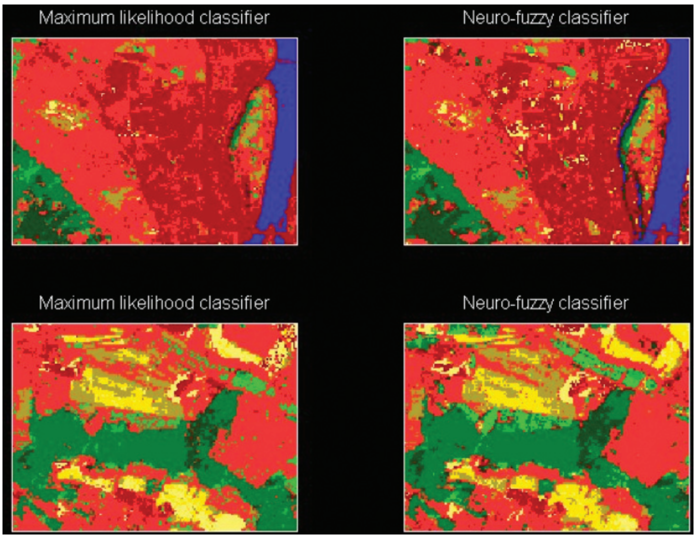

Figure 2. Statistical (maximum likelihood) and neuro-fuzzy classification compared using Landsat image about Budapest

Neural network techniques can be easily combined with other artificial intelligence tools, like evolutionary computation and fuzzy logic. If fuzzy logic is appended to the neural processing way, smoother and more accurate differentiation can be achieved. *Figure 2* illustrates a comparison between statistical and neuro-fuzzy classification results.

Unsupervised classification

The unsupervised techniques have two well-known versions: k-means and ISODATA. The k-means classification is an iterative approach: after an adequate initialisation its classifying step is repeated until a category (cluster) stability measure or other similar criteria will not stop. The initialisation generates the starting cluster centres, and then every mostly randomly taken sample will be ordered to the nearest cluster centre. Pixels having the same cluster label form a category can be represented by its average intensities: an intensity mean vector is derived. This hyperpoint acts later as a cluster centre. Other cluster centres are created in the same way. The next iteration epoch clears the pixels' membership and orders them to the new clusters. The cluster centres successively approximate the final and stable status. The iteration lasts till

1) a fixed amount of sample pixels are in the unchanged cluster, or
2) the cluster centres move less than a fixed distance, or
3) a fixed number of iteration steps are reached. The k-means technique has several versions depending on their implementation environment (VAN DER HEIJDEN, 1994).

The ISODATA clustering method is an advanced k-means technique. ISODATA stands for Iterative Self-Organizing Data Analysing Technique. This method increases the performance of k-means by introducing cluster merge and split functionality. If during the processing two cluster centres get too near to each other, these clusters will be merged (and the number of clusters will be reduced by one). The opposite situation is when a cluster has extreme elongation in a direction, then the cluster will be split into two parts and a new cluster is put into the cluster list (DUDA, 2001). The cluster check is to repeat in all iterative epochs.

The unsupervised classification can be realized also by using neural network techniques. Two types of artificial neural networks are applied: competitive neural nets and self-organizing maps. Both techniques require an input cluster amount and some control parameters. The result of the run looks similar to that of the traditional techniques. Self-organizing maps are widely used in sophisticated data mining systems (FAYYAD, 1996), so imagery data sets (containing e.g. complex feature space) can be effectively clustered by this method.

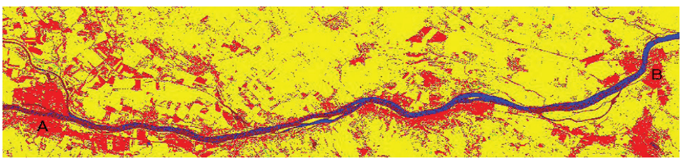

Figure 3. ISODATA clustered Landsat TM image of the Upper Danube (DOBOS, 2004)

Object oriented classification

The object-oriented approach is the topic of current research activities. It starts with the image segmentation, as it is demonstrated by the eCognition software (ECOGNITION, 2000). The segmentation is controlled by giving three input parameters: weight of the pixels' intensities, the shape of the found patches, their smoothness and compactness.

The segmentation cuts the image into homogeneous compartments. These atoms get several (or even several hundred) features like texture measures: homogeneity, form parameters, intensity means etc. The classification is executed in an iterative way: after every ordering phase the candidate pixels are checked whether they are in the same group or not. If a special stability („calm") of the clustered pixels can be noticed, the procedure is stopped, otherwise a refinement is required. The refinement is followed by a reclassification of the pixels, then statistical measures are derived, and the whole procedure will restart again.

The eCognition package (the so-called Dalmatian segmentation software) executes the mentioned processing structure, but collapses the categories continuously. These are the objects in the classification procedure. The segmentation of a city cut-off is shown in *Figure 4*.

Figure 4. The segmentation result of an image (ECOGNITION 2000)

Conclusion

The paper was aimed to give an overview „about the state-of-the art" sensing technology, especially the aerial photogrammetry or digital image processing. The supervised and non-supervised traditional classifications are getting more and more spread and popular. The non-iterative forum must have to be checked. These techniques handle the digital images in pixel forms. The object oriented approach transfers the original image into homogenous parts, and then these parts are ordered to the thematics. The so produced thematic maps carry basic information about the Earth surface.

References

BARSI A.: *Neural networks in the thematic mapping.* [in Hungarian], PhD thesis, 1998, 96 p.
CAMPBELL, J.B.: *Introduction to Remote Sensing,* London, 1996, Taylor & Francis.
DOBOS B.: *Analyzing automatic classification possibilities of satellite imagery.* [in Hungarian], Thesis work (advisor: Árpád Barsi), Budapest, 2004.
DUDA, R.O. – HART, P.E. – STORK, D.G.: *Pattern Classification*. Wiley, New York, 2001.
Ecognition. User's Guide, Definiens AG, München, 2000.
FAYYAD, U.M. – PIATETSKY-SHAPIRO, G. – SMYTH, P. – UTHURUSAMY, R.: *Advances in Knowledge Discovery and Data Mining,* AAAI Press/The MIT Press, Menlo Park, 1996.
RUSS, J.C.: *The Image Processing Handbook*, Third Edition, CRC Press, 1999.
VAN DER HEIJDEN, F.: *Image Based Measurement Systems, Object Reconstruction and Parameter Estimation*, Wiley, Chichester, 1994.