Toward a fully automatic cartographic feature extraction

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Abstract. The problem of cartographic feature extraction is too complex to be solved in its entirety any time soon. Clearly it represents a research challenge for the geographic information academic community. Here we discuss some ideas about how to tackle the problem and emphasize the need for collaboration with the mapping agencies and industry in order to increase the efficiency of feature extraction research.

Keywords: Cartographic feature extraction, automatic cartography, GIS updating

1 Cartographic Feature Extraction

The expectations of the scientific community in the 1960s and 1970s for artificial intelligence (AI) were large in terms of obtaining expert systems for almost anything. After the release of the book on artificial vision by Marr [5], many thought that the problems of artificial intelligence have its days numbered. After a number of years, the problems of artificial vision turned out to be more difficult than previously thought, and consequently expectations became more modest and realistic.

What happens in artificial vision research is relevant to cartographic feature extraction (CFE) research, and the advances in one run in parallel with the advances in the other. Photogrammetry and remote sensing are crucial technologies for extracting cartographic features in order to input and update data for a geographic information system (GIS). Today most of the cartography features from images are obtained manually by a human operator, sometimes assisted by semi-automatic methods. Cartographic features change with the passing of time, and these changes occur very rapidly in urban or developing areas and to a lesser degree in rural areas. These changes mean a large amount of data has to be updated, and it is necessary to expend time and money on human operators to correct the outdated layers of the GIS. The extensive human resources required for this operation could be avoided by using machine automated methods if they were available.

At the practical level, CFE can be found between two extremes. At one extreme there is the manual extraction of cartographic features from images and at the other the complete automation of the cartographic process. By a complete or fully automated operation we mean that after receiving space or aerial images, together with some other information stored in a cartographic database or GIS, the system is able to obtain the required map without having to resort to any manual intervention of a human operator.

There is a great deal of scepticism in the geographic information community about having a fully automated CFE system. Baltsavias [1] wrote: “The photogrammetric, GI and remote sensing systems allow, with very few exceptions, only a manual object extraction. Understandably, fully automation is not feasible today (or maybe will never be).”

Even though today the practice of CFE is found to be closer to the manual extreme than to the fully automated one, between the two extremes there are many intermediate steps of semi-automatic processes that could be of some use to the industry in order to lighten the cartographer’s workload and speed the process. Due to the large amount of georeferenced data, new imagery from airplanes or satellites, and the vector and raster data stored in cartographic databases, the need for automatic updating is of great importance, or at least the effort should aim as much as possible toward semi-automatic methods that are closer to fully automated ones.

Not every cartographic feature will be visible or deductible from the imagery, so additional information apart from the information of the imagery in the updating process is necessary (for example, changes in cartographic features occurring in a tunnel or under vegetation). These changes will not be extractable from the information in the images alone. If a human operator knows that a road goes under a mountain through a tunnel, it is because he/she has context information along with a “complex algorithm” running in his/her brain solving the road extraction problem.

Optimal performance in CFE should be obtained through the fusion of features from different sources of information and processing methods. The more information placed into the system, the greater the chance to obtain cartographic features in a correct and accurate manner under a wider variety of circumstances, but also the more complex the extraction algorithm will become. In addition the data acquisition cost will be higher, with some of the information from multisources being very expensive. Clearly the research objective should be to use the minimal amount of multisource information (or the least expensive) in order to solve the problem at hand.

A general diagram for an automatic CFE can be seen in Figure 1. Of particular importance are the two main blocks “Knowledge Representation” and “Inference Machine.” Research is required to determine which technique is optimal for each block and for each particular problem for CFE. Baltsavias [1] stated, “The model and knowledge representation should neither be too simplistic and restrictive, nor too detailed and monstrous (although theoretically complete and appealing), but rather fit the target requirements and the characteristics of the input data. Data and knowledge storage, data mining, knowledge extension and learning are important issues, which have been largely neglected.”

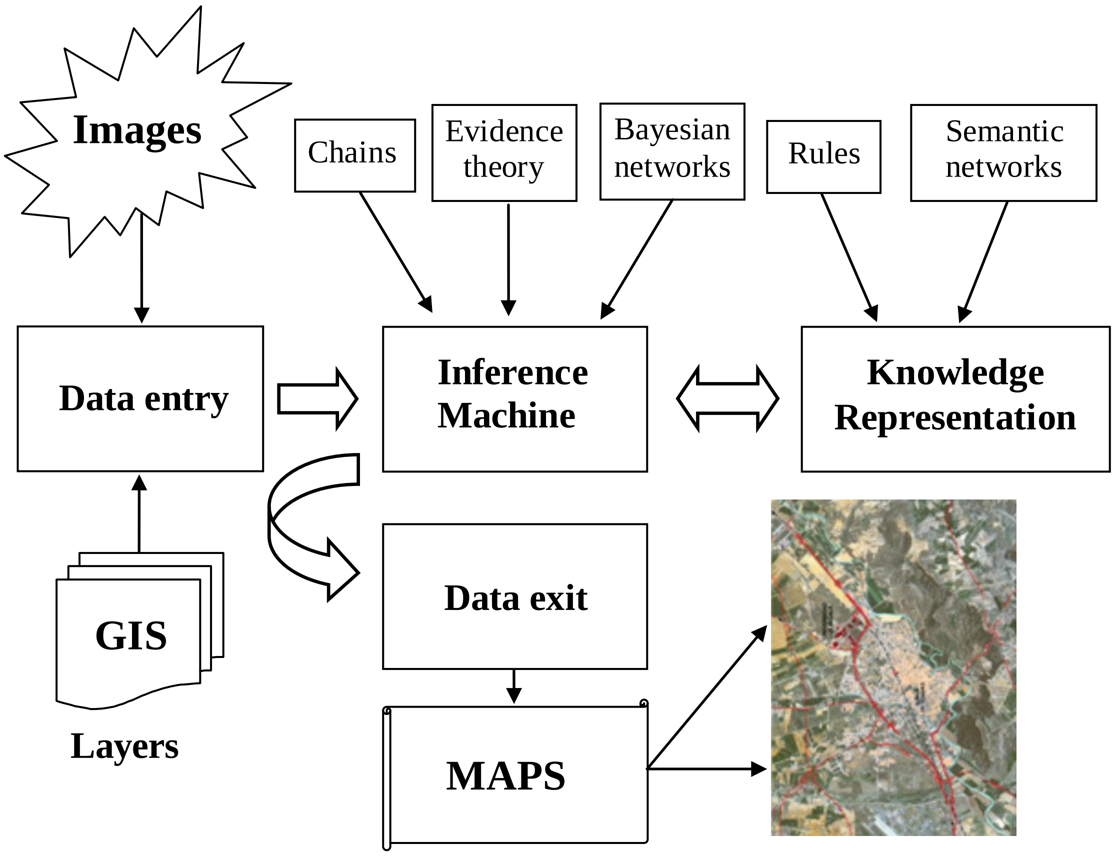

Fig. 1. A general view of a cartographic expert system

2 Tackling the problem of CFE

The problem of CFE is primarily obtaining cartographic information from images in order to make a new map or update an old one. If cartographic information is already stored in a cartographic database, this would considerably reduce the total cost for a project in CFE. Therefore, some authors have proposed to try to use this information store in a GIS or other kind of cartographic database for the automatic extraction of cartographic features. Since the problem is too complex and too large to deal with globally, most authors have focused instead on one kind of cartographic feature under specific circumstances. The problem can then be defined in terms of the updating of a road or building layers from a GIS once new remotely sensed information is available.

In the area of extraction of cartographic features from images, work is currently underway on the extraction of vegetation, buildings, and roads. The major effort to date has been put into roads and buildings. Although fully automatic methods have not been achieved, some progress has been made, as can be seen in the many international meetings and research papers on photogrammetry and remote sensing.

Let us take one specific cartographic feature, such as a road, for example. To look for a unique automatic method in order to extract roads from satellite or aerial images for all cases and for all kind of images would be premature at this stage. Different resolutions require different techniques. The method used to find a highway in a Spot or Landsat satellite image would probably not work well for an Ikonos satellite image. Even within the same resolution and the same type of image, there is no (or it has not been found) general algorithm or general method; for example, different methods are needed for rural, urban, or suburban areas.

Computer vision has become a very wide area of research since the digitalization of the data in photogrammetry and remote sensing. Their new methodological problems could be considered as computer vision problems as well. State of the art in CFE until 2000 is provided by Sowmya and Trinder [7]. They provided a list of studies by experts in the field of photogrammetry and remote sensing on research in the semantic information of images and they also commented about the need to continue collaboration between researchers in the field of machine vision, photogrammetry, and remote sensing. Today a multidisciplinary approach among people working in these fields is a clear objective. Another state of the art in CFE, but only for one type of CFE, is roads, which is presented in Mena [6]. In the nearly 250 references of work related to road extraction, many different approaches are explained and classified.

The recognition of objects in aerial and space images can be consider in three levels in a simple model. Low level usually corresponds to the segmentation of the image. The fusion of information from the different sources is made at an intermediate level. The third and final level corresponds to the formation of the topology and the real cartographic extraction.

Algorithms for solving problems in CFE usually require that several parameters be adjusted. If the final manual edition is to be avoided or at least reduced, the algorithms should probably be put in a loop under a learning algorithm. The feedback should go from the lower levels to the higher levels and vice versa, modifying the segmentation with the new information from the higher levels and adjusting the parameters of the algorithm so that manual editing can be reduced.

Today there are semi-automatic CFE systems that correct and update cartography. After all the manual work to adjust the parameters and later to edit what the system did wrong, the question the user might ask is: Could it be simpler doing it manually from the very beginning? If the answer is no, then a useful system for the industry has been created. But before a successful final industry system is obtained some interactive process and algorithms could be useful for the academic world, this would be interesting because this system provides some ideas that could lead to a better system in the future. Many interactive systems for some types of CFE have been proposed ([2], [3] and [4]).

There are many paths for research in CFE. The industry, which uses this technology, should select which path is the more appropriate and necessary for the applications. Therefore, collaboration among national mapping agencies, industry, and academia should be strengthened.

The theoretic level should be in a cartographic object language, which could relate cartographic objects creating the necessary topology. A new high-level language is needed that is object oriented and specific for geographic information where the objects represent the cartographic entities, such as roads, rivers, and buildings. Also, in order to facilitate research activity; the desirable new language should be a type of open source.

3 Conclusions

CFE is too large an enterprise to be tackled alone or by a few separate groups. For efficient development of CFE, stronger collaboration among scientists and engineers working in different disciplines of computer science, computer vision, photogrammetry, remote sensing, and pattern recognition is needed. A deeper collaboration between academia and national mapping agencies and industry is also needed. The role played by EuroSDR and ISPRS in stimulating these two types of collaboration is appreciated, and this role should be fostered and strengthened in the future by the GI community. The group working in Alcala in this area of CFE, although small and aware of its limitations, hopes to join with other academic groups as well as people from cartographic agencies and industry. This relationship would allow the academic community to work on specific useful cartographic products.

Acknowledgements

Authors wish to thank the Spanish National Mapping Agency (Instituto Geográfico Nacional) for financial support for presenting this paper in the symposium GIS Ostrava 2010.

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