Communication networks recognition from SPOT images*

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ABSTRACT

This paper proposes a framework for automatic extraction, description and recognition of communication networks (roads, rivers networks) from satellite SPOT images. The main idea is to use an hybrid process to progressively go from low level detection to high level description of the networks. Results are presented on SPOT satellite image around Poyang lake, in China.

INTRODUCTION

Networks define lines —i.e., *1-manifold structures*—, that are linked together to form a graph-like structure. In satellite images, they correspond to the *communication networks*, ie, road or river networks. Their detection and description will be useful for direct application or further analysis of the image, such as automatic or semi-automatic cartography, matching, change analysis, flood monitoring [6, 7, 5]. Because of the huge size and increasing quantity of data, automatic procedure for extraction and description is now more and more required. Moreover, a precise location and estimation is a pre-requisite for any application.

This paper aims to present a framework for automatic network detection, representation and classification. We will describe the networks in term of his class (road or river), his spatial organization, and its geometrical local and global properties.

The developed approach follows two principles: the first one is that the lines that form the network can be detected by local characteristics; the second is that the network description must be done trough both local and global information.

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RELATED WORK

We introduce thereafter some authors who, from our opinion, proposed interesting recent research works for linear structures extraction or road detection. They are presented by increasing interpretation level of the features extracted.

Yang and Ma [9] proposed an approach for lines structures detection. They introduce a method developed from the concept of perceptual vision: based on an energy function, it enables to reconstitute the entire lines extracted incompletely with an edge detector. Applications are on satellite and medical images.

Roux [6] gives a symbolic representation to the detected objects (roads or intersections) from SPOT images and maps. He uses it for matching them together.

Dynamic algorithm in satellite SPOT have been developed by Jedynak and Geman. With a probabilistic approach —so called *Game of 20 questions*—, the road is tracked after giving a starting point and direction [1].

McKeown [3] and Weiss [8] use geometrical constraints for connection of fragmented linear features, from airbone optical images.

Methods showing high level of interpretation include a-priori knowlege to built road model. The limitation is that any other linear structures, for example railways or rivers, cannot be detected.

We present a method general enough to be applied for the detection of any types of networks (roads, rivers,..), and to differentiate them in the last step.

METHODOLOGY

Global description of the method

The main idea is to use an hybrid process to progressively go from low level detection to high level description of the objects, ie the networks. Our approach is guided by three major steps: 1) *feature extraction*, or detection of linear structures that constitute the network: 2) *symbolic representation* in order to retrieve the network as a graph representation; 3) *classification* of the network.

Linear structures extraction

The approach for local features extraction is based on differential geometry. It can be shown from simple mathematical models that crest-points, ie third order differential characterisitcs, localize the axes of linear structures of the image [4]. But these lines do not correspond to the whole line-object. Thus, we process to perceptual grouping, which, by using geometrical constraints, will enable to merge two crest-lines at their extremities, in order to recover one whole line.

Network recovering

It is applied to encode the spatial relationship of the retrieved lines and their branching points. For this purpose, we use graph teory approach [2]. Each line L_i is mapped onto a node $n \in N$ of the graph $G(N, V)$, where V is the set of vertices v. To build the graph consists in deciding wether a vertex has to be put between two nodes or not.

The general idea of the connection criteria is to first compute the intersection point C between two arbitrary lines, and then, to calculate the distance between this point and each of the lines. The vertex is set if C belongs to one of the two lines and if the distance from the other is under a given threshold. Thus, we retrieve simple connected graphes.

Classification process

Recognition results from the observation of the real word. It is based on the type of the crossing points C and on the geometrical and radiometrical properties of the connected lines around this point. It is achieved during the graph building in order to differentiate road networks from river networks.

We define four types of crossings C: "T" or "+", if C results from the intersection of two perpendicular lines, "X" or "Y" otherwhise. "T" and "Y" are the jonctions between the extremity of one line and any point of the other line. For "X" or "+", C belongs to both lines.

We assume two classes of networks: roads or rivers. The road-class has three sub-class: roads, highways, railways. The type of a jonction determine the class of the network it belongs to. When one jonction has set up the class of the network, then all the lines that will be further connected to it will have the same class.

The classification, processed during network building, enables, in case of the presence of a bridge, not to confuse two road and river networks into one network only.

The resulting structure extracted is then described by: the type of the network, the spatial organization of the lines that constitutes the network, the size of the network and the local –ie, at each point– and global –mean on the lines– width and curvature.

RESULTS

Illustration of the process is presented at figure 1. The image (size of 900x900 pixels) is acquired in the proximity of Poyang lake, in Jiangxi province of China. The crosses represent the jonctions detected as road intersections. Note that for detection of linear features of different widths, different filters have been applied. Whereas not visible in the image, the process has recognized the network as being roads –due to jonction characterisitics– and the two isolated lines as rivers –due to the signe of the gradient at the crest-points.

CONCLUSION

We have presented a method for network detection and representation from SPOT images. This method will be extended to SAR image, and applied for the purpose of flood monitoring [5].

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Figure 1: Illustration of the detection and classification process from a SPOT-image (up-left) (courtesy to CNES-SPOT-image); up-right: crest-points detection; down left: after grouping and network retrieval, main road-lines and rivers have been recovered and distinguished; the crosses localize the jonctions, recognized as road intersections; down right: superimposition with the original image.