LINE SEGMENT VECTORIZATION ON HIGH-RESOLUTION SATELLITE IMAGES

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1. INTRODUCTION

Linear features on high-resolution satellite images, such as building tops and road edges, are the most significant artifacts of man-made objects. They are important in machine understanding of the images obtained by air/space-borne sensors. With the increase of the image resolutions, it is possible to digitally reconstruct city structures with reasonable precisions. Due to the economic and academic importance, automatic and semi-automatic modeling of digital cities draws much research and development efforts in recent years [1][2].

This paper presents a "Sweep & Scan" algorithm for the extraction of directed linear features from images. The "Sweep" part uses the Wallace parameterization of the Muff Transform [3] to identify straight lines globally, and the "Scan" part uses edge continuation and intensity correlation to identify edge vectors locally. Some of the applications of this algorithm include the extraction of the boundaries of man-made objects from high-resolution satellite images, and the skew estimation of document images [4].

As one of the recent developments of the digital Hough Transform, the Muff Transform deploys a parameterization scheme called the Wallace parameterization that provides several advantages in line detection over its predecessors, such as the direct graphical mapping of transform parameters and the constant line resolution in the parameter space. Since the general Hough Transform with various parameterization schemes do not retain the complete localization information, it is used to identify lines rather than segments, circles rather than arcs, and so on [5]. This paper borrows the idea of the Wallace parameterization scheme rather than the Muff Transform itself, to sweep on the edge maps of high-resolution satellite images to extract the vectors of line segments that are sufficiently long for representing man-made objects.

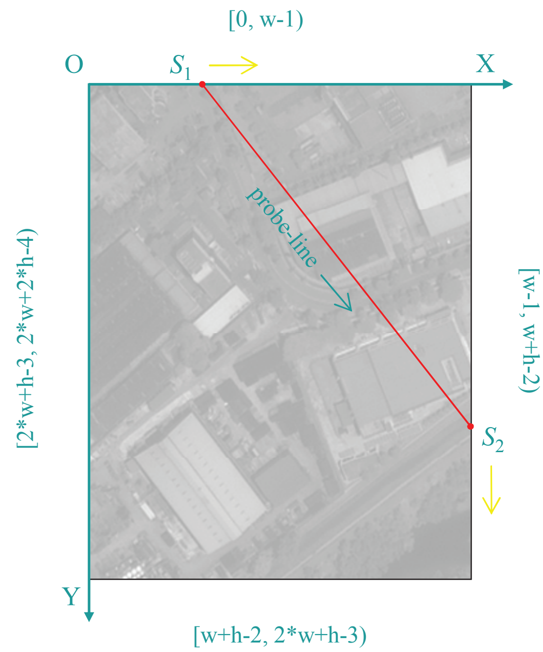

Figure 1. The proposed "Sweep & Scan" line segment vectorization scheme.
Edge maps are used to identify the boundaries of the man-made objects.

2. LINE SEGMENT VECTORIZATION

The proposed "Sweep & Scan" line segment vectorization scheme is based on the Wallace parameterization (S_1, S_2) of the Muff Transform, as shown in Figure 1, where w and h are the width and height of the image, respectively. The line from S_1 to S_2 forms a probe-line. The parameters (S_1, S_2) are in a bounded range of $0 \leq S_1 < S_2 < 2(w + h)$ in order to achieve unique probe-lines in this configuration. Like the Hough Transform and all its variants in the general form, the Muff Transform sweeps for straight lines on the edge map. This is the foundation of the "Sweep" part of the proposed algorithm. In order to identify the endpoints and directions of the line segments, a binary edge continuation test along a probe-line is performed with given tolerance of broken pixels. This is the "Scan" part of the proposed algorithm.

When the proposed "Sweep & Scan" algorithm is applied on the edge map of an image, each edge segment corresponds to a bunch of edge vectors that share most of the same edge segment as shown in Figure 2. This is due to the aliasing problem of the probe-lines on the image grid. In order to resolve the ambiguity of the edge vectors, a subsequent correlation test is performed on the edge map and the edge vectors in grayscale. The edge vector with the maximum correlation is considered to be the only representation of the edge segment. The experimental result of the proposed algorithm on a sample IKONOS image of dimension 2000×2000 pixels and

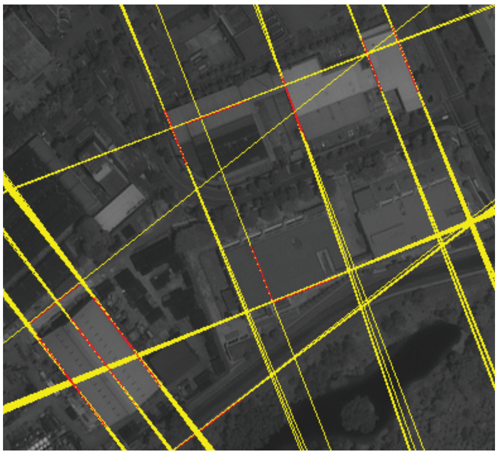

Figure 2. The probe-lines and the bunches of edge vectors
(only edge segments with length ≥ 40 pixels are shown).

minimum segment length of 20 pixels is shown in Figure 3, which takes about 193 seconds to complete on a 3GHz Pentium 4 PC running Java Virtual Machine 5.

3. CONCLUDING REMARKS

The Wallace parameterization of the Muff Transform provides an efficient and easy-to-implement configuration for identifying straight lines, and the proposed vectorization extension in this paper solves the edge ambiguity problem by a further correlation test. The experimental results using high-resolution satellite images show that the proposed line segment vectorization algorithm in this paper is both effective and efficient for real world applications, such as automatic matching of stereo satellite images based on the edge vectors assuming same elevations for each edge vectors.

An alternative way of using the proposed algorithm is to apply the Connected Component Analysis (CCA) on the edge map of an image first, then “Sweep & Scan” locally on the image areas that correspond to the bounds of the individual components, resulting in much faster edge vectorization with comparable accuracy to the global version, which is the extreme case of all the components being treated as one.

Because of the independent nature of the line “Sweep & Scan” algorithm, it is a good candidate to apply parallelization to drastically improve its performance on multi-core computers. A 20% increase in performance is observed in a hyper-threading single-core Pentium 4, and multi-core machines are becoming more and more widely available to achieve this goal for future applications.

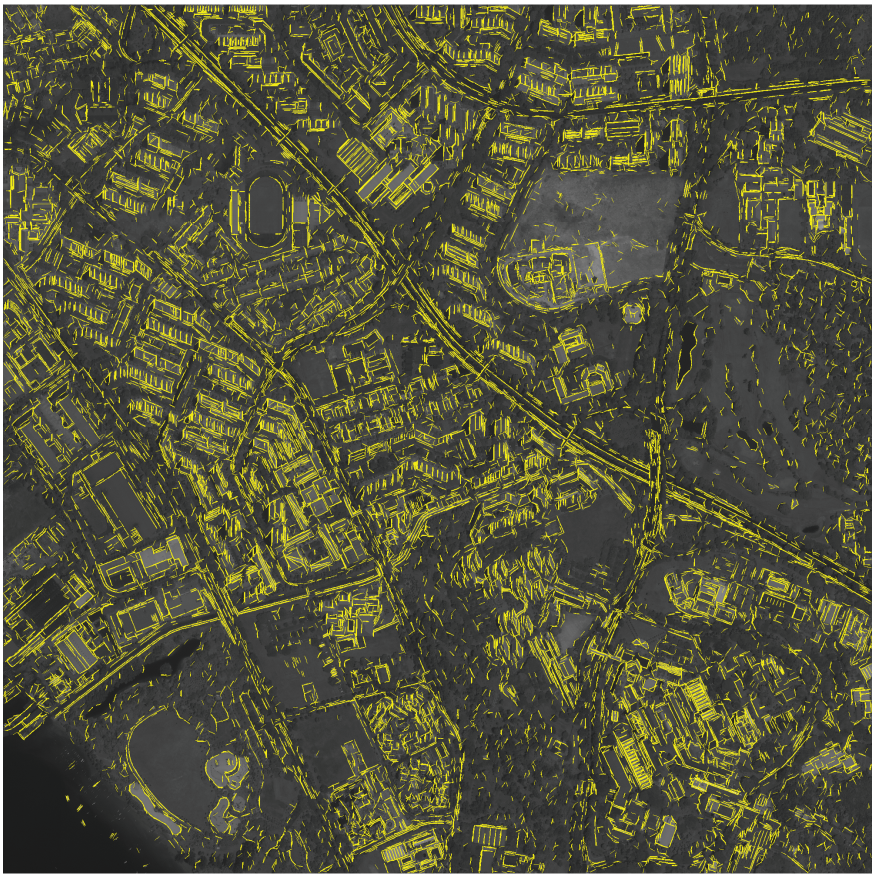

Figure 3. Edge vectors superimposed on a sample IKONOS image, with the dimension of 2000×2000 pixels, and the minimum segment length of 20 pixels.

4. REFERENCES

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