УДК 528.711:004.353.245

LINEAR INFRASTRUCTURE MONITORING USING DISTRIBUTED REMOTE IMAGING

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Мониторинг объектов линейной инфраструктуры при помощи распределённой дистанционной съёмки

Предложено автоматическое детектирование объектов линейной инфраструктуры на дистанционных изображениях на основе оптимального преобразования Радона в комбинации с эффективными алгоритмами векторизации. Полученные результаты могут использоваться для дистанционного мониторинга дорог, продуктопроводов, магистральных ЛЭП и т.д.

Linear infrastructure facilities include railroads and highways, major bridges, oil, gas and petroleum products pipelines, trunk power lines, underground utility lines, etc. A continuous automated monitoring of linear infrastructure is very important and relevant topic now.

The main interpretation feature of linear infrastructure is a small area with a long linear distance. Such facilities can be monitored conveniently and efficiently using a distributed remote imaging [1].

Automation of linear infrastructure monitoring implies at least automatic extraction of linear objects in the images. The basis for linear objects extraction is a brightness patterns and special geometric features of spatial pixel segments in image.

A lot of methods for linear objects extraction from remote sensing imagery are known. A large variety of edge detection operators, support vector machines, triangulation, and topological vectorization are used for this purpose [2].

The main drawback of most existing approaches is relatively low energy of linear objects in image. Therefore, the presence of noise leads to significant degradation of vectorization quality [3]. Traditionally, to suppress high-frequency spatial noise of digital image the integrating operators are applied [4].

An effective tool for parameterized lines and shapes extraction in digital image is the Radon transform [5]. The Radon transform is a special case of the generalized ìntegral-geometric transform that maps the function $f(\cdot)$ at a certain set into its representation $F(\cdot)$ specified by integrals of $f(\cdot)$ along any and all possible subsets of this set [6]. An integral Radon transform of two-dimensional image itself is an expansion of the $f(\cdot)$ function in integrals along all possible right lines [7]:

$$F(\xi) = \int_{\xi \in X} f(x)\, dx \tag{1}$$

The inverse Radon transform exists, which restores the original function by the values of its Radon transform:

$$f(x) = \sqrt{\frac{2}{\pi}} \frac{\partial^2}{\partial x^2} \int_{x \in X} F(\xi)\, d\xi \quad (2)$$

In the real-life digital image processing the integration should be replaced by the summation, and the continuous set of all possible direct lines – by ones discrete set with a given quantization step.

Fig.1 illustrates the consistent application of direct and inverse Radon transform to fragment of digital remote image for linear objects extraction.

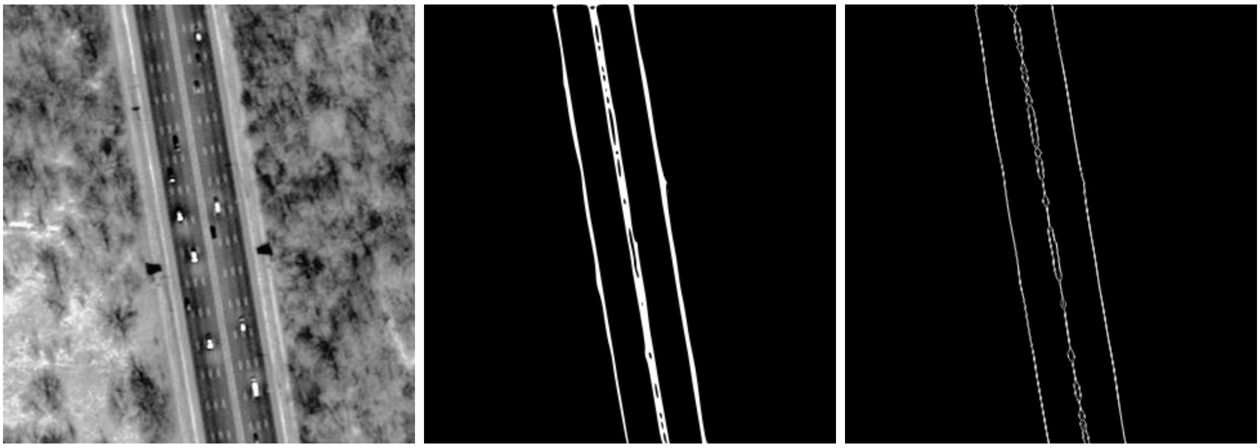
a *b* *c* *d*

Fig.1 – Integral Radon transform: source remote image (*a*), direct Radon transform (*b*), inverse Radon transform (*c*), vectorized linear objects (*d*)

Common Radon transform effectively identifies the straight lines of known direction only [8]. To extract the lines of arbitrary direction Radon transform must be optimized at each point of the image: the transformation is performed along the line with the maximum response among all possible directions. The optimization payback is a very large computational complexity of optimal Radon transform: a digital image fragment with linear dimensions of several hundred pixels processed for many hours. Therefore, for the practical implementation of linear objects extraction the special measures necessarily need to speed up the processing, such as fast Radon transform, or some hybrid technologies [9].

Fig.2 demonstrates the possibility of automated monitoring of the road section using Pléiades 1A high resolution satellite imagery. In this case a combination of fast Radon transformation with skeletonizing based on advanced Canny edge detector is used [10].

An important requirement for just distributed monitoring is capability to identify mutual linear facilities at different remote images. This operation is much more convenient to formalize and perform over vector entities using their topology analysis [11]. It is another argument in favour of the need for vectorizing images of linear infrastructure facilities.



a *b* *c*

Fig.2 – Road extraction demo: source high-resolution satellite image (*a*), inverse Radon transform (*b*), vectorized highway traffic lanes (*c*)

Thus, the presented approach can be useful in information system development for remote monitoring of linear infrastructure facilities.

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