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LANDMARK-BASED IMAGE REGISTRATION USING A PLAIN OBJECT MODEL IN REMOTE SENSING TASKS

Summary. *Development of automated remote sensing image registration algorithm has become a major concern to researchers in the field of image processing. A novel landmark-based remote sensing image registration algorithm is presented in this paper. It relates to the developed by the author plain object detection and recognition algorithms. The mathematical model of elementary and plain objects of an image based on the contour analysis is considered. The analytical solution, which allows the analysis of a specific image object, is obtained.*

Key words: *the vertex, contour analysis, image registration.*

Introduction. Development of automated remote sensing image registration technique has become a major concern to researchers in the field of image processing. The recent advances in the working out of remote sensing systems, hardware, and software make possible the practical use of various automated information systems aimed to support decision-making activities. The techniques for processing remote sensing data are increasingly used in scientific and applied researches in the various fields of human activity. In this regard one of the most important tasks of geographic information systems is the development of techniques for registration of images covering the same area of the Earth's surface. By establishing those techniques, researchers mainly focused on using ready-made commercial software products that have multi functionality and provide many opportunities for processing remote sensing data. In this case, emphasis is placed on the use of automated image registration techniques. This is cause mainly by the necessity of processing regularly received remote sensing data. Operator participation in processing of large volumes of data introduces subjectivity into the results, which entails decrease their reliability and that in turn leads to increases in the operating costs of image processing systems. Therefore, the development of an automated remote sensing image registration technique is relevant in scientific and practical terms.

Image registration is a problem often encountered in many application areas like, for example, astro- and geophysics, computer vision, medicine and remote sensing [1, 2]. Here, we focus on remote sensing applications. Typical remote sensing tasks include monitoring of air pollution, deforestation and others.

Researchers have collected a wealth of valuable material on the problem of image registration. Unfortunately, no unified treatment for image registration has been yet established [3] Therefore, each application area has developed its own algorithms. The primary modern desktop applications for geographic information system professionals are: Gvsig [4], Quantum GIS [4], GRASS [5] and ArcGIS [6]. They perform remote sensing image registration in manual mode. Meeting the challenge of automated remote sensing image registration should be built in conjunction with answers on other image processing puzzles. Image registration is closely related to the problems of image segmentation and object detection and recognition, thus applying solution of one issue to the others.

Image segmentation is one of the fundamental tasks in image processing. Despite numerous algorithms have been established for image segmentation, there is no general theory yet. Therefore, image segmentation is of current scientific and practical interest.

The aim of this study is the development of automated remote sensing image registration algorithm. Its distinguishing feature is the use of the vertex of a plain object as a landmark. The mathematical model of elementary and plain objects of an image developed by the author has been given.

Contour Analysis-Based Mathematical Model of Elementary and Plain Objects of an Image

The task of image segmentation is to subdivide an image into its constituent parts [7, 8]. It is ill-posed since the solution is not singular. A problem is well-posed in the sense of Hadamard if it has a solution, the solution is unique and depends continuously on the data; otherwise it is called ill-posed [3, 9].

An image I is a continuous mapping f: $\Omega \to \mathbf{R}$, $\Omega \subset \mathbf{R}^2$, where f is compactly supported. An object O of an image I is a domain: $\Omega \subset \mathbf{R}^2$. Let $k \in \mathbf{N}$ and $k > 0$. A contour Γ of an image I is a connected set in Ω: $\Gamma = \{a_i\}$. A finite contour Γ_Λ of an image I is a closed interval in Ω: $\Gamma_\Lambda = [a_0, a_{k-1}]$. A closed contour Γ_Ω of an image I is a closed interval in Ω, the endpoints of which are the same: $\Gamma_\Omega = [a_0, a_{k-1}]$, $a_0 = a_{k-1}$.

A closed contour Γ_Ω is equivalent to a corresponding object O boundary: $\Gamma_\Omega \Leftrightarrow O$. The problem of contour detection is well set out in [11, 12].

Definition 1. Let an image I be given. Moreover, let X be a set of all closed contours of an image I and O be an object of the image I. Under a closed contours decomposition set Y of the object O is understood to mean a subset X' of the set X. Here, X' is a set of all closed contours of the object O.

Definition 2. Let an image I be given. Moreover, let X be a set of all closed contours of the image I, O be an object of the image I and Y be a closed contours decomposition set of the object O. Then the object O is an elementary object *el* of the image I, if:

1. the cardinality of the set Y is equal to one: $q = 1$;
2. the set Y does not intersect with set Y_i of any other object O_i of the image I: $Y \cap Y_i = \emptyset$.

Definition 3. Let an image I be given. Moreover, let X be a set of all closed contours of the image I, O be an object of the image I and Y be a closed contours decomposition set of the object O. Then the object O is a plain object *pl* of the image I, if the cardinality of the set Y is equal to one: $q = 1$.

In addressing a significant number of urgent scientific and technical problems analysis of a finite contour Γ_Λ is required. This is basically due to processing of an image object having a size which is near to a size of a sensor element, i.e. one or several pixels. In this case, the finite contour Γ_Λ is assumed to be closed Γ_Ω: $\Gamma_\Lambda \Leftrightarrow O$.

A small-sized plain object *sspl* is a plain object *pl* the perimeter of which does not exceed k pixels. It can be considered an example of a model of an image I noise.

Note the task of decomposition of a contour Γ into sets of finite Γ_Λ and closed Γ_Ω contours, which is the basis of plain object detection issue. It is not discussed in this study, see, e.g., [11, 12] for details.

Landmark-Based Remote Sensing Image Registration Algorithm Using Plain Object Model

Image registration is of the central challenging problem in image processing today. Let us be given two images a reference R and a template T, which have taken, in particular, from different devices, at different times. The task is to determine a suitable transformation such that a transformed version of a template image T is similar to another one. The aim of image registration is to remove the artificial differences introduced, for example, by movement, but to retain the real differences due to the variations of the different objects [2, 3]. The general image registration problem reads as follows.

Problem 1. Given two images R and T: $\Omega \rightarrow \mathbf{R}$, $\Omega \subset \mathbf{R}^2$ find a mapping $y{:}\circ\mathbf{R}^2 \rightarrow \mathbf{R}^2$ and a mapping $g{:}\circ\mathbf{R} \rightarrow \mathbf{R}$, such that the reference R and a deformed template $g\circ T_y(x)$ images are similar, where $T_y(x) := T\circ y(x) = T(y(x))$.

The problem (1) is ill-posed. A direct approach is not possible. Regularization of the problem is well set out in [3].

Landmark-based image registration [1−6] is the major approach to register remote sensing data today. Techniques for automatization are well set out in [1, 13]. Here, we consider the application of the vertex as a landmark. The usage of it in comparison to other types of landmarks has several advantages. The vertex has the geometric meaning and is invariant under projective mapping, except for the case when an angle is converted into the angle of 0, π or 2π rad. Also, the vertex represents coordinates of one pixel. It is more efficient in comparison with the representation of other geometric landmarks (e.g., curves). Therefore, it is easier to establish correspondence between different datasets of vertices. It worth to mention that there is a lack of invariance under projective mapping in all vertex detection algorithms are known in literature [14]. Consequently, the developed by the author remote sensing image registration algorithm consists of the following steps:

1. The vertex detection.
2. Conjugate vertices pair detection.
3. Image registration.

The vertices are determined straight with the help of the vertex detection algorithm [14] or in conjunction with conjugate plain objects (the plain object detection and recognition algorithms [12, 15]). The advantage of the developed by the author vertex detection algorithm [14] is that it is invariant to projective distortion compared to competing algorithms [14]. Besides, it is at the heart of the plain object detection and recognition algorithms [12, 15]. Therefore, the algorithms [12, 14, 15] complement each other and are invariant under projective mapping. Also, the usage of conjugate plain objects minimizes the datasets of vertices.

All the rest steps of the algorithm are well set out in [1−3, 13].

The main drawback is the mapping *y*, because it is fully determined by the choice of the vertices. In case when it is not satisfying, an improvement in obtained results can be achieved only by adding or removing vertices. Therefore, operator participation is required.

Conclusion. This study proposed the developed by the author landmark-based remote sensing image registration algorithm. It is based on the use of the vertex as a landmark and relates to the plain object detection and recognition algorithms. The examined mathematical models of elementary and plain objects of an image lead to analytical solution of the problem of analysis of a specific image object.

References

1. Moigne J. L., Netanyahu N. S., Eastman R. D., Image registration for remote sensing, Cambridge University Press, Cambridge (2011).
2. Modersitzki J., Numerical Methods for Image Registration, Oxford University Press, Oxford (2004).
3. Modersitzki J., FAIR: Flexible Algorithms for Image Registration, SIAM, Philadelphia (2009).
4. Free Gis Software: Postgis, Ilwis, Quantum Gis, Grass Gis, Gvsig, Geoda, Whitebox Geospatial Analysis Tools, Mapbender, Jump Gis, General Books, Memphis (2010).
5. Neteler M., Mitasova H., Open Source GIS: A Grass GIS Approach, 3rd ed. Springer, New York (2008).
6. Keranen K., Malone L., Instructional Guide for The ArcGIS Book, ESRI Press (2016).
7. Gonzalez R. C., Woods R. E., Digital image processing, 2nd ed. Prentice Hall, New-Jersey (2002).

8. Kazlouski A. M., "Contour analysis-based elementary and plain objects in image processing mathematical models [in Russian]", International scientific journal, No. 3, 75-77 (2016). DOI:10.21267/IN.2016.3.1107.
9. Tikhonov A. N., Arsenin V. Y., Solutions of Ill-Posed Problems, Wiley, New York (1977).
10. Canny J., "Computational Approach to Edge Detection", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 8, No. 6, 679-698 (1986).
11. Kazlouski A. M., "Influence of Canny algorithm parameters on a plain object detection results in remote sensing tasks [in Russian]," 26th International Scientific Conference of Eurasian Scientific Association. Current issues of the development of science in the world. Moscow, 45-47, (April 2017).
12. Kazlouski A. M., "Plain object detection and recognition algorithms [in Russian]", 10th International Scientific Conference of Eurasian Scientific Association. Effective researches of modernity. Moscow, 58-61 (October 2015).
13. Rohr K., Landmark-based image analysis: Using Geometric and Intensity Models, Kluwer Academic Publishers, Dordrecht (2001).
14. Kazlouski A. M., "Vertex detection algorithm in image processing based on binary image contour approximation [in Russian]", International scientific journal, No. 9, 63-73 (2016). DOI:10.21267/IN.2016.9.3288.
15. Kazlouski A. M., "Plain object recognition algorithm in image processing based on stochastic geometry [in Russian]", International scientific journal, No. 11, 70-73 (2016). DOI:10.21267/IN.2016.11.3860.