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Registration of the Roads with the Use of a Satellite Image and a Road Map: Application to Road Map Update

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Abstract

Among different satellite images analysis tasks, roads registration plays an extremely important role as it is often the essential step for various applications such as improving the approach of the road network extraction, update map and producing a new map. In this paper, we present an iterative algorithm for linear registration of roads with the use of satellite images of Algeria and a road map. The proposed approach incorporates a priori information given by the road network of the road map extracted from the corresponding satellite image. The proposed algorithm was tested on the satellite images; the experimental results show that this algorithm achieved good results.

Key words

Registration, road network, node, satellite image, road map.

1. Introduction

Actualization of cartographic data using imagery is an important application in the earth sciences (Nougrara, 2015) and (Nougrara and al., 2011). The spatial remote sensing is a powerful tool in managing the environment. Indeed, this technique allows covering large scenes with a certain temporal frequency (Ba and al., 2015). The digital image analysis usually carries on producing maps that accompany different types of objects (roads for an example) and updating of these objects in case of damage caused by natural disasters (Cavayas, 2010). Digital images are an important source of information on the state of a country at a given time (Richard and al., 2008). It is necessary to carefully evaluate the input images with reference to other data sources to ensure their correct geographic reference (Shan and al., 2010). To georeference means to associate something with locations in physical spaces (Al-dami, 2015). Georeferencing may be applied to any kind of object or structure that can be related to a geographical location such as roads, buildings, etc. This term is commonly used in the geographic information systems GIS field to describe the process of associating a physical map or raster image of a map with spatial locations; GIS environment is used to compare ancient and recent maps as well as remote sensed images (Giannini and al., 2011). Information about a location can be imprecise and context-dependent (Albuquerque and al., 2012). In a road network, where streets may be long, just the name of a street may represent low-valued information for certain applications. To improve precision, geocoding commonly includes the number of a building on the street for example. Another way to reference locations, frequently used in human communication, is to use a proximity attribute such as neighborhood. Another relevant aspect of location description using natural language is the direction attribute such as the direction of a street toward a location. The map scale controls most often the nature of a research entity: for example, a road segment may be considered as a linear entity on a small scale or as a polygon feature on a large scale (Cavayas, 2010). Classification algorithms consider the pixel as an autonomous geographical entity whose identity is sought; the result is a thematic map. After calculations, we can then correct any data since we have a pass card giving the projection of each point on the ground. In fact, the need to register images has arisen in many practical problems in diverse fields. Registration is often necessary for integrating information taken from different sensors, finding changes in images taken at different times or under different conditions, inferring three dimensional information from images in which either the camera or the objects in the scene have moved and for model-based object recognition (Brown, 1992).Three major research area which the registration methods are studied: (1) Computer vision and pattern recognition for numerous different tasks such as object recognition, (2) Medical image analysis including diagnostic medical imaging, such as tumor detection, and biomedical research including classification of microscopic images of blood cells, cervical smears, and chromosomes and (3) Remotely sensed data processing for civilian and military applications in agriculture, urban studies, target location and identification, cartography, integration information into SIG, creation super-resolution images, etc. In particular, for the road network of a satellite image, the registration is used to improve the detection of roads in case of existing difficult areas in image. Also, it is used for updating the maps indicating the differences compared to the image. The major problem of registration is bad road network detection on the image and the map. Also the problem of having an optimal mapping resides in the choice of the best transformation. In fact, the fundamental characteristic of any image registration technique is the type of spatial transformation or mapping used to properly overlay image and map. The most common general transformations are: rigid, affine, projective, perspective and global polynomial. The most frequently used transformation model in registration is the affine transformation: it is sufficiently general and can handle rotations, translations, scaling and shearing.

In this paper, we propose a method for registration of the roads (the goal of this registration is to update the road map) with the use of satellite images of Algeria. The basic idea of this proposed method is derived from our previous works (Nougrara, 2015) and (Nougrara and al., 2011). This paper is structured as follows: section 2 presents an overview of the literature, section 3 describes the proposed method in details and section 4 gives results and comparisons on satellite images of Algeria. Finally, conclusion is drawn and possible directions for future research indicated in section 5.

2. Literature overview

Registration is a fundamental task in image processing. During the years, several techniques have been developed for various applications resulting in several methods, such as the work (Brown, 1992) establishes the relationship between the variations in the images and the type of registration techniques which can most appropriately be applied. Knowledge about the characteristics of each type of variation effect the choice of feature space, similarity measure, search space, and search strategy which will make up the final technique. All registration techniques can be viewed as different combinations of these choices. The work (De Falco and al., 2008) presents a software system grounded on differential evolution to automatically register multiview and multitemporal images; this system is implemented and tested through a set of 2D satellite images on two problems, i.e. mosaïcking and changes in time. Another work (Vandewalle and al., 2006) which presented a new frequency domain method for the registration of a set of low-resolution, aliased images that out performs previous frequency domain registration methods. This image registration technique is then applied to super-resolution imaging to reconstruct a double-resolution image (in each dimension) from a set of aliased images. After the image alignment, bicubic interpolation was used to reconstruct the high-resolution image. The major goal of the paper of (Zitovà and al., 2003) is to provide a comprehensive reference source for the researchers involved in image registration, regardless of particular application areas. Finally, one of the major research area which the registration methods are studied is remotely sensed data processing for integration information into GIS;

some works have been considered related to GIS applications such as the works of (Mandal and al., 2004) and (Aït Ouahman and al., 2008).

Registration of the roads with the use of the satellite image and the road map plays an extremely important role as it is often the essential step for various applications such as improving the approach of the road network extraction, update map and producing a new map.

3. Proposed methodology

The basic idea of our methodology is mainly derived from our previous works on extraction of road network with its nodes from satellite images (Nougrara, 2015) and (Nougrara, 2011). The reader is referred to these references for more details. Here a brief summary is presented. The previous algorithm in (Nougrara, 2011) of registration concerns the transformation of any pixel of satellite image with its digital coordinates to the corresponding pixel with its geographical coordinates. The present algorithm concerns only the information obtained by the road network and its nodes which are extracted from a satellite image (Nougrara, 2015); this algorithm improves our previous algorithm by incorporating a priori information provided by the extracted road network. We consider the road network of the satellite image as a set of pixels; then an affine transformation of registration is used to have the corresponding pixels in the roadmap. The set of pixels of each road of the extracted road network represents the list of adjacent road pixels; this list guarantees a road that is both homogeneous and piecewise linear. The use of these pixels represents the decision criterion to have a best registration. Also the road network is composed of a set of nodes (a node is defined like an intersection point between two roads); these nodes serve in the choice of pixels of support (the nodes have been proven to be one of the potential features serving reliable identification basis). This process of registration has been applied in iterative way.

3.1 Principle of registration

NR: number of roads of the extracted road network from a satellite image

PR: number of the adjacent road pixels which form each road

- For each road of the extracted road network from a satellite image and for each pixel's road, we calculate its new coordinates in road map.

- The algorithm is defined as follows:

For i=1 to NR

For j=1 to PR

$x= a*z+b*t+c$

y=d*z+e*t+f

endj

endi

- The parameters a, b, c, d, e, and f are determinate by the use of the three selected pixels of support.

4. Experimental results and discussion

In this section, some experiments which test the proposed methodology are described and its evaluation is doing to show its advantages and disadvantages.

4.1 Experiments

Data sets:

In this paper, the results (Nougrara, 2015) of the extracted road network from satellite image (see figures 1 and 2) are used for testing our proposed approach and compare the results with some existing information (a priori information). The figures 1 and 2 show original and subsets of satellite image over Laghouat area of Algeria and their extracted results.

Figure 1. An original 280x419 satellite image of Laghouat area of Algeria.

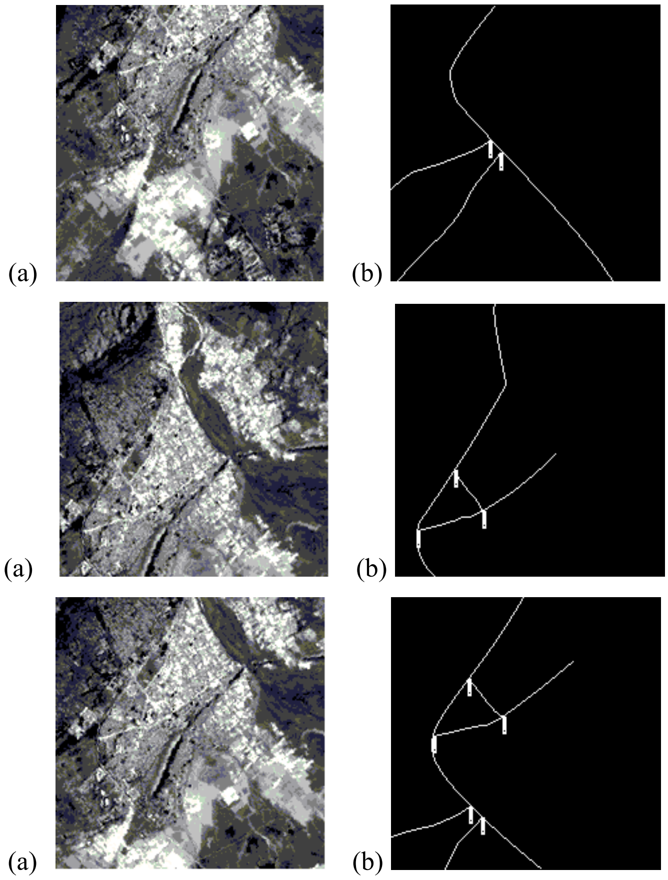


Figure 2. Road networks with their nodes extraction from a 200x200 satellite image: (a) sub image of the original image in figure 1and (b) the final result.

Results:

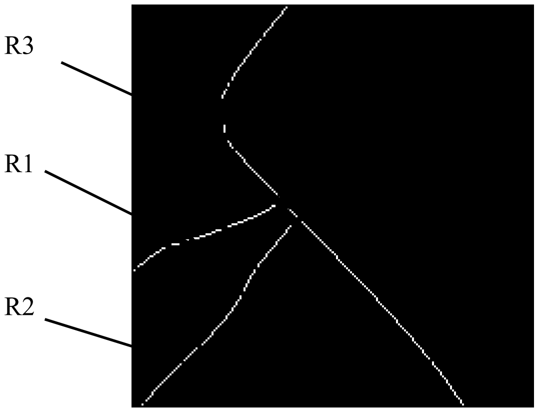
With the following three selected pixels of support:

Digital coordinates (z, t)	Geographical coordinates (x, y)
(107, 169)	(487905, 3740069)
(86, 139)	(487307, 3740895)
(59, 183)	(486566, 3739613)

We determinate the parameters a, b, c, d, e, and f of the algorithm in Section 3.1, and we can calculate the new geographical coordinates of any digital coordinates. Table 1 shows the results of registration of the three images of the extracted road network of the figure 2.

Table 1. Passage of the digital coordinates to the geographical coordinates (Points are with Black color in each road)

(a)



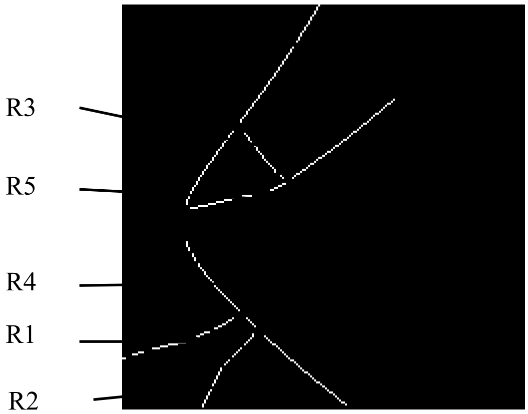
	Digital coordinates	Geographical coordinates
R1	(0, 133)	(484965.838, 3741001.146)
	(16, 120)	(485334.020, 3741397.227)
	(25, 118)	(485554.276, 3741465.499)
	(47, 111)	(486087.452, 3741693.791)
	(74, 99)	(486733.365, 3742073.127)
R2	(4, 200)	(485231.820, 3739056.813)
	(34, 170)	(485908.234, 3739963.079)
	(55, 145)	(486371.820, 3740713.813)
	(62, 131)	(486512.318, 3741128.883)
	(83, 105)	(486973.428, 3741908.704)
R3	(166, 200)	(489285.563, 3739238.576)
	(149, 178)	(488805.699, 3739859.414)
	(83, 105)	(486973.428, 3741908.704)
	(74, 99)	(486733.365, 3742073.127)
	(50, 72)	(486065.959, 3742831.545)
	(47, 65)	(485973.558, 3743031.787)
	(44, 55)	(485873.729, 3743319.290)
	(43, 47)	(485828.898, 3743550.863)
	(49, 38)	(485956.753, 3743819.377)
	(78, 0)	(486588.336, 3744957.216)

(b)

	Digital coordinates	Geographical coordinates
R1	(17, 165)	(485470.462, 3740089.439)
	(49, 155)	(486246.441, 3740416.212)
	(57, 155)	(486446.626, 3740425.188)
	(65, 151)	(486636.907, 3740550.512)

	(119, 108)	(487881.688, 3741861.835)
R2	(44, 121)	(486037.143, 3741399.556)
	(56, 137)	(486377.036, 3740947.630)
	(65, 151)	(486636.907, 3740550.512)
R3	(31, 200)	(485907.444, 3739087.107)
	(21, 187)	(485625.025, 3739454.016)
	(17, 178)	(485502.649, 3739711.310)
	(17, 165)	(485470.462, 3740089.439)
	(18, 159)	(485480.629, 3740265.083)
	(44, 121)	(486037.143, 3741399.556)
	(65, 89)	(486483.397, 3742353.898)
	(83, 57)	(486854.582, 3743304.874)
	(78, 37)	(486679.947, 3743881.001)
	(74, 0)	(486488.243, 3744952.728)

(c)



	Digital coordinates	Geographical coordinates
R1	(0, 176)	(485072.304, 3739750.410)
	(14, 171)	(485410.248, 3739911.552)
	(31, 168)	(485828.213, 3740017.887)
	(43, 162)	(486113.634, 3740205.872)
	(59, 153)	(486491.720, 3740485.606)
R2	(39, 200)	(486107.629, 3739096.083)
	(48, 179)	(486280.841, 3739717.005)
	(53, 177)	(486401.005, 3739780.789)
	(61, 169)	(486581.382, 3740022.460)
	(68, 162)	(486739.212, 3740233.922)
R3	(58, 60)	(486236.432, 3743189.563)
	(77, 84)	(486771.294, 3742512.796)

	(83, 88)	(486931.337, 3742403.181)
R4	(112, 200)	(487934.316, 3739177.988)
	(68, 162)	(486739.212, 3740233.922)
	(59, 153)	(486491.720, 3740485.606)
	(37, 128)	(485879.313, 3741188.094)
	(34, 123)	(485791.864, 3741330.162)
	(31, 113)	(485692.035, 3741617.665)
	(31, 101)	(485662.323, 3741966.707)
	(58, 60)	(486236.432, 3743189.563)
	(86, 20)	(486838.040, 3744384.454)
	(96, 0)	(487038.752, 3744977.412)
R5	(31, 101)	(485662.323, 3741966.707)
	(65, 94)	(486495.777, 3742208.463)
	(72, 94)	(486670.939, 3742216.317)
	(83, 88)	(486931.337, 3742403.181)
	(136, 46)	(488153.571, 3743684.295)

Performance evaluation:

The evaluation of this proposed algorithm is doing by a measure of similarity and a measure of consistency. For the similarity measure, we have taken other points of the original image (nodes of the extracted road network) that we know their real geographical coordinates and we have compared them by the new coordinates calculated by this algorithm of registration (the results are satisfactory). For the consistency measure, we have evaluated the results obtained in (Nougrara, 2015) which represent the information on the roads; so the results obtained by the registration algorithm represent the linear objects (roads).

4.2 Discussion

The suggested methodology achieved good degree of success according to the level of extraction. Its performance was evaluated through methods recently proposed in the literature (Govindarajulu and al., 2012) and (Zaletelj and al., 2013). The obtained results were competitive compared to these methods. The main drawback of our method resides in the size of the image if it is very big and in this case the registration is difficult.

Conclusion

It is interesting to transform the images defined by digital coordinates into geographical coordinates. Especially the digital coordinates concerning the obtained information from the extracted road network to solve the update road map problem. Our proposed solution is to develop an iterative algorithm of linear registration using a satellite image of areas in Algeria.

We presented in this paper a method for registration of a satellite image and a road map. Its originality lies in the use of primitives concerning the extracted roads (the fixation points of a road and the nodes that represent the points of intersection between roads). These primitives are used to have good results in rural areas (acceleration and stability of the mapping process).

The obtained results were in general good, but this work can be also developed by treating other elements of the map (buildings for example).

References

1. Z. Nougrara, Towards robust analysis of satellite images of Algeria. Application to road network and its nodes extraction, AMSE Journals, Series: Advances B; vol.58, no. 1, pp. 53-66, 2015.
2. Z. Nougrara, A. Benyettou, A. Abdellaoui et al.¸ Development of georeferenced database of an extracted road network and its nodes from satellite imagery over Algeria sites, AMSE Journals, Journal of Advances in Modeling and Simulation techniques in Enterprises (Signal Processing and Pattern Recognition), vol. 54, no. 2, pp. 1-13, 2011.
3. A. Ba, P. Launeau, M. Robin et al. Apport du lidar dans le géoréférencement d'images hyper spectrales en vue d'un couplage Lidar/Hyperspectral, French Journal of Photogrammetry and Teledetection, no. 210, pp. 5-15, 2015.
4. F. Cavayas, Télédetection numérique, Book, Department of Geography, University of Montreal Canada, 2010.
5. J.P. Richard, J.M. Jaquet and L. Niggeler, Comment exploiter l'information des anciennes photos aériennes, Information Systems of territory, Geomatics Suisse, pp. 8-11, 2008.
6. J. Shan, E. Hussain, K. Kim et al., Flood mapping with satellite images and its web service, Photogrammetric Engineering & Remote Sensing, pp. 102-105, 2010.
7. H.A.N. Al-dami, Use different frequencies of 500 MHz Antenna and Geographic Information System Technique to assessment Road Stricture, International Journal of Current Engineering and Technology, vol. 5, no. 1, pp. 274-276, 2015.
8. M.B. Giannini, P. Maglione, C. Parente et al., Cartography and remote sensing for coastal erosion analysis, WIT Transactions on Ecology and the Environment, vol. 149, pp. 65-76, 2011.
9. F.C. Albuquerque, I. Barbosa, M.A. Casanova et al., Georeferencing Facts in Road Networks, Proceedings XIII GEOINFO, pp. 120-127, Campos do Jordao Brazil, 2012.

10. L.G. Brown, A survey of Image Registration Techniques, ACM Association for Computing Machinery Computing Surveys, vol. 24, no. 4, pp. 326-376, 1992.
11. I. De Falco, A.D. Cioppa, D. Maisto et al., Differential Evolution as a viable tool for satellite image registration, Applied Soft Computing 8, pp. 1453-1462, 2008.
12. P. Vandewalle, S. Süsstrunk and M. Vetterli, A Frequency Domain Approach to Registration of Aliased Images with Application to Super-resolution, EURASIP Journal on Applied Signal Processing, pp. 1-14, 2006.
13. B. Zitovà and J. Flusser, Image registration methods: a survey, Image and Vision Computing, 21, pp. 977-1000, 2003.
14. J.K. Mandal, S. Mal and S. Dutta, Toward implementation of security and storage efficiency for geographical information systems, A.M.S.E. Journal, Advances B (Signal Processing and Pattern Recognition), vol. 47, no. 3, pp. 1-12, 2004.
15. A. Aït Ouahman, T. Agouti, M. El Adnani and A. Tikniovine, A hybrid model of mathematical programming and multi-criteria decision analysis for the geographical information systems to multiple representations: industrial localization in Morocco, A.M.S.E. Journal; Modelling D, (Production Engineering and Management, Organization, Human and Social Problems), vol. 29, no. 2, pp. 1-18, 2008.
16. S. Govindarajulu and K. Nihar Kumar Reddy, Image registration on satellite images, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), ISSN: 2278-2834, ISBN: 2278-8735, vol. 3, Issue 5, pp. 10-17, 2012.
17. J. Zaletelj, U. Burnik and J. F. Tasic, Registration of satellite images based on road network map, Image and Signal Processing and Analysis (ISPA), 8th International Symposium on, Trieste, Italy, 2013.