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전역 구조 구속 조건에 기초한 Relaxation Matching 알고리즘

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Relaxation Matching Algorithm Based on Global Structure Constraint Satisfaction

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Key Words: constraint satisfaction, relaxation matching

Abstract

This paper represents a relaxation matching algorithm based on global structure constraint satisfaction. Relaxation matching algorithm is a conventional approach to the matching problem. However, we confronted some problems such as null-matching and multi-matching problems by just using the relaxation matching technique. In order to solve the problems, in this paper, the matching problem is regarded as constraint satisfaction problem, and a relaxation matching algorithm is proposed based on global structure constraint satisfaction. The proposed algorithm is applied a landslide picture to show the effectiveness. When the algorithm is processed at landslide inspecting and monitoring system, motion parameters such as displacement area and its direction are computed. Once movement is recognized, displacements are estimated graphically with statistical amount in the image plane. Simulation has been done to prove the proposed algorithm by using time-sequence image of landslide inspection and monitoring system.

Nomenclatures

A	: set of object in scene image
a_i	: line feature of A (object)
n	: number of object A
Λ	: set of label of model image
λ_j	: line feature of Λ (label)
m	: number of label Λ
(a_i, λ_j)	: a pair of matchable a_i and λ_j
$P_{(i,j)}$	: matching probability of (a_i, λ_j)
$P^{(k)}_{(i,j)}$	: kth matching probability of (a_i, λ_j)
$N_{(i,j)}$	: set of neighboring objects of (a_i, λ_j)
$r_{(i,j,h,k)}$	: compatibility coefficient.
$W_{(i,j,k)}$	: matching window defined by (i, j, k)
$S_{(i,j)}$	: Euclidean distance of (a_h, λ_j)
$Q_{(i,j)}$	: the support for (a_i, λ_j)
k	: iteration number
μ	: known scaling factor
S_μ	: mean value

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1. Introduction

Image matching is very important technique for motion detecting, stereo matching, and so on. Relaxation matching based on feature[3] is a conventional approach to the matching problem. This method was proposed by Rosenfeld et al. in

1976[5] and is useful for multidimensional optimization problems in image processing and pattern recognition, etc. We also apply the above technique for matching time-sequence images for moving objects detection of landslide inspecting and monitoring system. When we match two images based on features, a label in the model image may be paired off with several objects in the scene image because of non-match results of time-sequence images segmentation. We call it as multi-matching. Sometimes there is not object to be matched, we call it as null-matching. In this paper, we regard the matching problem as constraint satisfaction problem and propose a relaxation matching algorithm based on global structure constraint satisfaction for solving null matching and multi matching problem. Constraint satisfaction problem (CSP) appears in many areas like artificial intelligence and operational research. Informally, the CSP is composed of a finite set of variables, each of which is taking values in an associated finite domain and a set of constraints between these variables. Resolving the CSP consists with to find one or all complete assignments of values for variables satisfying all the constraints[8]. To explain the proposed algorithm, first the classical probabilistic relaxation technique is introduced and the relations of global constraint satisfaction is described. Second, we illustrated the proposed global constraint satisfaction algorithm. Last, simulation has been done to prove the effectiveness of proposed algorithm by using time-sequence image of landslide inspection and monitoring system.

2. Relaxation matching algorithm based on global structure constraint satisfaction

Relaxation matching is an iterative process. In this algorithm, when we calculated the matching probability, a global constraint satisfaction Q which is shown next section must be calculate. So, we proposed the new algorithm for choice of Q. In this section, we introduce how to derive the new global constraint satisfaction.

2. 1 The proposed algorithm incorporating global structure constraint satisfaction

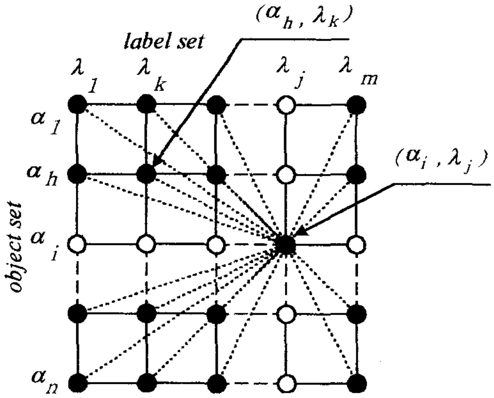


Fig. 1 Global structure constraint satisfaction in one layer

Global structure constraint satisfaction is defined by referring Fig. 1. Object set A is drawn on the vertical coordinate axes, and label set Λ is drawn on the horizontal coordinate axes. The matchable pair of (α_i, λ_j) is defined by circle point. The dash line between (α_i, λ_j) and (α_h, λ_k) is a geometric constraints[2]. The geometric constraint mean that when a label λ_j is assigned to object α_i, an assigned object α_h with label λ_k should be found in a certain window area which is denoted as $W_{(i,j,k)}$. In the Fig. 3, the object α_i, the one label λ_j, and the another label λ_k are represented with a vector $\overrightarrow{P_jQ_j}$, $\overrightarrow{A_iB_i}$, and $\overrightarrow{P_kQ_k}$, respectively. Then, we can determine the four extreme points R_1, S_2, R_1, S_2 of the $W_{(i,j,k)}$ using the following relations :

$$\overrightarrow{A_iR_1} = \mu * \overrightarrow{C_jC_k} \quad (1)$$

$$\overrightarrow{R_2S_2} = \mu * \overrightarrow{C_kD_k} \quad (2)$$

We identify B_i with Q_j to define the points R_2 and S_2 :

$$\overrightarrow{B_iR_2} = \mu * \overrightarrow{Q_jC_k} \quad (3)$$

$$\overrightarrow{R_2S_2} = \mu * \overrightarrow{R_kQ_k} \quad (4)$$

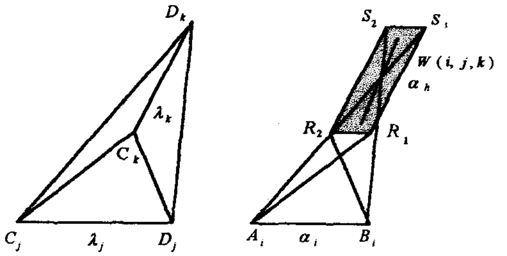


Fig. 2 Example of a window design

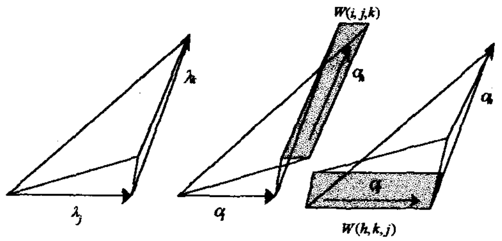


Fig. 3 Example of the non-match of a window

In Fig. 3, if α_i is matched to λ_j, α_h and α_i must be in $W_{(i,j,k)}$, $W_{(h,k,j)}$, respectively. In that case, we say that (α_i, λ_j) is compatible with (α_h, λ_k). On the contrary, if α_i is not matched to λ_j as shown in Fig. 3, (α_i, λ_j) is uncompatible with (α_h, λ_k). Also, in case of, α_h, α_i are not in $W_{(i,j,k)}$ and $W_{(h,k,j)}$, we define no supportive. Then, we can define compatibility coefficient $r_{(i,j,h,k)}$ as follows:

$$r_{(i,j,h,k)} = \begin{cases} 1 & \textit{compatible} \\ 0 & \textit{if there is no supportive} \\ -1 & \textit{uncompatible} \end{cases} \quad (5)$$

Finally, the global constraint satisfaction $Q_{(i,j)}$ can be defined as follows :

$$Q_{(i,j)} = \frac{1}{m} \sum r_{(i,j,h,k)} P_{(h,k)} \quad (6)$$

where, $(h \neq i, k \neq j)$

For solving null-matching problem, we use a zero label for the object that can not be matched to a label in Λ. For solving multi-matching problem, we use the relation between n, the number of object A and m, the number of object Λ. Then, we can define the matching relation as follows:

If $n \leq m$,

$$P(i) = Max\{P(i,j)\} \quad (7)$$

If $n > m$,

$$P(i) = Max\{P(i,j)\} \text{ if } Q(i) = Max\{Q(i,j)\} \quad (8)$$

From above equation, we can define that i which has the maximum matching probability according to j is matched with j.

2. 2 Relaxation matching algorithm

In relaxation labeling method, there are four mathematic models : discrete model, fuzzy model, linear model and nonlinear model. In this paper, we use nonlinear relaxation labeling algorithm. In order to realize nonlinear relaxation labeling algorithm, first, we obtain the matching probability of (α_i, λ_j) by making an iterative process. An iterative process is used to adjust the probabilities for each vector in the images. The probabilities for each vector is explained by using Fig. 4.

A three dimensional lattice is made up of object A, label Λ and iteration number k as shown in Fig. 4. The black point represents that it has the constraint relationship with the (α_i, λ_j) in the kth layer. The white point represents that it does not have the constraint relationship with (α_i, λ_j). The dash line illustrates the constraint relation with arbitrary two points. For example, the constraint relationship is represented as the dash line between (α_i, λ_j) and (α_h, λ_k).

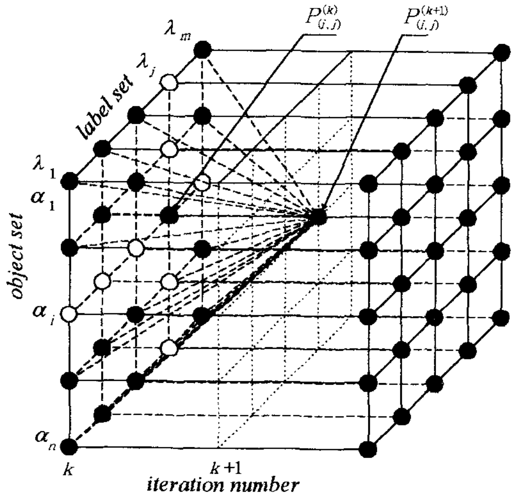


Fig. 4 Global structure constraint relations

Using Fig. 4, we can calculate an Euclidean distance and initial estimator as follows :

$$S(i,j)=|\alpha_i-\lambda_j| \tag{9}$$

$$P^{0}_{(i,j)}=\frac{1/[S(i,j)-S_\mu]}{\sum_{j=1}^{m}1/[S(i,j)-S_\mu]} \tag{10}$$

where, mean value S_μ is given by as follows :

$$S_\mu=\frac{1}{m}\sum_{j=1}^{m}P_{(i,j)} \tag{11}$$

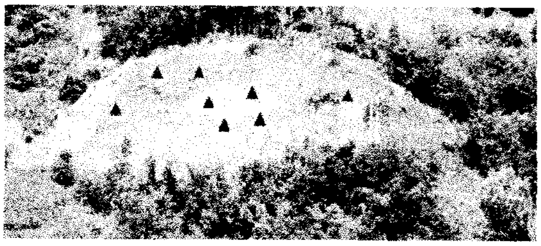
Then, we can obtain the matching probability of (α_i, λ_j) in $(k+1)$th layer by using initial estimator Eq. (10) as follows:

$$P^{(k+1)}_{(i,j)}=\frac{P^{(k)}_{(i,j)}[1+Q^{(k)}_{(i,j)}]}{\sum_{j=1}^{m}P^{(k)}_{(i,j)}[1+Q^{(k)}_{(i,j)}]} \tag{9}$$

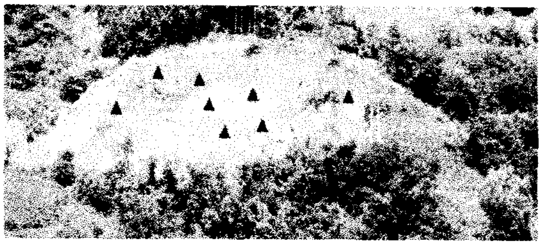
where, the global constraint satisfaction Q is derived section 2.1.

3. Simulation Results

To show the effectiveness of the proposed algorithm, a landslide picture is used as shown in Fig. 7. We assume that the target points to be inspected in real-time are marked arbitrarily at appropriate points. Fig 8 shows the line features extraction results by using image segmentation, edge detection and line feature extraction methods[7] for Fig. 7.

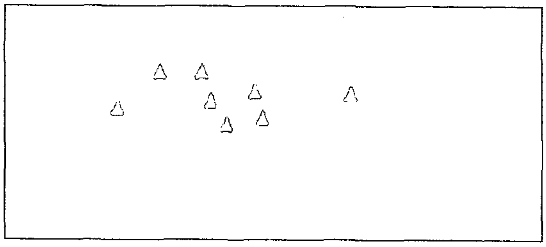


(a) Model image

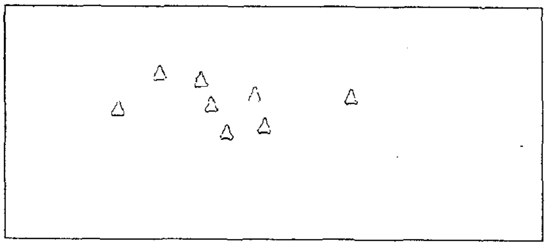


(b) Scene image

Fig. 5 Model and scene images of original landslide picture



(a) Model image



(b) Scene image

Fig. 6 Line feature extraction results

Let $f_s(x, y)$ is a scene image as shown in Fig.

6(b) and $f_m(x, y)$ is a model image as shown in Fig. 6(a). Then, we can obtain the line feature sets which is defined that the $A(\alpha_1, \alpha_2, \cdots, \alpha_n)$ is line feature set of $f_s(x, y)$ and the $\Lambda(\lambda_1, \lambda_2, \cdots, \lambda_m)$ is line feature set of $f_m(x, y)$ by using line feature extraction algorithm. Then, we apply the proposed matching algorithm for two line feature set. After adjust 4th iterations of proposed algorithm, we can see the matching probability of the arbitrary line feature ($i = 11$) of scene image according to model image as shown in Fig. 5.

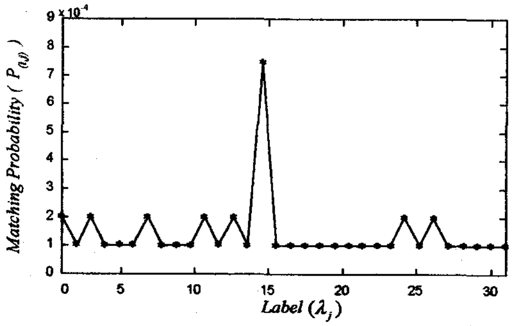


Fig. 7 Matching result of α_i and λ_j

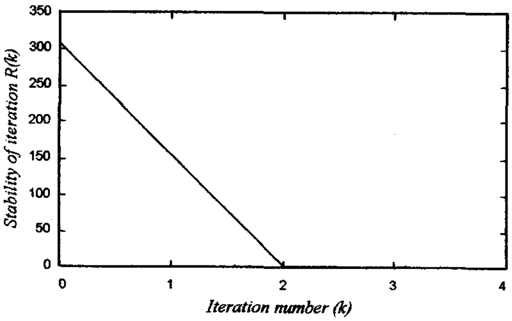


Fig. 8 Stability result of the proposed algorithm

Referring Fig. 7, we can find that the only one of labels has the biggest probability. It means that the optimal label value λ_{15} is only matched to object α_{11}. Fig. 8 described the stability result of the proposed algorithm. The more algorithm has been iterated, the more stability value decreased. It means that the iteration of algorithm is stable.

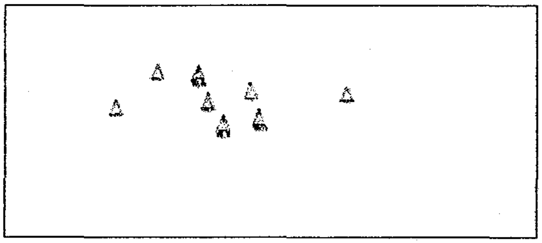


Fig. 9 Matched image

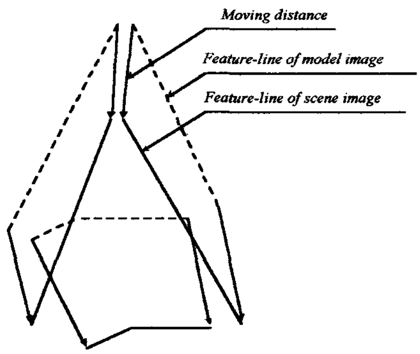


Fig. 10 Local magnifiable image

The matching result of all adjusted label by using the proposed relaxation matching algorithm shows in Fig. 9. Fig. 10 is the magnified image of one matched label. The dash lines are the feature lines of model image, the solid lines are the feature lines of scene image, and the direction lines are the moving distance between two matching lines. Therefore, motion evaluation parameters of landslide image are illustrated in Fig. 11.

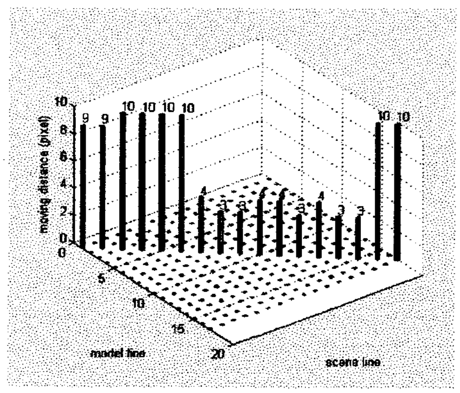


Fig. 11 Motion evaluation parameters

4. Conclusion

This paper represents a relaxation-matching algorithm based on global structure constraint satisfaction for an example of a landslide picture. We propose the relaxation matching algorithm for analyzing landslide movement in real time. When the algorithm is processed, motion parameters such as displacement area and its direction are computed. Once movement is recognized, displacements are estimated graphically with statistical amount in the image plane. We prove the effectiveness of the proposed algorithm as matching result of time-sequence images.

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References

[1] S. Baronti, A. Casini and F. Lotti, "Robust Estimation Of Slow Changes Natural Outdoor Scenes Through A Geometric Matching Approach", IEEE DSP 97, pp. 1115-1118, 1997.

[2] Gerard Medioni and Ramakant Nevatia "Matching Images Using Linear Features", IEEE Trans. Pattern Anal. Machine Intell., Vol. 6, No. 6, pp. 675-685, 1984.

[3] Dana H. Ballard, Christopher M. Brown Computer Vision, 1982.

[4] Robert J. Schalkoff Digital image processing and computer vision, 1989.

[5] T. Horiuchi K. Toraichi K. Yamamoto H. Yamada "Relaxation Optimizing Processing in Extended Probabilistic Space", IEEE, pp. 266-269, 1995.

[6] Chin-Tu Chen, Eric Chen-Kuo, Tsao and Wei-Chung Lin, "Medical Image Segmentation by a Constraint Satisfaction Neural Nework", IEEE Trans. Nucl. Sci., 1991.

[7] Hur Chul, Yang-Bae Jeon, Choon-Sik Kim and Sang-Bong Kim, "Development of Real-time Landslide Inspecting and Monitoring System", Porceeding of 15th KACC, pp. 243-247, 2000.

[8] Thang Nguyen and Yves Deville, "A Distributed Arc-Consistency Algorithm"