RESEARCH ON TECHNIQUES OF APPROXIMATE RECOGNITION OF CONTINUOUS DEFORMATION OF IMAGES WITH MULTI-GREY-LEVELS*

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Abstract: A new algorithm of recognition of continuous deformation of the images with multi-gray-levels is put forward in this paper, which the following steps are made: the fist is the adoption of griddings procedures, the other is the classification of continuous deformation into continuous deformation with preserving topological structure and continuous deformation with non-preserving topological structure， and introduction of a new method approximate identifying continuous deformation. The main characteristics of this algorithm are the flexible modulations between accuracy to calculate and time to process, and so the needs from different applications be satisfied easily. Finally, a few examples are given to test the versatility of the techniques, from which it is verified that the algorithm developed here exhibits good performance.

Key words: Continuous deformation, gridding, Recognition techniques

1. INTRODUCTION

The recognition to continuous deformation images is not only one of the most important issues in the field of pattern recognition in computer science, but also has significant theoretically value and wide applications in the field of robot vision systems.

Colonna de et. al [1] present a method named phase-shifting techniques, and discuss its application in the field of metrology. Colonna et. al[2] improve its some demerits which desires to keep the stability of phase in deformation, by means of comprehensive consideration continuous five frames for phase of some point. However, computing point by point limits its speed and therefore affecting time gap between continuous frames. Zhu Zhongtao et.al [3,4] propose put forward a new method by means of studying image arithmetic operators, obtaining differential invariance of image under boundary, but getting transform clots is not a easy job there being some theoretical issues to be solved. As a whole, the mainstream is adoption of various invariance[5-16],but it is difficult to harmonize the conflict between sufficient conditions and necessary conditions.

As a tool, gridding has been introduced into research on continuous deformations in [18], but ignore the relationship between gridding and continuous deformations.

Hopfield network can realize association recognition of network model by means of constructing energy function and finding the network status minimizing energy, which is suitable for limited noise and deformation. However, its storage capacity is limited and must be told models to be recognize, which makes it difficult to recognize objects with arbitrary and random deformations. Therefore, we propose a new similar invariance in [19], upon which discusses the recognition issue on the continuous deformation objects. But it limits the meaning of objects.

2. BASIC DEFINITIONS

2.1 Edge-gridding

If a gridding covers at least two different greys on its four edges, this gridding is called as a edge-gridding. Especially, when the height and width of a edge-gridding are 1 pixel, this edge-gridding is called a edge point of the image.

2.2 Topological relationship

Topological relationship, means adjacent relationships among areas of the given objects.

2.3 Continuous deformation

Let the edge images of i-th and i+1 th frames are I_i and I_{i+1} respectively, and the time gap between continuous frames is Δt, if

$$\lim_{\Delta t \to 0} I_{i+1} = I_i \tag{1}$$

and I_i and I_{i+1} is homoeomorphism, we call the deformation from frame i to frame i+1 is a continuous deformation with precision Δt.

2.4 Gridding features

The features, such as grey sequence, grey number, dimension of the gridding,gridding coordinate and so on, are calledthe gridding features of the gridding. The coordinate of upper-left point of the gridding is referenced as gridding coordinate of the gridding.

2.5 The condition NS

For an arbitrary edge-gridding, （i, s, a）, among which s is the coordinate of the edge-gridding and a is the feature of the gridding of frame i, U(i, s) notes the eight neighbors gridding of the gridding, if $U(i+1,s) \supset (I,s,a)$,we call the gridding (i,s) satisfies the condition NS

2.6 The condition NC

For an arbitrary edge-gridding, （i, s, a）, among which s is the coordinate of the edge-gridding and a is the feature of the gridding of frame i, U(i, s) notes the eight neighbors gridding of the gridding, if

$$U(I,s) \supset (i+1,s,a)$$

We call the gridding (i,s) satisfies the condition NC

2.7 Escapable gridding

Under allowed precision, a gridding is called escapable gridding, if it need not be further refined into sub-gridding.

2.8 The continuous deformation with topological structure holding

If the relationship keeps unchangeable during deformation of the images, this deformation is referenced as the continuous deformation with topological structure holding.

2.9 Topology break

This is the case when adjacency relationship among areas of the deformed images changes. For example, if some two areas is separated ,or one area is divided into two or more different areas after deformation, a topology break takes place. The another example is the case that two or more different areas are conglutinated into one area.

2.10 The continuous deformation with topological structure non-holding

The continuous deformation with topological structure non-holding is a deformation in which topological breaks are allowed to appear in limited scope and limited time.

3. RECOGNITION ALGORITHM

First of all, we give our overall algorithm flow chart as follows(Figure 1).

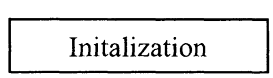
3.1 Basic theorem

Theorem 1 the sufficient and necessary condition of being a continuous deformation with topological structure holding between two adjacent frames is that the condition NS and condition NC are be satisfied at the same time.

Proof:

Firstly, proof sufficient condition is true. If the condition NS is satisfied, no split occurs after deformation, meaning that two areas are still connected after deformation if they are connected before deformation. Otherwise, if one area is divided into two or more different areas, there are no griddings with the same feature girddings in the neighbor of breaking point in frame i+1, compared with the image before deformation, which is a conflict with the definition of the condition NS. Similarly, if the condition NC is satisfied, no conglutination occurs after deformation, meaning no new connection among areas is produced. Otherwise, if produces new connection among areas, exists a neighbor areas round the new connection in the frame i and doesn't include any griddings with the same feature at the same position as frame i in frame i+1, which is a conflict with the definition of condition NC.

Necessary condition is clear and need not further proof.



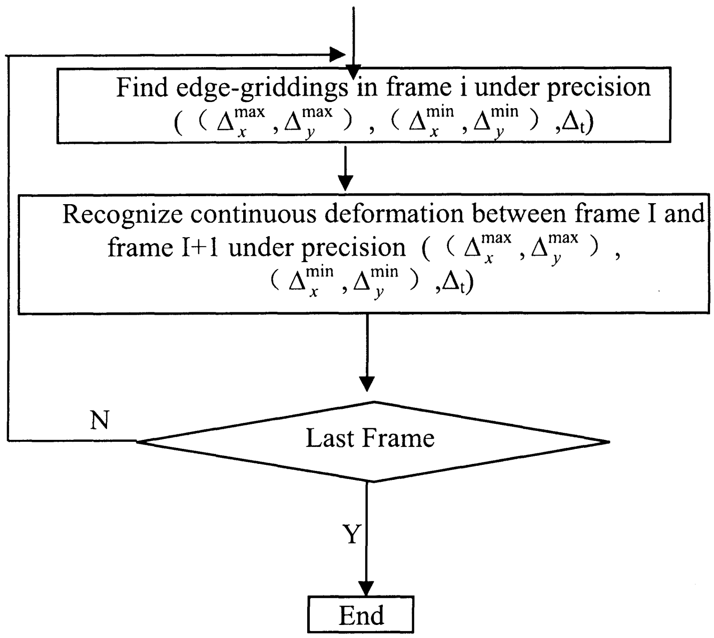


Figure 1. The Overall Diagram of our algorithm

3.2 An algorithm to find edge-griddings

The main purpose of an algorithm to find edge-griddings is to identify all edge-griddings under desired precision, essentially, obtaining the edges with some difference and rudeness. The algorithm is given as follows.

Step1: Set edge-gridding collection with null;

Step2: $\Delta_x = \Delta_x/2$, $\Delta_y = \Delta_y/2$, and if the condition $(\Delta_x, \Delta_y) > (\Delta_x^{min}, \Delta_y^{min})$ is satisfied, turn Step3 else turn Step9;

Step3: divide each griddings into four griddings, with sub-griddings with width and height Δ_x and Δ_y;

Step4: Find gridding features of each sub-griddings;

Step5: For a gridding, s, if its grey number is more than two, turn Step7 else turn next step;

Step6: Is the condition $(\Delta_x, \Delta_y) > (\Delta_x^{max}, \Delta_y^{max})$ satisfied? If yes, turn Step8 else turn Step2;

Step7: Add this gridding into new edge-gridding collection, turn Step2;

Step8: Return.

In initalization, Δ_x is the width of the image, and Δ_y is the height of the image,Counter=0.

3.3 Recognition to continuous deformation

3.3.1 The continuous deformation with topological structure holding with precision (($\Delta_x^{\max}, \Delta_y^{\max}$) , ($\Delta_x^{\min}, \Delta_y^{\min}$) , Δ_t)

Generally speaking, it is impossible to recognize accurately a continuous deformation by the definition on account of time gap Δ_t between two adjacent frames. So, we consider recognizing to continuous deformation with topological structure holding with precision (($\Delta_x^{\max}$, $\Delta_y^{\max}$) , ($\Delta_x^{\min}, \Delta_y^{\min}$) Δ_t). The continuous deformation with topological structure holding demand objectively no separation or conglutination in the procedure of deformation, meaning that the condition NS and the condition NC should be checked between two frames with time gap Δ_t We describe our algorithm as follows:

Step1: Initalization the current griddings;
Step2: Is the condition NS satisfied? if yes turn Step3 else turn Step6;
Step3: Is the condition NC satisfied? if yes turn Step4 else turn Step6;
Step4: s=next gridding;
Step5: Are all griddings finished? if yes turn Step7 else Step2;
Step6: failure, return.
Step7: successful, return.

The continuous deformation with topological structure non-holding with precision (($\Delta_x^{\max}, \Delta_y^{\max}$) , ($\Delta_x^{\min}, \Delta_y^{\min}$) , Δ_t , $\sum$)

The continuous deformation with topological structure non-holding allows of topology break of local topological structure after deformation. Based upon the algorithm with topological structure holding, it is easy to obtain the following algorithm to recognize the continuous deformation with topological structure non-holding with precision (($\Delta_x^{\max}$, $\Delta_y^{\max}$) , ($\Delta_x^{\min}, \Delta_y^{\min}$) , Δ_t , $\sum$).

Step1: Initalization the current griddings;
Step2: Is the condition NS satisfied? if yes turn Step3 else turn Step6;
Step3: Is the condition NC satisfied? if yes turn Step4 else turn Step6;
Step4: s=next gridding;
Step5: Are all griddings finished? if yes turn Step7 else Step2;
Step6: T=T+1;
Step7: If $\frac{T}{TOTAL} < \sum$, be successful and return else failure and return.

Once a topology break occurs, the algorithm counts the number of griddings related to topology break,. When all griddings are dealt with, if the ratio of T to total number of griddings,TOTAL, is in limited scope, we believe occurs a continuous deformation with topological structure non-holding with precision $((\Delta_x^{\max}, \Delta_y^{\max}), (\Delta_x^{\min}, \Delta_y^{\min}), \Delta_t, \sum)$.

3.4 Match with database

Some typical static images are stored in a database in advance. After recognizing to each image, compare it with every image in the database, checking the condition NS and the condition NC. In a continuous image sequence, as long as exists a image matches with a image in the database, continue to identify whether or not the last image matches with the first frame.

4. PERFORMANCE ANALYSIS OF THE ALGORITHM

We compare this algorithm with that put forward in [19]. In paper[19], the time complexity is O(s∗n), among which s is the number of circle in object and n is the number of vertex in each circle. So s∗n stands for the total number of vertex in original image, showing that our time complexity is improved, to some extent.. Furthermore, the time complexity is not related to the complexity of topological structure of image, which is another important feature of our algorithm .

5. EXPERIMENTAL RESULTS

Example 1 Take continuous deformation of face as a example, getting satisfactory result. We obtain a video with number camera and divide it into a image sequence with time gap 1ms. Figure 2 is a snippet we arbitrarily cut. Our programming results show that this is a The continuous deformation with topological structure holding with precision with precision $((\Delta_x^{\max}, \Delta_y^{\max}), (\Delta_x^{\min}, \Delta_y^{\min}), \Delta_t) = ((10, 10), (3, 3), 1)$. By further experiment, if let $\Delta_t = 1$ and $(\Delta_x^{\min}, \Delta_y^{\min}) = (2, 2)$, the recognition fails.

Figure 2. a continuous deformation sequence of a real example

So, ($\Delta_x^{\min}$, $\Delta_y^{\min}$) affects the recognition precision.

Example 2 Word Recognition

Figure 3 shows a 3DSMAX move, which is by our programming, a continuous deformation with topological structure non-holding with precision (($\Delta_x^{\max}$, $\Delta_y^{\max}$) , ($\Delta_x^{\min}$, $\Delta_y^{\min}$) Δ_t)= ((12, 12), (2, 2), 1) , occurring a topology break.

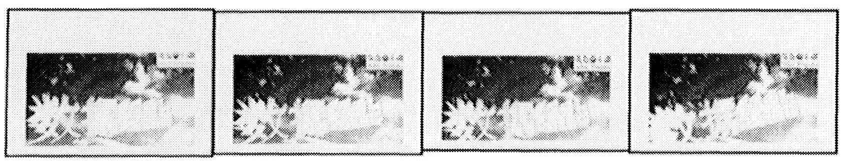


Figure 3. a continuous deformation with topological structure

Example 3 a example of non-continuous deformation

Figure 4 shows a example of non-continuous deformation , in which occurs a break in background and the scope of changes exceeds our limitation $\sum$ (here $\sum$=30%) .

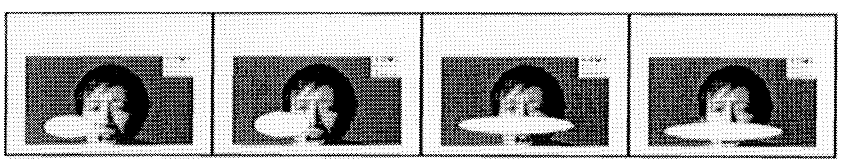


Figure 4. a non-continuous deformation

6. CONCLUSIONS

On one hand, our world is complex and is of diversity; on the other hand, error occurs everywhere when we collect data from objects, and the process speed is limited by hardware conditions. Taking all above factors into consideration, to find a algorithm suitable for all situation to recognize continuous deformation is not a easy job. In this paper, we just put forward an approximate and rude method in attempt to deal with this issue.

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REFERENCE

1. Colonna de Lega X, Jacquot P, "Deformation measurement using object induced dynamic phase-shifting" ,Applied Optics,received 21 December 1995,revised manuscript received 15 March 1996
2. Colonna de Lega, "Continuous deformation measurement using dynamic phase-shifting and wavelet reansforms" ,IOP Publishing Ltd,sep. 1996:261-267
3. Zhu ZhongTao,Zhang Bo,Zhang ZaiXing. The Differential Invariance of Image Under Boundary Extracting Operator. Chinese J.Computers, 1999, 22(9): 903–910.
4. Zhu ZhongTao,Zhang Bo,Zhang ZaiXing.The quasi-invariants of curves under the topological deformation. Chinese J.computers, 1999, 22(9): 897–902
5. J Perantonis, P J G Lisboa. Translation, rotation, and scale invariant pattern recognition by high order neural networks and moment classifiers. IEEE Trans Neural Networks, 1992, 3(2): 241-251.
6. E Rivlin, I Weiss. Local invariance for recognition. IEEE Trans Pattern Anal. Mach. Intell., 1995, 17(3): 226-238.
7. J Wood. Invariant pattern recognition: a review. Pattern Recognition, 1996, 29(1):1-17.
8. J Wood, J Shawe-Taylor. Representation theory and invariant neural networks. Discrete Applied Mathematics, 1996, 69(1-2):33-60.
9. Weiss I. Projective invariants of shapes. Proceedings of DARPA Image Understanding Workshop, Cambridge, 1998: 1125-1134.
10. Zhao Lei,Fengzhiquan,LiJingping. Research Advances on the Theory of Visual Invariants in Computer Vision. The theories and applications of Modern Information Technology:CIE-YC'2002.HeFei,China,2002,589-593.
11. Zhang Ling,Zhang Ba,Wu Chaofu.Multilayer Neural Networks for Motion Invariant Pattern Recognition.Chinese J.Computers， 1998, 21(2): 127–136.
12. Yan Sunzhen,Sun Jixiang.The Research and Application of Moment Invariants in Object Shape Recognition.Journal of National University of Defense Technology， 1998， 20 （5）： 75~80.
13. Liao yuan,Yuan jie.Recognition of Occluded Target with Fused Data of Several Invariances.Journal of Wuhan University),1998， 44 （1）： 81~84.
14. Zhao Nanyuan.The Topology Properties Algorithm of Image.Journal of Tsinghua University， 1989， 29 （4）： 74-79.
15.Guo Lianqi,Li Qingfen.A study of the Graphic Recognition Method by Using the Topological Relation.Journal of Harbin Engineering University, 1998, 9(4):38~43.
16. Feng ZhiqQuan. A New Kind of Similar Invariant and Its Apply to Object Recognition Algorithm. Computer Science,2002,29(9):360-361

17. Musse, O.; Heitz, F. Topology preserving deformable image matching using constrained hierarchical parametric models. Image Processing, 2000. Proceedings. 2000 International Conference on Computer Vision and Pattern. 2000 vol.1:505-508
18. Zhu; M. Gotoh . "Automatic remeshing of 2D quadrilateral elements and its application to continuous deformation simulation: part I. remeshing algorithm" , Journal of Materials Processing Technology. 1999, vol.87, no.1-3 .165:178
19. Feng Zhiquan, Lijingping, Dong et al..Computer Recognition of 2-D Objects with Continuous Deformation. Chinese Journal of Computers.2003. Vol.26(12):1637-1644.