Object Tracking and Recognition using Deformable Grid with Geometrical Templates

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ABSTRACT

This paper presents a deformable model object recognition and tracking approach with deformable grid. A new method of geometrical templates is proposed for tension calculation in a grid. It is shown with examples, that a method of geometrical templates can be used for object recognition and tracking in real time.

Keywords: deformable models, image analysis, object recognition, object tracking

1. INTRODUCTION

Deformable models make a class of image analysis techniques, that originates with the method called *snake* (or *active contour*) introduced by Kass at al. in 1988 [1]. An active contour model is an elastic curve, which changes its shape and position under the influence of the potential energy created by the image properties. This prior model basically serves as an image segmentation tool. Since that time, variety of deformable models have been developed and used for many applications in analysis of 2D (snake, balloon [1,3], deformable grid [4]) and 3D image space (deformable surface [2]). The main advantage of these methods, between other image analysis techniques, results from their better performance in case of noisy images and images presenting object with occluded or absent parts.

2. DEFORMABLE GRID

The scope of this paper focuses on deformable grid that belongs to *model-based recognition* methods. The concept is to compare and match a model from a database with a fragment of image being analysed. Deformable grid can be applied for digital image object recognition, finding object position and aspect, object details characterisation and for object tracking in a sequence of images.

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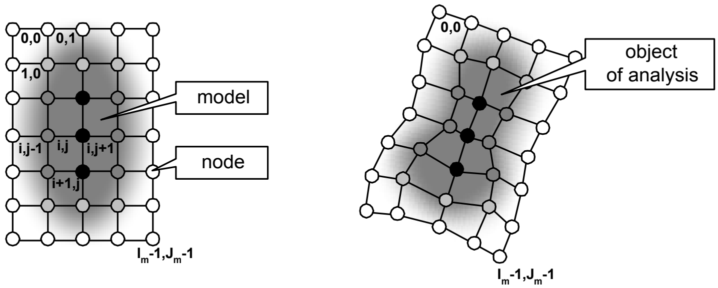
Deformable grid is composed of nodes (active elements) *(i, j)*, connected to form a planar graph. Each node gives partial information on model object features at its position in such a way, that entire collection of nodes carries out complete information on model object properties (shape, colour, etc). Image analysis with deformable grid is an evolution process, called matching process, which systematically displaces and deforms the structure to fit an object of interest. All the active elements need initialisation that means, setting preliminary positions at the beginning of the process. Then nodes move over the image being analysed, seeking desired locations. Changing the position of an active element depends simultaneously on image property and elasticity of interconnections between neighbouring nodes.



(a) (b)

Fig.1. Deformable grid: defining image features at model nodes (a), deformable grid on completion of the matching process (b).

Co-ordinates of nodes are $\mathbf{v}(i,j,t) = (x(i,j,t), y(i,j,t))$, where t is a time and x, y are the corresponding co-ordinate functions. The graph deforms during matching process as a result of nodes movements, what is determined by equation of motion (1). According to this equation, a certain mass m is associated with the moving node, which dissipates its kinetic energy of movement due to the presence of viscosity l of an abstract environment. Force $\mathbf{F}_i$ and $\mathbf{F}_p$ cause the motion. The former depends on graph shape and models internal tensions of deformable grid. This component limits excessive deformation. The later defines influence of image local characteristics. This component push node toward desired location, where properties of investigated image are similar to properties carried by node.

$$m\frac{\partial^2\mathbf{v}(i,j,t)}{\partial t^2}+l\frac{\partial\mathbf{v}(i,j,t)}{\partial t}=\mathbf{F}_i(i,j,t)+\mathbf{F}_p(i,j,t) \tag{1}$$

3. Geometrical Templates

The contribution of this paper is to introduce a method of geometrical templates for calculation of tension force $\mathbf{F}_i$. There are four templates modelling local tensions, namely, a right-angled isosceles triangle (Fig.2.a), parallelogram (Fig.2.b), section (Fig.2.c) and rectilinear, regular grid. Size and position of templates is adjusted according to co-ordinates of appropriate nodes. In case of triangle two vertex points are defined by two neighbouring nodes **b** and **c**. The third vertex point at the right-angle indicates an expected position of node **a**. A component of tension force $\mathbf{F}_i$ is defined by vector directed from actual position of the node to a position indicated by vertex point of template (3). Procedure of tension force calculation using parallelogram and section is similar. Equation (4) and (5) give the adequate definitions of tension vectors. Note that for every node, except nodes situated at (near) the border of a grid, four different templates of each kind should be considered. One or two templates of each kind must be used in case of nodes located at the corner or border of deformable grid.

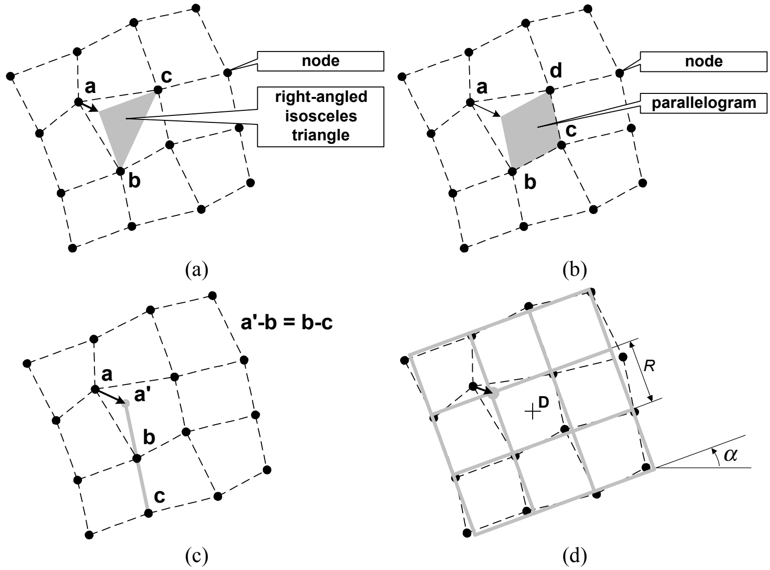


Fig.2. Geometrical templates for tension calculation.

The fourth template is rectilinear, regular grid (Fig.2.d). It is characterised by three averaged parameters of deformable grid: co-ordinates of its centre **D**, size parameter *R* and angle *α*. Tension force component vector is directed from actual location of node to the location of equivalent node in the rectilinear, regular grid (6).

$$\mathbf{f}_1 = 2\begin{bmatrix} x_a - \dfrac{x_b + x_c + y_b - y_c}{2} \\ y_a - \dfrac{y_b + y_c - x_b + x_c}{2} \end{bmatrix} \tag{3}$$

$$\mathbf{f}_2 = 2\begin{bmatrix} x_a - x_b + x_c - x_d \\ y_a - y_b + y_c - y_d \end{bmatrix} \tag{4}$$

$$\mathbf{f}_3 = 2\begin{bmatrix} x_a - (2x_b - x_c) \\ y_a - (2y_b + y_c) \end{bmatrix} \tag{5}$$

$$\mathbf{f}_4 = \mathbf{v}_a - \mathbf{D} - \begin{bmatrix} R\cos(\alpha)\left(i - \frac{I_m}{2}\right) + R\sin(\alpha)\left(j - \frac{J_m}{2}\right) \\ R\cos(\alpha)\left(j - \frac{J_m}{2}\right) - R\sin(\alpha)\left(i - \frac{I_m}{2}\right) \end{bmatrix} \tag{6}$$

4. OBJECT RECOGNITION

Deformable grid model with geometrical templates can be used for object recognition. The deformation scale demonstrates how much the analysed object is different from the model object. Coefficients of deformation can be defined as integrals of squared magnitudes of tension forces in nodes. The smaller coefficient values the greater similarity between object of analysis and model object.

Fig.3 presents a graph of two deformation coefficients. Coefficient Φ_{t1} is calculated with triangle template tension forces and coefficient Φ_e with rectilinear, regular grid template. Two classes of X-ray wheat grain images were analysed. The first class (ZA4) represents grains in front projection (Fig.4.a), the second (ZB) in side projection (Fig.4.b). A selected grain in side projection defines a model object of deformable grid. Obtained results give in correct classification of every object within these two classes.

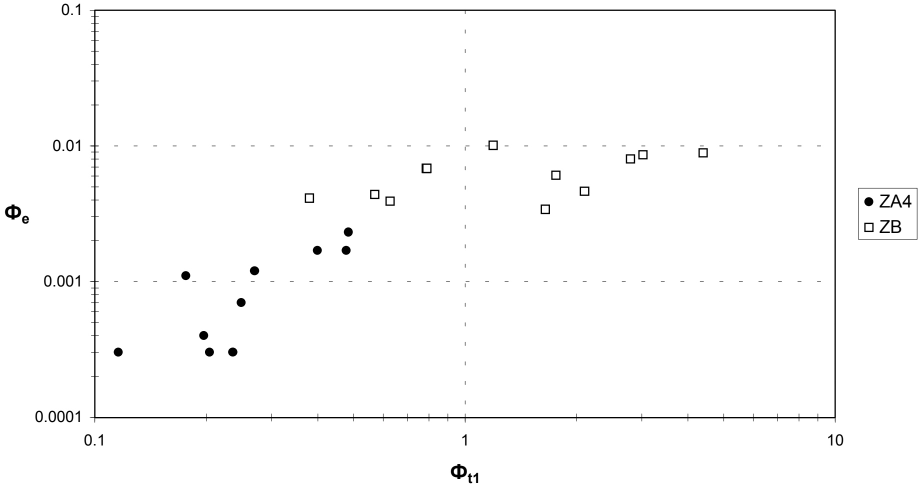
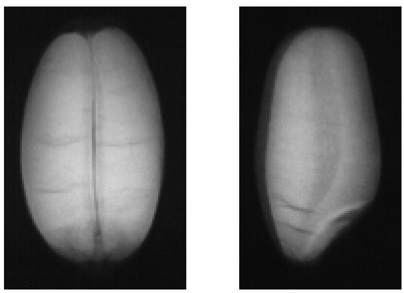


Fig.3. Graph of deformation coefficients for two classes of images.



(a) (b)

Fig.4. X-ray images of wheat grain in front projection (a) and side projection (b).

5. OBJECT TRACKING

In a variety of applications, such as medical image analysis, human motion modelling and surveillance, it is desirable to track position of non-rigid objects and to analyse their motion. In this paper, a deformable grid model is proposed to solve a problem of object tracking in sequence of images.

At the beginning of the tracking process, position of an object must be detected. Then, deformable grid is initialised at the determined position. After a few iterations of matching process, the object of interest may be recognised. Lower values of forces $\mathbf{F}_i$ and $\mathbf{F}_p$ indicate larger similarity between the object and its model. If the object is an object of interest, the tracking process continuous, in such a way, that position of object obtained from the previous frame in a sequence of images becomes an initial position in the next frame.

Fig.5. Reference model of selected person silhouette in Fig. 6.

Result of object tracking process in sequence of images using deformable grid is shown in Fig.5 and Fig.6. Fig.5 presents an object used as a reference model. Fig.6 presents a sequence of images showing a group of people in motion [6]. Person selected from the group is an object of interest. A position of matched grid is visible in a form of black mesh.

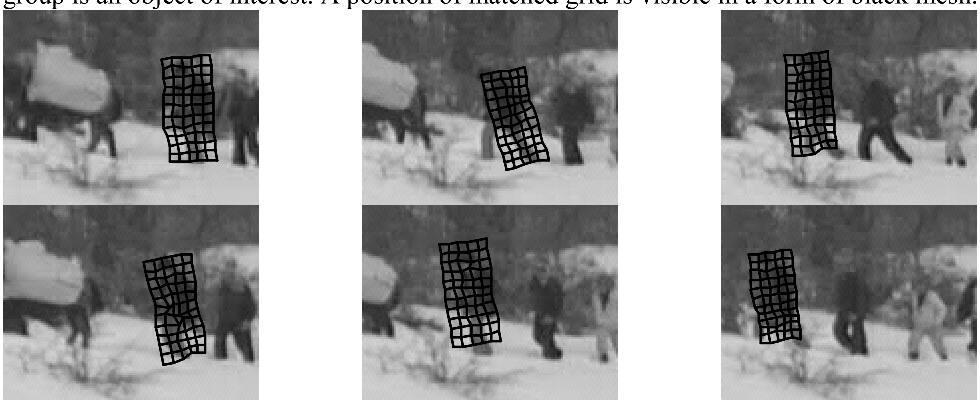


Fig.6. Example of object tracking using deformable grid (selected frames are presented).

It was measured that such analysis can be performed in a real time with use of PC computer. Time needed to accomplish matching process per single frame is shorter than 25ms using PC computer with Intel Celeron 400MHz processor, while standard frame duration in TV system is 40ms (PAL/SECAM) or 33ms (NTSC).

In the presented example a slow movement of an object is considered. Object displacement between two consecutive frames is small, about 20% of object region. In other case, however, a so-called prediction step is needed for object tracking in image sequence. The prediction step can be included by defining additional force in equation of motion. The example of such predictive defromable model is a Kalman snake [5].

6. CONCLUSIONS

Deformable grid method is efficient and reliable tool of object tracking in image sequence. Obtained resulting data give information about position and aspect of object. The method can be applied in case of rigid objects as well as in case of flexible objects that changes their shape, like human beings, animals, etc.

Proposed method of tension calculation together with method of equation of motion, implemented on a computer, has proven to be an efficient tool for object recognition and object tracking in real time. These techniques would be useful in medical diagnostics, robotics and surveillance.

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