A Fast Snake-based Method to Track Football Players

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Abstract

We present in this paper a new method to track moving objects. It is based on snakes or active contour models. We are concerned with football game analysis and so the moving objects tracked are representing football players. The camera is moving too. Our active contour algorithm does not need any preprocessing step contrary to most of the snake-based methods. It is based on classical energies used in active contour algorithms but also on a balloon energy in order to reduce the contour to fit the tracked object. The tracking step does not include any position prediction and is based on a snake initialisation followed by snake deformation. The method implemented is fast enough to consider a real-time framework and has been successfully tested on football game image sequences.

1 Introduction

Tracking moving humans is a difficult task. We have developed a method that deals with non-rigid moving objects relying on snakes or active contour models. Processing time of our method is very short. This method is applied here to football players tracking.

Our snake-based method is performed on a colour image sequence acquired with a moving camera. The main contributions of this method are first the use of colour with an active contour model, second the capacity of the method to keep with a moving camera source, and thirdly the absence of any filtering or segmentation before snake deformation in order to decrease processing time. The difficult managing of the variety in texture of the players is counterbalanced by the presence of grassfield.

We will first introduce active contour models and then describe the specific energies we have defined for the snake deformation. The tracking method will be next explained and finally some results will be presented and commented.

2 Active Contour Model

Football players can be considered as non-rigid moving objects. So they should be tracked with an adequate method, like snake-based method. The snake, or active contour model, has been introduced by Kass and al [1]. An active contour is represented as a parametric curve

$$v(t) = [x(t), y(t)]\,,\ t \in [0, 1] \qquad (1)$$

which can be closed or not.

In order to decrease processing time, we use a discrete and local implementation of the active contour model: the greedy algorithm, which is known to be faster than dynamic programming or variational calculus [2]. The parametric curve will be iteratively deformed in order to minimize an energy function. For each point v_i of the active contour, this energy function $E(n_i)$ is computed on every point n_i belonging to the neighbourhood of v_i. The point n_i which has the minimum energy $E(n_i)$ is then selected to replace v_i if $E(n_i) < E(v_i)$. In the other case, the contour point v_i is not modified. This process is iterated until convergence (when the current contour is identical to the previous contour). So the deformation depends directly on

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the energy function. The energies used to compose this function will be presented in the next part.

3 Definition of the Energies

The energy to be minimized in an active contour model is classically composed of two different parts: internal energy and external energy, as shown in the following equation.

$$E = \alpha \cdot E_{int} + \beta \cdot E_{ext} \tag{2}$$

where E_{int} and E_{ext} are respectively the internal and external energies.

The former represent physical properties of the contour whereas the latter links contour to data contained in the image (like gradient or intensity). We will now describe the forces used to define these two terms.

3.1 Internal Energy

Internal energy is defined by three forces linked respectively to continuity, balloon, and curvature:

$$E_{int} = a \cdot E_{con} + b \cdot E_{bal} + c \cdot E_{cur} \tag{3}$$

where E_{con}, E_{bal}, and E_{cur} are the energies associated to the forces representing respectively continuity, balloon, and curvature.

Continuity force influence the curvature of the model. It forces the points of the contour to be equally distant, so the contour tends to be a circle. The energy $E_{con}(n_i)$ is defined for a point n_i in the neighbourhood of v_i as the absolute value of the difference between two distances: the average distance between two successive points of the contour (which is computed at each iteration) and the distance from the previous contour point v_{i-1} to the point n_i.

Balloon force has been introduced by Cohen [3] and allows the contour to extend or to decrease. We will use a reduction force to force the area of the snake to decrease. The energy $E_{bal}(n_i)$ is defined as the scalar product of the normal vector of the contour at the point v_i with the vector $\overrightarrow{v_i n_i}$. The direction of the normal vector allows the contour to grow or to reduce.

The last force used in the intern energy is the curvature. The goal of this force is to avoid isolated points which will not be coherent with the global shape. So the energy $E_{cur}(n_i)$ is proportional to a discrete expression of the second order derivative.

3.2 External Energy

External energy is composed of two forces linked respectively to colour gradients and green intensity. It is defined by:

$$E_{ext} = d \cdot E_{gra} + e \cdot E_{gre} \tag{4}$$

where E_{gra} and E_{gre} are the energies representing respectively the colour gradients and the green intensity.

The first force is based on a combination of the gradients calculated on the three colour components (red, green, and blue). It makes the model to stop on the real contours present in the image. We use Sobel operator to calculate an approximation of the gradient, which is then thresholded. The use of a threshold allows us to eliminate most of false contours. In order to decrease processing time, we compute the gradient only once per frame on a window around the initial snake position.

The second force is based on the green intensity of the image. We use a priori information about the colours present in the image to lead the contour to be close to green pixels, which correspond to the football field. By this way we force the snake to remain on the extern contour of the players. The energy E_{gre} is defined as the difference between the green intensity and a fixed threshold T_G.

4 Tracking Method

We have to track moving non-rigid objects (football players) in a moving environment (camera). In order to decrease processing time, we do not add any preprocessing step to our method (opposite to most of the methods presented in the literature, like [4]) nor any movement estimation algorithm. The tracking method is composed at each frame of two parts: rectangle initialisation and snake deformation.

4.1 Rectangle Initialisation

The rectangle initialisation is done in two steps. First a rectangle parallel to the image border is created around the snake obtained from the previous image. Next the size of the rectangle is increased in order to englobe the expected contour at current frame. The initial snake is obtained in setting its points all around the contour of the rectangle. A specific processing is done on the first frame where there is no a priori information about the contour: instead of the rectangle, at present we use a manual initialisation of the contour. In near future the initial contour will come from a previous processing step.

4.2 Snake Deformation

The snake deformation is then performed and will lead the snake to reduce around the football player. This reduction is done until convergence using the process described before. We use a reducing balloon force instead of an increasing one because it gives better results. Indeed, reducing the snakes means deforming it through the area around the players (usually the playfield), which does not contain too many contours. On the opposite, increasing the snakes means taking into account all the points representing the football players, which would make our method very sensitive for example to colour or contour information present in the sportswears.

5 Results

Our method has been tested on football video sequences. These sequences were acquired from TV channels with a frame rate of 15 images per second. The images are 24 bits colour (RGB) images and their width and height are respectively 384 and 288 pixels.

The active contour was initially composed of 16 points. The deformation step is limited to a maximum of 30 iterations. However, the contour converges most of the time before this number of iterations. Convergence has not been obtain for 30 % of the frames. At each iteration, the energy is calculated in a neighbourhood of 5-by-5 pixels around the previous contour point. We choose Sobel operator and a threshold value of 500 to compute the thresholded gradient.

The coefficients for pondering all the energies are listed in table 1.

Energy	Description	Coefficient
E_{int}	Internal	$\alpha = 1$
E_{ext}	External	$\beta = 2$
E_{con}	Continuity	$a = 0.1$
E_{bal}	Balloon	$b = 0.2$
E_{cur}	Curvature	$c = 5$
E_{gra}	Gradient	$d = 1$
E_{gre}	Green intensity	$e = 0.01$

Table 1: Energies and coefficients used in snake deformation.

The figure 1 shows the result of the snake deformation on the two first frames. The initial contour is manually initialized on the first frame (a human user sets the different points of the initial contour), whereas it is automatically initialized on the second frame, thanks to final snake position from the first frame.

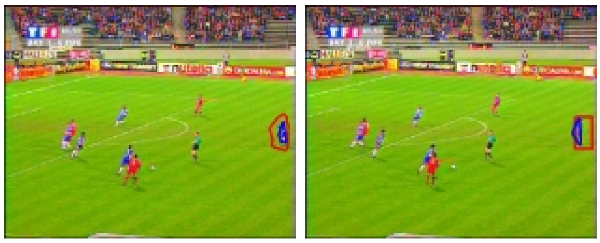

Figure 1: Initial contour and final contour on the first and second frames. The initial contour has been manually initialized on the first frame whereas it has been automatically initialized on the next frames.

The results presented on figure 2 represent the tracking of a moving player on several frames, corresponding to a seven seconds long sequence (100 frames). We can see that the football player and also the camera are moving. However the tracking algorithm is not affected by these movements.

The main limitations of the proposed method are linked to close positions of two moving objects and also with background. In fact, the method is able to track a player as long as he is not too close from the other players. If the tracked object is close to another object, the snake will englobe both objects and the method is unable to separate the two objects when they are not close anymore.

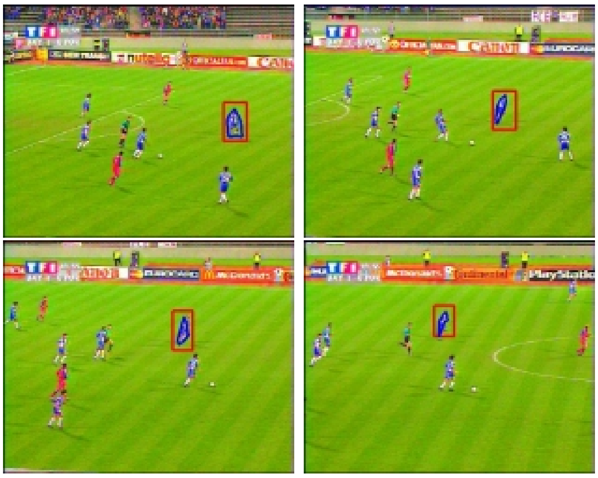

Figure 2: Initial contour and final contour on the 20th, 40th, 60th, and 80th frames. Initial contours were automatically initialized thanks to final contour obtained on previous frames.

Another drawback is linked to background present in a soccer game image. It usually contains white lines to show field borders. Pixels representing these lines are characterized by high gradient values. So the snake fixes often on these white lines. These two drawbacks can be seen on figure 3.

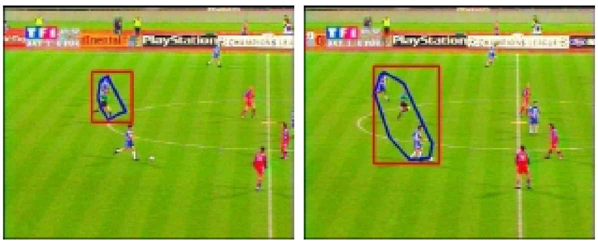

Figure 3: Initial contour and final contour showing respectively sensitivity to background (especially white lines) and impossibity for the snake to divide in order to track several objects.

These tests have been done on a Personal Computer (Intel Celeron 600 with 128 MB). The method has been implemented with Matlab (the code is interpreted). The processing time is about 2 seconds per frame. It allows us to consider a real-time framework with an implementation in a compiled language (like C).

6 Conclusion

The method presented here is able to track football players as non-rigid objects. It used a fast implementation of the active contour model, without global filtering or other processing. It deals with colour image sequences and is robust to camera movement.

Future work will include improvement of the method in order to make it able to track players even if they are close to other moving objects or to background like white lines. This will be done by adding a scission step in the algorithm in order to divide the snake in two active contours when two objects move away one from the other. Effect of the white lines will be limited thanks to the inclusion of a new energy linked with region homogeneity. Others improvements will concern optimization and implementation of the algorithm on a multiprocessor workstation in order to track objects in true real-time (25 images per second). Tests on other kind of images will also be performed to check if the method could be adapted to others contexts. Finally we will try to implement other energies defined in the literature, as those in [5].

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