A DUAL ACTIVE CONTOUR FOR HEAD BOUNDARY EXTRACTION

S. R. Gunn and M. S. Nixon

1 Introduction

The position of a head in an image is germane to automatic face recognition. Several techniques have been proposed to extract an approximation to the head boundary. One used a conventional snake approach [Waite and Welsh, 1990] to shrink an active contour onto a face boundary, whilst another [Bennett and Craw, 1991] used a deformable template based on candidate points. An alternative approach [Huang and Chen, 1992] used an expanding active contour aiming to achieve a similar result, though targeted at face description. The choice between expanding and contracting contours concerns how to handle the upper part of the face and whether to extract the lower hairline or the top of the head. Another approach [Lanitis et al., 1993] based on flexible template matching trained a Point Distribution Model which used the face boundary as part of the face template aimed at face recognition, but omitted the top part of the head.

The face boundary was shown in human cue saliency tests [Davies et al. 1981] to be more important than the chin, lips and mouth, but less important than the eyes, nose and eyebrows. It has practical advantages in that in poor illumination, serving to reduce the possibility of extracting individual face features within a face, the contour can still be well marked so long as it is distinguishable from its background. Inherent disadvantages include a susceptibility to change when the head turns though this could perhaps be compensated for. The face boundary has appeared in a number of recognition systems but usually as point measures across the face. In a study on extending the feature set for use in automatic face recognition [Jia and Nixon, 1992] a description of the face contour was included as one of four feature sets. The contour was extracted by parametric and edge analysis and described using Fourier descriptors and shown to clarify discrimination between different faces.

This paper presents a new approach to improve robustness of face contour extraction by extending active contour techniques. The main problems with the basic snake technique [Kass et al., 1988] include sensitivity to initialisation and obstruction of evolution by insignificant localised features. In deployment, these factors can force selection of an initial contour which is close to the target. By combining an expanding contour with a shrinking one, in a dual active contour, we can reduce sensitivity to initialisation, effectively by constraining the space in which the target contour is expected to lie.

It is clear that the basic snake technique can become snagged on insignificant localised features as a consequence of many local minima in the snake's energy function. Global shape information can be included *a priori* to improve the snake's probability of finding the target minimum. This global shape information can be included by incorporating a model within the dual active contour. This model guides the two snakes towards an appropriate minimum specified by the model. This can be compared with an earlier approach to face contour extraction [Reinders et al., 1992] which used pushing and pulling displacement vectors to seek a minimum of a cost function involving displacement difference. Unfortunately the model used was based on mirroring the lower part of the face to the upper part to handle difficulty in modelling the upper part of the face outline, hence reducing fidelity in the extracted contour.

The model incorporated within the dual contour can be tailored to specific applications. Here we seek to extract the human face outline which has been shown to possess a parametric approximation to its lower part [Jia and Nixon, 1992] though it is clear that no suitable model

---

S. R. Gunn and M. S. Nixon are with the Vision Speech and Signal Processing group, Department of Electronics and Computer Science, University of Southampton.

exists for the upper part of the face. By estimating the parametric approximation from the shapes of the two contours we guide the snakes to extract contours which better match the target shape. By virtue of a snake's formalisation, this gives a high order description of the face boundary.

2 Head Boundary Dual Snake

2.1 The Snake Model

A contour is described parametrically by $\mathbf{v}(s)=(x(s),y(s))$ where $x(s)$, $y(s)$ are x, y co-ordinates along the contour and $s\in[0,1]$ is arc length. The snake model defines the energy of a contour $\mathbf{v}(s)$, the snake energy E_{snake}, to be,

$$E_{snake}(\mathbf{v}(s)) = \int_{s=0}^{1} E_{int}(\mathbf{v}(s)) + E_{image}(\mathbf{v}(s)) + E_{model}(\mathbf{v}(s))ds \tag{1}$$

where E_{int} is the internal energy of the contour, imposing continuity and curvature constraints, E_{image} is the image energy constructed to attract the snake to desired feature points in the image; the functional used, $E_{image}= -|\nabla I(x,y)|$ attracts the snakes to edges in the image, and E_{model} is the model energy which allows geometric constraints to be applied during the minimisation process.

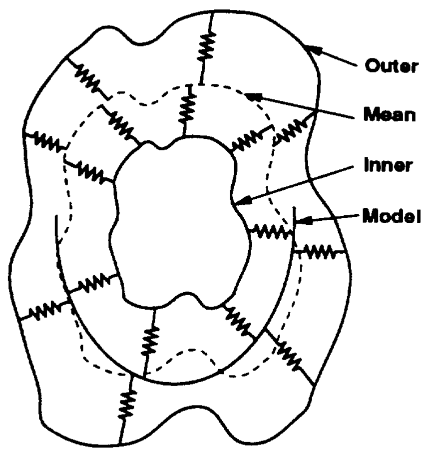

Figure 1. Face contour model

2.2 Model Based Dual Snake

In the dual contour approach, an interior contour lies within the region of the desired feature and an exterior contour outside it. The two contours are coupled using springs which cause the two contours to be attracted to each other as well as to suitable image features. The purpose of two contours is to integrate the information from a contour expanding within the feature to a contour contracting from without the feature. The dual snake reduces sensitivity to initialisation whilst providing superior performance by incorporating the information from two snakes approaching the desired boundary from both sides. The design of the snake has the advantage that high-level information, such as geometric shape may be included in the extraction process to improve performance in the presence of imperfect image data.

A particular problem in the extraction of head boundaries is that the chin is often poorly characterised in the edge functional as a consequence of poor contrast. To increase robustness in the chin area a model is added, Fig. 1. The bottom half of the face can be approximated well with a parametric shape model; an elliptical segment is used in this example. The elliptical model is fitted by the method of least squares using the inherent shape information in the interior and exterior contours. The boundary of the upper part of the head is the hair boundary and so the inner contour aims to select the lower hairline and the outer contour the top of the head.

A mean contour is computed from the interior and exterior contours, **inner** and **outer**, as

$$\mathbf{mean}(s) = \frac{1}{2}(\mathbf{inner}(s) + \mathbf{outer}(s)) \tag{2}$$

A model contour, **model**, combines the upper (mean contour) and lower (modelled contour) as

$$\mathbf{model}(s) = \begin{cases} \mathbf{chin}(s) & \text{bottom half of face} \\ \mathbf{mean}(s) & \text{top half of face} \end{cases} \tag{3}$$

where the lower contour, **chin**, is a least squares fit of an ellipse to the bottom half of the mean contour, **mean**. The model energy for a contour **v** is derived from the spring energy connecting the contour to the model (Fig. 1)

$$E_{model}(\mathbf{v}(s)) = \lambda(s)\frac{1}{2}(\mathbf{v}(s) - \mathbf{model}(s))^2 \tag{4}$$

where $\lambda(s)$ controls the weighting of the model.

Given an initial interior and exterior contour the contours are evolved by minimising E_{snake}(**inner**) and E_{snake}(**outer**) simultaneously. The technique is implemented iteratively which allows the model contour, **model**, to be updated between iterations. The contribution of the model is relinquished as the snakes reach equilibrium and progress no further. In this manner the final contours selected by the snake relate precisely to the image data and are only prejudiced by the model in the evolution of the snakes.

3 Results

Face images were acquired as 512 by 512 8-bit images under ambient lighting. A variety of backgrounds were considered, varying from plain to highly cluttered. The head boundary dual active contour was initialised from several locations for the inner and outer contour inside and outside the head respectively. An example application for a plain background is given in Fig. 2. Fig. 2(a) shows the initial contours, Fig. 2(b) shows mid-evolution, Fig. 2(c) shows the final result, and Fig. 2(d) shows the gradient magnitude functional used. Fig. 2(a) shows that the exterior and interior contours had to pass over some local face features to reach the final result. In mid-evolution the effect of the dual contour is to pull the exterior and interior contours over these local minima and Fig. 2(b) also shows the influence of the chin model which has to guide the contours to weak edge data (Fig. 2(d)). The model is then relinquished after the snakes reach equilibria leading to the final extraction of a face boundary which is clearly related to exact picture data. The inner contour follows the chin and lower hair line, whilst the upper contour follows the chin and the top of the head.

The technique was also investigated in cluttered backgrounds. The inner contour continued to extract the chin and lower hairline with realistic initialisations, whereas the outer contour can become snagged on extraneous data. This effect can be particularly marked at the top of the head, as expected, since there is no exact model to guide the contour over localised image features.

4 Conclusions

A new technique has been developed to extract the head boundary. The new technique uses two active contours to handle problems with initialisation of this now popular technique. A model of the face boundary is included within the two contours to guide extraction to the target head boundary. In the lower part of the face a parametric approximation is used, whereas the average of the two contours is used in the upper part where no model exists. In application this new

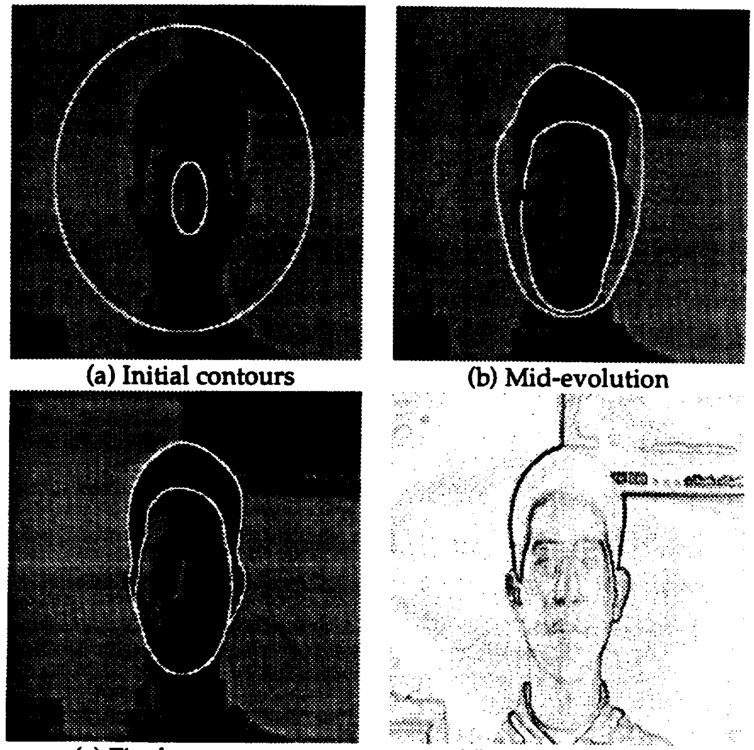

Figure 2. Head boundary dual snake results

technique can be shown to extract face contours successfully though if the background is cluttered the outer contour can become snagged on non-head boundary data because of the difficulty in modelling the upper head boundary. This motivates continued research in the incorporation of additional knowledge in the extraction process. Region-based information, providing distinct information may be advantageous to guide the technique in these areas. However, the results for this new technique augur well not only for continued performance assessment, but also for investigation in its use as a biometric.

5. References

Bennett, A., and Craw, I.: Finding Image Features using Deformable Templates and Detailed Prior Statistical Knowledge, BMVC '91, 1991, pp233-239.

Davies, G.M., Ellis, H.D., and Shepherd, J.W., Perceiving and Remembering Faces, Academic Press, London, 1981.

Jia, X., and Nixon M.S.: Extending the Feature Set for Automatic Face Recognition, IEE IPA '92, 1992, pp155-158.

Kass, M., and Witkin, A., and Terzopoulos, D.: Snakes: Active Contour Models, Int. J. Comp. Vis., 1988, pp 321-331.

Lanitis, A., Taylor, C.J., and Cootes, T.F.: A Generic System for Classifying Variable Objects using Flexible Template Matching, BMVC 93, 1993, pp 330-338.

Reinders, M.J.T., Sankur, B., and van der Lubbe, J.C.A., Transformation of a General 3D Facial Model to an Actual Scene Face, IEEE IAPR, 1992, pp75-78.

Waite, J.B., and Welsh, W.J.: Head Boundary Location using Snakes, Br. Telecom Technology Journal, 1990, pp127-136.