

ACTIVE APPEARANCE MODEL (AAM)

From Theory to Implementation

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Abstract: Active Appearance Model (AAM) is a kind of deformable shape descriptors which is widely used in computer vision and computer graphics. This approach utilizes statistical model obtained from some images in training set and gray-value information of the texture to fit on the boundaries of a new image. In this paper, we describe a brief implementation, apply the method on hand object and finally discuss its performance in compare to Active Shape Model(ASM). Our experiments shows this method is more sensitive to the initialization and slower than ASM.

1 INTRODUCTION

Model-based approaches analyze different variations of an object using some samples of the object in a training set and finally calculate a model based on the object variations. Active Appearance Model (AAM) of Cootes et al. in (T.F.Cootes and C.J.Taylor, 2001) is one of the well-known model-based methods.

To build an AAM model, a training set of images is assumed in which corresponding landmark points have been marked on every image. A statistical model of the shape variation by using these landmarks and Principle Component Analysis (PCA), a model of the texture variation (sampling of the gray values of images) using mean shape, delaunay triangles and another PCA and a model of the correlations between shape and texture, are computed. The final shape-texture model and the images in the training set are a basis to learn a multi-variate regression matrix. With enough training examples this model should be able to synthesize any image of normal anatomy. By finding the parameters which optimize the match between a synthesized model image and a target image all the structures represented by the model can be located. Obtaining a model by AAM includes two main stages which are:

- **Offline stage:**
 - *Manual Labeling:* Placing landmarks surround-

ing objects in images inside training set manually. (T.F.Cootes and J.Graham, 1995) explains different kinds of landmarks.

- *Shape Alignment:* The differences among shapes, which are rotation, x-y translations and scaling, are omitted and mean shape is created.

- *Statistical Shape Model:* using PCA the aligned shape variations are modeled as an eigenvector matrix and a few parameters.

- *Texture Sampling:* The gray-value of each pixel under each shape in the training set is obtained.

- *Texture Alignment:* Texture alignment is used in order to omit the illumination differences among the images in the training set.

- *Statistical Texture Model:* After texture alignment another PCA is utilized to model the typical texture variations.

- *Joint Shape-Texture Statistical Model:* Both shape and texture models are merged together to construct an unit model.

- *Training Regression Matrix:* A multivariate linear regression matrix is trained using the joint model and some images in the training set.

- **Online stage:**

- *Search in a New Image:* The obtained AAM model along with the regression matrix are used to find the modeled object in a new image.

In this paper, we describe a brief implementation of AAM, then we examine AAM on hand object and finally compare AAM performance with another model-based method named Active Shape Model (ASM).

2 OFFLINE STAGE

This stage utilizes some statistical analysis by using Principle Component Analysis (PCA) on the shape variations and also texture variations of some gathered images in a training set.

2.1 Manual Labeling

In the analyzed model, the shape is represented by a set of points (or landmarks). These landmarks are placed manually for each shape in the training set. The corresponding landmarks in the shapes must be approximately in the same location because each point represents a particular part of the object or its boundary. To increase accuracy some additional points are added between two points when the distance is more than a threshold.

2.2 Shape Alignment

All objects in the training set has different scaling, rotation and x-y position(or translation), named pose parameters, compare to the others. In order to remove the pose differences and only remain the object shape variations the alignment procedure is used. The center of mass of the shape is calculated and moved to the coordinate origin for removing X-Y translation. After removing the X-Y translation the obtained shape becomes unity scale by dividing the shape on its L_2 - norm. To remove the rotation, another shape is needed as a reference. It can be proved mathematically that Singular Value Decomposition (SVD) calculates the rotation matrix between the shape and the reference shape. A comprehensive explanation of shape alignment with its procedure can be found in (Babai Rizvandi et al., 2007). The mentioned procedure is only for one shape. For the shapes in the training set, we align all shapes to the first shape and calculate the mean shape. Then we align all shapes to the mean shape and we recalculate the mean shape. This procedure, which aligns to the mean shape and recalculates the mean shape, is continued until the mean shape does not change significantly in two iterations.

2.3 Statistical Shape Model

The $2N$ elements are highly correlated, so it is possible to represent them much more compactly. One approach is Principle Component Analysis (PCA) that is widely used in pattern recognition to reduce the dimension. Using PCA the number of elements reduces from $2N$ to M while $M \ll 2N$. The final shape model is

$$X = \bar{X} + \Phi_{shape}^T \cdot b_{shape} \quad (1)$$

where \bar{X} is the mean shape, Φ_{shape} contains the shape eigenvectors and b_{shape} includes the shape parameters.

2.4 Texture Sampling

The question to make a texture model is which gray values must be used in the model and how the model should be defined. The answer to the first question is that only pixels including the object are necessary. Dividing the shape into a combination of triangles by delaunay triangulation is the common solution for the second question.

The problem with delaunay triangulation is that these triangles cover all regions including background of the convex hull (Stegmann, 2000), (T.F.Cootes and J.Graham, 1995). So in order to form a suitable texture model, a convex hull algorithm must be used.

After removing the background pixels, the next step is to find the corresponding pixels in the object textures and warp these pixels positions. To do this task, the pixels inside the mean shape are sampled and the related pixels in the other images textures in the training set are obtained by using the corresponding triangles. (Stegmann, 2000) and (Babai Rizvandi et al., 2007) explain the complete algorithm.

2.5 Texture Alignment

Within the object there are usually some variations in gray values because of different illumination intensities. Since the goal is to build a stable model without these unwanted effects, these variations must be eliminated. The common method is to align all textures to the standardized mean texture, with zero mean and unit variance, and continue this procedure till the difference between the standardized mean texture in two following iterations is less than a threshold [(T.F.Cootes and C.J.Taylor, 2001) ,(Stegmann, 2000) and (Babai Rizvandi et al., 2007)].

2.6 Statistical Texture Model

The same as section 2.3 another PCA is used to represent the obtained texture information much more compactly. Because the number of elements in the texture is much higher, using the traditional PCA takes a lot of time. If N_g and N are the number of texture pixels and the number of shapes in the training set, so the covariance matrix will have $N_g * N_g$ dimensions. When $N_g \gg N$, calculating the covariance matrix, and therefore the texture eigenvectors and eigenvalues, is computationally expensive. The idea is to calculate the covariance between the textures and then convert it to the covariance between the pixels (Stegmann, 2000). The final texture model is

$$T = \bar{T} + \Phi_{tex}^T \cdot b_{tex} \quad (2)$$

where \bar{T} is the mean texture, Φ_{tex} contains the texture eigenvectors and b_{tex} includes the texture parameters.

2.7 Joint Shape-Texture Model

Both b_{shape} and b_{tex} models should be merged to form a unit model including both texture and shape variabilities and keeping the correlation between them. Since the nature of shape and texture are different, some weighting is necessary. In the absence of these weighting, spread of the points in the space will be undesirable (Stegmann, 2000). A simple weighting matrix is a diagonal matrix:

$$W = wI = \begin{pmatrix} w & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & w \end{pmatrix} \quad (3)$$

where $w = \frac{\sum \lambda_{tex}}{\sum \lambda_{shape}}$ and λ_{tex} and λ_{shape} are eigenvalues of b_{shape} and b_{tex} , respectively. The merged model is a simple column vector:

$$b_{joint} = \begin{pmatrix} W * b_{shape} \\ b_{tex} \end{pmatrix} \quad (4)$$

To eliminate correlation between shape and texture parameters, another PCA should be performed on the combined data (b_{joint}):

$$b_{joint} = \Phi_{joint} * c \quad (5)$$

where Φ_{joint} is the eigenvector matrix of joint shape-texture parameters and c is the final combined model parameters. The same as the section 2.3, the order of model is reduced after calculating the PCA.

The final shape and texture models are calculated with the following equations (T.F.Cootes and C.J.Taylor, 2001), (Zambal, 2005):

$$\begin{aligned} X &= \bar{X} + \Phi_{shape} * W^{-1} * \Phi_{joint,shape} * c \\ T &= \bar{T} + \Phi_{tex} * \Phi_{joint,tex} * c \end{aligned} \quad (6)$$

where

$$\Phi_{joint} = \begin{pmatrix} \Phi_{joint,shape} \\ \Phi_{joint,tex} \end{pmatrix} \quad (7)$$

These two equations are the basis to calculate the regression matrix in the next level.

2.8 Training a Regression Matrix

The search procedure in AAM is considered as an optimization problem in which the gray value differences between the artificial object obtained by AAM and an actual image is to be minimized:

$$\delta I = I_{image} - I_{model} \quad (8)$$

In this case the optimization can be enhanced by adjusting the model and pose parameters in order to fit the artificial object with the image. So δI can be replaced by δT because this procedure is based on the normalized texture vectors (Stegmann, 2000). One possibility is that to consider the relation between δT and the model-pose parameters changes, δc , as linear and use the information obtained from the joint shape-texture model and the texture of some images in the training set in a linear regression matrix (R) as following:

$$\delta c = R \delta T \quad (9)$$

where $c = [c, t_x, t_y, \theta, S]$. The idea of the standard AAM approach is to estimate R in a precalculation step. The parameters of a model instance are changed and the according differences in texture are measured. If the parameter differences are the column vectors of a second matrix Δ_c and each of Δ_T represents the texture differences corresponding to the parameters differences, the last equation becomes

$$\Delta_c = R \Delta_T \quad (10)$$

The final R can be calculated as (Zambal, 2005)

$$R = \Delta_c \Phi \Lambda^{-1} \Phi^T \Delta_T^T \quad (11)$$

where Λ and Φ are eigenvalues and eigenvectors for matrix $\Delta_T^T \Delta_c$, respectively.

3 ONLINE STAGE

In the online stage, we use the constructed AAM model in order to fit the model on a target object in a new image. The following is the standard AAM search algorithm (T.F.Cootes and C.J.Taylor, 2001) and (Zambal, 2005).

- Place an initial shape near the desired object in the new image.

- **Repeat**
 - Calculate the texture differences δ_T .
 - Calculate the parameter differences by using $\delta_\xi = \mathbf{R}\delta_T$.
 - $\hat{c} \rightarrow \hat{c} + \delta_\xi$.
 - Calculate the differences between artificial model texture and image texture belong the artificial model shape(\mathbf{E}).
- **until** $\mathbf{E} \leq \text{Threshold}$

4 EXPERIMENTAL RESULTS

Hand Gesture Extraction is one of the common applications of Active Appearance Model (AAM) and Active Shape Model (ASM). In this section, we applied our implementation of Active Appearance Model (AAM) and Active Shape Model (ASM) on images of hand in order to compare these method efficiencies. At first the images of hand must be labeled with some landmarks. In our implementation both AAM and ASM iterate 40 times. Figure.1 shows the result of both AAM and ASM for a suitable initialization. Our experiment shows the efficiency of both methods has an extreme dependence on two factors: (a) comprehensive object variations in the training set that means all changes outside of the training set are not included by the model and (b) a suitable initialization.

ASM searches around the current location so it has a larger capture range than the AAM which only considers the image directly under its current area. ASM only uses data around the model landmarks and does not involve all the grey-level information available across an object as the AAM does. Thus it may be less reliable. In compare to AAM, ASM is faster and achieves more accurate feature point location than the AAM, but tends to be less reliable.

5 CONCLUSIONS

In this paper, we examined the AAM model performance for finding the boundary of hand. We also compared its efficiency with another deformable method named Active shape model (ASM). The results show that because this method uses gray-values information of images, it is slower than the ASM. Moreover, due to using the local information its capture range is less than ASM and so more sensitive to the initialization than ASM.

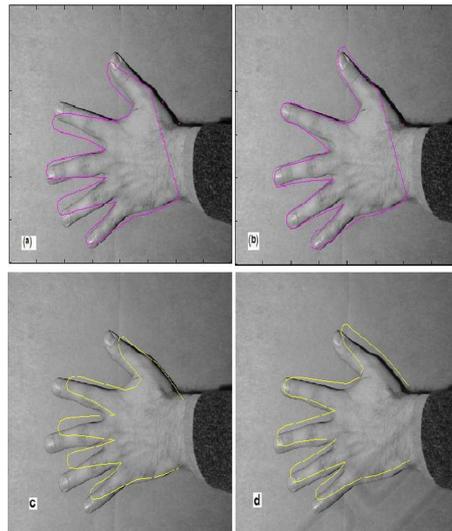


Figure 1: Experimental results for AAM in compare to ASM: (a) initial shape for ASM (b) Final Shape for ASM (c) Initial for AAM (d) Final shape for AAM.

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