Hair Strand Extraction by Template Matching using Gabor Filter and Histogram

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***Abstract*— Hair modelling is an essential part for many applications in computer graphics. Hair modeling starts with viewing hair as individual strands. In this work with an image-based technique we extract two dimensional hair strands to pass them (as inputs) to another system which generates their 3-D hair models. The key idea is that working on small sub-images is easier than using the whole image at once to extract strands. We break down the input hair image to blocks and replace each with the matched template from created manual database. The method uses Gabor filter to find the orientation map of the pixels in the input image and templates in database. A similarity measurement is applied to find the best match. In next step we make connection between blocks to create strands.**

***Keywords*—Image processing, Template matching, Gabor filter, Orientation map, Histogram.**

I. Introduction

Hair simulation is an essential and challenging part for many applications in computer graphics since it is an important part of virtual humans. However, there have been noteworthy works in 3D construction of face and body based on strict features in those; but realistic hair simulation is an open challenge due to the complexity of hair. There are thousands of thin hair strands and the appearance of hair varies widely from one person to another. There are some works that show realistic hair model. But for example in [3] there are a lot of efforts to configure lights and cameras which makes it not always available for regular users to model hair. There are some modeling methods that need a user-assistant process [1, 2]. These clearly allow a fine control over the geometry but it becomes tedious if someone wants to reproduce complex features like curls and waves of a real character. Therefore, creating a system which needs less interaction with the user and also has an easy setup and reduce the complexity to capture 3D model is considerable.

Three major processes in hair modeling illustrated by Magnenat-Thalmann and Hadap in [1] are styling, animating, and rendering. Styling is modeling the shape and geometry of hair as well as form and quality of hair strands in aspect of distribution and density. Animating involves the dynamic motion of hair such as collision detection or interaction of strands together. Rendering is handling hair colour, shadow and in general issues related to visual presentation of hair on the screen. Hair modeling begins by viewing hair as individual strands. This paper is focusing on extracting 2D hair strands which is the first part of a proposed method to create 3D hair modeling by considering minimum user-assistant, simple and relatively inexpensive configuration. In proposed system a Logitech webcam and one Kinect are used to capture image and infrared depth information from different viewing angles of real hair. In this paper, we address two dimensional hair images to apply image-based techniques to extract two dimensional hair strands. We mosaic the input image with manual strands templates from a database. In the next step, it needs only to connect strands in each mosaic to strands in surrounded mosaics. This template-based method facilitates image processing on the input hair image which is computationally inefficient. In this work we look for the best matching of the original hair image with the template database. In section 2, a background and related works on hair simulation is reviewed. In third section, Gabor filter is introduced since the key feature in matching process comes from this filter's output. Also, template matching in the field of image processing is introduced. PCA is another method we applied to find the matching is explained as well. System configuration and results are explained is section 4 and section 5 presents the conclusions.

II. Background and Related Works

Hair modeling is an active area of research and yet there is no widely accepted method in the graphic industry standard. There are different types of applications that might need hair modeling. Cosmetic industry needs a precise and specific modeling to test their products. Virtual environments and video games are the types of application that the speed performance is more important concern over the appearance in the modeling system. Other type of applications are in the entertainment industry that the endeavor is to decrease the complexity of modeling and hair modeling research is not a concern. By considering the application, sometime it is the artist/user that makes his desire model by means of facilities and tools the system provides and sometime a given hair model is the aim of the modeling system. Different applications effect the approach which is taken to create modeling system. Cem Y et al in [10] well categorized works in hair modeling. One group is the techniques that are based on the surface representation. Cem in [10] uses hair meshes in modeling hair using polygon surface tools. Koh and Huang [11] showed a group of hair strands by a patch of parametric surfaces in particular NURBS. Adding texture and thickness improve the hair modeling in this group [12] however they are far from realistic hair modeling. There are physical-based techniques as well, that are trying to simulate hair model by a physical view. In [1] they simulate hair as a fluid flow around an obstacle. Sketch based interface is another technique that is used in hair modeling [16] and cartoon hairs [17] and more realistic models [18] can be built by this model. Image-based techniques in hair modeling are more related to our work [3, 6, 7, 13, 14, 15, and 20]. Some techniques need complex configuration of cameras and lights which are expensive and not easy to use; however for example in [3] they have very promising results and there is no corporation between system and user. In other works hair is modeled by studying the subject's hair under various lightning conditions. They draw information from the scattering properties of the hair and by image-based techniques capture the geometry of hair [6]. Also there are other packages for generating hair models [4, 1, 2], but they start from scratch and it can be time-consuming to generate complex hairstyles. However 3D scanners recently are readily available in many different areas but they have difficulty to capture hairs because of complex reflection properties of light on hair strands.

III. System outline and methodology

In this section we describe our proposed method for extracting 2-D hair strands in detail. 2-D hair strand extraction is considered as the underlying step for making 3D model of hair. As the aim of our system is to simulate a real hair model, we capture photo from different angles of the head to have the whole area. Image registration techniques helps us to stitch images. We benefit from a lighting system to increase the quality of captured pictures. By taking several photos, a database of template images would be collected. The selected images are mostly the ones with straight hair styles. Figure 1 illustrates a sample of template database.

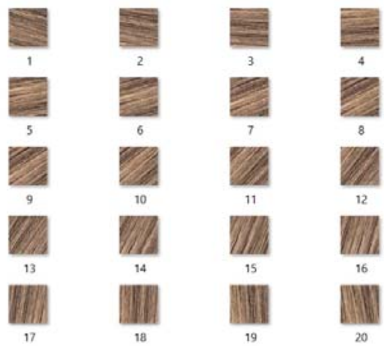

Figure 1: Hair template database are mostly straight hair and later image processing simpler.

Using these images makes later image processes easier. Template images in the database provide all orientations between 0^0 and 180^0. Preparing corresponding manual template database is the only part which needs to be done manually. By comparing the gain of having a fast and simplified hair modeling system, this manual drawing is worth to do. Some sample of hair database and corresponding manual hair database are shown in Figure 2.

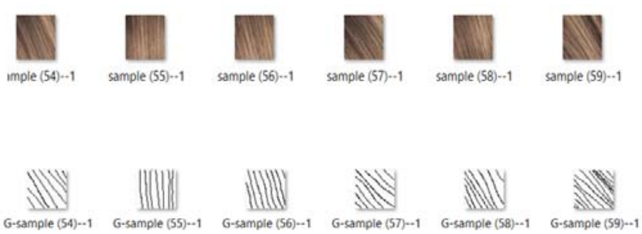

Figure 2. First row is sample of hair template database, Second row is corresponding manual hair template database

After the preparation phase, the reference image gets broken down into blocks with the same size as templates. Each block of reference image and the whole hair template database are sent to a bank of Gabor filters to calculate the orientation of each pixel known as orientation map [8]. Among a variety of descriptors, histogram demonstrated the best results to measure the similarity between each block and hair database. Principal component analysis (PCA), wavelet [21] and averaging were other descriptors that have been tried to find the texture similarity. As an example the best result in finding the most similar light scattering was been obtained by using PCA. After finding the most similar template in database, the corresponding template from manual database is replaced with the blocks in the reference image. Figure 3 represents the schema for our method. By finding all templates in the next step, the manual strands would connect together and will show smooth splines which is the input for 3D modeling system.

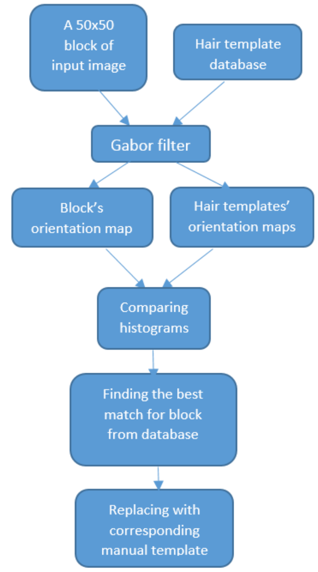

Figure 3. The template matching process for one block from reference image

A. Gabor Filter

Gabor filters are similar to the human visual system, and they have been found to be particularly appropriate for texture representation and discrimination. They can be designed for a number of dilations and rotations. Paris et al in [6] shows that oriented filters are well suited to estimating the local orientation of hair. Similar to [8] we apply a bank of Gabor filters $\{K_\theta\}$ on the input image I, which here is each block, where a filter kernel K_θ is designed to produce a high response for textures that are oriented along the direction θ when it is convolved with the image. The images are converted from RGB to HSV space and saturation channel (S) is used to find the texture features.

Let $F(x,y,) = (K_\theta * S)(x,y)$ be the response of K_θ at pixel (x,y), an estimated local orientation $\tilde\theta(x,y)$ at each pixel is then given by $\tilde\theta(x,y) = argmax_\theta(|F(x,y,\theta)|)$.

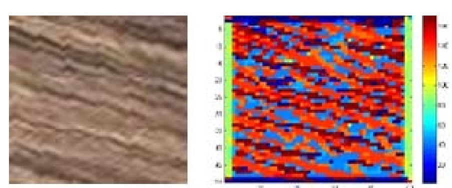

Figure 4. A template image and its orientation map 50x50

In this experience, filter bank contains even-symmetric Gabor kernels [4] with evenly intervals between 0^0 and 180^0:

$$K_\theta(u,v) = exp\left(-\frac{1}{2}\left[\frac{\tilde u^2}{\sigma_u^2}+\frac{\tilde v^2}{\sigma_v^2}\right]\right)cos\left(\frac{2\pi\tilde u}{\lambda}\right) \quad (4)$$

where $\tilde u = u cos\theta + v sin\theta$ and $\tilde v = -u sin\theta + v cos\theta$. In [7] it is proved that this cosine Gabor kernel is a credible orientation estimator at image-space. In reality, the parameters of the Gabor kernel are sensitive to the texture features in the image.

We are using histogram representation of obtained orientations in this work and the errors by this filter are negligible.

B. Template Matching

Template matching is an interesting area of research in the field of computer vision and image processing in recent times. In general this technique is classifying an object by finding the similarity between two input/reference image and template image. The matching method, depend on the nature of the image, could be considered Area-based or Feature-based. When there is no strong feature with the image, matches are estimated based on the intensity values of both image and template called Area-based matching. When the image and in our case hair image has strong features, strands' orientations, Feature-based methods can be used. Mean Squared Error (MSE), Sum of absolute differences (SAD), mutual information, and Principal Component Analysis are some of developed technique to measure similarities between reference image and the templates [9]. The approach we take to measure similarity is comparing the histogram of orientation maps of input image and template image. The result shows a very good matching in hair images which comes from this dominant feature in the nature of hair image. Figure 5 demonstrates the histogram of three blocks' orientation map. Two of them are similar and the other one has completely different histogram. The difference of two histogram is calculated as follow:

$$\min_i (Hist_{temp_i} - Hist_{block})^2 \qquad (1)$$

where Hist is histogram of hair template i and a block of reference image.

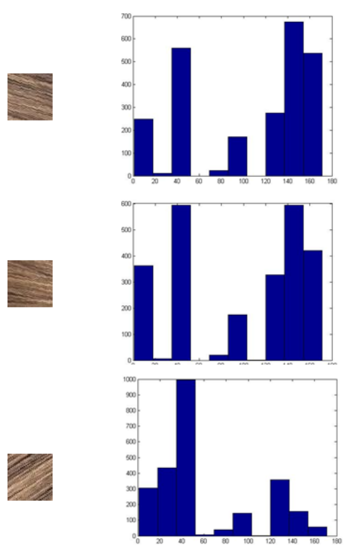

Figure 5. Templates and their orientation map's histogram

C. PCA theory

Principal component analysis (PCA) in signal processing described as a transform of given input vectors to new coordinate system such that the greatest variance of the data which contains the most information lie down on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on. It is a widely used feature extraction method that helps to extract the most important features and avoid redundancies in feature space with minimum loss.

C.1. Generating "eigenvectors"

RBG image from our database which are used for … are called "template images". Each 50x50 template image could be represented as a point in a 2,500-dimensional space. As images in this database are representatives of different hair strand directions, they are similar in overall configuration, which implies this fact that are not randomly distributed in the image space. Therefore it is possible to represent them in a relatively smaller space. Instead of RGB intensity values as features we used once orientation of pixels which Gabor filter provides them with high precision. There are some error and noise but in transformed feature space, PCA will discard them as it goes for the majority of distributions. Each $N \times N$ template image will be represented by a vector of length N^2 . These vectors define the subspace of template images, which are the eigenvectors of the covariance matrix corresponding to the original Vectors in these spaces are linear combinations of the original features.

Given $N \times N$ RGB template images $\Gamma_1, \Gamma_2, \cdots, \Gamma_M$ as training set get passed once through the Gabor filter which supplies us the pixels' orientations for template images $O_1, O_2, \cdots, O_M$ of size $N \times N$ with high accuracy. The classical calculations of PCA [19] looks for the average orientation template images

$$\Lambda = \frac{1}{M}\sum_{i=1}^{M} O_i \qquad (2)$$

The second step is subtracting from the mean. The difference of each orientation template image from average of orientation template will produce data with mean of zero in all dimensions. And for S channel a

$$\Phi_i = O_i - \Lambda \qquad (3)$$

This set of vectors is then subject to principal component analysis, which seeks a set of M orthonormal vectors u_n and their associated eigenvalues λ_n which best describe the distribution of the templates in database. The vector u_n and scalar λ_n are eigenvectors and eigenvalues, respectively of covariance matrix

$$C = \frac{1}{M}\sum_{n=1}^{M} \Phi_n \Phi_n^T \qquad (4)$$

The features with larger eigenvalues contain more information and are considered as principal components. Dimensions with smaller eigenvalues carry less information. The eigenvectors need to be ordered by eigenvalues. By choosing a subset of eigenvectors, the data is compressed and will be reduced. In this way the dimensions which are not carrying much information will be ignored.

To check whether color values are a good feature to find the best matching, images are converted from RGB to gray space, and it is used to apply PCA on it. Figure 6 shows the original image I in RGB as well as the gray level. In next section the results of PCA on orientation map and gray level are discussed and compared with histogram to evaluate the success of them in template matching.

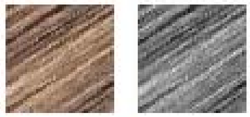

Figure 6. RGB image and its gray level

IV. RESULTS

The reference images in this experience are mostly selected from bright hairs since we need to use infrared depth information of Kinect for 3D construction of hair and dark colours would absorb the beams emitted from Kinect. We did our experiment with three different size of blocks: 15x15, 25x25, and 50x50. Based on our experiment, sizes of 15x15 and 25x25 were too small and data of these blocks were not sufficient for measuring methods to work well. Therefore, we selected 50x50 which is not very big to add complexity again. Our database has 250 hair templates with different colours and angles. We made a corresponding manual hair strand with high precision.

Gabor filters parameters we used in this paper are set by these values like [8] for: $\sigma_v = 2.4$ and $\lambda = 4$. They can be changed depending on the input image. Using Gabor filter for the reference image and then breaking it down to blocks did not result a satisfactory output. We first break down the image to blocks of 50x50 then sent them to the Gabor filter.

To match the templates of database with the blocks of reference image we applied different similarity measuring methods. Surprisingly, PCA on orientation map did not provide us with a good result. However, PCA on gray level of input image could match the light scattering very well. Figure 9 and 10 show the precision of this method in matching the light information.

Figure 7 and 8 display the results using measuring similarity of histogram presentation of orientation maps between input image and hair templates in our database.

We did experience on Haar wavelet to match the templates; however, the results were not satisfactory.

Figure 7. Template matching on a curly hair using histogram similarity

a)

b)

c)

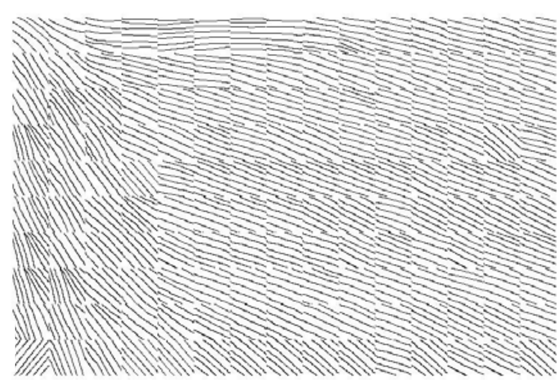

Figure 7.Template matching on a straight hair using histogram similarity

Figure 9. Applying PCA on the gray level of the input image (on the left) would be a perfect matching the light scattering (on the right)

a)

b)

c)

Figure 10. Applying PCA (b) and using histogram (c) on the input image (a) to match the templates

V. CONCLUSION

The extracting 2D hair extraction method presented in this paper could be used as a part of three dimensional hair modeling system. The introduced method has two advantages. First, it reduces the complexity of image processing during the extraction of strands. It also decreased the user assistant to the level of setting up a camera and Kinect and simple light system and capturing images from different viewing angles. Hair styles can be simplified by replacing with a hair template which is mostly straight hair and are big enough (50x50). This is getting done by a template matching approach and based on the nature of the hair images, orientation map of blocks in reference image and hair template database are the most informative feature to measure the similarity. According to the results, similarity of histogram presentation of orientation maps describes the best matched template from the database. Intensity values in gray level are not a good candidate for hair images for this purpose. Instead, gray level showed good results in finding the light scattering in the input image by PCA. The concern in this work is speed and simplicity of the system in the 2D hair styling which this could put it in entertainment category of applications.

VI. FUTURE WORK

Hair modeling is a challenging task and we proposed a new method for which can be improved in future works. As a part of image-based hair modeling, extracting 2D hair strands is a primary task. In this work we substitute the original hair image with hair template database of the same size. Trying different template sizes can help improve the results. When the hair is twisted or curly, using fixed size blocks decreases the precision of matching. A dynamic template matching algorithm is needed to mosaic the reference image with blocks of different size without big gaps. Connecting the replaced manual strands in different blocks is vital for making a smooth simulation of hair strands. Finding clear splines on the strands with enough control points and depth information from Kinect would be the input data for the 3D modeling system. Also, registration techniques would be applied to connect images from different viewing angles.

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