2D Hair Strands Generation Based on Template Matching

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Keywords: Hair Strands Generation, Orientation Map, Template Matching, Spline Representation.

Abstract: Hair modelling is an important part of many applications in computer graphics. Since 2D hair strands represent the information of the hair shape and the feature of the hairstyles, the generation of 2D hair strands is an essential part for image-based hair modelling. In this paper, we present a novel algorithm to generate 2D hair strands based on a template matching method. The method first divides a real hairstyle input image into sub-images with the predefined size. For each sub-image, an orientation map is estimated using Gabor filter and the orientation feature is presented by the orientation histogram. Then it matches the orientation histograms between each sub-image and template images in our database. Based on the matching results, the sub-images are replaced by the corresponding manual stroke images to give a clear representation of 2D hair strands. The result is refined by connecting the strands between adjacent sub-images. Finally, based on the control points defined on the 2D hair strands, the spline representation is applied to obtain smooth hair strands. Experimental results indicate that our algorithm is feasible.

1 INTRODUCTION

Hair modelling is an important part in many computer graphic applications. For example, it can help to create a convincing virtual character in computer games by providing certain identity and personality based on different hairstyles. Another example is in cosmetic industry, 3D hair models with different hairstyles can be applied to avatars of the customers in order to help the customers to design suitable hairstyles.

There are three major steps of hair modelling: styling, animating and rendering (Magnenat-Thalman et al. 2000). Hairstyling is the process of modelling the shape and geometry of the hair. It provides the density, distribution and orientation of hair strands. Hair animating includes the dynamic motions of hair, such as collision detection between hair strands as well as between hair and other objects (e.g. head and body). Hair rendering focuses on the visual presentation of hair on screen. However, the characteristic of hair, such as omnipresent occlusion, specula appearance and complex discontinuities, make it very difficult to model (Ward et al. 2007).

Recent hair modelling research works focus on estimating and reconstructing 3D hair strands from multi-view 2D hair images (Paris et al. 2008) (Luo et al. 2012, 2013a, 2013b) . However, those systems usually need complex configuration of digital cameras and lighting sources. Furthermore, user assistance is needed to a certain extent, thus the procedure would become time-consuming. In our proposed system, we use one digital single-lens reflex (DSLR) camera and one Kinect sensor to obtain both hair images and hair depth information from different view angles of a real hair. Our system extracts 2D hair strands from hair images. 2D hair strands are curves that represent the orientation and distribution of hairstyle. Based on the 2D hair strands, we can obtain the corresponding 3D hair strands by projecting the 2D strands on 3D point clouds. For this paper, we only focus on extracting 2D hair strands from hair images which is the fundamental procedure in our system.

In our system, 2D hair strands geometry can be estimated and a collection of hair strands can be obtained. The hair strands reflect the shape of the hair as well as the changes of the main orientations of the hairstyle. Compare to previous hair modelling systems, our system does not need the complex capture configuration as well as the user assistance. Furthermore, we notice that the most significant information of hair image is the orientation of hair strands. However, instead of using the orientation information of every pixel directly, we believe that the orientation of certain local area is more

Sun C., Cheraghchi F. and Lee W..
2D Hair Strands Generation Based on Template Matching.
DOI: 10.5220/0005107102610266
In *Proceedings of the 4th International Conference on Simulation and Modeling Methodologies, Technologies and Applications* (SIMULTECH-2014), pages 261-266
ISBN: 978-989-758-038-3

representative. Thus we divide the input hair image into sub-images with predefined size and use the orientation histograms to represent the orientation feature of each sub-image. In addition, based on the orientation histogram, we apply a template matching method to obtain 2D hair strands information from our manual stroke image database directly. Finally, we use splines to represent those manual strokes in order to obtain smooth hair strands.

2 RELATED WORKS

Existing hair capture systems use various methods to acquire the orientation field and geometry of the hair. (Paris et al. 2004) used a hair image capture system with a fixed camera and a light source moving along a predefined trajectory. They estimated the hair orientation of the highlight on the hair images and used the hair orientation to constrain the growth of hair strands. (Wei et al. 2005) introduced a technique that used a coarse visual hull which was reconstructed using multi-view images. They used the visual hull as the bounding geometry for hair growing constrained with orientation consistency. (Paris et al. 2008) presented an active acquisition system called Hair Photobooth. The system was composed by several video cameras, light sources and projectors. It can capture accurate data of the exterior hair strands appearance. The hair model was generated from the scalp to the captured exterior hair layer under constrains of the orientation field. (Jakob et al. 2009) proposed a system to capture individual hair strands by using focal sweeps with a robotic-controlled macro-lens equipped camera. (Herreraet al.2012) performed hair capture using thermal imaging device. (Beeler at al. 2012) used a high resolution dense camera array to reconstruct facial hair strand geometry by matching distinctive strands. However, since there was a strong contract between the skin colour and the facial hair colour, this method may not suitable for general hair geometry estimation. (Chai et al. 2012) proposed a method to generate an approximate hair strand model from single hair image with modest user interaction. (Chai et al. 2013) extended their system to create hair animations based on video input. The system can handle animations of relative simple hairstyle. (Luo et al. 2013a) developed several hair modelling methods based on multi-views. One of them was a wide-baseline hair capture method using strand-based refinement. In the system 8 cameras were used to capture the complete hair, geometry. (Luo et al. 2013b) also proposed a structure-aware hair capture method which can achieve highly convoluted hair modelling.

3 OVERVIEW

Given a real hairstyle input image, our goal is to obtain the hair strands which can reflect important feature of the hairstyle: the shape and orientation of the hair. 2D hair strands extraction is an essential step for the 3D hair modelling. The procedure of our method is shown in Figure 1.

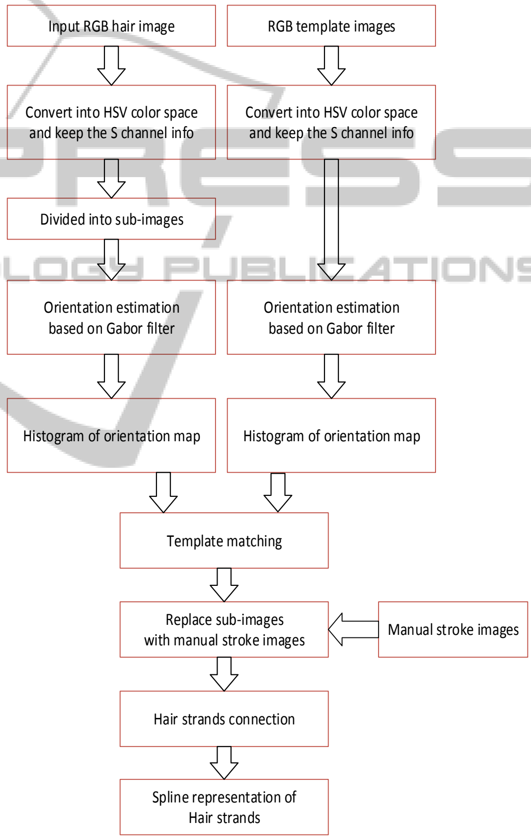

Figure 1: The procedure of our method.

We first convert the hair image from RGB to HSV color space and we choose the information from the S channel as our input for the following steps. Then we divide the input hair image into sub-images with predefined size and we calculate the orientation map of each sub-image using Gabor filter. The orientation feature of each sub-image is presented by the orientation histogram. Furthermore, we match the orientation histograms between each sub-image and the template images in our database. Based on the matching results, we replace the sub-images with the corresponding manual stroke images to give a clear representation of 2D hair strands. The result is refined by connecting the strands between sub-images. Finally, based on the control points defined on the hair strands, the spline presentation is applied to obtain smooth hair strands.

In the rest of paper, we will describe our image templates database in section 4. In section 5, we will present our 2D hair strands generation algorithm in detail with experimental results and analysis. Conclusion and future work are given in section 6.

4 HAIR TEMPLATES DATABASE

Our hair templates database contains both the RGB hair image templates and corresponding manual stroke image templates.

There are 202 RGB hair image templates with the size of 50x50 and those templates cover the orientations from 0 degree to 180 degree. There are 202 manual stroke image templates with the same size of 50x50. In addition, we use splines to give a refined representation of the strokes in each manual stroke image. We use four points to define each spline: one start point, two control points and one end point.

As shown in Figure 2, the first row presents the samples of the RGB hair image templates. The second row shows the corresponding manual stroke image templates. Those manual stroke image templates are created from the RGB hair image templates manually. The third row is the spline representation of the corresponding manual stroke images.

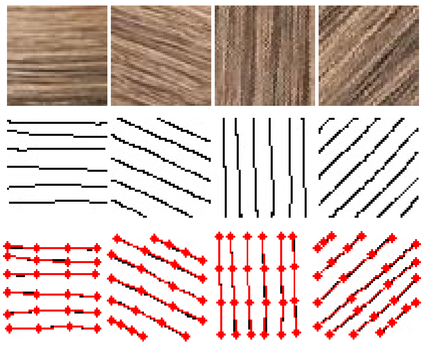

Figure 2: RGB hair image templates, manual stroke image templates and spline representation of the manual stroke templates.

5 HAIR STRANDS GENERATION

5.1 Pre-Processing

The input image of our system is captured by digital cameras. Real hair images have a variety of colours, however the information we want to obtain from the hair image is the geometry of hair strands. Thus we first convert the RGB input image into HSV color space and use the S channel information, as shown in Figure 3. The S channel image is then divided into sub-images with the size of 50x50.

Figure 3: Input RGB hair image and S channel information image.

5.2 2D Orientation Estimation

Previous research works (Paris et al. 2004) show that oriented filters are well suited to estimating the local orientation of hair strands. They employ different filters at multiple scales and determine the best score based on the variance of the filters. In our experiments, we filter the input image with a bank of oriented filters. An oriented filter kernel K_θ is a kernel that is designed to produce a high response for structures that are oriented along the directionθ when it is convolved with an image. In our method, we use the real part of a Gabor filter (Jain et al. 1991).

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

where $\tilde{u} = u\,cos\theta + vsin\theta$ and $v = v\,cos\theta - vsin\theta$. The parameters of the Gabor kernel in our experiments are$\sigma_u = 1.8$, $\sigma_v = 2.4$ and $\lambda = 4$.

The S channel image is convolved with the filter kernel K_θ for different θ (we use 10 different orientations from 0 degree to 180 degree, each one is 18 degree). Let $GR(x,y,\theta) = (K_\theta * I)$ be the response of K_θ at pixel(x,y) , the orientation that produces the high score response is stored in the orientation map $OM(x,y) = \tilde{\theta}$. A template image and its orientation map are shown in Figure 4.

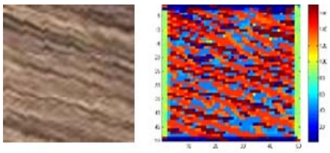

Figure 4: A template image and its orientation map 50x50.

5.3 Template Matching

The template matching method in our system is based on the orientation information that we obtained from 2D orientation estimation. As shown in Figure 5, we can see that the templates from the image database with similar orientation share similar orientation histograms. Meanwhile, different orientation can be easily distinguished using orientation histogram.

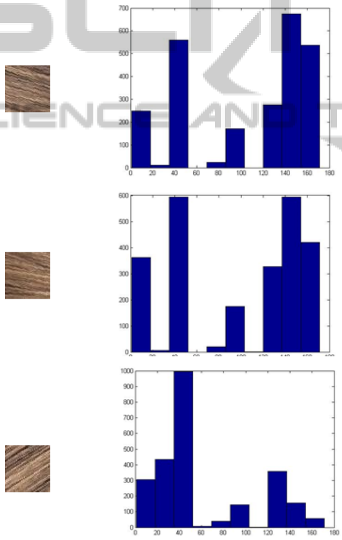

Figure 5: Template images and their orientation map's histogram.

We estimate the similarity between the orientation histograms of the input sub-image and the orientation histograms of the template images. The similarity between two orientation histograms is calculated using the following formula:

$$min_i = (hist_{template_i} - hist_{sub-image})^2 \quad (2)$$

where $hist_{template_i}$ is orientation histogram of the template images and $i = 1,2,\dots,20$, $hist_{sub-image}$ is the orientation histogram of the input sub-image. After obtain the matching results, we replace the sub-images with the manual stroke images corresponding to the template images. Manual stroke image can directly shows the 2D hair strands geometry. The experimental results are shown in Figure 6. Figure 6(a) is the input RGB hair image In order to obtain only the hair area, we first perform image binarization to get the hair area mask as shown in Figure 6 (b). Figure 6 (c) is the 2D hair strands extraction result. The 2D hair strands extraction in the hair area is shown in Figure 6 (d). Figure 7 shows the experimental result of relative curly hairs. Figure 7 (a) is the input hair image and (b) is the hair strands extraction results.

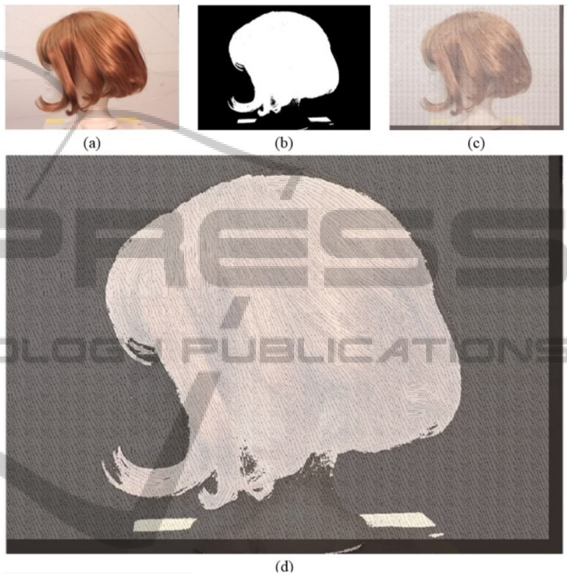

Figure 6: 2D hair strands extraction using manual stroke image templates on real wig.

Figure 7: 2D hair strands extraction using manual stroke image templates on curly hair image.

5.4 2D Hair Strand Connection and Spline Representation

For each manual stroke image block in Figure 6, there are several edge points (start points and end points on the spline). We calculate the Euclidean distance between the each edge point of current block and edge points of adjacent 8-neigbor blocks. We choose the pair of points that has the minimum distance. In addition, we compare this minimum distance with a predefined threshold. Base on the size of the manual stroke template images and the distribution features of the manual strokes, we set the threshold to be 5 in our system. If the minimum distance is smaller than the threshold, we define those two points should be connected and those two manual strokes belong to one hair strand. Otherwise, those two manual strokes do not belong to the same hair strand. Furthermore, we apply the line tracking algorithm to obtain relative long hair. The procedure of the hair strands tracking algorithm is:

- Start from point x as the current pixel;
- Consider its eight neighbours (in a 3x3 window);
- Check which of its neighbour pixel is of value zero (black). Define this pixel as “N1”;
- Change the current pixel to be “N1”;
- Repeat the same procedure for “N1” and the following pixel until reach the border of the hair or there is no further connection available.

By applying the hair strands tracking algorithm, we can obtain the length information of each hair strands as well as all the coordinates of the hair strands’ points. Knowing the length of each hair strand can help us to remove relative short hair strands. In addition, we can use the coordinates of the hair strands’ points to generate more smooth hair stands based on spline presentation. The 2D hair strands connection result and refined results are shown in Figure 8. The image in the first row is the 2D hair strands connection results based on spline representation. The second image shows the details of our 2D hair strands connection results. The last image shows the refinement of the connection result based on our hair strands tracking algorithm and spline representation. The yellow 2D hair strands are smoother than the previous ones.

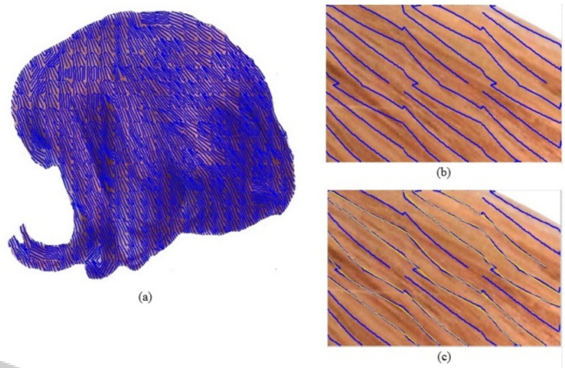

Figure 8: 2D hair strands connection and refined result.

6 CONCLUSION AND FUTURE WORK

We present a 2D hair strands generation method based on template matching. The introduced method does not need a complex system configuration or any user assistant. We focus on the orientation information of hairstyle. Instead of using the orientation information of every pixel directly, we use the orientation histogram of local area to represent the geometry of the hair strands. We simplify the hair strands extraction procedure by apply template matching based on the orientation histograms. We also apply spline presentation to obtain smooth the hair strands. The experimental results show that our method is feasible.

In the future, we need to improve our template matching algorithm in order to obtain more accurate hair strands geometry. We also need to improve our hair strands connection and spline representation methods to generate more smooth 2D hair strands. Based on the refined 2D hair strands, we can combine the depth information from the Kinect in our system to obtain 3D model of real hairstyle.

REFERENCES

Magnenat-Thalmann, N., Hadap, S., 2000. State of the art in hair simulation. *Proceedings of International Workshop Human Modelling and Animation.* 3-9.

Ward, K., Bertails, F., Kim, T., Y., Marschner, S., R., 2007. A survey on hair modelling: styling, simulation, and rendering. *IEEE Trans. on Visualization and Computer Graphics.* 13:2, 213-234.

Paris, S., Chang, W., Kozhushnyan, O., I., Jarosz, W., 2008. Hair photobooth: geometric and photometric acquisition of real hairstyles. *ACM Trans.Graph.* 27:3, 30:1-30:9.

Luo, L., Li, H., Paris, S., Weise, T., Pauly, M., Rusinkiewicz, S. 2012. Multi-view hair capture using orientation fields. *In CVPR*. 1490-1497.

Luo, L., Li, H., Rusinkiewicz, S. 2013. Structure-aware hair capture. *ACM Trans. Graph.* 32, 4, 76:1-76:12.

Luo, L., Zhang, C., Zhang, Z., Rusinkiewicz, S. 2013. Wide-baseline hair capture using strand-based refinement. *In CVPR.* 265-272.

Paris, S., Briceno, H., M., Sillion, F., X., 2004. Capture of hair geometry from multiple images. *ACM Trans. Graph.* 23, 3, 712-719.

Wei, Y., Ofek, E., Quan, L., Shum, H. Y. 2005. Modelling hair from multiple views. *ACM Trans. Graph.* 24, 3, 816-820.

Jakob, W., Moon, J. T. Marschner, S. 2009. Capturing hair assemblies fiber by fiber. *ACM Trans. Graph.* 21, 3, 620-629.

Lay Herreara, T., Zinke, A., Weber, A. 2012. Lighting hair from the inside: a thermal approach to hair reconstruction. *ACM Trans. Graph.* 31, 6, 146:1 – 146:9.

Beeler, T., Bickel, B., Noris, G., Marschner, S., Beardsley, P., Sumner, R., W., Gross, M. 2012. Coupled 3D reconstruction of sparse facial hair and skin. *ACM Trans. Graph.* 31, 117:1-117:10.

Chai, M., Wang, L., Weng, Y., Yu, Y., Guo, B., Zhou, K. 2012. Single-view hair modelling for portrait manipulation. *ACM Trans. Graph.* 31, 4, 116:1- 116:8.

Chai, M., Wang, L., Weng, Y., Jin, X., Zhou, K. 2013. Dynamic hair manipulation in image and videos. *ACM Trans. Graph.* 31, 2, 75:1-75:8.

Jain, A., K., Farrohnia, F. 1991. Unsupervised texture segmentation using Gabor filters. *Pattern Recognition 24*, 12, 1167-1186.