International Journal of Innovative
Computing, Information and Control
Volume **9**, Number **10**, October **2013**

ICIC International ©2013 ISSN 1349-4198
pp. 4205–4214

A REALISTIC STYLE FACIAL COMIC GENERATION

Der-Lor Way[1,*], Chiao-Kai Juan[2], Wen-Kai Tai[3]
and Chin-Chen Chang[4]

[1]Department of New Media Art
Taipei National University of Arts
No. 1, Hsueh-Yuan Road, Peitou, Taipei 112, Taiwan
*Corresponding author: adler@newmedia.tnua.edu.tw

[2]Department of Computer Science
National Chiao-Tung University
No. 1001, Ta Hsueh Road, Hsinchu 30010, Taiwan

[3]Department of Computer Science and Information Engineering
National Dong Hwa University
No. 1, Section 2, Dashiue Road, Hualien 97401, Taiwan

[4]Department of Computer Science and Information Engineering
National United University
No. 1, Lienda, Miaoli 36003, Taiwan

Received September 2012; revised March 2013

Abstract. *Comic is popularized around the world through mass media. Recently, a facial comic has been an interesting research topic due to many applications such as entertainment, Internet and mobile application, face recognition, information visualization, education and user interface agent. Many researches try to convert the process of drawing comic into the formula and algorithm. A realistic style comic is characterized by its detail-oriented and realistic presentation, wide range of themes, and diversified style. This paper proposes a novel NPR (non-photorealistic rendering) algorithm to generate a facial comic according to analyzing the brushwork of the artist. The research of facial comics consists of three core techniques including facial feature drawing, hair sketching, and hatching line drawing. A facial comic is created according to the facial feature points. A highlight hair sketching is processed from a hair patch and skeleton with a pseudo light. Moreover, the hatching line drawing is carried out for the dark-and-light tone using cross ink lines to express the intensity. All simulated pictures of various parts are merged to form a realistic style facial comic. Finally, the proposed method is demonstrated with many experimental realistic style examples.*

Keywords: Comic, Caricature, Facial comic, Non-photorealistic rendering, Facial feature points, Hair sketching, Hatching

1. **Introduction.** Comic has over one thousand years of history around the world, generally known as caricature. It is an art form established itself in the late 19th and early 20th century, alongside the similar forms of film and animation. A comic was popularized around the world within the recent five decades through mass media. With the appearance of Internet and mobile technology, a facial comic has been used for social communication and entertainment over web or mobile device. Comic is also used as an avatar in a blog or website on the social networking. Recently, facial comic generator becomes a particularly interesting research topic due to many applications. Sadimon et al. reviewed the state of the art in the major topics of comic generator [1]. They briefly surveyed the applications

of comic including entertainment and political magazine, Internet and mobile application, face recognition, information visualization, education and user interface agent.

Comic is an unforgettable impression of a user in visual messenger or visual chat room. It is also used as an avatar in virtual community or virtual game. Therefore, a facial comic as an avatar might be a good representation since the comic can provide users with important information about their partners [2]. Many studies have provided the use of comics in Internet and mobile phone application [3-5]. In facial recognition, facial comic is frequently used to recognize the criminal faces in police investigation. In human computer interaction, comic is also used as an interface agent and helps users interact with the agent and understand the agent's characteristic [6]. Comic could also make a computer more human-like and comprehensible to the user and make the users feel more comfortable with computers [7].

Many researches try to convert the process of drawing comic into the formula and algorithm that will be executed by computer [1]. However, a realistic style comic is made to make the comics look as convincing, as natural as possible. No exaggerations are used. It is characterized by its detail-oriented and realistic presentation, wide range of themes, and diversified styles. Only a few papers research about this topic. Therefore, this paper focuses on a realistic style and attempts to emulate an artist in drawing facial comic, as shown in Figure 1 [8]. An artist generally uses a pencil to sketch the basic structure of a face and hairstyle, and then uses ink to draw the contour of the face and hair. The ink lines are usually finer than the sketch. Moreover, an artist uses hatching skill to draw overlapped and interlaced lines for tone presentation to express the chiaroscuro of shadow.

FIGURE 1. A facial comic drawn by Takehiko Inoue and a reference photo

This paper attempts to use NPR technology to imitate the brushwork of comic and convert a face image into a realistic style facial comic. The major contributions of this paper are summarized as follows.

(1) This paper proposes a novel NPR algorithm to generate a realistic style facial comic according to analyzing the brushwork of the artist.
(2) A facial comic is generated using the facial feature points with the local model.
(3) A novel hair sketching is presented to draw the highlight using a pseudo light source.
(4) Realistic style facial comic generation software can be executed on many applications, such as mobile entertainment, cartoon animations and virtual reality.

2. **Related Works.** Face is a unique trait of people and an important feature in providing human identity. Therefore, faces have been the subjects of many major researches such as image processing, computer vision, cognitive psychology, biometric, computer graphic and animation. Synthesizing facial comic is not only one of the face recognition and reconstruction studies, but also involves the non photorealistic rendering research. Sadimon described the process of generating comic from input face image [1]. They also classified four approaches to generate facials: interactive, regularity-based, learning-based and predefined database of caricature illustration. In this section, only most related papers are discussed briefly.

2.1. **Facial feature extraction.** A mature face recognition process could be divided into two steps: feature representation and classification [9-13]. The face recognition result highly depends on features that are extracted to represent the face pattern. A lot of researches in generating facial comic used modified Active Shape Model (ASM) and modified Active Apperance Model (AAM) to extract facial feature points [1]. ASM and AAM is a model of the shape variations and texture variations of facial images using Principal Component Analysis (PCA). The PCA finds a set of basis faces, called eigenfaces, to span a linear subspace for representing each face sample. With eigenfaces, an input face with distortion can be recovered to a distortion-free face by linear combination of eigenfaces [10]. The coefficients of eigenface are also used as parameters to represent the face shape and face texture. The feature vectors invariant to image scaling and rotation are extracted with a different local gradient descriptor [12]. By adjusting the parameters, the model can be well fit to a new facial image.

These defined facial feature points are also known as landmark points. Besides, it should be defined what parameters to be extracted. The parameters that are always being used in caricature generation are facial feature points, size feature, shape feature, aspect ratio, distance between features and curvature property of each facial segment. Chen et al. presented an example-based approach for automatically generating a life-like portrait from a frontal face image [14,15]. An ASM model is trained to automatically locate the facial feature points in any input image. A deformable mesh template has been created from acquired knowledge on comic creation [16-18]. Arruda et al. used deformable mesh template to generate facial comic [16]. Chiang et al. utilized Canny edge detector and Hough transform for iris localization and applied Active Contour Model (ACM) to obtain the final face mesh [17]. Chen et al. proposed a system which combines two separate but similar subsystems, one for the face and the other for the hair, each of which employs a global and a local model [19].

2.2. **Facial comic synthesis.** Most general technique used to create facial comic from the input facial image is image metamorphosis [1]. Image metamorphosis is carried out by cross-dissolve and correspondence with pairs of feature primitives of two images, usually known as morphing. Each primitive describes an image feature or landmark. The feature correspondence is used to compute mapping functions between the spatial relationships of two images. The main challenge is to specify corresponding feature points of the images that can produce acceptable result and decrease computational time. Sadimon et al. [1] proposed four styles of facial comic created by previous works such as photographic comic [20-22], sketch comic [18,22,23], hand-drawn like comic [17] and outline comic [24-27], as

(a) (b) (c) (d)

FIGURE 2. (a) Photographic comic [21], (b) sketch comic [22], (c) hand-drawn like comic [17], (d) outline comic [27]

shown in Figure 2. Some outline comics are created by connecting the feature points using lines, cubic Hermite interpolation [26], B-Spline curves [27]. Many morphing methods are developed including mesh morphing [20,21], feature-based morphing [17] and thin plate spline warping [18]. Moreover, Mo et al. [22] and Tseng [23] did not state the specific technique of morphing. Obaid et al. employed a quadratic deformation model [24].

2.3. **Non photorealistic rendering.** The NPR technology has attracted wide attention in the computer graphics, such as pencil sketches, watercolor painting, oil painting. Besides, some papers present Chinese ink painting and brushwork of calligraphy [28-30]. NPR can not only present the aestheticism and artistry of images, but also imitate artist's brushwork. This paper attempts to use NPR technology to imitate the brushwork of comic and convert a face image into a realistic style facial comic. Hair is a significant visual feature of characters in cartoon animations and comics. Cote presented a powerful procedure to imitate the appearance of cartoon-like hair with a small set of parameters. Their approach is inspired by an inking technique called feathering, which consists of drawing hatches along the hair orientation while emphasizing the highlights with ink stains [31]. Koh and Huang provided a simple physics model to animate human hair modeled in 2D strips in real time [32]. Shin et al. offered a modified technique for specular highlighting and a new hair rendering technique for Anime characters [33].

3. **Facial Comic Generation.** This paper proposes a process flow of a realistic style facial comic generation, as shown in Figure 3. A portrait image is separated into face and hair. All stroke lines are created to imitate the artist's instrument of drawing. A facial comic is created according to the facial feature points. A highlight hair sketching is processed from a hair patch and skeleton with a pseudo light. Besides, the hatching line drawing is carried out for the dark-and-light tone using cross ink lines to express the intensity of facial comic. Finally, the simulated images of various parts are merged to form a realistic style facial comic.

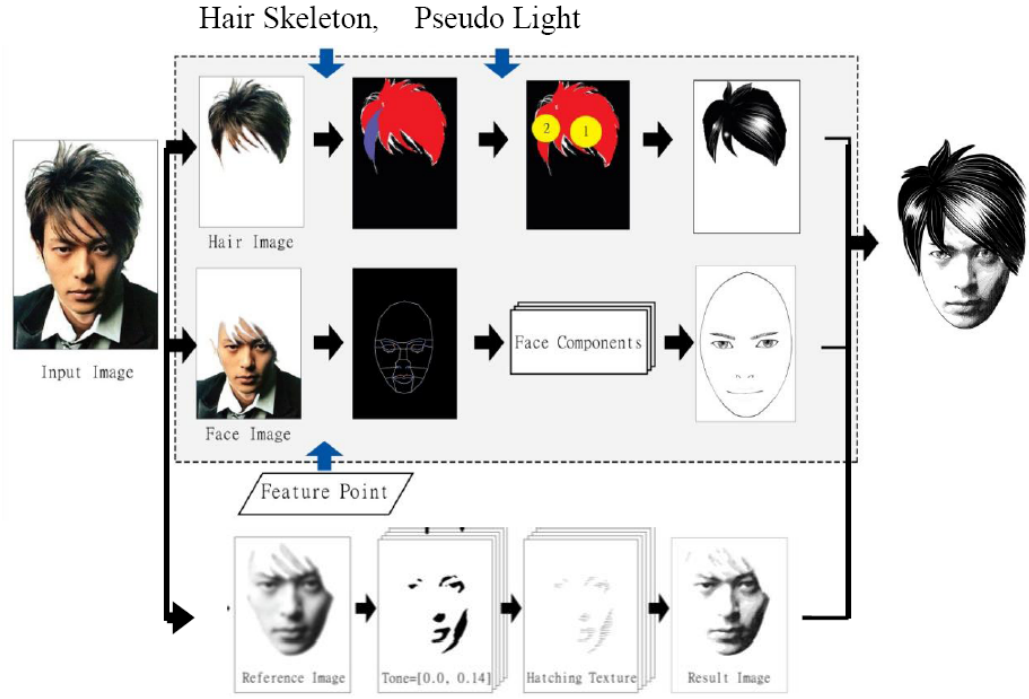
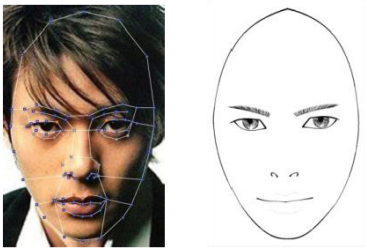


FIGURE 3. The process flow of a realistic style facial comic generation

3.1. **Facial feature points.** The AAM and ASM are often used to search for the facial feature points. The facial feature points contain ***eyebrows***, ***eyes***, ***nose***, ***lips*** and ***face contour***. All lines of five senses organ are drawn according to the lines drawn by the artist. All facial features are drawn and merged to form a figure drawing. Figure 4 describes the corresponding relation between facial feature points and drawing lines.

Each eyebrow contains 8 feature points. A fixed number of random number points are extracted from various reference lines. They are paired one by one to draw dense curvilinear path. Each eye contains 14 feature points. The upper eyelid, lower eyelid, and eyelid lines are defined on the eye contour. Artists often draw similar pupil. Hence, several groups of eyeball models are used to draw. A nose contains 8 feature points. Artists usually use chiaroscuro of shadow to present the nose shape, only the naris lines shall be drawn. The lips are divided into upper lip and lower lip, containing 12 feature points, respectively. The upper and lower lips are drawn by two lines. A face contour contains 20 feature points. Three line segments are defined to describe two cheeks and the chin. All lines drawn based on the above characteristics are explicit in changeful thickness. The stroke line model is modified from our previously proposed method [29,30]. Finally, all facial features are merged to a facial comic, as shown in Figure 4(b).

3.2. **Comic hair sketching.** According to a hair image, a contour line and hair line are imported into the hair growing zone. For example, Figure 5(a) is original drawn by T. Inoue [8]. A hair extension path is the direction of hair skeleton in Figure 5(a). A hair drawing with the highlight effect can be obtained as shown in Figure 5(b). A few B-Spline curves describe a hair patch and orientation of hairstyle. Some hair line trajectories are generated by linear interpolation between the two curves. The line of a hair is irregular, so the trajectory derived from linear interpolation should be disturbed. To draw natural hair, the hairy root is disturbed slightly, and the hair ends may present more disturbance.



(a) (b)

Facial Features	Number of Points
Eyebrows	8
Eyes	14
Nose	8
Lips	12
Face Contour	20

FIGURE 4. The distribution of facial feature points and comic drawing

(a) (b)

FIGURE 5. (a) A hair patch, (b) comic hair sketching

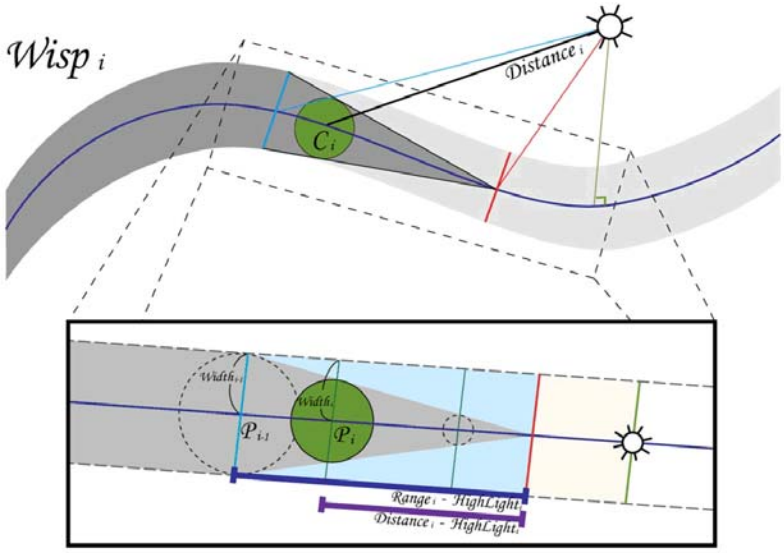


FIGURE 6. Width of hair strand pointy

The processing of hair sketching is to recalculate the width of each hair strand. When a light source is closer to a hairline, the contact circle is smaller; on the contrary, a contact circle expands as the distance to the light source increases. A hairline maintains the original width outside the influence range of light source, as shown in Figure 6.

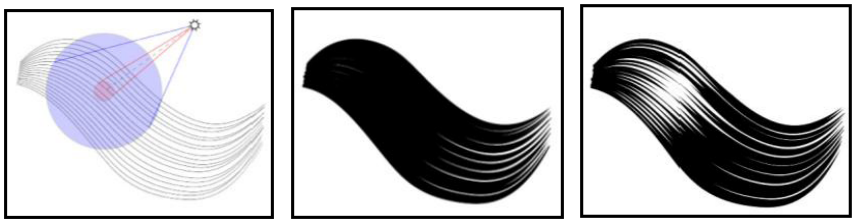
The stroke line model defines a radius R_i of the contact circle C_i on the hairline path according to the relation between the hairline and light source. The defined equation is shown below:

$$R_i = Width_i * \prod_{i=0}^{n} \left(\frac{Distance_i - Highlight_i}{Range_i - Highlight_i} \right) \tag{1}$$

Equation (1) is used to calculate the influence coefficient $\left(\frac{Distance_i - Highlight_i}{Range_i - Highlight_i}\right)$ of light source on the contact circle C_i, where $Width_i$ is the original width of hairline, $Distance_i$ is the distance between a light source and the center of contact circle P_i, $Distance_i$ and $Highlight_i$ are light source parameters. If the distance between P_i and light source center exceeds the influence range of light source, the original hairline width is maintained. If the distance is within the highlight range, it means the hairline may not be drawn. If the distance is between the two ranges, the width is calculated by interpolation. The rest may be deduced by analogy. All the hairlines on the curved surface of hair are drawn identically.

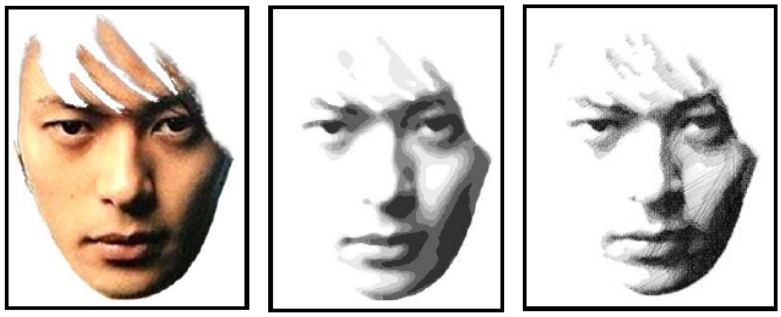
An artist often uses irregular feathery to draw the highlight effect of hair. There should be light source information for the highlight effect. The hairlines within the light source influence circle are thinner, and vice versa. Figure 7(a) explains the influence range of the light source, and the center area represents the range of the highlight effect. Figure 7(b) shows the result of hair patch without highlight. Figure 7(c) demonstrates the highlight effect after disturbance. In order to get natural hand drawing effect, the influence range of light source is disturbing to some extent.

3.3. **Hatching line drawing.** The hatching line drawing uses various approximately parallel ink lines. When lines are thick and the density is high, then the image tone is dark; on the contrary, the tone is brighter. First, the intensity of input image is taken as the reference image. Afterwards, the image intensity is split to many layers as the tone distribution range of a facial comic. The hatching textures generated in each tone



(a) (b) (c)

FIGURE 7. (a) Influence area, (b) no highlight, (c) highlight and disturbance



(a) (b) (c)

FIGURE 8. (a) An input photo, (b) reference image, (c) hatching line drawing

layer are merged to obtain the result of hatching line drawing. The hatching texture can present the image gray tone by the relation between line thickness and distribution density. If the parallel hatching lines are drawn in one direction, the tone and parallel lines can be described by the following relationship:

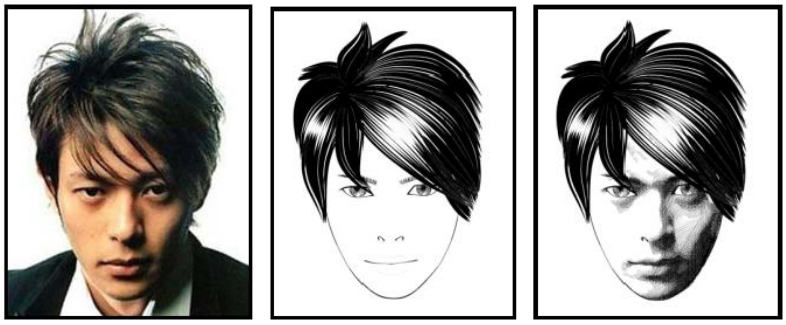
$$t = 1 - \frac{Width}{interval}, \quad t: \ tone\ value \in [0 : black, 1 : white] \tag{2}$$

where t is the tone value presented by hatching material, the *width* is the maximum width of line, the *interval* is the line spacing. In addition, the extended hatching line drawing is drawing cross hatching, the equation of hatching material derived from cross hatching in different directions is:

$$\begin{array}{ll} T(n) = t^n \text{ for } n \geq 0 & T(n) \in [0 : black, 1 : white] \\ T(0) = 1,\ T(1) = t & t \in [0 : black, 1 : white] \end{array} \tag{3}$$

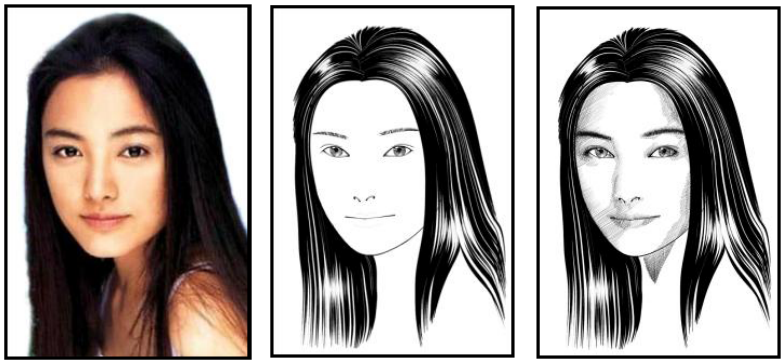
where $T(n)$ is the tonal brightness generated after n times of cross hatching line drawing, t is the material brightness after one-directional hatching drawing. When n is large, the tone is darker; on the contrary, the tone would be brighter. Next, the target tone information is defined. The information is derived from the reference image, including brightness range $T_{\min}$, $T_{\max}$ and average brightness T_{avg}. The required hatching overlapping number np for the target tone can be obtained by Equation (2). According to above analysis, Figure 8 shows the hatching lines drawn according to the drawing range and tonal information by splitting the image intensity information to each image layer.

4. **Experimental Results.** The experiment was carried out on an Intel Core i5 CPU 2.8GHz and 1G RAM. Figure 9(a) shows a short hair male portrait, Figure 9(b) imitates a facial comic without hatching line drawing, and Figure 9(c) demonstrates a realistic style facial comic with facial feature drawing, hair sketching and hatching line drawing.



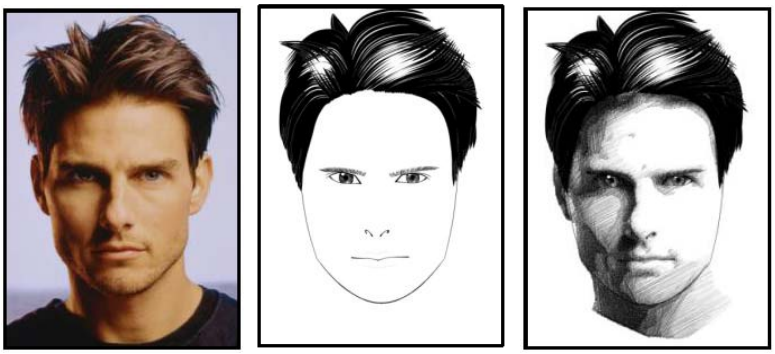
(a) (b) (c)

FIGURE 9. (a) A short hair, (b) no hatching line, (c) experimental result



(a) (b) (c)

FIGURE 10. (a) A long hair, (b) no hatching line, (c) experimental result



(a) (b) (c)

FIGURE 11. (a) A short hair, (b) no hatching line, (c) experimental result

Figure 10(a) displays a female portrait with long hair, Figure 10(b) is also composited without hatching line drawing, and Figure 10(c) shows the experimental result. Figure 11 is another male facial comic experimental example. In order to compare with Takehiko Inoue's work, an input image from Takehiko Inoue's comic was converted by our proposed method, shown as Figure 12.

5. **Conclusion and Future Works.** A realistic style facial comic is characterized by its detail-oriented and realistic presentation. This paper proposed an integrated method

(a) (b) (c)

FIGURE 12. (a) Inoue's comic, (b) no hatching line, (c) experimental result

to imitate a realistic style facial comic drawing. The proposed method observes and analyzes the brushwork of an artist. In comparison with the simple drawing style of the previous facial caricature, this work produced finer drawing effect, including facial features drawing, hair highlight effect, and chiaroscuro. The investigation of facial comics consists of three core techniques according to an artist's style, including facial feature drawing, hair sketching, and hatching line drawing. The user can import the facial feature points and hair skeleton into the algorithm and the system will complete the drawing process.

In the future, the proposed algorithm could be executed with hardware acceleration to improve on real-time efficiency. This proposed method will be applied to cartoon NPR conversion of video conference. An artist's style imitated in this study is rich and changeful. For the purpose of creating more cartoon styles, more additional stroke models and drawing characteristics could be used for imitation and drawing objects other than face.

Acknowledgment. The authors would like to thank the National Science Council of Taiwan for financially supporting this research under Contract No. NSC99-2221-E119-001.

REFERENCES

[1] S. B. Sadimon, M. S. Sunar and H. Haron, A review of facial caricature generator, *Journal of Computing*, vol.3, no.5, pp.20-33, 2011.

[2] K. L. Nowak and C. Rauh, The influence of the avatar on online perceptions of anthropomorphism, androgyny, credibility, homophily, and attraction, *Journal of Computer – Mediated Communication*, vol.11, 2005.

[3] J. Liu, Y. Chen, W. Gao and R. Z. R. Fu, Creative cartoon face synthesis system for mobile entertainment, *Lecture Notes in Computer Science*, pp.1027-1038, 2005.

[4] R. Q. Zhou and F. X. Liu, Cartoon facial animation system oriented mobile entertainment, *Computer Engineering and Applications*, vol.45, pp.96-98, 2009.

[5] J. Liu, Y. Chen, X. Gao, J. Xie and W. Gao, AAML based avatar animation with personalized expression for online chatting system, *Advances in Multimedia Information Processing PCM2008*, vol.5353, 2008.

[6] T. Koda, User reactions to anthropomorphized interfaces, *IEICE Transactions on Information and Systems*, vol.E86-D, pp.1369-1377, 2003.

[7] R. Catrambone, J. Stasko and J. Xiao, Anthropomorphic agents as a user interface paradigm: Experimental findings and a framework for research, *Proc. of CogSci*, pp.166-171, 2002.

[8] T. Inoue, *Vagabond Gashuu – Sumi*, Kodansha Company, Limited, Japan, 2006.

[9] Y.-W. Chen, R. Xu and A. Ushikome, Serially-connected dual 2D PCA for efficient face representation and face recognition, *International Journal of Innovative Computing, Information and Control*, vol.5, no.11(B), pp.4367-4372, 2009.

[10] C.-C. Chiang and Z.-W. Chen, Recognizing partially-occluded faces by recovering normalized facial appearance, *International Journal of Innovative Computing, Information and Control*, vol.7, no.11, pp.6219-6234, 2011.
[11] J. S. Lee and S. F. Lin, A hierarchical face recognition scheme, *International Journal of Innovative Computing, Information and Control*, vol.6, no.12, pp.5439-5450, 2010.
[12] S. D. Lin, J.-H. Lin and C.-C. Chiang, Using gradient features from scale-invariant keypoints on face recognition, *International Journal of Innovative Computing, Information and Control*, vol.7, no.4, pp.1639-1649, 2011.
[13] X. Wei, C. Zhou and Q. Zhang, ICA-based features fusion for face recognition, *International Journal of Innovative Computing, Information and Control*, vol.6, no.10, pp.4651-4661, 2010.
[14] H. Chen, L. Liang, Y. Q. Xu, H. Y. Shum and N. N. Zheng, Example-based automatic portraiture, *Proc. of the 5th Asian Conference on Computer Vision*, Melbourne, Australia, pp.23-25, 2002.
[15] H. Chen, Y. Q. Xu, H. Y. Shum, S. C. Zhu and N. N. Zheng, Example-based facial sketch generation with non-parametric sampling, *Proc. of the ICCV*, pp.433-438, 2001.
[16] F. A. P. V. Arruda, V. A. Porto, J. B. O. Alencar Jr., H. M. Gomes and J. E. R. Queiroz, A new NPR approach for image stylization: Combining edges, color reduction and facial exaggerations, *Proc. of the International Conference on Computational Intelligence for Modeling, Control and Automation*, pp.1065-1070, 2008.
[17] P. Y. Chiang, W. H. Liao and T. Y. Li, Automatic caricature generation by analyzing facial features, *Proc. of Asian Conference on Computer Vision*, Jeju Island, Korea, 2004.
[18] L. Liang, H. Chen, Y. Q. Xu and H. Y. Shum, Example-based caricature generation with exaggeration, *Proc. of the 10th Pacific Conference on Computer Graphics and Applications*, pp.386-393, 2002.
[19] H. Chen et al., Example-based composite sketching of human portraits, *Proc. of the 3rd International ACM Symposium on Non-Photorealistic Animation and Rendering*, New York, USA, pp.95-153, 2004.
[20] K. H. Lai, P. W. H. Chung and E. A. Edirisinghe, Novel approach to neural network based caricature generation, *IET International Conference on Visual Information Engineering*, Bangalore, India, pp.88-93, 2006.
[21] J. Liu, Y. Chen, J. Xie, X. Gao and W. Gao, Semi-supervised learning of caricature pattern from manifold regularization, *Proc. of the 15th International Multimedia Modeling, LNCS*, vol.5371, pp.413-424, 2009.
[22] Z. Mo, J. P. Lewis and U. Neumann, Improved automatic caricature by feature normalization and exaggeration, *Proc. of ACM SIGGRAPH Sketches*, New York, pp.57, 2004.
[23] C. C. Tseng, Synthesis of exaggerative caricature with inter and intra correlations, *Proc. of Computer Vision – ACCV 2007*, vol.4843, pp.314-323, 2007.
[24] M. Obaid, D. Lond, R. Mukundan and M. Billinghurst, Facial caricature generation using a quadratic deformation model, *Proc. of the International Conference on Advances in Computer Enterntainment Technology*, Athens, Greece, 2009.
[25] Y.-S. Choi, I.-K. Lee and B.-K. Koo, Painterly caricature maker, *SIGGRAPH'09*, Posters New Orleans, LA, USA, 2009.
[26] W. Gao, R. Mo, L. Wei, Y. Zhu, Z. Peng and Y. Zhang, Template-based portrait caricature generation with facial components analysis, *IEEE International Conference on Intelligent Computing and Intelligent Systems*, vol.4, pp.219-223, 2009.
[27] T. Kamimura and Y. W. Chen, Facial caricaturing system based on multi-view active shape models, *The 5th International Conference on Natural Computation: IEEE Computer Society*, pp.17-21, 2009.
[28] J. Yin and X. Ren, An interactive system for Chinese traditional calligraphy and painting, *International Journal of Innovative Computing, Information and Control*, vol.6, no.2, pp.509-518, 2010.
[29] D. L. Way, W. J. Lin and Z. C. Shih, Computer-generated Chinese color ink paintings, *Journal of the Chinese Institute of Engineers*, vol.29, vol.6, pp.1041-1050, 2006.
[30] D. L. Way and Z. C. Shih, Wrinkle rendering of terrain models in Chinese landscape painting, *IEICE Transactions on Information and Systems*, vol.E89-D, vol.3, pp.1238-1248, 2006.
[31] M. Cote, P.-M. Jodoin, C. Donohue and V. Ostromoukhov, Non-photorealistic rendering of hair for animated cartoons, *Proc. of the GRAPHICON'04*, 2004.
[32] C. K. Koh and Z. Huang, A simple physics model to animate human hair modeled in 2D Strips in real time, *Proc. of Eurographics on Computer Animation and Simulation*, pp.127-138, 2001.
[33] J. Shin, M. Haller, M. Mukundan and M. Billinghurst, A stylized cartoon hair renderer, *Proc. of the ACM SIGCHI International Conference on Advances in Computer Entertainment Technology*, 2006.