ISSN1000-9825 Journal of Software 软件学报 2000,11(9):1159～1166

Interactive 3D Canvas for Virtual Action Painting*

Horace H S Ip[1] Leanne S Y Tsang[1] Ken C K Law[1] Young Hay[2] Christine M H Choy[3]

[1](Image Computing Group Department of Computer Science City University of Hong Kong Hong Kong)
[2](Independent Artist)
[3](School of Creative Media City University of Hong Kong Hong Kong)
E-mail: {horace,leanne}@cs.cityu.edu.hk/cskckl@cityu.edu.hk/smchris@cityu.edu.hk

Abstract Traditionally paint work is always done on a piece of paper, canvas, on a wall or on the surface of some material. Augmenting it into 3D virtual reality space is a breakthrough. By the inspiration of Jackson Pollock's "action painting", human body could act as a paintbrush to drive the paintings by his/her body motion. Fusing the concepts of action painting and virtual reality together not only introduces new aesthetic perspectives on paint art, but also raises potential multi-disciplinary researches over the end product. In this paper, a framework is presented for building an action studio to experiment a new form of paint art that utilizes human body as paintbrushes to drive the painting process and then visualizes the paint work in a 3D canvas in real-time. Further, based on its inherent correlation characteristic of human behavior and cognition, the system could be extended for a joint research with other potential disciplines such as music and psychotherapy.

Key words Virtual reality, action painting, motion capture, color segmentation.

The advent of computers and technology brings us to a new age. From pencil to pixels, from paper to monitor, the culture in modern life has been shaped by the digital world in the past decades. People now make use of computers for a wide variety of purposes. Virtual surgery enables doctors to learn and practice before operating with real patients. Military simulates real wars for tactic research with computers. In these applications computer plays a vital role to assist and advance human work. Artists in different disciplines also find creative ways

---

* This research is partly supported by City University Strategic Research Grant (香港城市大学策略研究资助,No. 7000608), City University DAG (香港城市大学直接分配资助,No. 7100089) and Hong Kong Arts Development Council (香港艺术发展局视艺发展资助). **Horace H S Ip** received his BS degree in applied physics and Ph. D. degree in image processing from University College London, United Kingdom, in 1980 and 1983 respectively. Presently, he is the Head of the Computer Science Department and the founding director of the AIMtech Centre (Centre for Innovative Applications of Internet and Multimedia Technologies) at City University of Hong Kong. His research interests include image processing and analysis, pattern recognition, hypermedia computing systems and computer graphics. **Leanne S Y Tsang** is an MPhil student at Department of Computer Science, City University of Hong Kong. She received a BS degree in computing from Hong Kong Polytechnic University. Her research interests are computer graphics and virtual reality. **Ken C K Law** received his Ph. D. degree from CNAA, United Kingdom. Now he is an associate professor of Department of Computer Science, City University of Hong Kong. His research interestes include computer graphics and multimdia workflow document systems. **Young Hay** is an independent artist. His main research interests are interactive electronic media art, multi-media art, painting and performance art. **Christine M H Choy** was trained as an architect. She received her Master of Science degree from the Graduate School of Architecture, Planning, and Preservation, Columbia University and Directing Certificate from the American Film Institute. Choy was a professor and the Chair of Graduate Film/TV Program at New York University, and she also taught at Yale and Cornell Universities as well as SUNY Buffalo. She was a visiting scholar at Evergreen State College, Oslo and Volda Film Institute, Norway.

Manuscript received 2000-03-16, accepted 2000-05-10.

to augment their work in this wired world. It cannot be denied that the fusion of the uses of computer with art has become popular[1,2]. In Ref. [1], an automatic, semi-autonomous computer-actor system has been built to allow a two-character theater play between the computer ("It") and human ("I"). An interesting feature it holds is that it can allow the audience to immerse into the story play as one of the main characters. In Ref. [2], Merce Cunningham's "Biped" honors the reality that computer-captured virtual dancer and human can fuse into one performing on stage. It makes use of Motion Analysis' optical motion capture technology employing ten cameras and a collection of strategically placed optical sensors. The optical sensors are mounted on the body so that human motion can be kept tracked. The captured data are then visualized with hand-drawn graphics in two distinct ways. The first way generates 2D animations that non-solid 2D hand drawings are made like a chalk skeleton. During the play, we would see fluid line drawings moving with fade-out effect. The second way works in a 3D approach. A simple spline-based 3D dance character is built and tethered to the skeleton using the Physique technology that enables the spline-based character to be influenced and deformed by the skeletal moves. The 3D character is made invisible and wrapped with chalky skeletal drawings. "Biped" is characterized by its full motion capture and the animation (fade-out) effect. It costs an arm and a leg without full gain, however. It requires complicated configurations but occlusions still exist and must be cleaned up manually.

Traditionally, artists paint on a canvas which is two-dimensional. No one has ever thought of brush-strokes having volumes such that a color web can be constructed in a three-dimensional canvas. The concept of Virtual Action Painting (VAP) presented in this paper is a breakthrough over traditional painting characterized by its 3D real-time action painting. The idea is inspired by the philosophy and practice of "action painting" developed by Jackson Pollock[3] as well as MIT's newly developed installation of an interactive environment[4]. Think of a human body as a paintbrush which would be swept through the space coloring the 3D canvas under the control of the body motion. The result would be a 3D virtual painting - a color web that allows us to walk-through. What we see for every frame immersed in the 3D color web could be a different piece of paint work such that the concept of painting is enriched and revolutionized. Apart from its aesthetic value, the correlation of human behavior and the brush-strokes obtained from this virtual painting would have tremendous significance in the research of human cognition and psychology of creativity. The contributions of VAP could be extensive.

In this paper, we present our work on building an interactive 3D canvas that experiments a new form of paint art using human body as paintbrushes to drive the painting process and then visualizes the paint work into a 3D canvas in real-time. The rest of the paper is organized as follows. Section 1 gives an overview of the interactive studio configuration for the VAP system. Section 2 describes the overall system architecture and branches in details for the implementations in each module. Finally, Section 3 draws a conclusion and discusses future work.

1 Interactive Studio Configuration

The motivation of our work can be traced to MIT's newly developed installation of an interactive environment[4]. In its design, an interactive environment which allows robust silhouette extraction is built. Two video projection screens are strategically positioned oppositely acting as two walls in a performing zone. A collection of infrared light emitters is put behind the back-projected screen directing the infrared light into the zone. With an infrared-pass filter equipped in front of a side-view camera, only the wavelength of the infrared light can pass through and be received by the camera as video signal. A person blocking some of the light will create an image. The design solves the inherent problems of traditional color-based methods like chroma-keying and background subtraction which rely on the color components to perform the extraction. Since this method is based on specialized infrared lighting and independent of the environment's color, the arrangement of the objects in the environment can be made more flexible.

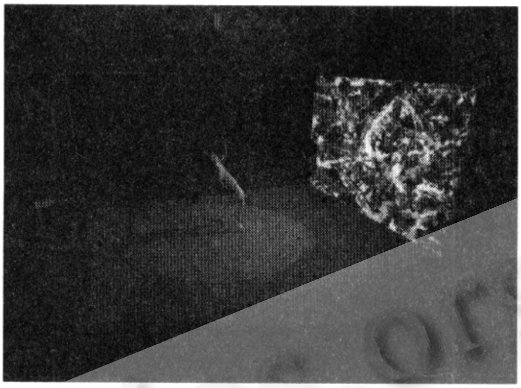


Fig. 1 Context diagram of the interface setup. The performing zone is configured with two cameras responsible for capturing the side-view and ceiling view of human motion. A collection of infrared light emitters is placed behind the large projection screen

For the 3D canvas constructed with the Interactive Media & Virtual Reality Laboratory at City University of Hong Kong, we design to put the whole performance from video capture to visualization in the same zone at the same time. Therefore, we have developed our configuration for side-view capturing process such that audience can watch the dancer performing while the paintings are being drawn and shown on the large projection screen. Figure 1 shows the context diagram for the interface setup. The performing zone is configured with two cameras responsible for video capture of the side-view and ceiling-view of human motion. A collection of infrared light emitters is mounted and an infrared-pass filter is equipped in front of the side-view camera. For the ceiling-view, we apply color segmentation for body extraction. Thus, we could simplify the configuration as much as possible. In the setup, we extract 3D information of the dancer's (i. e. the painter) motion for action painting. Occlusions may occur with the interface setup mentioned above, but accuracy is not the major concern in our case. We do not need to know in details the body motion like hands and legs because we apply indirect mapping to interpret the human motion into 3D drawings. Complex capture systems with high accuracy[2] are not necessary.

2 VAP Architecture

The architecture of VAP system can be decomposed into several modules: video capture, digitization, synchronization, body extraction, mapping and rendering (Fig. 2). The whole process is done at real-time and the performance takes place in the same zone. We first setup a user interface (Fig. 1) that accepts human motion as input. While the painter is performing, two cameras are taking the videos. Grabbed video signals are then transmitted into the capture card for digitization. The two sets of image sequences representing two perspective views are separately transmitted through two different input channels. In order to gather full and appropriate information in each frame, we need to synchronize the image pair for two views in the same frame. The synchronized image pair is then fed into body extraction process. We would extract the body shapes (projected area in $x-y$ and $x-z$ planes) by applying simple image processing (IP) methods. Number of covered pixels and the body shape are maintained for both projections for each frame. By utilizing this pixel behavior as the input of the indirect mapping, we could analyze how it is interpreted as rendering attributes.

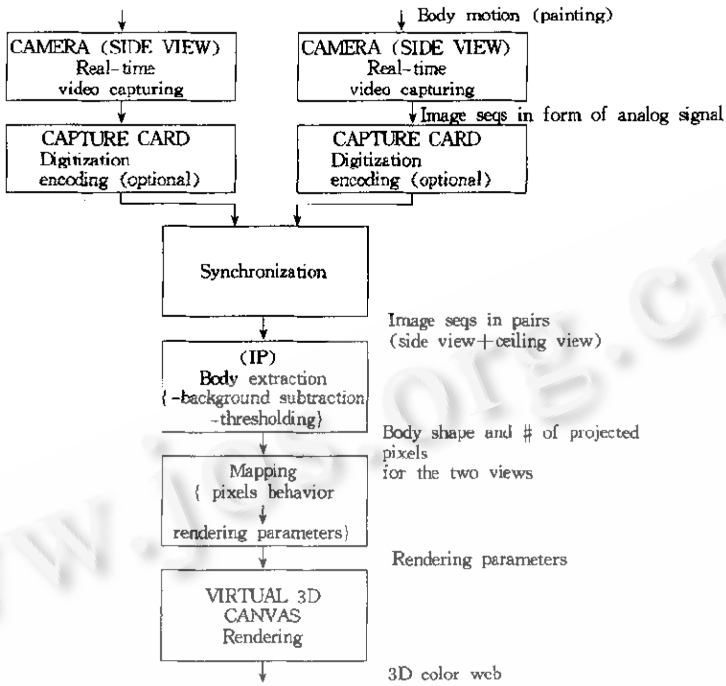


Fig. 2 Architecture of the VAP system. The architecture shows all the decomposed modules in the VAP system: video capture, digitization, synchronization, body extraction, mapping and rendering

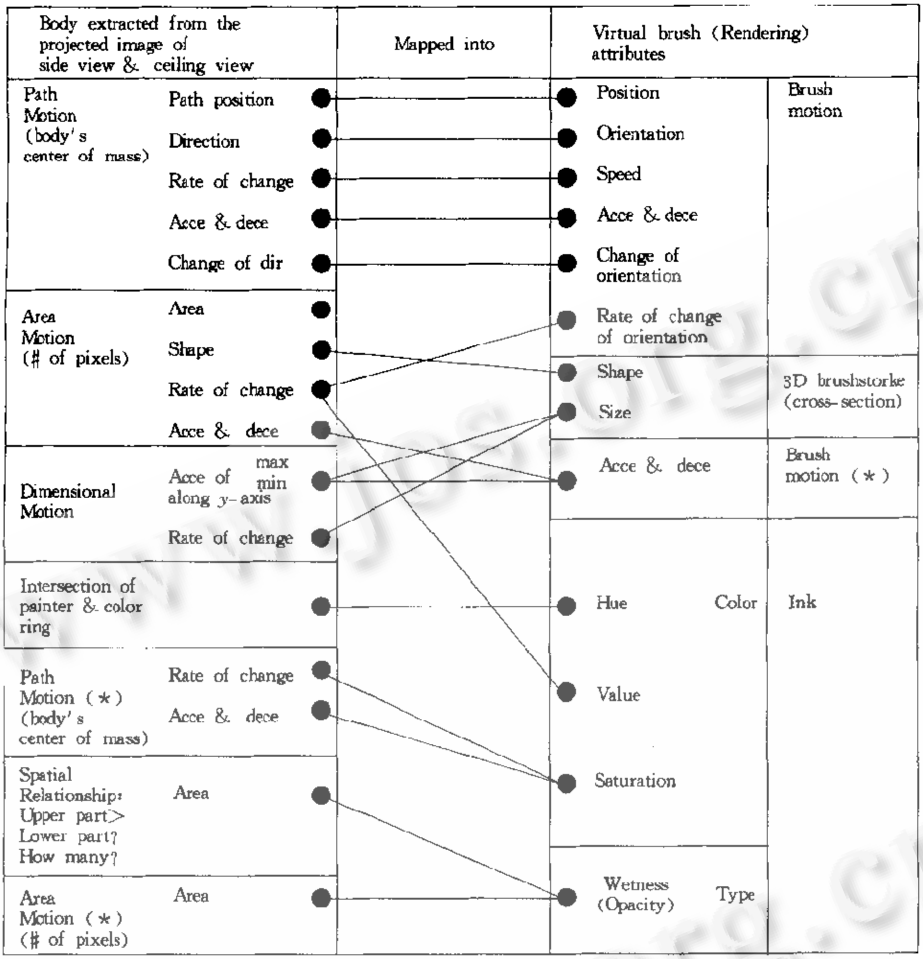
2.1 Body extraction

Since the approaches in motion capture for side-view and ceiling-view are different, we would employ different extraction methods. For the side-view, robust silhouette images are created using the infrared cameras setup. To extract the body, we may use simple thresholding method to find the body shape. However, as the degrees of brightness of the captured silhouette image are not evenly distributed, we need to apply background subtraction before thresholding is made. We first take an image of the zone without the presence of the painter. Subsequent capture images will be compared with the reference image. A pixel is marked as the body when the difference of the captured image and the reference image is above some threshold. Some fake pixels may be found because of the noises and the digitized resolution, but accuracy in our case is not the most concern. Small discrepancies are acceptable. For the ceiling-view, we configure with blue-screen floor and use simple color segmentation method to extract the body shape.

2.2 Mapping

The output of the body extraction is raw data, i.e. the pixels of the body. In order to interpret them as rendering attributes, we have to create a mapping mechanism that defines the source and target attributes as well as how they match each other. Based on some artistic and physiological implications, we come up with the specification of mapping (Fig. 3). We categorize the source attributes into three groups: path motion, area motion and dimensional motion. Additionally two attributes are defined: intersection of the painter and color ring and the spatial relationship with which we divide the body (along y) into upper part and lower part. Also, the target virtual brush attributes are categorized into three groups: 3D brush-stroke (cross-section), brush motion and ink.

Since the mappings have their own artistic and physiological implications, we would describe them in



(*): repeat

The table shows the source and target attributes of mapping and how they match each other.

Fig. 3 Mapping

general.

1. Path motion (position, direction and rate of change): It is obvious that the path of brush follows the trajectory of the body movement. This will create a virtual 3D canvas in which the direction and displacement made by the painter are corresponding to the movement of the brush. Figures 4, 5 and 6 illustrate an example of how a painter directs the path of the virtual brush in the 3D canvas. Thus the painter could have total control of where to lay a brush-stroke.

2. Path motion (rate of change, acceleration and deceleration): Because of the limited space of the demonstration studio, the farthest displacement of the virtual brush is restricted to fall within studio's physical dimensions (especially in y dimension, the gravity limits the displacement of the virtual brush). To avoid this situation, we use multiple attributes to control the acceleration of virtual brush so that it can "fly" farther with full degree of freedom.

We take this acceleration as one of the attributes to magnify the displacement (in y-axis) of the virtual brush. Both the acceleration and deceleration signify the energy change of the body. We take it to reflect the density of the brush stroke. When accelerating, a body-brush resembles a fast moving brush. When decelerating, the body-brush resembles a slow moving brush.

In addition to magnifying the virtual displacement, the rate of change, acceleration and deceleration are used to map into saturation component. Intense body movement means a vibrant body expression. This corresponds to a more saturated color since saturation is related to expression and emotion. Increase in intensity or saturation of color will raise the expressiveness of color, and vice versa.

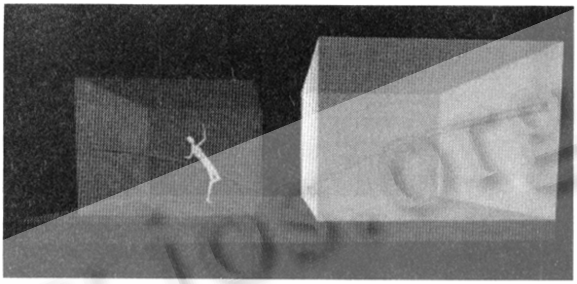


Fig. 4 Illustration of the trajectory of a moving body and the path of brush-stroke

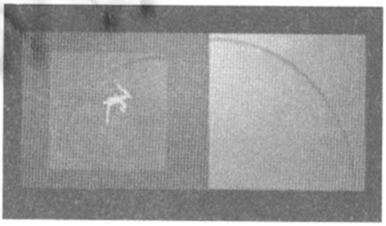


Fig. 5 Illustration of the ceiling-view

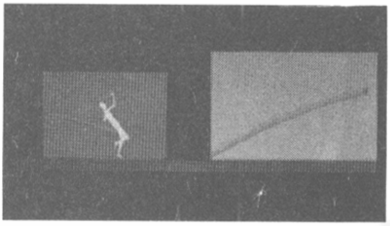


Fig. 6 Illustration of the side-view

3. Area motion (area, i.e. number of pixels): We will sum up the number of covered pixels for ceiling-view and side-view. With reference to the body's normal standing posture, we can control the opacity by comparing with their summed pixels. The default opacity, referring to the normal standing posture taken before beginning of painting, is set to 70%. The opacity changes in accordance with the openness of the gesture. When the number of pixels increases, it means the body expands and thus more open. This infers a more transparent brush-stroke, and vice versa.

4. Area motion (shape, i.e. cross-section of the 3D brush-stroke): The human body as a whole is conceived as a brush. The cross-section of the 3D brush is defined by the body shape in ceiling-view.

5. Area motion (rate of change of area): It maps into the rate of change of the orientation. It means the angularity of turning of the path. When there is a rapid increase in the rate of change of area, it is attributed to a bolder body expression. Bolder expression is represented by a more angular turning of the brush path, and vice versa.

Besides, it reflects the value component of color. An increase of gesture openness (increasing change of number of pixels) signifies a lighter tone - an increase in value, and vice versa.

6. Area motion (acceleration and deceleration): These two attributes are another ones for magnifying the virtual displacement of brush-strokes.

7. Dimensional motion (acceleration of the highest point reached by the body): We take this as another one of the attributes to magnify the displacement (in y-axis) of the virtual brush. The acceleration signifies the psychological effect of body extending along the y-axis. Also, it controls the brush-stroke size.

8. Dimensional motion (acceleration of the lowest point detached from the studio floor): This attribute accompanies item 7 to magnify the displacement (in y-axis) of the virtual brush. When both take effect, the magnification will not be doubled but only this acceleration takes effect.

9. Dimensional motion (rate of change along $x-$, y-, and $z-$ axes): The brush-stroke size is additionally controlled by these three attributes. They are summed up and quantized to reflect different sizes of brush.

10. Intersection of the painter and color ring: The range of value of hue is evenly distributed on the color ring so that intersection of the body and color ring (from ceiling-view) results in picking the value hue.

11. Spatial relationship: upper part > lower part? (Area): The body will be divided into two parts along y-axis and we will compare their areas to determine the opacity. When the lower part of the body is larger than the upper part, it reflects that more pressure is exerted on the canvas. That means more ink is painted into the canvas, thus a more opaque brush-stroke, and vice versa.

2.3 Rendering and aesthetics

With the rendering attributes being specified and converted, 3D brush-strokes can be created and rendered for display. The whole process of rendering is made visible such that the audience can watch both the performer dancing and the virtual brush "flying" almost synchronously. Another interesting point is that during the performance, the painter can see what he/she is drawing immediately (Fig. 7). The whole performance can be treated as a new kind of performing art. Furthermore, what is generated in the end would no longer be a piece of 2D paint art but a virtual 3D canvas containing a 3D color web. By wearing the head-mounted display (HMD), people can immerse into the 3D color web. During the walk-through, what have been seen can be perceived as another new form of arts. Each frame grabbed can be a piece of paint work. Or we could record the video of the walk-through which itself can be an art work. The impact of our system over traditional paint art is tremendous. Figures 8, 9 and 10 show that the physical configuration of the interactive studio, infrared emitters and the top camera mounting and a demonstration of the relationship between the body movement and artistic effects.

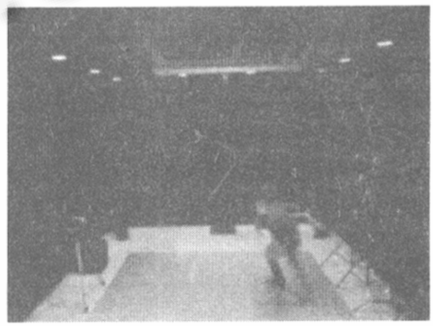


Fig. 7 Demonstration of the relationship of the body movement and artistic effects

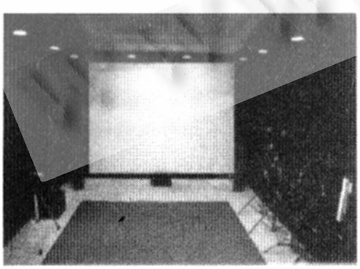


Fig. 8 Physical configuration of the interactive studio

Fig. 9 Top camera

Fig. 10 The collection of infrared emitters

3 Conclusions and Future Work

In this paper, we have presented a framework on building an interactive studio that accepts body-brush motion and transforms it into 3D paintings visualized in a 3D canvas. Our approach allows representation of a new form of paint art. The impact not only introduces new aesthetic perspectives on paint art, but also raises potential multi-disciplinary researches over the system. To consider the mapping mechanism, it is based on the inherent correlation characteristic of human behavior and cognition. So our system can be used for analysis of human behavior in psychology. Furthermore, our system is characterized by the philosophy of "acting painting" that the painter's emotion and expression can more directly be reflected compared with hand drawing. The feature that the painter can see what he/she draws immediately makes our approach well suited for art therapy.

References

1 Claudio S Pinhanez, Aaron Bobick. "It/I", a theater play featuring an autonomous computer graphics character. Technical Report 455, MIT Media Laboratory Perceptual Computing Section, Jan 1998

2 Jeffrey Abouaf. "Biped": a dance with virtual and company dancers. IEEE Multimedia, 1999,6(4):4~7

3 Steven Naifeh, Gregory W Smith. Jackson Pollock: an American saga. Clarkson N. Potter, Inc., 1989

4 Davis J W, Bobick A F. A robust human-silhouette extraction technique for interaction virtual environments. In: Proceedings of the IFIP Workshop on Modeling and Motion Capture Techniques for Virtual Environments. Geneva, Switzerland, 1998

虚拟动作绘画的互动三维画布

叶豪盛[1] 曾秀妍[1] 罗志强[1] 杨曦[2] 崔明慧[3]

[1](香港城市大学计算机科学系影像计算研究组 香港)

[2](独立画家)

[3](香港城市大学创意媒体学院 香港)

摘要 传统油彩艺术多在纸张、画布、墙壁或任何质料制成的物件表面上作业.将油彩艺术带进电脑虚拟现实的三维空间里是一突破性的试验.美国著名画家Jackson Pollock激发了"动作绘画"的意念,以人体作为画笔,不仅为油彩艺术带出一种新的审美视野,还可有引发交错学科研究的潜在可行性.利用一开发动作绘画工作室的骨架,试验出一种用人体作为画笔去控制绘画工作、并把三维画布的绘画工作视觉化的新形式绘画艺术.

关键词 虚拟现实,动作绘画,动作抓取,颜色分割.

中图法分类号 TP391