MAI Painting Brush++: Augmenting the Feeling of Painting with New Visual and Tactile Feedback Mechanisms

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ABSTRACT
We have developed a mixed-reality (MR) painting system named the MR-based Artistic Interactive (MAI) Painting Expert and MAI Painting Brush, which simulate the painting of physical objects in the real world. In this paper, we describe how the MAI Painting Brush was upgraded to the "MAI Painting Brush++," enabling virtual painting on virtual objects. The improved system has a visual and tactile feedback mechanism that simulates the effect of touch when used on a virtual painting target. This is achieved using deformation of the brush tip and reaction force on the hand.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. - Haptic I/O, Interaction styles, Input devices and strategies; H5.1 [Information interfaces and presentation]: Multimedia Information Systems - Artificial, augmented, and virtual realities.

General terms: Design, Human Factors

Keywords: Painting system, mixed reality, input device, paintbrush, visual and tactile feedback

INTRODUCTION

We are developing the MR painting system, which enables the user to paint both real and virtual objects with an actual painting sensation, which makes digital painting more closely resemble real-world painting. Our system aims to meet the following three requirements:

(1) Provide the sensation of an actual painting brush using tip bending and interaction with a computer

(2) Enable users to paint on both 2D and 3D objects

(3) Enable users to paint both on a real and virtual object's surface while directly holding these objects

In a previous study, we developed a painting brush device named the MAI Painting Brush for the painting of real objects and a mixed-reality (MR) painting system named MAI Painting Expert [1].

In the MR space, both real and virtual objects can be manipulated. However, while painting on virtual objects, the MAI Painting Brush cannot provide the sensation of an actual painting brush, because unlike with real objects, there is no tactile feedback such as the reaction force between the device and a virtual object. Therefore, as the next step, we consider a painting brush device whose painting target is virtual objects before targeting both real and virtual tasks.

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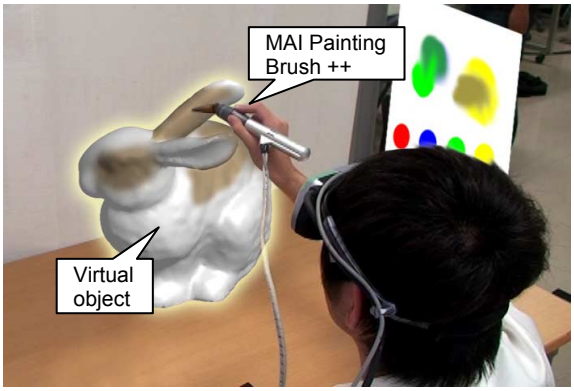


Figure 1: Concept image of MAI Painting Brush++ with visual and tactile feedback mechanisms.

In this paper, we describe how a new painting brush device called the MAI Painting Brush++ is developed, including visual and tactile mechanisms, which seeks to create a realistic sensation of actually painting on virtual painting targets (Figure 1).

RELATED WORK

There have been several simulations of painting and kinesthetic sensation created with haptic feedback for enabling the user to experience the realistic sensation of brush handling. ArtNove [2] and Visuo-Haptic Systems [3] use a haptic display called PHANTOM to create the sensation of virtual painting. However, PHANTOM (brush) is required to be grounded, restricting the user's movements within the range of mechanical linkages. Therefore, it is necessary to have a haptic display that provides much flexibility. Pen de Touch [4] is a tactile device that does not need to be grounded, and thus does not restrict the user's movements. This device allows tactile interaction with virtual environments by generating kinesthetic sensations on the user's fingers. However, this device is not developed for brush painting, so the sensation it provides is different from actual painting using a brush. In this study, we create a device that can provide the physical sensation of actual brush painting by focusing on some specific features of a brush, such as visual (tip bending) and tactile (reaction and friction force) features.

MAI PAINTING BRUSH++

While painting, a paintbrush undergoes various changes, such as (i) bending of the brush tip, (ii) reaction force due to

the painting surface, and (iii) frictional forces between the brush tip and the painting surface. To realize such changes and the sensation of actually painting, we developed the MAI Painting Brush ++, which has visual and tactile feedback mechanisms (Figure 2). As the visual feedback mechanism representing (i), a bendable plastic core connected to three wires is built into the brush tip, and the bending direction and degree are controlled by pulling each wire. The tactile feedback mechanism representing (ii) and (iii) consists of a cylindrical part mounted on the grip that is touched by the user's thumb, index finger, and middle finger. A reaction force is applied to each finger by moving this part. In addition, by pulling wires to control the angle of this part, this mechanism can generate a force in a direction determined by the brush movement. These mechanisms are controlled by the same three wires, which are each linked to a separate motor. By controlling these motors with the feedback model described below, the direction and strength of the feedback can be represented.

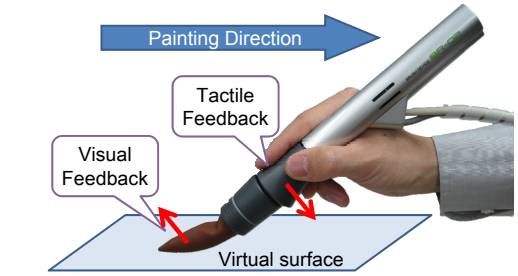
VISUAL AND TACTILE FEEDBACK MODEL

With real-world painting, the extent to which the tip of the paintbrush is deformed depends on the force with which it is pressed onto the painting surface and the direction in which it is moving. Similarly, in our model, the bend direction and bend angle of the brush tip are calculated based on its position, orientation, and painting direction. In addition, in the real world, the greater the pressure with which a paintbrush is pressed onto a painting surface, the greater will be the reaction force to which the gripping finger is subjected. This implies that there may be a correlation between the bend direction and angle of the brush tip and the direction and angle of the reaction force. Therefore, in our model, we calculate and present the reaction force based on the bend direction and angle of the brush tip.

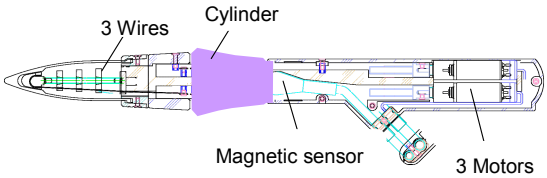
MIXED-REALITY PAINTING SYSTEM

The new painting brush device and the feedback mechanisms are implemented in the digital painting system called the MAI Painting Expert [1], which is an MR system with stereo vision. A magnetic sensor (Polhemus Liberty) installed in a video see-through head-mounted display (Canon VH-2002) is used to detect the position and orientation of the user's head in the MR space. The new device and virtual object that is manipulated also have a magnetic sensor to generate the painting result and feedback, according to the direction of painting and the pressure that is applied onto the painting surface of 3D virtual objects. The occlusion problem that virtual objects hide the device and user's hand is solved by extracted the area from captured images. For this extraction, we use the position and orientation of the device and their brightness contrast with the background. By masking the area, virtual objects are not rendered there.

Figure 3 shows painting examples using this system.



(a) appearance and feedbacks



(b) Mechanism

Figure 2: MAI Painting Brush++.

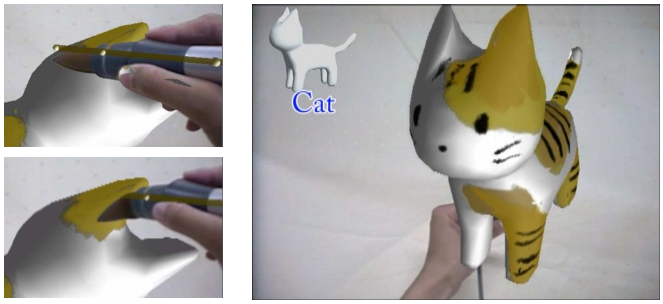


Figure 3: Painting Examples

CONCLUSION

In this paper, we have proposed a visual and tactile feedback model and mechanisms for virtual painting derived from observations of real-world painting. We have developed the MAI Painting Brush ++, which is a brush device with feedback mechanisms installed. In user study, users commented that they felt a sensation of touching to the surface although it is virtual. This indicates that the device can create a realistic sensation of actually painting on virtual painting targets.

However, some users commented that the device sometimes could not respond quickly enough in the case of continuous tapping. Therefore, as the future work, algorithms to control the motors should be improved, or higher performance motors should be adopted.

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