SpatialWhiteboard: A New Wearable Air-Writing Interaction with Kinect Sensor and Vibrating Ring Interface

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Abstract

SpatialWhiteboard is a spatial finger writing system that enables complex spatial interactions through 3D handwriting via a Kinect sensor and vibrating ring interface. By incorporating depth and skin color information, we can directly separate the hand from the cluttered background. We can also accurately differentiate the fingertip from the hand by a mixture model of distance transforming and osculating circle. Users receive physical feedback in the form of vibrations from the wearable ring interface as their finger reaches a certain 3D position. Thus, it is now conceivable that anything people can do on contemporary touch based devices, they could do in midair with a pseudocontact interface.

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [User Interfaces]: Graphical user interfaces—Input devices and strategies

1. Introduction

In this paper, we explore a finger writing system that recognizes characters written in the air using a Kinect sensor and a small finger-worn vibrating device to capitalize on virtual surface area in midair as if touchscreen provides a surface to touch, write, and interact. We propose using a wearable finger device to write in the air, regarding the fingertip as an imaginary pen. This system would allow novel user interaction experiences, especially in 3D based virtual environments or for remote applications such as generating physical feedback from 3D virtual objects or teaching young children how to write. The *SpatialWhiteboard* system allows users to write in the air in a natural and unrestricted way, which may become the next generation of user interfaces.

2. Related Work

Recently, handwriting research has moved towards the examination by allowing hand-free interaction with finger-worn devices [log14] and [Nod14]. Gestures are devised not to rely on any sort of device that requires to be held in the user's hand. [YZJ*13] proposed a Kinect sensor based bare

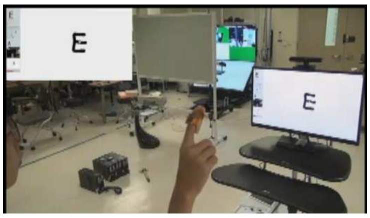

Figure 1: *SpatialWhiteboard can write in the air with feeling of contact.*

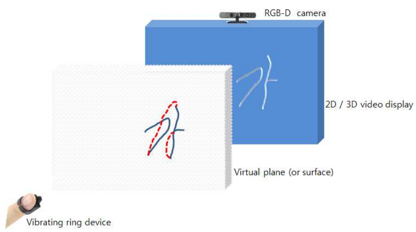

Figure 2: *Constituents of SpatialWhiteboard.*

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hand writing system. This system is most similar to our system in terms of airwriting and using Kinect. But since it does not provide any contact feeling in midair, users have to rely on only visual information from a distant monitor. Our system, on the other hand, can provide much natural writing experience including size (minimum size in 36 by 36 pixels), contact feeling, and real time response and recognition of the written character.

3. Hardware

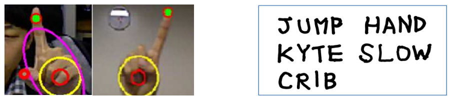
Our proof-of-concept, *SpatialWhiteboard*, seen in Figure 2, consists of two components. First is the Kinect camera, which provides a 320x240 depth map at 30 FPS. We learned that hand and finger as close as 1∼1.2m can be captured by this sensor with minimal error in the depth(Z axis) of approximately 1mm. Otherwise depth accuracy decreases and noise increases. Therefore, for our prototyping application, which considers interaction within a 1∼1.2m in front of the user, this is the best location for airwriting. The second component is a custom ring device, which can generate vibration according to user's spatial depth position in a predefined surface area in the air (we call it 'air-bounce'). There are two vibrating motors, which are installed at the front and the middle of the ring, have 30∼250Hz range frequency and can be controlled using PWM (see Figure 3). The ring can

Figure 3: *Our prototype finger worn ring device for Spatial-Whiteboard.*

generate two different vibrating mode, mild and strong. As the user's finger begins to touch the surface in the air, the front motor starts to quiver and then if the finger is within the potential writing area both motors strongly vibrate with 250Hz frequency during writing.

4. Fingertip Tracking

This ensures that both hand and forearm regions are extracted from the depth map. The palm circle then equals to the largest inscribed circle of the contour F. To reduce the computational complexity of palm localization, the center of palm is tracked with minimum enclosing circle. We build a robust skin model characterizing both skin and nonskin distributions as Mahalanobis distance in the $YCbCr$ color space The fingertip can be considered as an extremity of the hand. Inspired by the concept of geodesic maxima [PGKT10], we define the fingertip position as the point that maximize the geodesic distance from the palm center. The center of palm is calculated by distance transform in the inverted binary images of hand. We assume that the fingertip can be only detected where the curvature is maximum. In other words, for



(a) (b)

Figure 4: *(a) Fingertip detection. (b) Results of air-writing.*

a slice of pixels to be a candidate, it has to show a steep positive derivative followed by a region of relative smoothness, and finally closed by a steep negative derivative, vice versa. We utilize osculating circle to discriminate the final fingertip position among candidates. The curvature (or radius) of the osculating circle must be less than 5mm, a range we found to cover typical finger diameters, including the critical fingertip.

5. Technical Evaluation

We asked 7 users to write each letter of the alphabet 4 times. As shown in Figure. 4(b), the result is quite excellent when we applied the proposed airwriting technique. The overall performance with 95% recognition rate was achieved from the handwriting recognition application. We analyzed how two vibration modes influence users' writing performance and style. Both of them was shorter (movement distance:38.5%, length of ligature:43%) than that of one vibration mode. When people write on the board or note, they slightly lift up their pen to move their hand to the next position of stroke. With two vibration modes, we can simulate similar hand movement because different vibration frequency makes them discriminate the writing surface and contact surface. For two vibration condition, the length of movement had an average of 5.53m and 4.53m of ligatures (std 4.04), and one vibration condition had an average of 9.00m and 8.02m of ligatures (std 3.90). The ANOVA indicated this to be significantly different ($p<0.05$).

6. Conclusions

We presented a vision-based handwriting system via finger-worn vibrating ring device for person independent single character and word recognition in the air. The system achieved recognition rates of 95% for character. The only requirement of the system is that users should wear a ring device, which offers users an intuitive and natural way to write text anywhere in a given area.

References

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