Limpid Desk: Transparentizing Documents on Real Desk in Projection-Based Mixed Reality

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ABSTRACT
Searching of spread documents on a real desk is an arduous task. The chaos on the desk makes users’ searching of the desired documents difficult. In this paper, we propose Limpid Desk which supports a document search on a desk by transparentizing the upper layer of a document stack in projection-based mixed reality environments. In the system, the special pattern light which is calculated to compensate the appearances of the upper layer documents as if they are transparent is projected to the stack, and as a result, users can visually access to the lower layer document. We propose a touch sensing method using a thermal image for the input interface of the system. The method realizes that users’ touch areas on real documents can be detected with no worn or hold devices. Hence, users can intuitively select the stack, which they would like to transparentize, by their simple touch gestures. We present three intuitive interaction techniques which allow users to figure out what the lower layer document is without physically removing its upper documents. Since the searching space, the manipulating space, and the display space are completely unified onto a real desk, users can directly access to the lower documents without PC monitor and interface. We claim that this kind of spatial consistency of the manipulation is the key for realizing the intuitive interaction.

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Keywords: Projection-Based Mixed Reality, Radiometric Compensation, Smart Desk, Transparentized Documents, Thermal Image, Touch Sensing

1 INTRODUCTION
It is difficult to search a desired document on a real desk where many documents are multiply stacked. In contrast, in a PC’s desktop, users can easily find the window which they would like to edit or see from all opening windows. For example, Application Switcher in Apple’s Mac OS X allows users to access to the desired applications only by Command-Tab key. Furthermore, Mac OS X offers an intuitive window search interface, Exposé, by which users can see all opening windows immediately and find the desired one only by their one action. And, Microsoft announces that the glass-like interface elements that users can see the lower layer windows through its upper ones is planned to implement on the next OS, Windows Vista. We apply these methods to the real document search task.

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In this paper, we propose an intuitive document search system, Limpid Desk, which utilizes a projection-based mixed reality (Fig. 1). In the system, a radiometric compensation technique is applied to transparentize the upper layer documents of the stacks, and users can visually access to the lower layer document without physically removing its upper ones. We also propose a touch sensing method, by which users’ touch areas on real documents can be detected, using a thermal image for the input interface of the system. And then, we describe three intuitive interaction techniques such as users can browse and direct the whole stacked documents which they would like to transparentize or see only by their simple touch gestures.

2 TRANSPARENTIZING DOCUMENTS IN PROJECTION-BASED MIXED REALITY
Some researchers used projector to transparentize real objects [1, 2]. Their target objects are suitable for projection because they are high quality screens like a refrigerator’s simple white door and a retro-reflective material. But, real documents like magazines and photos have spatially varying reflectance properties which modulate the appearance of the projected image. There are some works on controlling real objects’ color appearances using the radiometric compensation method of a projection-based mixed reality technology to solve this problem [3, 4]. We apply these methods to transparentize upper layer documents which have complex textures.

Figure 2 shows the result of the transparentizing of the upper layer document by the radiometric compensation method. Figure 2a and 2b shows the document stack and the lower layer document before projection. Figure 2c and 2d shows the projection result when the original and compensated image of the lower layer document is projected to the upper layer document. It is confirmed that the appearance of the lower layer document is not reproduced in Fig. 2c because of the spatially varying reflectance properties of...
the upper layer document, but in contrast, it is almost reproduced in Fig. 2d. This result indicates that the projection-based mixed reality technology is able to almost transparentize real documents in limited applications of human interface.

3 Touch Sensing Method

It is important to construct an input interface of the system which can detect users’ touch areas on real documents without any user-worn or -hold devices, to realize seamless and consistent interactions as the users browse and direct stacked documents only by touching them. But, it has been a difficult problem to detect users’ touch areas on real objects. In this paper, we propose a touch sensing way to realize such interface suitable for desktop environments using thermography.

The thermographic method uses the heat storage phenomena on users’ touch areas on real objects. For example, when a user touches an object, his/her body heat is transferred to it. And then, when the user releases his/her hand from it, the heat remains at its surface for a while. The method measures this heat storage on the real object through a thermal image to detect the user’s touch area.

A temperature varied area in the thermal image denotes a user’s touch area. Particularly, not only a touch area but also a user’s body itself causes a temperature varied area in the thermal image. We involve a CCD camera to use a visible image to eliminate the user’s body area from the thermal image. The process flow is shown in Fig. 3. First, the background subtraction eliminates the user’s body in the visible image and the mask image is created. And then, the temperature varied areas extracted from the masked thermal image is obtained as the user’s touch areas.

4 Interaction Techniques

Limpid Desk consists of a video projector, a CCD camera, and a thermo infrared camera. We implemented three types of interaction techniques for the system (Fig. 4). The first one is "Touch Area Transparent Interaction" in which user’s touch areas on an upper layer document are transparentized (Fig. 4a, 4b). And the second one is "Thumbnail Type Document Search Interaction"; a user touches the upper layer document, then the thumbnail images of the all lower layer documents are projected to the upper layer document. And then, the user touches the thumbnail image of the desired document (Fig. 4c). As a result, the upper layer documents are transparentized and the user can see the desired lower layer document. The third interaction technique is "Direct Select Interaction" in which a user can directly point at the document they would like to see in the stack by touching it (Fig. 4d).

5 Conclusion

In this paper, we proposed Limpid Desk in which users can visually access to the lower layer of document stacks on a real desk by transparentizing the upper layer documents in the projection-based mixed reality. We also proposed the input interface which can detect users’ touch areas on real documents. We described about the system and three intuitive interaction techniques on it. In future work, we evaluate the intuitiveness of the proposed interaction techniques and the effectiveness of the document search through the system.

References