Interactive Display Conglomeration on the Wall

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ABSTRACT

We present a work in progress for a paradigm of wall-top displays for future offices, where instead of a small desktop, we treat the available walls as the desktop. Multiple projector-camera units, mounted on pan-tilt units (PTU), allow for the creation of the conglomeration of one or more high resolution displays, whose position, size, and aspect ratio can be changed by the user. This can be achieved by lucid gesture based interactions. Multiple wireless keyboard and mouse can be used to interact with the display(s) for shared collaborative or personal individual interactions. The system can also be extended to support stereoscopic projection and data input by superimposing projection displays and processing data from multiple cameras. This is achieved by a distributed network of projector-camera systems, and associated distributed registration and interaction methodologies.

Index Terms: D.4.7 [Organization and Design]: Systems—Distributed system

1 INTRODUCTION

Imagine an office where the desktop is transported on to the walls of the office. When working with a collaborator, one no longer need to crouch in front of the desktop, but has the freedom of having the entire desktop in front of them, on the wall. Imagine the user being able to change the position, size, and resolution of the conglomeration of one or more displays by using simple gestures. The user then will be able to use the wall as a single desktop, or split it up into multiple desktops, to satisfy the desired interaction model. The users will also be able to communicate with different applications on the desktop via wireless mouse and keyboard.

The aforementioned vision is much more than what was shown in the science fiction movie Minority Report. It allows for both personalized individual interaction and collaborative multi-user interactions. It allows the same walls of the room to be used for other purposes when not in used as a display.

In this paper, we present a work in progress for such a paradigm of wall-top displays, achieved by a network of active display modules. Each active display is made of a projector-camera ensemble on a PTU. Each unit and acts like a flashlight, which can provide a display anywhere and everywhere in the room. A conglomeration of such active displays is mounted on the ceiling in a distributed network, to provide the configuration desired by the user.

Interaction with these displays can be facilitated via gestures, laser, or any other device that can be seen by the cameras. Currently, we are using a gesture-based interface since it provides the most natural interaction modality.

Once the user has decided on the position, size, and aspect ratio of the conglomeration of displays, the displays self-register and create one or more rectangular displays. Identification of the display configuration and registration are achieved via distributed configuration identification and registration techniques. Interactions are achieve via distributed interaction and reaction management techniques. Hence, no centralized server is responsible for driving this conglomeration of displays, making them extremely robust to faults.

1.1 Related Work

Tiled multi-projector displays have been used in VR and visualization environments for a long time [6, 3]. However, they tend to be large systems, with minimal flexibility, driven by a centralized server, and therefore need to be maintained by a crew of trained professionals. Different distributed rendering frameworks have been proposed to use them effectively for visualization of large data [12, 7, 9, 1, 10]. More recently, the work by Raskar et al. [11] proposes the idea of using immersive displays in office environments to create completely immersive 3D worlds, where telepresence can be achieved in the truest sense. However, limited resources (e.g. network bandwidth) and imperfect methodologies (e.g. real-time 3D reconstruction of large scenes, holographic displays) has inhibited the progress of this grand vision. Our vision is a hybrid model of the previously cited works, where we plan to have interactive displays all around the user, making them available to the user ubiquitously. In [2] we present a distributed network of projector-camera systems and associated distributed registration methodologies, for this purpose. Although such a distributed paradigm is most suitable for individual and collocated collaborative interaction, with the current technology, it is the most practical way to achieve the grand vision of the Office of the Future [11]. In [13] we design the first distributed interaction paradigm for 2D applications on such a display, formed by a network of projector camera systems. However, this system does not use PTUs and assumes rectangular projection with negligible keystoning and a single tiled display. It also does not facilitate interactive reconfiguration of the display using simple natural gestures. Figure 1 depicts the aforementioned system.

(a) (b)

Figure 1: *(a) A 3x3 projector system self registerting itself using statically placed QR codes. (b) Multiple collocated collaborative users interacting with the display.*

1.2 Main Contribution

In this paper, we consider a distributed network of projector camera systems mounted on PTUs to facilitate the movement of each projector's projection area anywhere in the room. Our research extends the distributed registration techniques to accommodate irregularities in display shape, due to keystoning and conglomeration. Further, we allow gesture-based interaction for reconfiguration of the conglomeration of the displays. This includes changing the number

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of displays, changing the position of displays, changing the specific projectors creating each conglomeration, and changing the way the projectors are tiled to create each conglomeration. We also offer intelligence to the displays, as follows: (a) if the user provides too small an overlap, the display corrects it by snapping itself into an existing display or (b) moving itself away from the existing display to create a disjoint display. We also allow ways for the desktop to be distributed across this conglomeration of displays, per the users needs and specifications. However, since this work presents a work in progress, we are only able to demonstrate a few of the above features.

2 The System

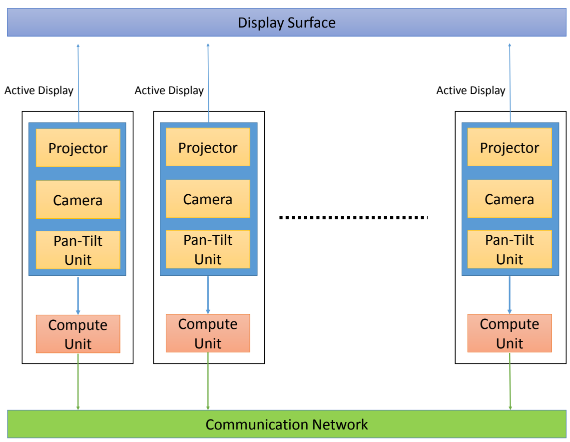


Figure 2: *The system is composed of a cluster of active displays. Each active display is made of a projector-camera ensemble on a PTU. Each active display is connected via a communication network.*

Figure 2 shows the architecture of our system. The system comprises of a distributed network of active displays. Each active display comprises of a projector-camera ensemble on a PTU. These three devices are connected to a computer. We will denote the projector and camera pair as a single visual input/output (VIO) device. All active displays are connected via a communication network. Figure 3 shows the three devices, assembled and mounted onto the ceiling of an office. Multiple active displays allow for the creation of a conglomeration of displays.

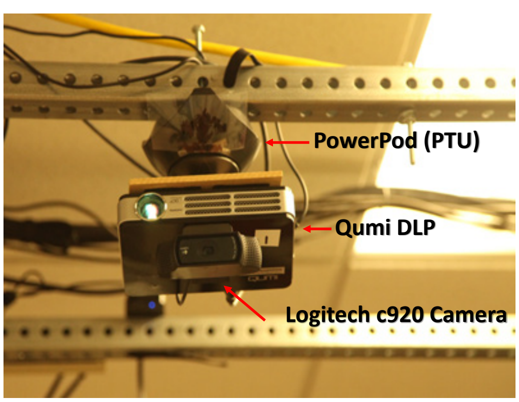


Figure 3: *The VIO device consists of a camera and a projector, mounted onto a PTU.*

Figure 4 shows an entire office environment containing four active displays. They are mounted to the offices ceiling, and project onto the front wall.

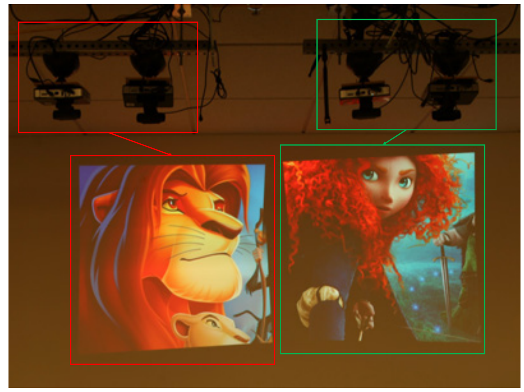


Figure 4: *The active display's VIO devices are mounted to the ceiling. The colored boundary designates which pair of active displays is projecting each image.*

3 Registration

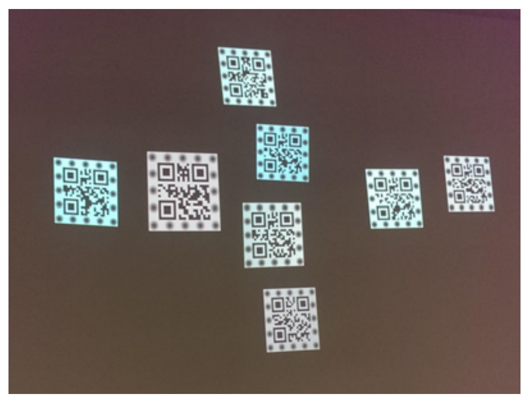
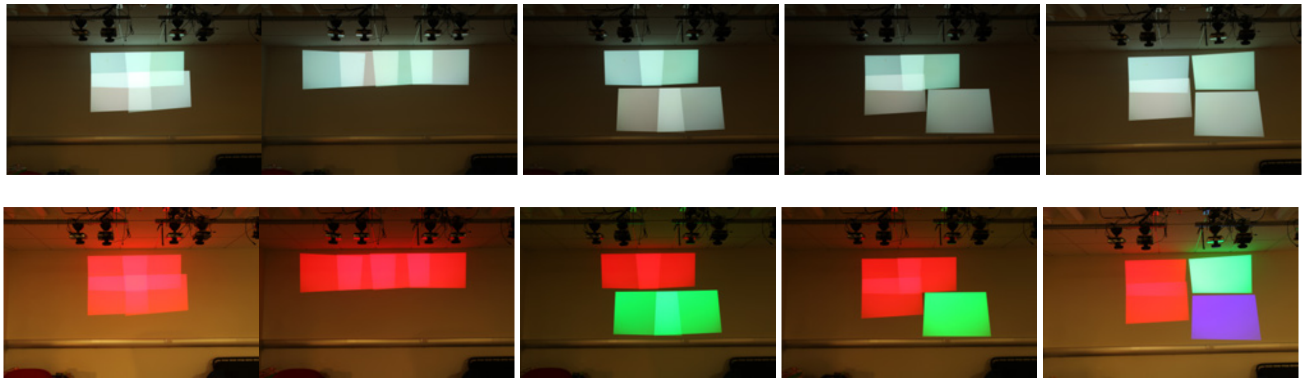


Figure 5: *QR codes are sized and placed according to the overlap area of each projector.*

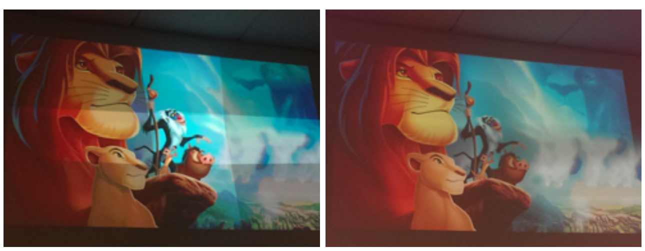
Once the user finishes repositioning the active display(s), the system identifies the configuration and self-registers. Active displays with contiguous projections are considered to be a set of displays in the conglomeration. Therefore, multiple sets of displays should be spatially disjoint from one another. To identify the configuration and self-register, we adopt the distributed registration technique of [13]. In this technique, each active display projects different QR codes, augmented with Gaussian blobs. The QR codes facilitate configuration identification, while the Gaussian blobs facilitate registration. However, since this method was designed for rectangular projection, we face the following challenges: (a) The QR codes may be too keystoned, thereby causing problems in configuration identification and registration. (b) The size of the QR code may be too big to fit in the overlap region. To alleviate these problems, we use the following steps: (a) Each active display takes turn displaying a white image, and capturing the projected white image. (b) Each active display uses this to calculate the overlap region and the approximate homography with other active displays. (c) Based on the overlap, each active display generates an augmented QR code (embedded with its own IP address and ID) of a certain size, such



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

Figure 6: *The top row shows the displays placement before registration. The bottom row shows the grouping of the displays to create a larger display, with various configurations. Some examples of such configurations are: (a) one display, made up of 2x2 projectors; (b) one panoramic display, made up of 1x4 projectors; (c) two panoramic displays, each made up of 1x2 projectors; (d) one display using 3 projectors in a non-rectangular fashion, and another display made up of a single projector; (e) one display, made up of 2x1 projectors, and two single projector displays.*

that it can fit into the overlap region. (d) The approximate homographies are then used to undo the keystoning of the QR codes and display them in the overlap region. (e) Each active display captures the projected QR codes in order to identity and communicate with its neighbors and begin registration.



(a) (b)

Figure 7: *(a) Result after geometric registration. (b). Result after color registration.*

Figure 5 shows the placement of the QR codes after the overlap regions are calculated. Figure 6 shows our method of identifying the configuration. Figure 7 shows the zoomed in view of the registration in one of the displays.

4 Gesture Based Repositioning

Once the active displays are powered ON, the user can use gestures to position them the way he wants, to create the conglomeration of displays. Each active display runs the distributed SPMD (single program multiple data) gesture management and reaction management technique presented in [13]. Since the user is not engaged in any work on the displays during this phase of configuring the conglomeration, we use the hotspot-based gesture recognition technique proposed by Chiu [5]. This greatly increases the accuracy of gesture recognition, at a very low latency. These are both extremely desired features in our application, since we want the displays to move along with the user until he decides on its position and configuration.

The steps of this method are as follow: (a) Change from display mode to reposition mode. (b) Project blob pattern in the display space. (c) Identify the open hand gesture used to select the desired active display. (d) Track the movement using hotspot-based tracking and move the active display to a different region. (e) If there are no movement for more than 3 seconds, identify that as the culmination of the reposition operation, and deselect the active display. This is illustrated in Figure 8.

Since the repositioning of the display is performed on each active display, any tracking system can be used to relay the position to the computer and trigger the PTU movement. There are many toolkits available to support sensor inputs and tracking (e.g SenScreen and Ubi Displays [4, 8]). For more information on extending the system, please refer to the future work section.

5 Application

Interactive conglomeration of displays on wall-tops can adapt to a variety of visualization purposes.

5.1 Stereoscopic Projection

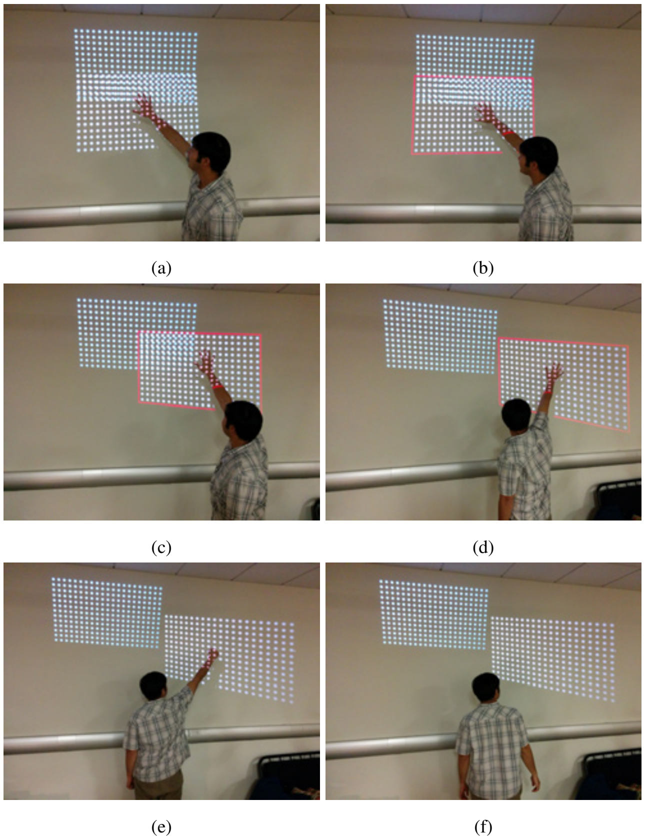
With the freedom to reposition each active display, one possible configuration is to superimpose two active displays to create a stereoscopic display. Since the VIO devices orientation is dependent on the PTUs position, simply placing a polarizer in front of each VIO device is not enough. A mechanism must be used to align the polarizer of each VIO device such that it is aligned with the viewer's polarized glasses. Anaglyphs can be supported without additional equipment.

5.2 Stereoscopic Input

By having two or more superimposing active displays, the cameras mounted on each display can serve as a stereoscopic input device. This would allow the system to obtain depth information. The information can be used to perform registration on non-planar surfaces, or to interpret 3D gestures.

6 Implementation

Our prototype system consists of four desktop computers. Each computer is equipped with an i5 processor, 4 GB of main memory, and an onboard Intel 3000 series graphics chip. Each computer is connected to a camera, projector, and PTU. The projector model is Qumi 300, the camera model is Logitech c920, and the PTU model is PowerPod. The total cost for each active display is 900.00 USD. Each computer runs the sample application and coordinates with one another via a gigabit network. The application is written in Java, and interfaces with a C++ program only to control the PTU. Each camera capture operation takes five seconds. The registration process requires two capture operations: one captures the projection region, and one captures the projected QR codes. The first capture operation needs to be done sequentially, while the second capture operation can be done in parallel. The exchange of information during the registration process is trivial and has no significant impact on the total registration time. The total registration time in seconds can be expressed as $N \times 5 + 5$. Where N is the number of active displays.



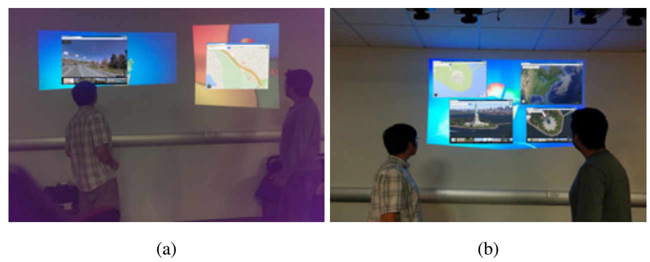
(a) (b) (c) (d) (e) (f)

Figure 8: *(a) User places hand over desired active display he wants to reposition. (b) The active display is selected. (c,d) User moves the active display to a different position. (e) User deselects the active display. (f) The active display is now repositioned.*

7 Future Work

We have identified three research directions for the system: (a) Gesture based interaction: With the freedom to turn any surfaces into a display surface, user should not be limited to a keyboard and mouse as modes of input. Using the VIO devices, we can add new gestures to perform different tasks, such as moving a cursor, or typing on a virtual keyboard. Our systems modular design allows for easy integration with other input devices (e.g. time-of-flight camera). Further, there are many toolkits available (e.g. SenScreen and Ubi Display) that will help with the integration process. Further research must be done on how to best utilize these new devices and available toolkits, and to extend their capabilities. (b) Content delivery and application interface on the conglomeration of displays: With many components working together, a control node is needed to coordinate the system. Such a control node should not disrupt the distributed nature of the system, to ensure that it does not become the systems bottleneck. At the same time, it must act as an interface between the system and the user. Research in this direction involves designing a control mechanism that is intuitive and robust, with the ability to control the content of each display. We want to change the way people collaborate, as shown in figure 9, by creating a display system that can be easily reconfigured for any application need: where one may need their own work space, or ones need is to corroborate on a large display. Figure 10 depicts such scenario. (c) VR Applications: There are many distributed visualization frameworks available, as mentioned in our related work. Further research needs to be done on how to integrate these frameworks into our system, and how to extend the frameworks capabilities through our system's input and output devices.

Figure 9: *Collaborating on a small display.*



(a) (b)

Figure 10: *(a) Users can create their own work space. (b). Users can join the active displays together to form a large display.*

8 Conclusion

Building on the previous work in the area of large tiled display, we have designed a flexible and scalable display system that can be reconfigured to meet the visualization need of the user. The work by Roman et al. [13] showed a system that is capable of registering itself with statically placed QR codes, where gestures can be used to interact with the system. We have improved upon this work by dynamically placing the QR codes, thus, allowing the system to adapt itself to any display configuration. We have shown how the displays can be repositioned with gestures. We have demonstrated the flexibility of the system, through its ability to register itself on the fly, after a change in position. Finally, we have shown how the display system can be partitioned into smaller displays, to accommodate different usage behaviors.

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