A Survey of Interaction Techniques and Devices for Large High Resolution Displays

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Abstract

Innovations in large high-resolution wall-sized displays have been yielding benefits to visualizations in industry and academia, leading to a rapidly growing increase of their implementations. In scenarios such as these, the displayed visual information tends to be larger than the users field of view, hence the necessity to move away from traditional interaction methods towards more suitable interaction devices and techniques. This paper aspires to explore the state-of-the-art with respect to such technologies for large high-resolution displays.

Keywords and phrases Interaction Techniques, High Resolution Displays

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1 Introduction

In numerous industrial and academic endeavors either a projector or tiled large high-resolution display is preferred over a standard desktop in order to cater to a larger audience, for more efficient collaborative work, to further immerse the client in virtual reality applications, or to facilitate visualization of large and complex datasets by maintaining both overview and detail views simultaneously [21]. In these situations the major drawback of using traditional input mechanisms is the stationary installation of such devices - an individual would be required to sit at a console and follow instructions from others as how to interact with the environment. Other flaws associated with traditional devices include their lack of natural interactions and intuitiveness.

Through the course of this paper we shall survey both cutting-edge and established interaction technologies that deal with the above-mentioned issues. The common theme in these tools is the increased usability of interaction devices when integrating them with large high-resolution displays in a more natural manner than traditional setups.

2 Related Work

In order to interact with large high-resolution displays, researchers have mostly focused on: interaction techniques [2, 23, 20], a particular interaction device [52, 49, 55], or certain modalities [38, 48, 25].

There are not many papers that specifically compare interaction technologies for large high-resolution displays. In this regards, the presented survey is quite similar to the one conducted by Bierz in which he examined interaction metaphors, devices, and techniques for large and immersive displays [8]. The distinction lies in the approach of this survey to explore different modalities for relevant interaction technologies. Further, the scope has been extended to include recent publications.

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3 Interactive System Components

Extensive studies have been conducted in the realm of high-resolution displays for desktops [29] as well as for large displays [19, 46, 5, 29]. In both contexts, a key benefit is the enhanced performance time for basic visualization tasks as documented by Ball et al. [4] - *high resolution displays help people find and compare targets faster, feel less frustration, and have more of a sense of confidence about their responses.*

However, large high-resolution displays stand out more so than desktops in their ability to not only immerse the user more deeply in a virtual environment, but also to efficiently explore and interact with complex datasets [56]. While implementing an interactive system, a number of factors have to be considered:

- Type of display technology: CAVE [17], Multi-Monitor Desktop [3], Tiled LCD Panels [43], Projector Arrays [50], or Stereoscopic Displays [18]
- Architecture and Data Distribution [21]
- User Interfaces and Interaction Devices

It is this latter criterion that shall be examined further in this paper, where distinct modality types are to be delved into. Relevant media and interaction techniques within each modality will be inspected by analyzing between two and three applicable implementations.

4 Modalities

In [30] modality is described as a means to convey information to, or receive information from a communication partner (human or machine). In the following sections, pertinent media and interaction techniques are further investigated.

4.1 Speech

The notion of implementing speech recognition and synthesis to issue digital commands is definitely not a novel concept. Yet supporters of multimodal interfaces will point out to its significance in modern-day environments, where the combination of speech and gestures is more natural and efficient [48].

An early implementation, Put-That-There multimodal system, allowed individuals to interact with large displays via deictic referenced speech commands [10]. More recent research asserts multimodal input as a shorter, simpler and more fluent modality than speech alone [41]. In this study, the authors considered speech and gestures in map-based user tasks and verified that the participants not only preferred this symbiosis but also that it was more efficient than speech alone.

Results from several research projects indicate the real benefit of speech technology is when it is merged with direct input or gestures to form a multimodal input device for selection and manipulation tasks [14, 15, 32, 16]. As the broad context of these studies suggests, a number of environments can benefit from a multimodal approach that utilizes speech including large high-resolution displays.

4.2 Tracking

Early implementations employed one of two main technologies that provided sufficient update rates, accuracy, and mobility: magnetic and optical tracking systems [8]. However, the latter was typically preferred due to its lower latency time and as magnetic trackers tend to be susceptible to ferromagnetic substances [40]. This section focuses solely on tracking interaction devices, whereas gestures and user tracking are inspected further in Section 4.3.

In [52], the authors suggest a technique to simultaneously track and identify multiple laser pointers in a large screen collaborative environment. The crux of this method lies in attaching a microprocessor to each laser pointer to modulate its brightness. A camera-based optical system is then used to process images that detect, group, and identify the laser points. Resulting identification and location is fed back to the application in order to update each pointers position.

Robertson et al. preferred motion-sensing Wii Remote controllers to touch screen or camera-based trackers in their multiuser collaborative environment [44]. Their results indicate that these controllers can proficiently facilitate several users to cooperate in controlling the virtual camera and to explore graphical objects. The three-axis accelerometer and infrared fiducial tracking camera of the Wii was used to report position and orientation.

Mobile phones or so-called smart phones may be employed as pointing devices if they are equipped with either an accelerometer or a camera. While the former is generally found in some high-end phones, cameras are packaged in almost all mobile phones. Work similar to the one by Haro et al. utilizes tracking algorithms to analyze live input images. In their research, a feature-based tracking algorithm was used to estimate the motion of the device [24]. This sort of tracking algorithm can be used in navigation and gesture-based interaction in virtual and augmented realities [11].

A promising application area is the interaction of mobile devices with large screen displays in public domains, one which is being researched thoroughly [23, 13, 6]. Hardy et al. postulate a technique, *Touch & Interact*, that facilitates the direct manipulation of dynamic displays using touch-based mobile interactions. Their results indicate an easy, intuitive, and enjoyable mechanism that is significantly faster than the alternative - usage of the mobile phone to control a mouse pointer remotely. Vajk et al. employ mobile phones as controllers for games (or applications) running on large public displays. Their work aspires to provide a generic framework that utilizes on-board phone sensors such as cameras, accelerometers, and Radio Frequency IDentification (RFID)/Near Field Communications(NFC) to run games and simulations on large public displays via Bluetooth [49].

As inspected in the above-mentioned research, it is common practice to employ tracking technologies to navigate virtual and augmented environments efficiently. Depending on the nature of the environment, one may choose to track interaction devices, the user, or a combination of both. Devices may be tracked in collaborative environments to distinguish users. In other scenarios, trackers may be implemented to gauge head, hand, or eye motion; allowing the adjustment of the perspective projection and auditory inputs to provide further realism.

4.3 Gestures

Interfaces that utilize gestures offer a natural way of interaction, one which is more accurate than the use of tracking devices and which is extremely intuitive. Of the various media employed, mobile phones, hand gestures, and the Wii Remote are particularly of interest due to their extensive usage in everyday life.

4.3.1 Mobile Phones

Innovative interaction techniques are required to offset the limitations posed by input and output modes of mobile devices [22]. One such technique is the usage of gestures as an interaction mode, empowering people to explore and achieve a task in a more instinctive manner.

Bhandari et al. conducted participatory interviews to establish the acceptance of gestures as an interaction mode for mobile devices like mobile phones [7]. Participants were asked to perform tasks using gestures that included *touching of the screen with fingers, movement of the fingers across the screen, and moving the phone in several directions*. A key observation was that the participants clearly favored gestures over traditional key-clicking modes of interaction. Relevant metaphors were indicated, such as: *unfolding a blanket, scraping off the dirt from surface, opening up a picture to zoom in, and crossing out incorrect items or information.*

Similarly, Dachselt et al. advocate a set of gestures that utilizes accelerometer-enabled mobile phones both as a remote control and as a conduit to transfer documents to and from large display interfaces [20]. The former is explored through two distinct application scenarios: 1) *discrete directional tilt* gestures are mapped to stepwise panning, up and down, and zooming in or out of a User Interface for browsing large music collections, and 2) *continuous tilt* gestures that employ pan, zoom, and tilt modes that are applied on 3D maps. The latter employs *throw* and *fetch-back* gestures to transfer items between a mobile device and a large display.

It is concluded that such interactive gestures lead to a natural and seamless integration of mobile devices and large displays.

4.3.2 Hand Gestures

Both hand gestures and postures are intrinsic components of our everyday lives giving us conscious and unconscious cues for non-verbal communication. Recent research aims to apply these cues in their most natural form, without the use of props, as a medium for interaction.

Work presented in [27] clearly categorizes hand movement vision techniques into two aspects: *static and dynamic*, referring to hand postures and hand gestures respectively. A technique based on the Modified Census Transform to extract relevant features in images is explored for Hand Posture Recognition [28] while existing models such as Hidden Markov Models and Input-Output Hidden Markov Models are compared for Hand Gesture Recognition.

Researchers at the University of Coimbra, Portugal, were one of the early pioneers in using computer vision to decipher human computer interfaces based on hand gestures [42]. Benefits associated with vision techniques include the usage of only cameras to capture hand related movements rather than sensors or devices. The key motivation of this research was to develop a natural interface based on the recognition of a set of hand gestures without computational latency. Analysis of the temporal variation of the hand contour was the basic premise of this recognition system, an approach that has been since extended to newer interface paradigms [1].

The ability to interact in real-time has traditionally been the bottleneck in realizing optical marker-less tracking. This concern has been tackled in the above-mentioned techniques and further resolved by delegating time-consuming computation to the graphics processing unit (GPU). Research akin to Bierz et al. has focused on performing image processing such as skin detection, noise filtration, and outline extraction on the GPU [9].

4.3.3 Wii Remote

Several aspects of the Wii Remote have been successfully reverse-engineered [35], resulting in software libraries [53, 34] and documented technical information about its inner workings [54]. Leading researchers to adopt it for a variety of purposes, such as: motion capture (see Section 4.2), gesture based applications [45], and robot control [33].

4.3.4 Other Technologies

Facial expressions, gaze tracking, and body postures tend not be favored in fine-grain manipulation due to their coarse nature, however they can be efficient in rough initial interactions and in augmenting other interaction mechanisms [8]. Further details can be found in [38, 47, 51].

4.4 Haptics

A brief mentioning of haptic input devices is imperative due to their potential in virtual environment applications. These devices are quite common in their simplest form and can be found in the vibrating alert function of mobile phones as well as in gaming force feedback devices. More sophisticated versions interpolate mass or stiffness of the objects and collisions with those objects to force output [30]. The biggest setback with the latter is that most of them are static grounded devices lacking the portability and freedom of movement to be used in combination with large screens.

Haptic devices have been successfully used in many different application areas such as training of medical students [31, 36], modeling objects in virtual reality [12, 37], or operation of tele-operating systems [39].

5 Conclusion

Careful inspection of the "state-of-the-art" in interactions with large high-resolution displays indicates that researchers have indeed freed users from their desks; empowering them with multimodal mechanisms that may be a combination of gestures, speech, tracking, and hand-held devices. A common theme emerges as a result - an approach that moves towards multimodal environments that are both natural and "fun".

Natural modalities such as speech and touch that compose easier and more effective interactions with applications and services are being adopted [26]. Whereas hand-held devices in earlier interface scenarios are being replaced in academia and industry by devices analogous to game controllers and smart phones. Researchers such as Iftode et al. indicate that smart phones are destined for universal acceptance due to their Bluetooth capabilities, Internet connectivity, significant processing power and combination of modality modes.

It is for these reasons that smart phones have a high potential to be used as remote controls and dual connectivity devices in large display interactions. Further, it is envisioned that the recent development of tablet devices such as the Apple iPad will have a larger impact on such interactions - as they combine the features of smart phones with a larger multitouch finger-sensitive touchscreen interface.

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