The GIS WallBoard:

Interactions with Spatial Information on Large-Scale Displays*

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Abstract

Displays of future geographic information systems (GISs) may be the size of an entire wall. This paper explores how such new technology would enable GIS users to work with information systems in completely new ways, by manipulating spatial objects or scenes with their bare hands and querying through gesture, voice, or a combination of the two. The central component of this interaction is the *WallBoard*, a GIS device whose design is based on the metaphor of an office whiteboard, with tools—both physical, such as markers and erasers, and virtual, such as lenses and measuring devices—that have similar usage capabilities to those tools associated with a regular whiteboard. The WallBoard replaces the look-and-feel of the desktop of today's personal computers. Unlike smaller-scaled devices where a user performs all interactions from more or less the same position and perspective, the WallBoard allows users to interact from three different spaces: Within *arm's length*, users may have physical contact with the objects they are manipulating; within *spitting distance* they gesture primarily; and *within sight* of the WallBoard they watch and at times interact with the WallBoard through the use of additional computing devices. Within arm's length, the WallBoard affords gesture interactions with geographic objects by selecting objects or areas, zooming in and out of a sub-area, panning, and rotating a scene.

1. Introduction

The design of today's geographic information systems (GISs) is limited by the physical size of computer displays, which are usually somewhere between 10 and 24 inches. This small display size requires objects to be shown in miniature and often restricts usage to a single person. Exceptions to this setting are recent considerations of *Virtual Worlds*, in which users get the impression of living in the same space as that which they are manipulating (Jacobson 1995) by wearing head gear in front of their eyes. An alternative is also envisioned with the advent of new hardware technology featuring large-scale displays (Elrod *et al.* 1992), which may take up the size of an entire wall (Negroponte 1995)—three by five meters or more. Interactions with *spatial data* on such devices may provide users with new spatial experiences and enable improved collaboration among users.

This paper explores what a GIS would be like if a wall-sized version were available. Such an environment would be useful for many applications, such as for planners attempting to deal with complex planning requirements for say, an urban renewal scheme, or for electric utility managers who currently rely on huge paper maps mounted on walls. It introduces the concept of a GIS wall

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device, referred to as the *WallBoard*, which allows multiple users to view and interact with a large-scale, touch-sensitive display. The WallBoard is the organizing metaphor for wall-sized GIS devices, much like the desktop is for office applications running on personal computers (Smith *et al.* 1982).

Unlike smaller-scaled devices where a user performs all interactions from more or less the same position and perspective, the WallBoard supports multiple spatial perspectives and experiences. Zubin's (1989) categorization of how humans perceive objects in the physical world includes small objects that can be perceived from a single perspective; objects that are too large to be manipulated with human hands and require scanning with the eyes; and larger objects that need walking through and multiple perspectives in order to be perceived. With current GIS technology, users are only exposed to the first type of experience. The large-scale display of the WallBoard, however, changes how users perceive and interact with spatial information. Where representations of geographic objects, such as buildings or forests, on desktop GISs could be manipulated by human hands and perceived at a single glance, representations of these same geographic objects on the WallBoard may be too large to be perceived from a single perspective and, therefore, require scanning back and forth. In fact, users may now have to step away from the WallBoard to see the big picture. Such experiences may be critical to evaluate correctly a model.

With the guiding principle being ease of use, we endow the WallBoard with a good measure of intelligence. It is assumed that the WallBoard has full multimedia capabilities including sound, graphics, and animation. It also has all the necessary sensors to accommodate multi-modal inputs from gestures, eye-contact, and voice. This may sound fiction today, but work in progress at research labs (Elrod *et al.* 1992; Cassell *et al.* 1994) indicates that such a scenario is not so far away.

This paper continues with a brief analysis of how the WallBoard contributes to collaborative spatial decision-making and presents two sample scenarios utilizing the WallBoard (Section 2). Section 3 describes the design of the WallBoard and Section 4 investigates multi-modal interactions with the WallBoard. The degree to which certain interaction modalities are either possible or not at different ranges from the WallBoard, leads to a categorization of three interaction spaces (Section 5). Section 6 studies GIS interactions—selections, zoom, pan, rotation, navigation—if the user is within an arm's length from the WallBoard. The paper concludes with a discussion of future research.

2. Collaborative Spatial Decision-Making on the WallBoard

Collaborative spatial decision-making, such as that undertaken by a group of planners, can make full use of the capabilities offered by the GIS WallBoard. Planners regularly work together on planning projects and have collaborative needs that are currently not fully satisfied by computer technology (Densham *et al.* 1995). Planners often draw on information retrieved from a wide range of multimedia materials including maps, surveyors' reports, aerial photographs, traffic information, and other miscellaneous audio, video, and verbal information, and often more than one office needs to work off the same version of a spatial data set. Presentations by planners to various groups typically involve verbal, visual, and gestural components. They spread maps out on tables, show slides of before- and after-development scenarios, play sound recordings of noise levels at various locations, and use hand gestures pointing out "where development will take place" or "all of this area will be included" (Shiffer 1995). An intelligent, interactive, wall-mounted device in this context would improve both the collaborative spatial decision-making process and the interactions with an interested audience, as shown by the following two scenarios:

- A group of planners are working together on a proposed development project for a new shopping mall. The large size of the WallBoard allows several persons to be in front of it. As they create different scenarios, users are in close contact with the objects on the wall and manipulate them through the use of gestures and voice. To review their design they may step back to see the full effect. Collaborating at the WallBoard may create a new paradigm of work for planners as they shift from a setting of people in separate offices working on the same

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spatial data set, to collaborative input at the WallBoard. Other co-workers can also contribute to the process by observing from a distance and viewing what is displayed there, while still using gestures or voice to interact.

- One of the above planners gives a presentation to the local council on the proposed development. The planner conducts the entire presentation through manipulations on the WallBoard, making full use of its multimedia capabilities. He or she shows before- and after-images of the proposed development, including an animated movie of a person's view when walking along the site during construction. Buildings or other objects of interest can be added or removed as desired. The council is sitting in front of the WallBoard, in easy viewing distance. When they ask questions they may interact with the WallBoard themselves through gestures such as pointing or, if necessary, a council member may walk up to the WallBoard and, by using markers, he or she may highlight items of importance or suggest changes.

Interaction with the WallBoard should not be seen in isolation from other computing environments. Others may access the GIS operating on the WallBoard from other networked computing devices, and give input as desired.

3. The GIS WallBoard

The size of the WallBoard device could vary—up to the physical size of the wall—but for our purposes we imagine it to be similar to a large, wall-mounted office whiteboard of two by three meters. For the look-and-feel of a WallBoard, we borrow heavily from the metaphor of a whiteboard. Successful user interface designs are often based on a metaphor from a real-world example (Kuhn 1992; Mark 1992). Users expect devices to behave according to what they see and what their experience has taught them to expect from such a design. In this way a user is able to establish a mapping from the familiar to the unfamiliar. This concept builds on natural mappings that take their root in universal physical or cultural standards that are immediately understandable (Norman 1990). For the WallBoard, the familiar domain is the whiteboard, and the unfamiliar is the domain of abstract computer operations on a WallBoard. The whiteboard also provides a rationale for arranging and organizing the various tools to be used in conjunction with the WallBoard. We assume that most users know how to use a whiteboard; therefore, users will find the WallBoard simple and easy to use if it mimics the whiteboard's behavior.

The layout of the WallBoard illustrates the large display area and the tool tray (Figure 1). It has been tailored for geographic collaborative applications, in a fashion similar to the LiveBoard (Elrod *et al.* 1992), a large interactive display system using a cordless pen, to facilitate interactions for generic group meetings and presentations.

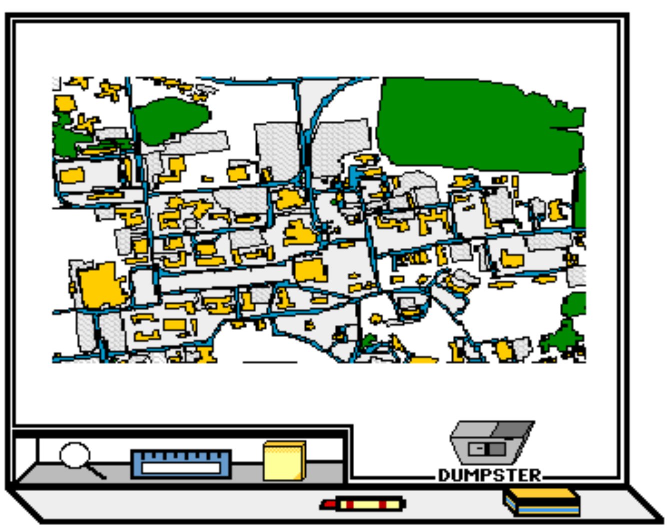

Figure 1: Layout of the WallBoard.

The principal component of the WallBoard is its large display area, where views of spatial scenes are shown as large-scale representations. Users manipulate them through various interaction modalities.

On the tool tray are actual physical objects such as markers and erasers with which the user can draw or erase objects through contact with the WallBoard. Experience from other studies with similar devices points to the success of markers or pens as collaborative tools (Moran *et al.* 1995; Elrod *et al.* 1992). The ability of anyone to approach the WallBoard and pick up a marker to highlight important areas or draw connections between related ideas, greatly enhances the collaborative potential of this device. Markers will need to provide a high degree of positional accuracy, and with a choice of color, they can be used much in the same way as people use different colored markers on a regular whiteboard to confer more meaning and provide for easier interpretation.

Virtual tools are similarly organized on a virtual tool shelf, located just above the tool tray. There may be more than one virtual tool shelf depending on how many tools are available, and users may toggle from one shelf to the next. The virtual tool shelf may include measuring devices to display lengths and areas, and lenses for locally filtering or adding information (Stone *et al.* 1994). One of the virtual tools is a sticky notepad for adhering notes, instructions, or memos to the WallBoard. The markers can be used to write on the sticky pad, and it can be attached or moved to any desired location for easy reference. Users may pick up virtual tools through gestures and move them across the WallBoard to perform an operation. These tools have been chosen in such a way that their design and use is based on real life tools or familiar icons, and so should be clear to most users.

The dumpster is the place to receive any trash—any virtual object the user wants to get rid of is simply put into it. Its functionality corresponds to the trash can on the office desktop, but its appearance was assimilated to the settings of a GIS WallBoard. This was necessary because geographic objects displayed on a WallBoard are generally large and, therefore, do not afford to be put into a trash can. The visualization of the dumpster may have to be adapted when the WallBoard is used in different cultures.

4. Interactions with the GIS WallBoard

WallBoard interactions allow users to concentrate on the tasks at hand, rather than on how to perform operations. They are supported by the WallBoard's rich interaction environment, which senses and interprets multi-modal inputs, much like humans interpret the inputs from other people. For example, if someone approaches, looks us in the eye, and says, "hello," then we know (i.e., sense through sight and sound) that the person is communicating with us and not someone else. Of course, this person may have instead shaken our hand or merely gestured hello by waving from a distance. Regardless, communicating a simple hello can be achieved in a variety of ways. Similarly, the WallBoard allows users to mix and match inputs such as those from gesture, tools, eye contact, voice, and other computing devices, into meaningful expressions.

4.1 Gesture

Gesture is a vital and expressive method for communicating, not only among people, but also between users and the WallBoard. The WallBoard accepts both touch-based gestures where the user physically touches the screen and natural, empty-handed gestures where users communicate through hand or body movements (Wexelblat 1995). Gestures are the primary method for selecting, panning, zooming, rotating, and other manipulations of geographic objects and scenes displayed on the WallBoard.

4.1.1 Touch-based gestures

Touch-based gestures for object or scene manipulations on the WallBoard, utilize a touch-sensitive screen and are based on the direct manipulation metaphor taken from haptic space (Mark 1992). Haptic space is mainly based on people's experiences in the real world through physical contact. Touch-based interactions require extending the metaphor of a whiteboard. For instance, when users rotate a 2-D scene on the WallBoard, they do this much like rotating a paper map in the physical world. This natural mapping from people's haptic space experiences with a paper map onto touch-based interactions on the WallBoard, helps to eliminate what Norman (1990) calls the *gulfs of execution and evaluation.* Touch-based gestures require the user to be close enough to the WallBoard to have direct contact.

4.1.2 Natural, empty-handed gestures

Natural, empty-handed gestures are the type of gestures that people use to complement their daily conversations. For example, when pointing in the direction of a toy box and telling a child, "When you are finished playing with your toys, put them in *there*." Similarly with the WallBoard, users may make a gesture to choose *this* tool from the virtual tool shelf, rather than explicitly stating the tool's name or approaching the WallBoard to physically select it. Some natural, empty-handed gestures like pointing and circling, may borrow intuitively from gestures based on touch; however, empty-handed gestures may occur away from the WallBoard's touch-sensitive screen and do not require any tools such as pointers.

4.2 Tools

Physical and virtual tools simplify interactions with the WallBoard by affording explicit behavior. For instance, pen-based interactions, extended to include colored markers, afford writing and sketching directly on the WallBoard. Whether the tools are physical (markers and erasers) or virtual (lenses and sticky notes), they allow users to concentrate on the task at hand.

4.3 Eye contact

Eye contact is another valuable interaction method, because people use their vision everyday to observe interesting things in the world. It may be important, for example, to know whether a user's gestures are directed toward the WallBoard or toward another person; or identifying to which area of the WallBoard users are referring. Through tracking of head- and eye-movements, the WallBoard senses eye contact on specific areas or objects. This interaction is similar to using a pointing device, though more natural.

4.4 Voice

The most widely used mode of communication between people is voice. Users may speak freely and naturally from anywhere near the WallBoard, and their verbal interactions with the WallBoard are not constrained to a set of commands. Voice will be interpreted independently or in combination with other interaction methods. "Show all cities in Maine with a population greater than 50,000," is one example of an independent natural-language query. However, if the query were, "Show all cities in *this* state with a population greater than 50,000," the natural-language query would need to be augmented through gesture, eye contact or tool-based interaction.

4.5 Computing devices

Computing devices, such as desktop and palm-sized computers, offer alternative methods of interaction with the WallBoard. These devices extend the collaborative process to others in the workplace. For example, users too far away to gesture or to be heard may employ their personal computing devices to interact with the WallBoard, rather than moving closer to it. Such interactions that are initiated from other devices, may include connecting a palm-sized GIS to the WallBoard for direct interaction, like a sketch pad for querying, or downloading data. Additionally, some tasks in the collaborative process, like filing and other administrative duties, may be more appropriate for the desktop metaphor. While the use of such additional devices may interrupt the natural interaction style with the WallBoard, their integration enhances the collaborative process.

4.6 Multi-modal inputs

Multi-modal interactions with the WallBoard combine gesture, tools, eye contact, voice, and computing devices in one way or another. Undoubtedly, people make such combinations, and users of the GIS WallBoard will want to maintain their most natural interactions. For example, the selection of a group of objects may involve touching the desired objects directly; a combination of voice and gesture such as, "Put that there," (Bolt 1980) where a user's gesture delineates which object is to be placed where; or by a combination of voice and tool-based interactions, e.g., when the user sketches an area with a marker and says, “All parcels in *this* area.” Such combinations of modalities may require the integration of interactions from multiple users, such as several users pointing at the same time, or one person pointing while the other gives a verbal instruction.

5. Interaction Spaces

As one moves further away from the WallBoard, the number of interactions available decreases. For example, contact-based pen interactions would be impossible from three meters away. The observation that certain interaction modalities are either impossible or lose their effectiveness at some distance from the WallBoard, leads to a classification of interaction spaces. Feasible interactions for each of the interaction spaces are shown in Table 1.

Interaction Space	Gestures		Tools		Eye contact	Voice	Computing devices
	touch	natural	physical	virtual			
Arm’s length	√	√	√	√	√	√	√
Spitting distance		√	√	√	√	√	√
Within sight							√

Table 1: Interactions in the three interaction spaces.

We refer to these spaces based on a person’s bodily relation to the WallBoard (Figure 2). In order to be able to touch the WallBoard, the user has to be within an *arm’s length* of the WallBoard. Farther away, the user’s gestures must be precise enough to be interpreted with respect to the WallBoard (*spitting distance*). Finally, *within sight* users are essentially observers, relying on vision and hearing, and any interaction with the WallBoard from this zone is through other computing devices. Since the interaction spaces are dependent on bodily relations, the spaces do not scale up with larger meeting rooms, such that for a regular meeting room, only the range of the Within-Sight Space may increase. A small office, on the other hand, may have just Arm's-Length space.

Figure 2: Interaction spaces on the WallBoard.

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5.1 Arm’s length

Within an arm’s length of the WallBoard, users are right up close to the WallBoard, using all of the available interaction methods including gestures, tools, eye contact, voice, and computing devices. The principal and unique interactions in Arm’s-Length Space are those involving gestures and tools. Here the metaphor of a whiteboard affords the use of tool-based interactions and is extended to include interactions through touch.

In the Arm’s-Length Space, objects on the Wallboard may appear much larger than the user’s physical size; therefore, touch-based interactions on the WallBoard may occur differently than those on desktop GISs. For example, positioning a building on a parcel through direct manipulation on a desktop GIS may utilize a snap-dragging technique (Bier 1989), however, such an operation becomes difficult to employ on the WallBoard, where the same building may appear to be two by three meters, and the parcel on which it is to be placed is even larger. Because users are so close to the large display, it becomes difficult for them to gain perspective. In the Arm’s-Length Space, users may be required to move their head back and forth, change their position within the space, or even step away from the WallBoard in order to see the big picture. Therefore, when working in the Arm’s-Length Space, users may frequently shift between spaces over the course of collaboration.

Benefits of interactions in Arm’s-Length Space are attributed to the touch-sensitive screen and its size. Users can interact with representations of geographic objects that are closer to their actual size. Additionally, touch-based gestures allow users to manipulate objects directly, rather than through a pointing device.

5.2 Spitting distance

The second interaction space is within *spitting distance* of the WallBoard. This space is directly behind Arm’s-Length Space, where gestures can still be detected and interpreted by the WallBoard’s sensors. In Spitting-Distance Space, touch-based gestures and most tool-based interactions are no longer possible because users are too far away to reach the touch-sensitive screen. The principal interactions in this space are natural, empty-handed gestures, eye contact, and voice.

In Spitting-Distance Space, objects and scenes still may appear larger than the user, however, the entire WallBoard may be perceived easily by scanning with the eyes. Whereas desktop GISs require users to look into the scene, the large size of the WallBoard, provides users with the feeling that they are actually part of the scene. This consequence provides a more intuitive and natural interaction environment for natural, empty-handed gestures. Additionally, the WallBoard offers a benefit over other environments, such as virtual reality, in that multiple users can view and interact with the same space at the same time, while observing the others' manipulations.

5.3 Within sight

Beyond spitting distance, users are *within sight* of the WallBoard. In this space, displayed information can still be viewed, but because of the physical distance from the WallBoard, the size of objects may appear smaller than a user’s hand. Even if gestures were detectable from this space, they would not be precise enough to be useful; therefore, interactions from this space only occur through other computing devices. A benefit of interacting in the Within-Sight Space is that user’s can observe other collaborators and the WallBoard simultaneously.

6. Operations within an Arm’s Length of the WallBoard

For manipulations on the WallBoard, we focus on some fundamental GIS operations: selecting, zooming, panning, rotating, and navigating through a scene. These examples are to illustrate the nature of WallBoard manipulations in the Arm’s-Length Space. Some of these operations are also possible if users are more remote from the WallBoard, but since they lack the opportunity to directly touch the display, different interaction methods may have to be employed.

6.1 Selection

Users may select spatial objects in a number of ways depending on how close they stand to the WallBoard. Within an arm's length, they may simply point to or touch any spatial object displayed on the WallBoard to select it. This interaction may require users to walk to the other end of the WallBoard, or stretch their arms above their heads. They may select a group of objects through a combination of gesture and voice, for example, "Remove *this* building … and … *this* one," while sequentially touching the objects of choice. Likewise, they may select a set of adjacent objects by drawing a circle around the area with one of the markers such that the enclosed region becomes the selected area (Figure 3a), or through a combined voice and gesture operation such as "Select all parcels *here* zoned as residential," where a user's gesture delineates the area in which parcels are to be selected.

6.2 Zoom

Zooming can be accomplished most easily when within an arm's length of the WallBoard, by using gestures. A pushing gesture towards the WallBoard, mimics pushing away a map, and results in the display zooming out. The opposite action, namely gesturing towards oneself, results in the display zooming in. These gestures are particularly effective for when the user wishes the entire display to be scaled. The zoom operation is to be an intelligent zoom (Frank and Timpf 1994), where more detailed information is brought up and a corresponding change in level of detail in object properties takes place.

To zoom on a part of the entire display, a user first draws a closed figure with a marker or makes an empty-handed gesture around a region of interest. The zoom operation is then performed by gesturing towards or away from the selected area. Although it is limited to the selected region such that the remainder of the WallBoard's display stays unchanged (Figure 3b), the boundary of the zoom area need not be sharp and a fisheye-like zoom operation with more detail in the center and continuously less toward the boundary is feasible.

(a) (b)

Figure 3: Zoom-in operation: (a) before zoom and (b) while zooming.

6.3 Pan

When panning, users change the field of view, while retaining its orientation, scale, and level of detail. Johnson's (1995) evaluation of user preferences for panning on a touch-controlled display indicates that users finds pushing the background easier and more intuitive to use than other methods of panning such as touching the side of the display screen or pushing the view-window over the scene. In the Arm's-Length Space, a user pans by placing his or her palm on the WallBoard and sliding it in the desired direction. The display moves as the pan takes place, giving the user the necessary feedback about the operation.

Panning also applies to selected sub-areas such as the zoom area (Section 6.2), when users move the field-of-view by sliding the zoom area around on the display until it is located over the desired area. Panning is dynamic as the user interacts with the WallBoard, so the user receives immediate feedback that the operation is proceeding satisfactorily. Such selective panning acts much like using a lens or magnifying glass and passing it over an image (Stone *et al.* 1994).

6.4 Rotation

Users change the orientation of entire scenes by rotating them through direct manipulation. They place both hands on the touch-screen display and carry out a rotation motion, turning the image —clockwise or counterclockwise, back and forth (Figure 4). Continuous updates of the rotated scene provide feedback to adjust the scene to the desired orientation. Rotation can be easily combined with panning to allow for more complex, iterative displacements.

(a) (b)

Figure 4: Rotation (a) before and (b) after rotation of the scene.

6.5 Navigation

The WallBoard is large enough to give a user an impression of being part of the displayed environment. With a three-dimensional animation on the WallBoard, a user may select to navigate through the space displayed in order to perceive how the environment changes as he or she moves around. Gestures play an important role in this navigation, as users can use their hands to indicate in which direction they wish to follow (Figure 5). The display keeps pace with the action and changes dynamically as the users moves *through* the view. In this role, the WallBoard is less cumbersome than a virtual reality environment, because the user can navigate without wearing gloves, goggles, or any other special apparatus.

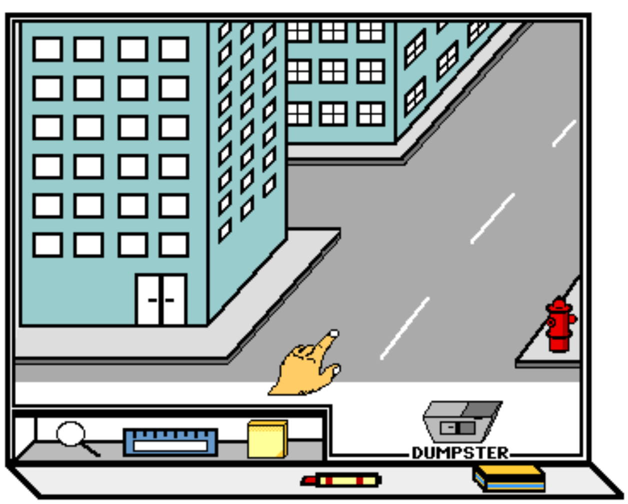

Figure 5: Navigation on the WallBoard.

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7. Conclusions

Having a GIS available on a large-scale, wall-mounted device enables users to interact with geographic information in completely new ways. This paper explored user-interface considerations for the WallBoard, an organizing metaphor for wall-size GIS devices. Basing the design on the metaphor of a whiteboard, affords most users an immediate idea of how the WallBoard can be used. Multi-modal interactions with the WallBoard occur primarily through a combination of gestures, eye-movements, and voice. Different modalities are used depending on how close or remote a user is from the WallBoard. The availability of a certain interaction mode leads to a categorization of interaction spaces, in which users perform different types of tasks. Most challenging is the use of hand gestures to perform some of the most common GIS operations, such as selecting, panning, zooming, but also for such innovative interactions as navigating through an animated 3-dimensional scene. Such interactions are dramatically different from those used for mouse-based panning and zooming on current desktop GISs (Jackson 1990). When users stay further away from the WallBoard, they lack immediate contact with the WallBoard, but still can select objects through gestures and voice. The farther away from the WallBoard, however, the lower the accuracy of their empty-handed gestures. To compensate for distance, remote users may use hand-held pointing devices such as a laser pointer for selection. Instead of contact, the selection of individual objects is made through pointing at the same location for a certain time interval.

We have simulated interactions with a WallBoard through an animated movie on a small-scale display, using MacroMind Director on a Macintosh. Gestures were derived from interactions with a whiteboard. The study was invaluable to identifying the nature of interactions possible with a GIS operating on a wall device, and the enhanced possibilities for collaborative spatial decision-making.

The WallBoard is a spatial technology that provides a framework for studies of innovative GIS interactions, allowing for entirely new approaches to problems. The mere existence of this concept will advance our knowledge of interaction methods with GISs through comparisons with the often-so-limiting constraints of today's GIS desktop environments. At the same time, the WallBoard concept is expected to serve as a framework for specific questions related to multi-modal interactions. The design of the WallBoard is certainly only the starting point and there is a long way to go before prototyping and user testing with a comprehensive scenario. Significant theoretical advancements will be necessary to enable smooth group work with the WallBoard.

Some of the open questions include:

- What hand gestures can be identified sufficiently precise in real-time?
- When do users combine voice and gesture, and how?
- In an experiential space such as the WallBoard, is it desirable to provide simultaneously multiple views, and if so what alternatives to windows integrate well with the WallBoard?
- Which new tools beyond lenses and measuring devices will enable innovative analysis methods on the WallBoard?
- What are the requirements for a spatial database management system to support real-time manipulations on the WallBoard, including choice of data models and data structures?

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