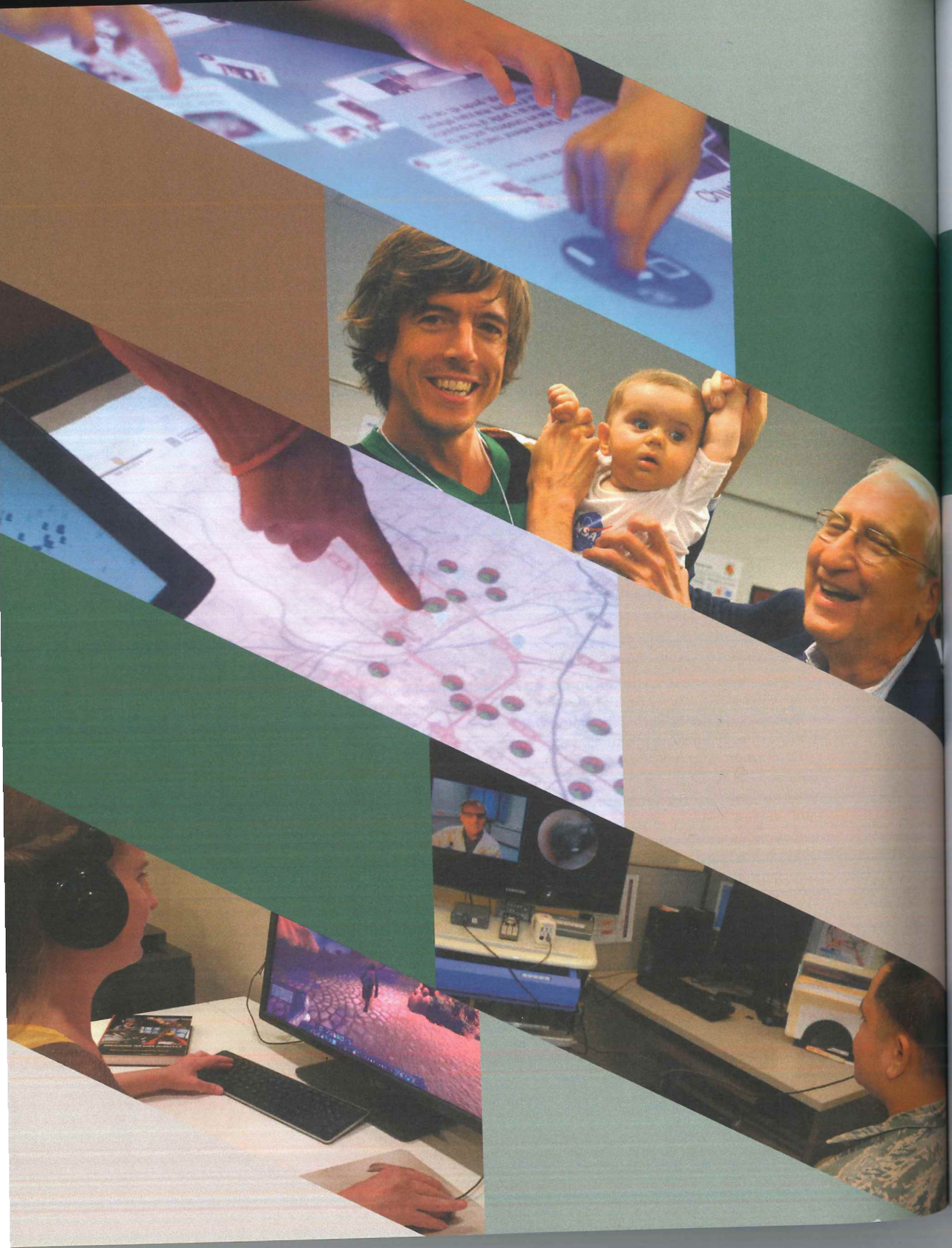

CHAPTER 7

Direct Manipulation and Immersive Environments

> "Leibniz sought to make the form of a symbol reflect its content. 'In signs,' he wrote, 'one sees an advantage for discovery that is greatest when they express the exact nature of a thing briefly and, as it were, picture it; then, indeed, the labor of thought is wonderfully diminished.'"

Frederick Kreiling
"Leibniz," *Scientific American*, May 1968

CHAPTER OUTLINE

7.1 Introduction
7.2 What Is Direct Manipulation?
7.3 Some Examples of Direct Manipulation
7.4 2-D and 3-D Interfaces
7.5 Teleoperation and Presence
7.6 Augmented and Virtual Reality

7.1 Introduction

Certain interactive systems generate a glowing enthusiasm among users that is in marked contrast with the more common reaction of reluctant acceptance or troubled confusion. The enthusiastic users report the following positive feelings:

- Mastery of the interface
- Competence in performing tasks
- Ease in learning originally and in assimilating advanced features
- Confidence in the capacity to retain mastery over time
- Enjoyment in using the interface
- Eagerness to show off the interface to novices
- Desire to explore more powerful aspects

These feelings convey an image of a truly pleased user. The central ideas in such satisfying interfaces, now widely referred to as *direct-manipulation interfaces* (Shneiderman, 1983), are visibility of the objects and actions of interest; rapid, reversible, incremental actions; and replacement of typed commands by a pointing action on the object of interest. Direct-manipulation ideas are at the heart of many contemporary and advanced non-desktop interfaces. Game designers continue to lead the way in creating visually compelling 3-D scenes with characters (sometimes designed and user-created) controlled by novel pointing devices. At the same time, interest in remote-operated (teleoperated) devices has blossomed, enabling operators to look through distant microscopes or fly drones. As the technology platforms mature, direct manipulation increasingly influences designers of mobile devices and webpages. It also inspires designers of information-visualization systems that present thousands of objects on the screen with dynamic user controls (Chapter 16).

Newer concepts that extend direct manipulation include virtual reality, augmented reality, and other tangible and touchable user interfaces. Augmented reality keeps users in the normal surroundings but adds a transparent overlay with information such as the names of buildings or visualizations of hidden objects. Tangible and touchable user interfaces give users physical objects to manipulate so as to operate the interface—for example, putting several plastic blocks near to each other to create an office floor plan. Virtual reality puts users in an immersive environment in which the normal surroundings are blocked out by a head-mounted display that presents an artificial world; hand gestures allow users to point, select, grasp, and navigate. All of these concepts are being applied not only in individual interactions but also in wider artificial worlds, creating collaborative efforts and other types of social-media interactions.

This chapter defines the principles, attributes, and problems of direct manipulation, including a way to categorize direct manipulation (Section 7.2). Some examples of direct-manipulation use are provided in Section 7.3. Section 7.4 discusses 2-D and 3-D interfaces. Teleoperation and presence are covered in Section 7.5. Lastly, augmented and virtual reality are discussed Section 7.6. Although the tenets of direct manipulation still hold true, regardless of the sophistication of the technology, the technology in this chapter is advancing rapidly. The references for this chapter include a combination of books and articles. The articles are taken from the recent conference proceedings showing some of the innovations and interesting projects being developed in research labs of industries and academia. Many pundits and popular press sources (Kushner, 2014; Kofman, 2015; Metz, 2015; Mims, 2015; Stein, 2015) feel the time for virtual and augmented reality is now. Researchers are looking into the theoretical challenges and opportunities in virtual worlds (de Castell et al., 2012) and continuing to improve upon the gaming experience (Kulshreshth and LaViola, 2015).

See also:
Chapter 10, Devices
Chapter 16, Data Visualization

7.2 What Is Direct Manipulation?

Direct manipulation as a concept has been around since before computers. The metaphor of direct manipulation works well in computing environments and was introduced in the early days of Xerox PARC and then widely disseminated by Shneiderman (1983). Direct-manipulation designs can provide the capability for differing populations and easily stretch across international boundaries. Section 7.2.1 explains the three principles of direct manipulation and advantages of using direct manipulation. Section 7.2.2 provides a way of discussing direct manipulation using a translational concept of strength. Section 7.2.3 discusses some problems with direct manipulation. Section 7.2.4 discusses the continuing evolution of direct manipulation.

A favorite example of direct manipulation is driving an automobile. The scene is directly visible through the front window, and performance of actions such as braking and steering has become common knowledge in our culture. To turn left, for example, the driver simply rotates the steering wheel to the left. The response is immediate and the scene changes, providing feedback to refine the turn. Now imagine how difficult it would be trying to accurately turn a car by typing a command or selecting "turn left 30 degrees" from a menu. The graceful interaction in many applications is due to the increasingly elegant application of direct manipulation. Although there is lively discussion on the

impact of driverless cars and their uses, research still continues. Driverless cars may soon respond to commands like "take me to Baltimore airport," but they are a long way from matching the skills of drivers at the wheel while navigating snow-covered roads or police hand signals at accident sites.

Before designing for current devices, it makes sense to reflect where early design has been. In the early days of office automation, there was no such thing as a direct-manipulation word processor or a presentation system like PowerPoint. Word processors were command-line–driven programs where the user typically saw a single line at a time. Keyboard commands were used along with inserting special commands to provide instructions for viewing and printing the documents often as a separate operation. Similarly, with presentation programs, specialized commands were used to set the font style, color, and size. Obviously, these were very limited compared to the numerous font families available today. Most users today are used to a WYSIWYG (What You See Is What You Get) environment enhanced by direct-manipulation widgets.

7.2.1 The three principles and attributes of direct manipulation

The attraction of direct manipulation is apparent in the enthusiasm of the users. The designers of the examples, provided in Section 7.3, had an innovative inspiration and an intuitive grasp of what users would want. Each example has problematic features, but they demonstrate the potent advantages of direct manipulation, which can be summarized by three principles:

1. Continuous representations of the objects and actions of interest with meaningful visual metaphors
2. Physical actions or presses of labeled interface objects (i.e., buttons) instead of complex syntax
3. Rapid, incremental, reversible actions whose effects on the objects of interest are visible immediately

Simple metaphors or analogies with a minimal set of concepts—for example, pencils and paintbrushes in a drawing tool—are a good starting point. Mixing metaphors from two sources may add complexity that contributes to confusion. Also, the emotional tone of the metaphor should be inviting rather than distasteful or inappropriate. Since the users are not guaranteed to share the designer's understanding of the metaphor, analogy, or conceptual model used, ample testing is required.

Using these three principles, it is possible to design systems that have these beneficial attributes:

- Novices can learn basic functionality quickly, usually through a demonstration by a more experienced user.
- Experts can work rapidly to carry out a wide range of tasks, even defining new functions and features.

- Knowledgeable intermittent users can retain operational concepts.
- Error messages are rarely needed.
- Users can immediately see whether their actions are furthering their goals, and if the actions are counterproductive, they can simply change the direction of their activity.
- Users experience less anxiety because the interface is comprehensible and because actions can be reversed easily.
- Users gain a sense of confidence and mastery because they are the initiators of action, they feel in control, and they can predict the interface's responses.

In contrast to textual descriptors, dealing with visual representations of objects may be more "natural" and in line with innate human capabilities: Action and visual skills emerged well before language in human evolution. Psychologists have long known that people grasp spatial relationships and actions more quickly when they are given visual rather than linguistic representations. Furthermore, intuition and discovery are often promoted by suitable visual representations of formal mathematical systems.

7.2.2 Translational distances with direct manipulation

The effectiveness and reality of the direct-manipulation interface are based on the validity and strength of the metaphor chosen to represent the actions and objects. Using familiar metaphors creates easier learning conditions for users and lessens the number of mistakes and incorrect actions. Adequate testing is needed to validate the metaphor. Special attention needs to be paid to the user characteristics such as age, reading level, educational background, prior experiences, and any physical disabilities.

One way of trying to understand and categorize the direct-manipulation metaphor is by looking at the *translational distance* between users and the representation of the metaphor, which will be referred to as strength. Strength can be perceived along a continuum from weak to immersive (See Box 7.1). This can be further described as the level of indirectness between the user's physical actions and the actions in the virtual space.

BOX 7.1

Examples of translational distances (strength).

- Weak—early video game controllers (Fig. 7.5)
- Medium—touchscreens, multi-touch (Fig. 7.1)
- Strong—data glove, gesturing, manipulating tangible objects (Fig. 7.2)
- Immersive—virtual reality, i.e, oculus rift (Fig. 7.14)

Weak direct manipulation is what can be described as basic direct manipulation. There is a mouse, trackpad, joystick, or similar device translating the user's physical action into action in the virtual space using some mapping function. The translational difference is large because interaction is completely indirect. For example, the user moves the mouse on a 2-D desk within a small circumscribed region and the mouse moves on the screen (again 2-D). Because this mapping function is not always fully understood and processed correctly by the user, sometimes the user will actually run the mouse off the surface of the desk. Weak direct manipulation was used with early game controllers that provided buttons and joysticks, where the action of the controllers needed to be learned explicitly by the players.

Medium direct manipulation is the next step moving along the continuum. The translational distance is reduced. Instead of communicating with the virtual space with the device, the user reaches out and touches, moves, and grabs the entities in the on-screen representation. Examples of this include touchscreens (mobile, kiosk, and desktop). This is still limited by the glass of the screen; the world is beyond the glass. This direct-manipulation strength supports pointing

FIGURE 7.1
Three users working concurrently on a large tabletop touch device. They can use their hands/figures to manipulate the objects on the device. Note the different hand gestures being used. (www.reflectivethinking.com)

and tapping, but other activities that would include the third dimension, like reaching into the device, cannot be accommodated by the simple metaphor. Instead, creating these other actions requires stepping outside the metaphor with a new artifact such as double-tap and assigning a corresponding action to it. This again requires learning on the user's part. Multi-touch (Fig. 7.1) allows new actions to be assigned to various combinations of finger touches. The two-finger actions like zoom in/out are intuitive, but others must be learned and take longer to discover. This accounts for why a young child can easily learn to tap, change screens, and touch on a tablet (the intuitive actions) but doesn't have the skills to rearrange the icons on the screen (the learned actions).

Strong direct manipulation involves actions such as gesture recognition with various body parts. It may be the user's hand, foot, head, or full body (whatever controls the action) that is "virtually" placed inside the physical space (Fig. 7.2). The users can see their hand in the 3-D space and can grasp, throw, drop,

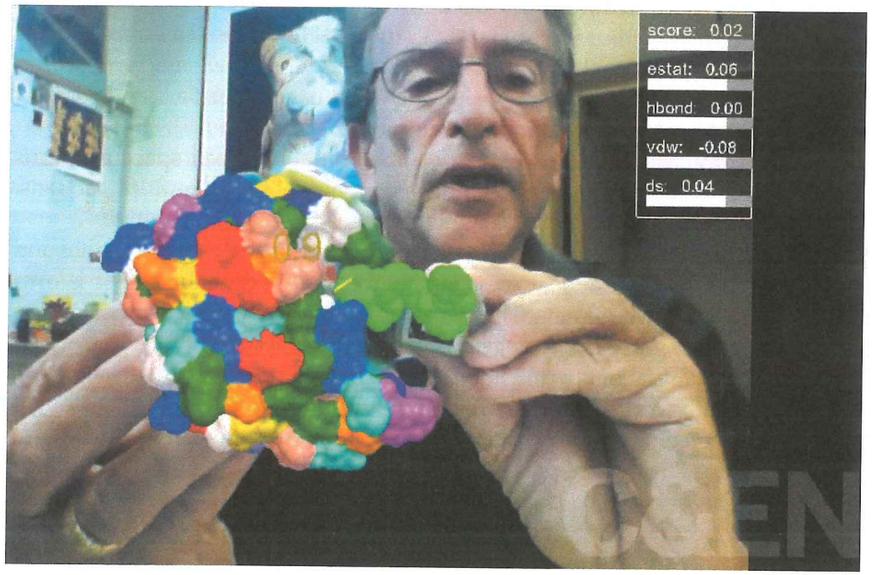

FIGURE 7.2
A tangible user interface for molecular biology, developed in Art Olson's Laboratory at the Scripps Research Institute, utilizes autofabricated molecular models tracked with the Augmented Reality Toolkit from the University of Washington Human Interface Technology Lab. The video camera on the laptop captures the molecule's position and orientation, enabling the molecular modeling software to display information such as the attractive/repulsive forces surrounding the molecule.

manipulate, and so forth. The users themselves still remain on the outside looking in. This works well when the spaces are small and simple, but when the spaces get bigger, the users need to move themselves outside the initial metaphor and enter another mode, such as move mode, and then traverse to the new region. See Chapter 10 for more on devices.

The notion of tangible and immersive user interfaces—in which users grasp physical objects to manipulate a graphical display that represents the object are becoming quite popular. Tangible devices use haptic interaction skills to manipulate objects and convert the physical form to a digital form (Ishii, 2008).

The last dimension is *immersive* direct manipulation. Here is where direct manipulation is combined with virtual reality (see Section 7.6). The users put on glasses or some other device and they are inside the space. The users can see themselves and can walk/fly through the space by walking, leaning in, and so forth—the scenery changes with the moves.

7.2.3 Problems with direct manipulation

Graphical user interfaces were a setback for vision-impaired users, who appreciated the simplicity of linear command languages. However, screen readers for interfaces, speech-enabled devices, page readers for browsers, and audio designs for mobile devices enable vision-impaired users to understand some of the spatial relationships necessary to achieve their goals.

Direct-manipulation designs may consume valuable screen space and thus force valuable information off-screen, requiring scrolling or multiple actions. This is an issue in the mobile world, where screen space is very limited.

Another issue is that users must learn the meanings of visual representations and graphic icons. Titles that appear on icons (flyover help) when the cursor is over them offer only a partial solution. The visual representation may sometimes be misleading. Users may grasp the analogical representation rapidly but then may draw incorrect conclusions about permissible actions, overestimating or underestimating the functions of the computer-based analogy. Ample testing must be carried out to refine the displayed objects and actions and to minimize negative side effects.

For experienced typists, taking a hand off the keyboard to move a mouse or point with a finger may take more time than typing the relevant command. This problem is especially likely to occur if the users are familiar with a compact notation, such as for arithmetic expressions, that is easy to enter from a keyboard but may be more difficult to select with a mouse. While direct manipulation is often defined as replacing typing of commands with pointing with devices, sometimes the keyboard is the most effective direct-manipulation device. Rapid keyboard interaction can be extremely attractive for expert users, but the visual feedback must be equally rapid and comprehensible.

Small mobile devices have limited screen sizes. A finger pointing at a device may partially block the display, rendering a good portion of the device not visible. Also, if the icons are small because of the limited screen size, they may be hard to select or, because of limited resolution and viewing capabilities (especially for older adults), not clearly distinguishable, resulting in their meanings becoming lost or confused.

Some direct-manipulation principles can be surprisingly difficult to realize in software. Rapid and incremental actions have two strong implications: a fast perception/action loop (less than 100 ms) and reversibility (the undo action). A standard database query may take a few seconds to perform, so implementing a direct-manipulation interface on top of a database may require special programming techniques. The undo action may be even harder to implement, as it requires that each user action be recorded and that reverse actions be defined. It changes the style of programming because a nonreversible action is implemented by a simple function call whereas a reversible action requires recording the inverse action.

7.2.4 The continuing evolution of direct manipulation

A successful direct-manipulation interface must present an appropriate representation or model of reality. With some applications, the jump to visual language may be difficult, but after using visual direct-manipulation interfaces, most users and designers can hardly imagine why anyone would want to use a complex syntactic notation to describe an essentially visual process. It is hard to conceive of learning the commands for the vast number of features in modern word processors, drawing programs, or spreadsheets, but the visual cues, icons, menus, and dialog boxes make it possible for even intermittent users to succeed. See Box 7.2 for a summary of the advantages and disadvantages of direct manipulation.

BOX 7.2

Advantages and disadvantages of direct manipulation.

Direct Manipulation

Advantages	Disadvantages
• Visually presents task concepts	• May be hard to program
• Allows easy learning	• Accessibility requires special attention
• Allows easy retention	
• Allows errors to be avoided	
• Encourages exploration	
• Affords high subjective satisfaction	

Users are trying to better understand all the data and other visual content that are now available. One way to manage this information is through the use of a *dashboard* (Few, 2013). Being able to see a large volume of information (big data) at one time and to directly manipulate it and observe the impact visually is a powerful concept. Businesses and companies are bombarded by volumes of data every day. The ability to organize this user-generated data into a useful graphical format can help them manage resources and spot trends (Chapter 16). Dashboards provide ways for users to manipulate data using the various widgets provided. Companies such as Tableau Software, SAP Lumira, and IBM Cognos provide this capability as do smaller user-oriented companies like dashboardsbyexample.

Weiser's (1991) influential vision of ubiquitous computing described a world where computational devices were everywhere—in your hands, on your body, in your car, built into your home, and pervasively distributed in your environment. The 1993 special issue of *Communications of the ACM* (Wellner et al., 1993) showed provocative prototypes that refined Weiser's vision. It offered multiple visions of beyond-the-desktop designs that used freehand gestures and small mobile devices whose displays changed depending on where users stood and how they pointed the devices. Almost 25 years later, Weiser's full vision has not yet been realized, but the social-media aspect of ubiquitous computing has blossomed.

Touchable displays from the small to the large (as large as wall size [Figs. 10.20 and 10.21] or even mall size) are becoming available as well. Interaction is all accomplished without users entering a long string of commands; instead, users physically manipulate the items of interest with their hands. An application of this is often seen on news programs, where the commentator can move the objects of interest on the screen and drill down to more detailed levels. Another application is virtual maps, which can be manipulated and zoomed by using hand motions as a multi-touch interface (Han, 2005). On a touchable display, interactions with both hands seem quite natural (although with small displays, issues of occlusion can be problematic).

There will certainly be many future variations of and extensions to direct manipulation, but the basic goals will remain similar: comprehensible interfaces that enable rapid learning, predictable and controllable actions, and appropriate feedback to confirm progress. Direct manipulation has the power to attract users because it is rapid, and even enjoyable. If actions are simple, reversibility is ensured, retention is easy, anxiety recedes, users feel in control, and satisfaction flows in.

7.3 Some Examples of Direct Manipulation

No single interface has every admirable attribute or design feature—such an interface might not be possible. Each of the examples discussed here, however, has sufficient features to win the enthusiastic support of many users.

7.3.1 Geographical systems including GPS (global positioning systems)

For centuries, travelers have relied on maps and globes to better understand the Earth and geographical systems. As graphic- and image-capture capabilities increased (both real-world and human-generated), it was a natural progression to create systems to represent both a current location—"where we are"—and a target location—"where we want to go." Of course, as prices dropped, these types of systems became available as commercial GPS systems for cars, for walking, and even for the mobile phone. Being able to directly see the alternatives on the devices as well as how to move from the current location to the target location including manipulating the routes is another application of direct manipulation.

Google Maps™, MapQuest, Google Street View, Garmin, National Geographic, and Google Earth™ combine geographic information from aerial photographs, satellite imagery, and other sources to create a vast database of graphical information that can easily be viewed and displayed. In some areas, the detail can go down to an individual house on a street or even inside a building (Fig. 7.3). With the well-populated databases of geographic *points of interest*, these systems provide an easy-to-use facility to point and select the nearest gas station or specific type of restaurant. Some systems provide real-time traffic to facilitate alternative routing in traffic-laden situations.

FIGURE 7.3
This is a screenshot from Google Street View of the inside of the University Center at Nova Southeastern University in Florida. On the bottom is a scrollable image of other views on campus. In the bottom left corner is a more conventional static map showing the physical street location of the campus. Users can move the "person" to a different location on campus, and the views will change accordingly.

7.3.2 Video games

For many people, the most exciting, well-engineered, and commercially successful application of the direct-manipulation concepts lies in the world of video games. The early but simple and popular game *Pong*® (created in 1972) required the user to rotate a knob that moved a white rectangle on the screen. A white spot acted as a ping-pong ball that ricocheted off the wall and had to be hit back by the movable white rectangle. Users developed speed and accuracy in placing the "paddle" to keep the increasingly speedy ball from getting past, while the computer speaker emitted a ponging sound when the ball bounced. Watching someone else play for 30 seconds is all the training that a person needs to become a competent novice, but many hours of practice are required to become a skilled expert. The interface objects were a single paddle, a ball, a single player, and some rudimentary sound. Games have come a long way with various controls, including full body, multiple objects of interest (both good and evil), full stereo sounds, detailed graphical environments, changing backgrounds, and the possibility of multiple players sitting physically next to one another or virtually across the globe.

Some cataloguers state that we are in the eighth generation of video games. Parkin (2014) provides an illustrated history of five decades of video games. Last generation's Nintendo Wii, Sony PlayStation 3, and Microsoft Xbox 360™ have given way to this generation's Nintendo Wii U, Sony PlayStation 4, and Microsoft Xbox One in a very short time, and continued advances are expected. These gaming platforms have brought powerful 3-D graphics hardware to the home and have created a remarkable international market. Gaming experiences are being enhanced by combining 3-D user-interface technologies, such as stereoscopic 3-D, head tracking, and finger-count gestures (Kulshreshth and LaViola, 2015). For a detailed survey of visual, mixed, and augmented reality gaming, refer to Thomas (2012).

Wildly successful games include violent first-person shooters, fast-paced racing games, and more sedate golfing games. Small handheld game devices still exist, but now users are playing games on their phones and other mobile devices. Multi-player games on the internet have also caught on with many users providing the additional opportunity for social encounters and competitions. Gaming magazines and conferences attest to the widespread interest. In Rochester, New York, part of the Museum of Play houses the International Center for History of Electronic Games (http://www.museumofplay.org/icheg).

There is a wide genre of games, and the borders between genres are becoming blurred. Some games are single-player games; others have multiple players. For a list of gaming genre acronyms, see Box 7.3. Players can be in the same physical space or a different physical space but shared virtual space. Players themselves can be virtual. For a more complete taxonomy of gaming systems, see Pagulayan et al. (2012). In conducting research with player performance and

BOX 7.3

Gaming genre acronyms.

The computer world is filled with a list of gaming genre acronyms. Some of the more widely used acronyms include:

- AA—action adventure games
- ARPG—action role play games
- FPR—first-person shooter
- MMORPG—massively multi-player online role-playing games
- MOBA—massive online battle arena
- RPG—role-playing games
- RTS—real-time shooter

experience, the games with multiple players seem to hold more interest in the social connection with others, teamwork, and collaboration. The single-player games seem to focus more on the game narrative and the characters, and players show more interest in the degree of immersion (Johnson et al., 2015).

Game environments provide intriguing, successful applications of 3-D representations. These include first-person action games in which users patrol city streets or race down castle corridors while shooting at opponents as well as role-playing fantasy games with beautifully illustrated island havens or mountain strongholds. Many games are socially enriched by allowing users to choose avatars to represent themselves. Users can choose avatars that resemble themselves, but often they choose bizarre characters or fantasy images with desirable characteristics such as unusual strength or beauty (Boellstorff, 2008).

Some web-based game environments may involve millions of users and thousands of user-constructed "worlds," such as schools, shopping malls, or urban neighborhoods. Game devotees may spend dozens of hours per week immersed in their virtual worlds, chatting with collaborators or negotiating with opponents. *World of Warcraft* (developed and published by Blizzard Entertainment) has been the mainstay and most popular of the MMORPG games with more than 5.6 million subscribers as of 2015 (Fig. 7.4). New games are constantly hitting the market, and the competition is fierce. A relatively new entry to the market (2012), *Guild Wars 2* (developed by Arena Net and published by NCsoft) already has sold more than 5 million copies. This game is slightly different from other MMORPG games because the game is responsive to individual player actions, which is more common in single-player role-playing games.

The Nintendo Wii, introduced in 2006, changed the demographics of the gaming world. Instead of young children (typically boys), older adults were using the

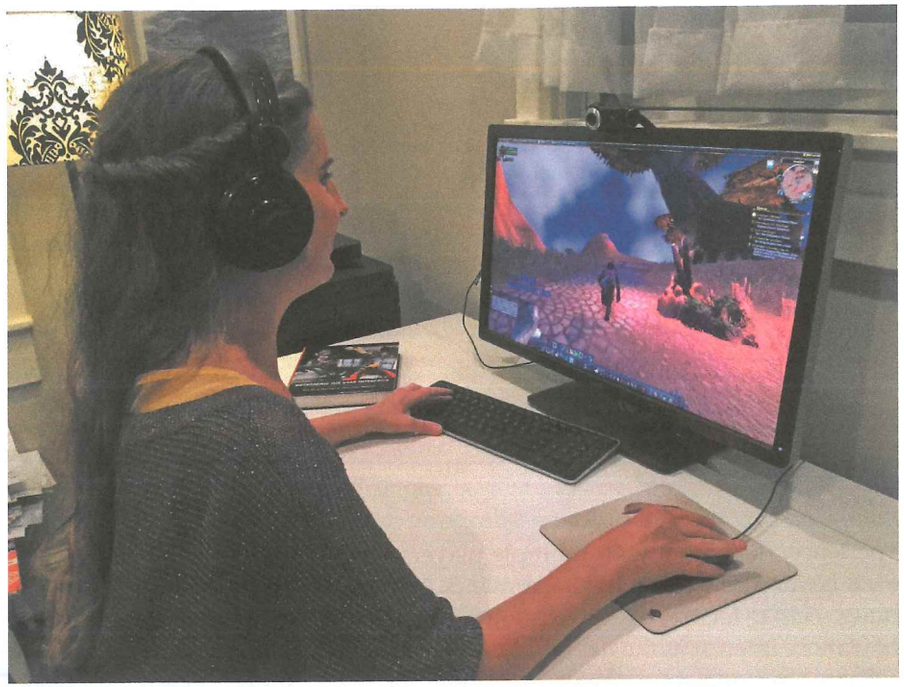

FIGURE 7.4
A woman playing *World of Warcraft*. She is using both her keyboard and mouse. She also can hear the sounds of the game via her headset.

Wii to play games like tennis and bowling. It also became an early fitness/wellness platform. With the introduction of the Kinect by Microsoft for Xbox in 2010 and then for Windows in 2012, more worlds opened up, and with a software development kit (SDK), developers can create their own worlds. These interfaces have been referred to as a *natural* user interface because the entire body can be used, but the possible actions still remain limited and need to be learned. The early Wii controller was modified with the addition of a wrist strap, since gamers were so immersed in play they sometimes accidentally hurled the controller at the screen. There is no syntax to remember, and therefore there are no syntax-error messages. Error messages in general are rare because the results of actions are obvious and can be reversed easily: If users move themselves too far to the left, they merely use the natural inverse action of moving back to the right. These principles, which have been shown to increase user satisfaction, could be applied to other environments. Examples of various game controllers are shown in Fig. 7.5. Customized controllers exist for games such as *Guitar Hero* (Fig. 1.8), flight control (Fig. 10.9), and Leap Motion (Fig. 10.16).

FIGURE 7.5
Various game controllers. Some are very specific and include a steering wheel or joystick; others use a series of buttons and direction arrows. The Wii Controller with the wrist strap is shown in the upper right corner. Although these game controllers do provide direct-manipulation actions, users still have to learn the meaning of the various buttons.

Most games continuously display a numeric score so that users can measure their progress and compete with their previous performance, with friends, or with the highest scorers. Typically, the 10 highest scorers get to store their initials in the game for public display. This strategy provides one form of positive reinforcement that encourages mastery. Studies with elementary-school children have shown that continuous display of scores is extremely valuable. Machine-generated feedback—such as "Very good" or "You're doing great!"—

is not as effective, since the same score carries different meanings for different people. Most users prefer to make their own subjective judgments and perceive the machine-generated messages as an annoyance and a deception. Providing this combination of behavioral data and attitudinal data adds to the immersion quality of the game (Pagulayan et al., 2012).

Although the marketing focus and consumer popularity have concentrated on action-type games, there are other game environments, and gaming (or gamification) has become a popular metaphor used in training and evaluation. Simulation and educational games abound. Games have been developed for young children (pre-readers) where the intuitiveness of the icons and real-world–type interfaces (buttons, sliders, finger pointing, etc.) control the game. Females seem more interested in role-playing games and games with narratives. A whole new generation of female gamers now exists. Games are also used for wellness benefits (Calvo and Peters, 2014; Jones et al., 2014). Researchers are trying to better understand how users think and get into their *flow state* (Csikszentmihalyi, 1990; Ossola, 2015). Gaming can be used to learn and enhance physical skills, modify behaviors, and increase wellness. Although there are some negative implications of gaming, McGonigal (2011) offers some rules for the positive impact of gaming: limit yourself to no more than 21 hours a week; play games face to face with friends and family; and play cooperative games or games that have a creator mode.

Studying game design is fun (Lecky-Thompson, 2008), but there are limits to the applicability of the lessons. Game players are engaged in competition with the system or with other players, whereas applications-systems users prefer a strong internal locus of control, which gives them the sense of being in charge. Likewise, whereas game players seek entertainment and focus on the challenge, application users focus on their tasks and may resent too many playful distractions. The random events that occur in most games are meant to challenge the users; in non-game designs, however, predictable system behavior is preferred. Throughout this book, we discuss the user experience (UX); the gaming world now designs for the player experience (PX). Research is continuing with the development of a growing set of metrics to measure PX (Johnson et al., 2015). Additional research is ongoing in the quantification and evaluation of playfulness providing meaningful and memorable experiences (Lucero et al., 2014).

Courses and majors (or minors) in video game design exist. Some are in computer science departments, but others show the more interdisciplinary nature of the subject and can be found in media design, visual communication, and art departments. The important take-away is to use clear affordances, good instructions, and informative feedback; limit the complexity; and be aware of human variability (Fisher et al., 2014). All these are basic tenets of HCI design as described in Section 3.3.4 (The Eight Golden Rules of Interface Design).

7.3.3 Computer-aided design and fabrication

Most computer-aided design (CAD) systems for automobiles, electronic circuitry, aircraft, or mechanical engineering use principles of direct manipulation. Building and home architects now have at their disposal powerful tools, provided by companies such as Autodesk, that provide components to handle structural engineering, floor plans, interiors, landscaping, plumbing, electrical installation, and much more. With such applications, the designer may see a circuit schematic on the screen and, with mouse clicks, be able to move components into or out of the proposed circuit. When the design is complete, the computer can provide information about current, voltage drops, and fabrication costs and warnings about inconsistencies or manufacturing problems. Similarly, newspaper-layout artists or automobile-body designers can easily try multiple designs in minutes and can record promising approaches until they find even better ones. The pleasure of using these systems stems from the capacity to manipulate the object of interest directly and to generate multiple alternatives rapidly.

There are large manufacturing companies using AutoCAD® and similar systems, but there are also other specialized design programs for kitchen and bathroom layouts, landscaping plans, and other homeowner-type situations. These programs allow users to control the angle of the sun during the various seasons to see the impact of the landscaping and shadows on various portions of the house. They allow users to view a kitchen layout and calculate square footage estimates for floors and countertops and even print out materials lists directly from the software. Some of the players in the field of interior-design software for residential and commercial markets include Floored, Inc. (Fig. 7.6), 2020 Spaces, and Home Designer Software. Their products are designed to work across multiple environments, desktop to web; they provide various views (top-down, architectural, front-view) to generate a more realistic overview of the design for the client.

Related applications are for computer-aided manufacturing (CAM) and process control. Honeywell's Experion® Process Knowledge System Orion provides the manager of an oil refinery, paper mill, or power-utility plant with a colored schematic view of the plant. The schematic may be displayed on multiple displays or on a large wall-sized map, with red lines indicating any sensor values that are out of the normal range. With a single click, the operator can get a more detailed view of the troubling component; with a second click, the operator can examine individual sensors or can reset valves and circuits. A basic strategy for this design is to eliminate the need for complex commands that the operator might need to recall only during a once-a-year emergency. The visual overview provided by the schematic facilitates problem solving by analogy because the linkage between the screen representations and the plant's temperatures or pressures is so close. The latest version of this software provides capabilities for

FIGURE 7.6
An office space layout from a company called Floored, Inc. This 3-D virtual CAD representation helps designers lay out office space. Items can be moved around between and within rooms; the design will be re-created to reflect any changes (http://www.floored.com).

virtualization and cloud support and includes customized dashboards to show status.

Another emerging use of direct manipulation involves home automation. Since so much of home control involves floor plans, direct-manipulation actions naturally take place on a display of the floor plan with selectable icons for each status indicator (such as a burglar alarm, heat sensor, or smoke detector) and for each activator (such as controls for opening and closing curtains or shades, for air conditioning and heating, or for audio and video speakers or screens). For example, users can route a recorded TV program being watched in the living room to the bedroom and kitchen by merely dragging the on-screen icon into those rooms, and they can adjust the volume by moving a marker on a linear scale. The action is usually immediate and visible and can be easily reversed as well.

With the advent of these types of systems, not only are graphical, sophisticated 3-D displays generated, but with 3-D printing technology, actual workable models can be generated. These models provide a more realistic view for clients and customers. These models can include an overall outside view or even be broken down to show component parts if necessary. The cost saving of these models versus building the actual structure or device can be enormous coupled

FIGURE 7.7
Astronaut Bruce Wilmore onboard the International Space Station with the ratchet wrench that was created with Made in Space's 3-D printer. This device was designed, qualified, tested, and printed in space in less than one week.

with the ease for incremental or larger modification or changes. 3-D printers have been installed on the NASA space station, where actual parts can be fabricated (Fig. 7.7).

7.3.4 Direct-manipulation programming and configuration

Performing tasks by direct manipulation is not the only goal. It should be possible to do programming by direct manipulation as well, at least for certain problems. How about moving a drill press or a surgical tool through a complex series of motions that are then repeated exactly? Automobile seating positions and mirror settings can be set as a group of preferences for a particular driver and then adjusted as the driver settles in place. Likewise, some professional television-camera supports allow the operator to program a sequence of pans or zooms and then to replay it smoothly when required.

Programming of physical devices by direct manipulation seems quite natural, and an adequate visual representation of information may make direct-manipulation programming possible in other domains. Spreadsheet packages such as Excel™ have rich programming languages and allow users to create

portions of programs by carrying out standard spreadsheet actions. The result of the actions is stored in another part of the spreadsheet and can be edited, printed, and stored in a textual form. Database programs such as Access™ allow users to create buttons that when activated will set off a series of actions and commands and even generate a report. Similarly, Adobe Photoshop records a history of user actions and then allows users to create programs with action sequences and repetition using direct manipulation.

It would be helpful if the computer could recognize repeated patterns reliably and create useful macros automatically while the user was engaged in performing a repetitive interface task. Most cellphones have buttons that can be programmed to call home or call the doctor or another emergency number. This allows the user to encounter a simpler interface and be shielded from the details of the tasks.

7.4 2-D and 3-D Interfaces

Some designers dream about building interfaces that approach the richness of 3-D reality. They believe that the closer the interfaces are to the real world, the easier usage will be. This extreme interpretation of direct manipulation is a dubious proposition, since user studies show that disorienting navigation, complex user actions, and annoying occlusions can slow performance in the real world as well as in 3-D interfaces (Cockburn and McKenzie, 2002). Many interfaces (sometimes called 2-D interfaces) are designed to be simpler than the real world by constraining movement, limiting interface actions, and ensuring visibility of interface objects. However, the strong utility of "pure" 3-D interfaces for medical, architectural, product design, and scientific visualization purposes means that they remain an important challenge for interface designers. So the power of 3-D interfaces lies in applying them in the appropriate domain or context where the added dimension provides more understanding and improves task outcomes.

An intriguing possibility is that "enhanced" interfaces may be better than 3-D reality. Enhanced features might enable outside of real human capabilities, such as faster-than-light teleportation, flying through objects, multiple simultaneous views of objects, and x-ray vision. Playful game designers and creative applications developers have already pushed the technology further than those who seek merely to mimic reality.

For some computer-based tasks—such as medical imagery (Fig. 7.8), architectural drawing, computer-assisted design, chemical-structure modeling (Fig. 7.2), and scientific simulations—pure 3-D representations are clearly helpful and have become major industries. However, even in these cases, the successes are often due to design features that make the interface better than reality.

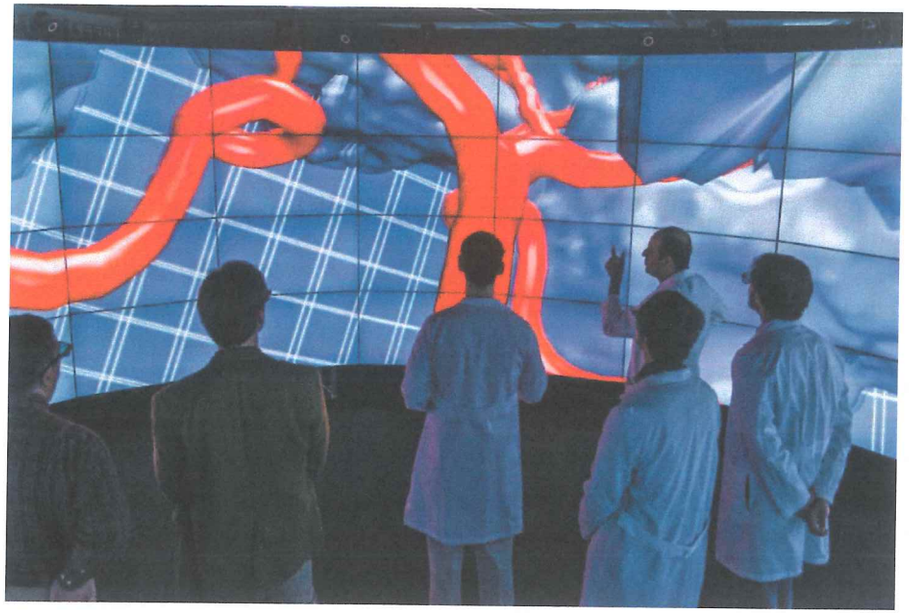

FIGURE 7.8
By using a medical simulation inserted into a large-scale visualization (using CAVE technology), physicians were able to find a solution that would not have been possible with the actual surgery. (http://www.nsf.gov/news/news_summ.jsp?cntn_id=126209)

Users can magically change colors or shapes, duplicate objects, shrink/expand objects, group/ungroup components, send them by various electronic means, and attach floating labels. Users can go back in time and even undo recent actions.

Among the many innovations, there have been questionable 3-D prototypes, such as for air-traffic control (showing altitude by perspective drawing only adds clutter when compared to an overview from directly above), digital libraries (showing books on shelves may be nice for browsing, but it inhibits searching and linking), and file directories (showing tree structures in three dimensions sometimes leads to designs that increase occlusion and navigation problems). Other questionable applications include ill-considered 3-D features for situations in which simple 2-D representations would do the job. For example, adding a third dimension to bar charts may slow users and mislead them (Hicks et al., 2003), but they are such an attraction for some users that they are included in most business graphics packages (Cognos, SAS/GRAPH, SPSS/SigmaPlot).

A modest use of 3-D techniques is to add highlights to 2-D interfaces, such as buttons that appear to be raised or depressed, windows that overlap and leave shadows, or icons that resemble real-world objects. These may be enjoyable, recognizable, and memorable because of improved use of spatial memory, but

they can also be visually distracting and confusing because of additional visual complexity.

This enumeration of features for effective 3-D interfaces might serve as a checklist for designers, researchers, and educators:

- Use occlusion, shadows, perspective, and other 3-D techniques carefully.
- Minimize the number of navigation steps required for users to accomplish their tasks.
- Keep text readable (better rendering, good contrast with background, and no more than 30-degree tilt).
- Avoid unnecessary visual clutter, distraction, contrast shifts, and reflections.
- Simplify user movement (keep movements planar, avoid surprises like going through walls).
- Prevent errors (that is, create surgical tools that cut only where needed and chemistry kits that produce only realistic molecules and safe compounds).
- Simplify object movement (facilitate docking, follow predictable paths, limit rotation).
- Organize groups of items in aligned structures to allow rapid visual search.
- Enable users to construct visual groups to support spatial recall (placing items in corners or tinted areas).

Breakthroughs based on clever ideas seem possible. Enriching interfaces with stereo displays, haptic feedback, and 3-D sound may yet prove beneficial in more than specialized applications. Bigger payoffs are more likely to come sooner if these guidelines for inclusion of enhanced 3-D features are followed:

- Provide overviews so users can see the big picture (plan view display, aggregated views).
- Allow teleportation (rapid context shifts by selecting destination in an overview).
- Offer x-ray vision so users can see into or beyond objects.
- Provide history keeping (recording, undoing, replaying, editing).
- Permit rich user actions on objects (save, copy, annotate, share, send).
- Enable remote collaboration (synchronous, asynchronous).
- Give users control over explanatory text (pop-up, floating, or excentric labels and screen tips) and let them view details on demand.
- Offer tools to select, mark, and measure.
- Implement dynamic queries to rapidly filter out unneeded items.
- Support semantic zooming and movement (simple action brings object front and center and reveals more details).

- Enable landmarks to show themselves even at a distance.
- Allow multiple coordinated views (users can be in more than one place at a time and see data in more than one arrangement at a time).
- Develop novel 3-D icons to represent concepts that are more recognizable and memorable.

3-D environments are greatly appreciated by some users and are helpful for some tasks (Laha et al., 2012). They have the potential for novel social, scientific, and commercial applications if designers go beyond the goal of mimicking 3-D reality. Enhanced 3-D interfaces could be the key to making some kinds of 3-D teleconferencing, collaboration, teleoperation, and telepresence popular. Of course, it will take good design of 3-D interfaces (pure, constrained, or enhanced) and more research on finding the payoffs beyond the entertaining features that appeal to first-time users. Success will come to designers who provide compelling content, relevant features, appropriate entertainment, and novel social-media structure support. By studying user performance and measuring satisfaction, those designers will be able to polish their designs and refine guidelines for others to follow.

7.5 Teleoperation and Presence

Teleoperation has two parents: direct manipulation in personal computers and process control, where human operators control physical processes in complex environments. Typical tasks are operating power or chemical plants, controlling manufacturing, surgery, flying airplanes or drones, or steering vehicles. If the physical processes take place in a remote location, we talk about *teleoperation* or *remote control*. To perform the control task remotely, the human operator may interact with a computer, which may carry out some of the control tasks without any interference by the human operator.

There are great opportunities for the remote control or teleoperation of devices if acceptable user interfaces can be constructed. When designers can provide adequate feedback in sufficient time to permit effective decision making, attractive applications in manufacturing, medicine, military operations, and computer-supported collaborative work are viable. Home-automation applications extend remote operation of various devices to security and access systems, energy control, and operation of appliances. Scientific applications in space, underwater, or in hostile environments enable new research projects to be conducted economically and safely. The recent introduction of affordable drones will be yet another facet of teleoperation.

In traditional direct-manipulation interfaces, the objects and actions of interest are shown continuously; users generally point, click, or drag rather than type, and feedback indicating change is immediate. However, when the devices being operated are remote, these goals may not be realizable, and designers must expend additional effort to help users to cope with slower responses, incomplete feedback, increased likelihood of breakdowns, and more complex error-recovery procedures. The problems are strongly connected to the hardware, physical environment, network design, and task domain.

A typical remote application is *telemedicine*, or medical care delivered over communication links (Sonnenwald et al., 2014). Telemedicine can be used more broadly to allow physicians to examine patients remotely and surgeons to carry out operations across continents. Telehealth is being widely used in the Veteran's Administration (Fig. 7.9).

Veterans can come into the local VA office where technology visits with the various medical personnel can be conducted via Telehealth. Cameras with

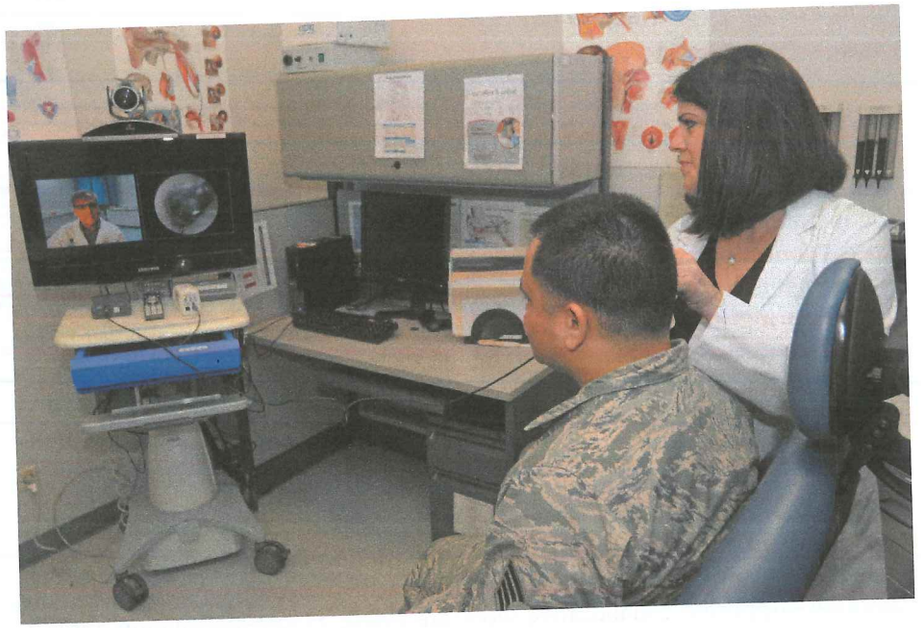

FIGURE 7.9
Erica Taylor, Nurse Director for the Telehealth Program at Landstuhl Regional Medical Center, demonstrates using the Telehealth cart otoscope to conduct a real-time tympanic membrane exam. On the screen is Physician Assistant Steven Cain, who from a remote location can see and evaluate the patient and provide an appropriate plan of care. Photo by Phil Jones.

FIGURE 7.10
When doing robotic surgery, the surgeon sits at the computer console and controls the robotic camera and surgical instruments remotely. Various devices on the controller can be adjusted by the surgeon including adjustments/magnifiers to clearly see the field of view.

high-resolution images can allow the doctor to see the physical condition as well as the added benefit of seeing the affect of the patient. A trained medical person can be in the office with the patient to help facilitate the examination. Other medical applications include robotic surgery. *Robotic surgery* is an alternative to conventional surgery that enables a smaller incision and more accurate and precise surgical movements. The robotic platform expands the surgeon's capabilities and provides a highly magnified 3-D image (Fig. 7.10). In addition, the surgeon has control over hand, wrist, and finger movement through robotic instrument arms. The surgeon is comfortably seated across the operating room at a console rather than being over the patient, and the system damps out some involuntary movements that can be problematic.

The architecture of remote environments introduces several complicating factors:

- *Time delays*. The network hardware and software cause delays in sending user actions and receiving feedback: a *transmission delay*, or the time it takes for the command to reach the microscope (in our example, transmitting the command over the network), and an *operation delay*, or the time until the microscope

responds. These delays in the system prevent the operator from knowing the current status of the system.

- *Incomplete feedback.* Devices originally designed for direct control may not have adequate sensors or status indicators. For instance, the microscope can transmit its current position, but it operates so slowly that it does not indicate the *exact* current position.
- *Unanticipated interferences.* Since the operated devices are remote, unanticipated interferences are more likely to occur than with physically present direct-manipulation environments. For instance, if a local operator accidentally moves the slide under the microscope, the positions indicated might not be correct. A breakdown might also occur during the execution of a remote operation without a good indication of this event being sent to the remote site.

One solution to these problems is to make explicit the network delays and breakdowns as part of the system. The user sees a model of the starting state of the system, the action that has been initiated, and the current state of the system as it carries out the action. It may be preferable for users to specify a destination (rather than a motion) and wait until the action is completed before readjusting the destination if necessary. Avenues for continuous feedback also are important.

Teleoperation is also commonly used by the military and by civilian space projects. Military applications for unmanned aircraft gained visibility during the recent wars in Afghanistan and Iraq. Reconnaissance drones and teleoperated missile-firing aircraft were widely used. Agile and flexible mobile robots exist for many hazardous duty situations (Murphy, 2014). Military missions and harsh environments, such as undersea and space exploration, are strong drivers for improved designs.

Telepresence was initially defined by Marvin Minsky (1980), but today the operative term is *presence*. The concept was that of not being remote but giving the feeling of "being there." Advances are being made with telepresence, and today's technologies and the internet-connected world have opened up additional possibilities. The commercial market is seeing a set of technologies called mobile remote presence (MRP) systems (Fig. 7.11). These are advancing video conferencing systems and allowing remote workers to have a feeling of presence. These devices facilitate formal communications as well as more informal chats in hallways. Some of the companies creating these devices include Suitable Technologies Beam, Mantarobot, Doublerobotics, and VGO. The controlling of these devices is another application of direct manipulation. Another application that extends the idea of video conferencing, made popular by Skype and other technologies, is a shared work space called ImmerseBoard, where the users are co-located but can work on the same screen (Fig. 7.12).

FIGURE 7.11
Three people having a conversation in a work environment, two are participating using MRP devices.

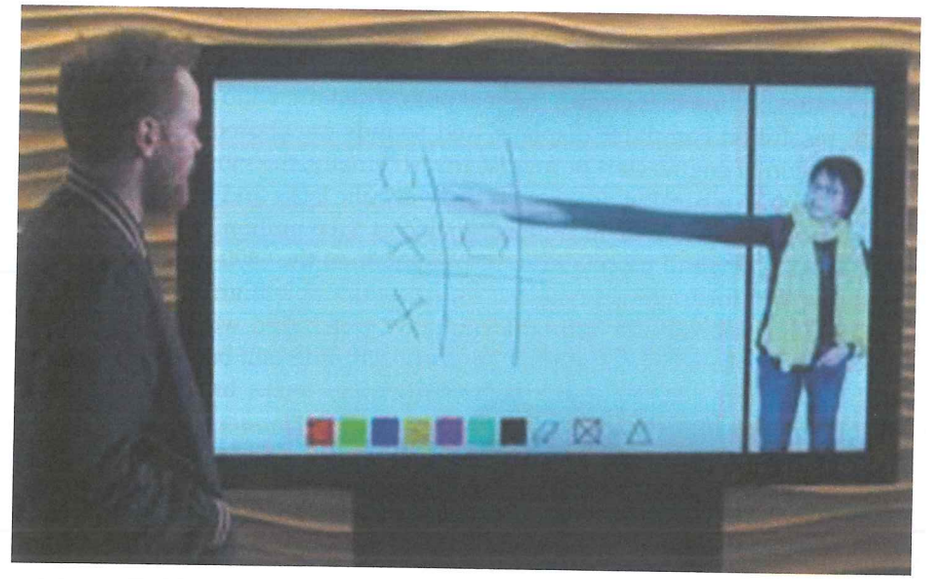

FIGURE 7.12
ImmerseBoard allows two users to be co-located and work on the same shared screen (Higuchi et al., 2015).

Robotics is a subfield of telepresence. Robots are being used in medical settings, office settings, education, and other specialized applications. New usage norms are being established for these types of devices and interactions (Lee and Takayama, 2011). The remote coworkers are often referred to as pilots. They can wander the hallways or "just hang out." Frameworks are being created with various design dimensions to better understand presence (Rae et al., 2015). It is important to understand the perspective of the users and especially that of the remote user. Doing various tasks with remote users in this type of set up can increase cognitive load. The remote person needs to concentrate on the task at hand as well as operating and positioning the device properly (Rae et al., 2014). Kristoffersson et al. (2013) provide an in-depth review of mobile robotic presence. Future work needs to be done on how mobility affects remote collaboration and on better understanding the design of mobility features. For individuals with limited mobility, robotics can facilitate more active participation. A full discussion of robotics and HCI is beyond the scope of this book.

7.6 Augmented and Virtual Reality

Flight-simulator designers work hard to create the most realistic experience for fighter and airline pilots. The cockpit displays and controls are taken from the same production line that creates the real ones. Then the windows are replaced by high-resolution computer displays, and sounds are choreographed to give the impression of engine start or reverse thrust. Finally, the vibration and tilting during climbing or turning are created by hydraulic jacks and intricate suspension systems. This elaborate technology may cost $100 million, but even so, it is a lot cheaper, safer, and more useful for training than the $400-million jet that it simulates. (And for training actual pilots, the reasonable flight simulators that millions of home computer game players have purchased won't quite do the trick!) Flying a plane is a complicated and specialized skill, but simulators are available for more common—and some surprising—tasks under the alluring name of *virtual reality* or the more descriptive *virtual environments*.

The gurus of virtuality are promoting immersive experiences. The miniaturization of electronics has provided less bulky gear to do that exploring. As computer systems continue to run faster, the obstacles that were in the way of immersive experiences are disappearing and the technology is becoming more affordable. Head-mounted displays are available from various manufacturers: Oculus Rift, Razer OSVR, HTC Vive, Sensics, Sony Glasses, and

FIGURE 7.13
Image-guided surgery can be done with the surgeon's hand attached to multiple sensors that can mimic the hand and finger positions and create accurate control. In the past, gloves were often used to attach the sensors and did not offer the flexibility and accuracy of the directly attached sensors. (http://polhemus.com/micro-sensors)

Polhemus. Bulky gloves are being replaced by more-lightweight materials (Fig. 7.13) and less-cumbersome connections (Fig. 7.14). Companies are advancing this technology very quickly. Magic Leap has just applied for a patent for a contact lens to facilitate augmented or virtual reality (Kokalitcheva, 2015).

The direct-manipulation principles outlined in Section 7.2.1 may be helpful to people who are designing and refining virtual and augmented reality environments. When users can select actions rapidly by pointing or gesturing

FIGURE 7.14
Oculus Rift head gear. This is an example of a virtual reality head-mounted display.

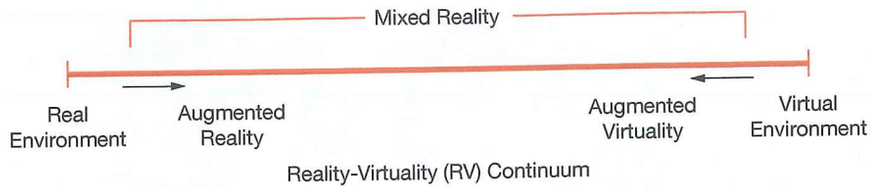

FIGURE 7.15
This figure shows the reality-virtuality continuum initially sketched by Milgram and Kishino in 1994. It still holds true today. Mixed reality is the reality that has some aspects of augmented reality within a virtual environment.

and display feedback occurs immediately, users have a strong sense of causality. Interface objects and actions should be simple so that users view and manipulate task-domain objects.

Graphics researchers have been perfecting image displays to simulate lighting effects, textured surfaces, reflections, and shadows. Data structures and algorithms for zooming in or panning across an object rapidly and smoothly are now practical on common computers and even some mobile devices. The immersive environment has some problems, including simulator sickness, nausea, and discomfort from wearing head-mounted gear and other equipment. Some of these problems are minimized by less-jumpy graphic transitions. Better understanding of the usability challenges, such as how much reality should be incorporated and when and how it can improve the user experience, is needed (McGill et al., 2015).

As our systems become more sophisticated, the distinction between different levels of virtuality blurs. It is best portrayed as originally conceived by Milgram and Kishino (1994): a continuum (Fig. 7.15). The last two sections of this chapter discuss augmented reality (Section 7.6.1) and then virtual reality (Section 7.6.2).

7.6.1 Augmented reality

Augmented reality enables users to see the real world with an overlay of additional information; for example, while users are looking at the walls of a building, their semitransparent eyeglasses may show the location of electrical wires and studwork. Medical applications, such as allowing surgeons or their assistants to look at patient while they see an overlay of a sonogram or other pertinent information to help locate a tumor, also seem compelling (Fig. 7.16). Augmented reality could show users how to repair equipment or guide visitors through cities (Fig. 7.17). Augmented reality strategies also enable users to

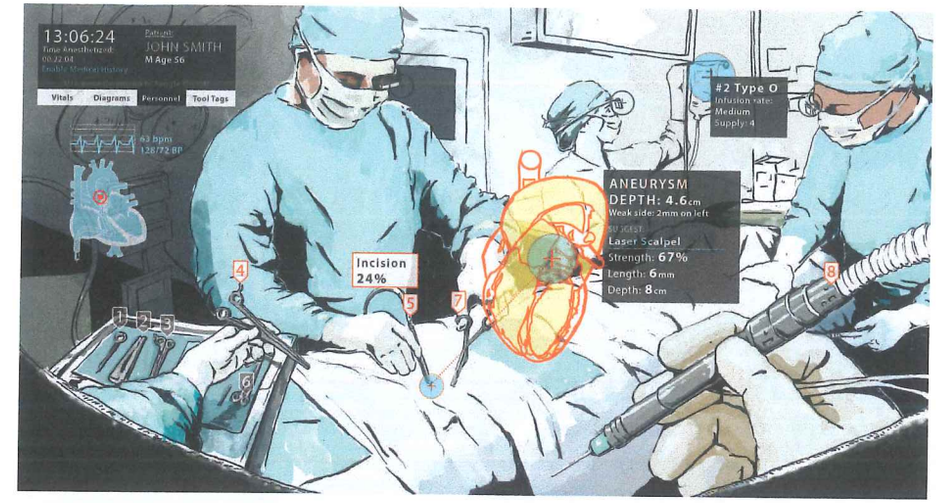

FIGURE 7.16
Virtual reality might be used to help surgeons or their assistants during surgery, by showing pertinent information superimposed on a view of the real world. (http://augmentarium.umiacs.umd.edu)

manipulate real-world artifacts to see results on graphical models (Poupyrev et al., 2002; Ishii, 2008) with applications such as manipulating protein molecules to understand the attractive/repulsive force fields between them. Using augmented reality systems to enhance social pretend play by young children (ages 4–6) promotes reasoning about emotional states as well as communication and divergent thinking (Bai et al., 2015).

An interior designer walking through a house with a client should be able to pick up a window-stretching tool or pull on a handle to try out a larger window or to use a room-painting tool to change the wall colors while leaving the windows and furniture untouched. Companies like IKEA are providing augmented reality tools so customers can visualize the products via their catalog in their own homes and rooms (Fig. 7.18).

7.6.2 Virtual reality

The presence aspect of virtual reality breaks the physical limitations of space and allows users to act as though they are somewhere else. Practical thinkers immediately grasp the connection to remote direct manipulation, remote control, and remote vision, but the fantasists see the potential to escape current

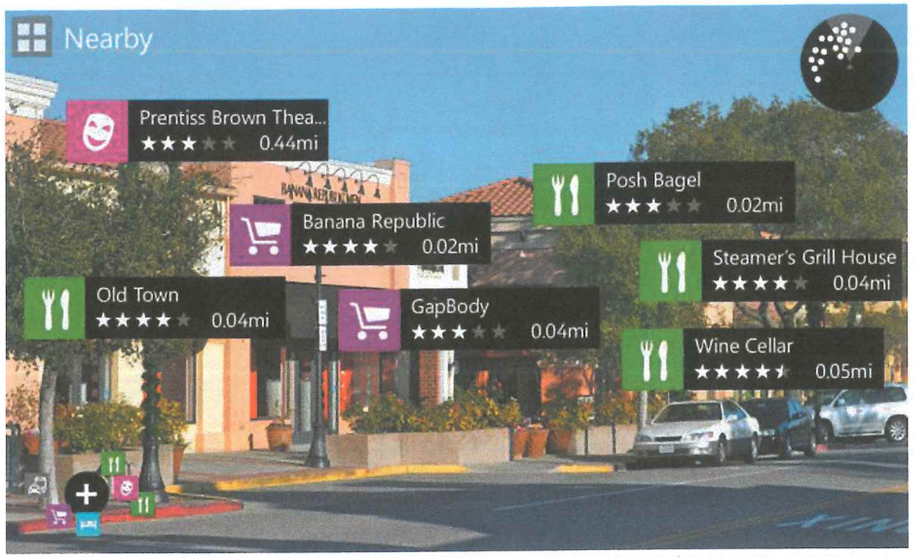

FIGURE 7.17
Using augmented reality overlays, the HERE City Lens app shows various points of interest on a mobile phone. Icons represent the types of places (food, shopping, etc.) and distances from the current location. In addition, links are provided to user reviews.

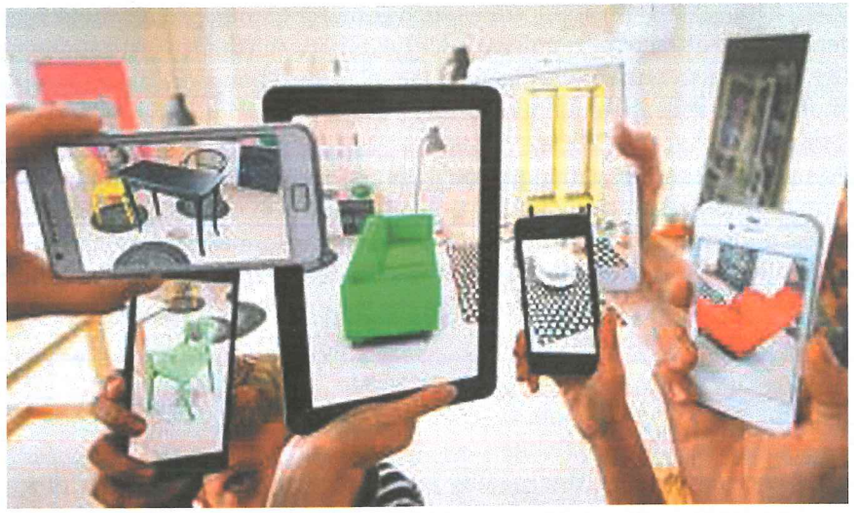

FIGURE 7.18
Customers can use their personal mobile devices to pull up objects from the IKEA catalog and see how the various items would look in their own house.

reality and to visit science-fiction worlds, cartoonlands, previous times in history, galaxies with different laws of physics, or unexplored emotional territories.

There have been many medical successes using virtual environments. For example, virtual worlds can be used to treat patients with a fear of heights by giving them an immersive experience with control over their viewpoint and movement. The safe immersive environment enables phobia sufferers to accommodate themselves to frightening stimuli in preparation for similar experiences in the real world. Another dramatic result is that immersive environments provide distractions for patients so that some forms of pain are controlled (Fig. 7.19). The immersive virtual reality environment has been used to treat military personnel suffering with PTSD (Fig. 7.20). Virtual worlds can be used for positive computing (Calvo and Peters, 2014) and wellness issues (Fig. 7.21).

FIGURE 7.19
A patient using UW HITLab/Harborview's SnowWorld pain distraction at Shriners Children's Burn Center Galveston. UW designer/researcher Hunter Hoffman's latest version of SnowWorld was created for the UW by gifted worldbuilders at www.firsthand.com using www.3ds.com Virtual World Development Software. The immersive experience seems to lessen the painful experiences.

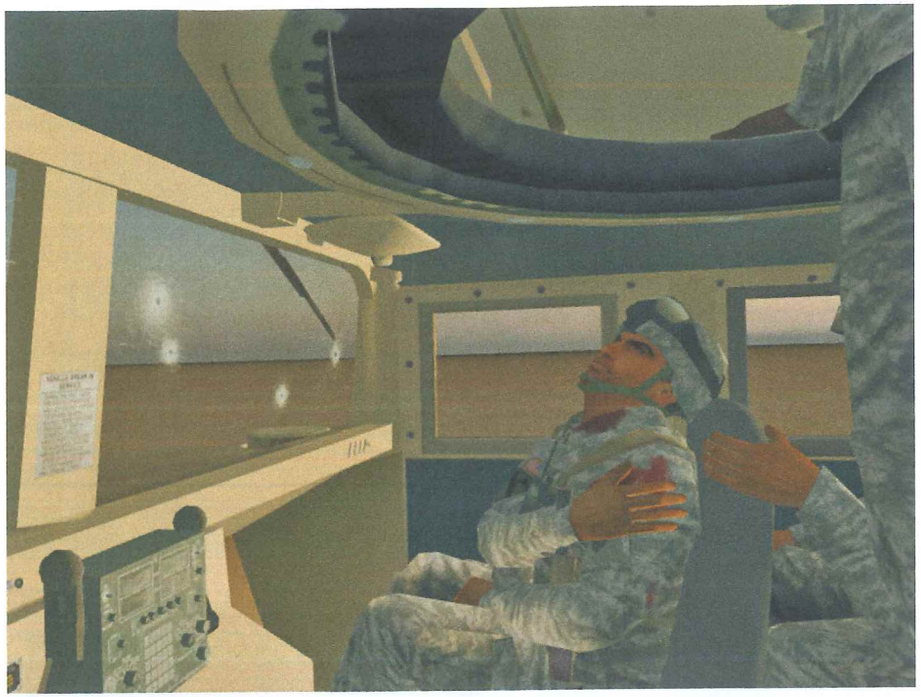

FIGURE 7.20
Soldiers can "re-live" portions of their combat experiences in a virtual reality setting with full immersion and sounds. Some systems even provide full immersion to include shaking and movement to make the experience as realistic as possible. Working with trained therapists, the soldier can be slowly desensitized from the traumatic experiences. (http://ict.usc.edu)

The opportunities for artistic expression and public-space installations are being explored by performance artists, museum designers, and building architects. Creative installations include projected images, 3-D sound, and sculptural components, sometimes combined with video cameras and user control by mobile devices. Other creative ideas include virtual dressing rooms where users can try on clothes on a model of themselves. The possibilities are truly endless.

Further information on virtual and augmented reality can be found in the wide assortment of textbooks available (Fuchs et al., 2011; Boellstorff et al., 2012; Kipper and Rampolla, 2012; Craig, 2013; Hale and Stanney, 2014; Barfield, 2015, Jerald, 2016). Billinghurst et al. (2014) recently compiled a comprehensive survey of augmented reality that gives both history of the field and details about the technologies and tools, including future research directions. The field is

FIGURE 7.21
Image of a virtual meditative world for engaging in meditation activities. The virtual world has sounds that change with each chakra (stage) of the meditation process. This is an application of positive computing. (http://nsuworks.nova.edu/gscis_etd/65/)

changing rapidly, and although avatars and virtual worlds still exist and are being explored (Blascovich and Bailenson, 2011), other virtual worlds like Second Life have almost disappeared (Boellstorff, 2008).

Practitioner's Summary

Among interactive systems that provide equivalent functionality and reliability, some systems have emerged to dominate the competition. Often, the most appealing systems have an enjoyable user interface with customized user-generated content that offers a natural representation of the task objects and actions—hence the term *direct manipulation* (Box 7.2). These interfaces are easy to learn, to use, and to retain over time. Novices can acquire a simple subset of the actions and then progress to more elaborate ones. Actions are rapid, incremental, and reversible, and they can be performed with physical movements instead of complex syntactic forms. The results of actions are visible immediately, and error messages are needed less often.

Using direct-manipulation principles in an interface does not ensure its success. A poor design, slow implementation, or inadequate functionality can undermine acceptance. For some applications, other approaches may be more appropriate. However, great potential exists for multiple and varied applications of direct-manipulation concepts. Compelling demonstrations of virtual and augmented reality are being applied in a growing set of applications with enhanced social interactions. Iterative design (Chapter 4) is especially important in testing advanced direct-manipulation systems because the novelty of these approaches may lead to unexpected problems for designers and users.

Researcher's Agenda

Research needs to refine our understanding of the contributions of each feature of direct manipulation: analogical representation, incremental action, reversibility, physical action instead of syntax, immediate visibility of results, characteristics such as translational distances, and graphic displays. Reversibility is easily accomplished by a generic undo action, but designing natural inverses for each action may be more attractive. Complex actions are well-represented with direct manipulation, but multi-layer design strategies for graceful evolution from novice to expert usage could be a major contribution. For expert users, direct-manipulation programming is still an opportunity, but good methods of history keeping and editing of action sequences are needed as well as increased attention to user-generated content. Better understanding of touchable interfaces and their uses as well as research on two-handed versus one-handed operations are needed. The allure of 3-D interaction is great, but researchers need to provide a better understanding of how and when (and when not) to use features such as occlusion, reduced navigation, and enhanced 3-D actions such as teleportation or x-ray vision and what are the best widths for field of view. Providing better semantic understanding of 3-D images can provide information for visually impaired users to better understand their environment. The impact of immersion on gaming and virtual worlds using rich social-media interactions across various ages and activities needs to be understood better.

Beyond the desktops and laptops, there is the allure of presence, virtual environments, augmented realities, and context-aware devices. Research is needed into how presence affects behaviors and interactions including privacy issues. The playful and enjoyable aspects will certainly be pursued, but the real challenge is to find the practical designs and a better understanding of "being there" when looking at 3-D worlds, both as individuals and as collaborators and players in the enriched social-media environments. A new set of tools is needed to investigate and better understand digital games research and its implications, both good and bad.

WORLD WIDE WEB RESOURCES

www.pearsonglobaleditions.com/shneiderman

Other Resources

Journals

- *Presence* (teleoperators and virtual environments): http://www.mitpressjournals.org/loi/pres
- *Virtual Reality*—Springer: http://www.springer.com/computer/image+processing/journal/10055
- *International Journal of Virtual Reality*: http://www.ijvr.org/
- *International Journal of Virtual Technology and Multimedia*: http://www.inderscience.com/jhome.php?jcode=ijvtm

Conferences

- VRST ACM Symposium on Virtual Reality Software and Technology: http://vrlab.buaa.edu.cn/vrst2015/
- IEEE Virtual Reality: http://ieeevr.org/2016/
- IEEE Symposium of Mixed and Augmented Reality, IEEE and ACM Symposium on Augmented Reality: http://ismar.vgtc.org

Additional information of this topic can be found in multimedia journals and conferences as well as journals and conferences that emphasize visualization.

Discussion Questions

1. Describe three principles of direct manipulation.
2. Give four benefits of direct manipulation. Also list four problems of direct manipulation.
3. Explain the differences between various kinds of direct manipulation with respect to translational distances.
4. An airline company is designing a new online reservation system. They want to add some direct-manipulation features. For example, they would like customers to click a map to specify the departure cities and the destinations, and to click on the calendar to indicate their schedules. From your point of view, list four benefits and four problems of the new idea compared with their old system, which required the customer to do the job by typing text.

5. Explain how virtual reality can be used for medical purposes.
6. List an example of teleoperation or virtual reality. Consider what a future application (that does not presently exist) might do. Be creative!

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