Large Displays in Automotive Design

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We explore the traditional and current uses of large displays in automotive design and present new applications that make innovative use of large-format electronic displays.

The ability to display and interact with large-scale representations of vehicles has always been a fundamental requirement of the automotive design industry. This requirement has traditionally manifested itself in a variety of media, including full-scale blueprints, tape drawings, and 3D clay models.

More recently, automotive design studios have begun to explore the use of large-scale digital displays in their design workflow. Often, the applications of these displays have direct analogues with traditional techniques; in other cases, new applications are evolving that use these displays to visualize and interact with design content in new ways. An interesting attribute of this evolution is that—unlike the desktop computer with its "one size fits all" universality—the size, resolution, and level of interactivity of these large displays and their applications vary depending on the physical and social settings of the task at hand.

Traditional use of large displays

In the automotive industry, the success of the final product depends not only on the engineering quality but equally or even more on the emotional response it invokes from a potential buyer. A recent example of the importance of this factor is the success of the new Volkswagen Beetle, which plays heavily on nostalgia. Getting the styling of the car correct early in the design process is extremely important. In this, the scale at which the designs are rendered play a surprisingly critical role. For example, the primary curves that define a car's style may look perfectly fine at quarter scale but elicit a completely different emotional response at full scale.

Another important factor in automotive design is the collaborative nature of the design process. Designers need to communicate their ideas to and receive feedback from their colleagues and management. This communication can happen either informally (that is, an awareness of who's working on what) or in more formal settings such as design critiques. In fact, according to one of our automotive customers, the design approval process alone, including waiting time, can represent up to 35 percent of the design cycle.

A variety of techniques have evolved to accommodate these two critical factors in automotive design. First, the designers' drafting tables (Figure 1) allow them to create designs on large sheets of paper, thus addressing the scale

1 **A traditional drafting table can be considered a large-format display that affords idea sharing by virtue of its visibility and a platform that enables collaboration and discussion about designs.**

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Image courtesy of Russell Paul

2 **An early automotive concept sketch, representative of the type of material generated to work out styling concepts. This is typical of the type of material posted on corkboards around the studio for sharing concepts among the design team.**

Photo courtesy of General Motors Design Center

3 **Tape drawing is a technique for drawing the basic outline curves of a vehicle, often 1:1 scale, on the wall using photographic tape, typically on top of the underlying engineering criteria, or "package." These sketches are executed early in the design process to evaluate the vehicle profiles at full, or near full, scale before moving to the next stage.**

issue. This also facilitates communication by allowing for informal discussion with colleagues gathered around the table who can view the design as it's worked on.

Second, large wall-mounted corkboards function as more public displays, on which concept sketches (Figure 2) and background material are posted. These serve as a repository for the designers. They also create a sense of shared awareness within the studio and permit designs to "incubate" by encouraging collaboration and feedback from others working on different parts of the design, without occupying valuable desktop space.

It's not unusual for a designer to post up to 40 sketches or images in a day. While these sketches and blueprints serve a valuable purpose, they suffer from several disadvantages inherent in the physical nature of their medium. One disadvantage is the difficulty in cataloging, storing, retrieving, and reusing these drawings.

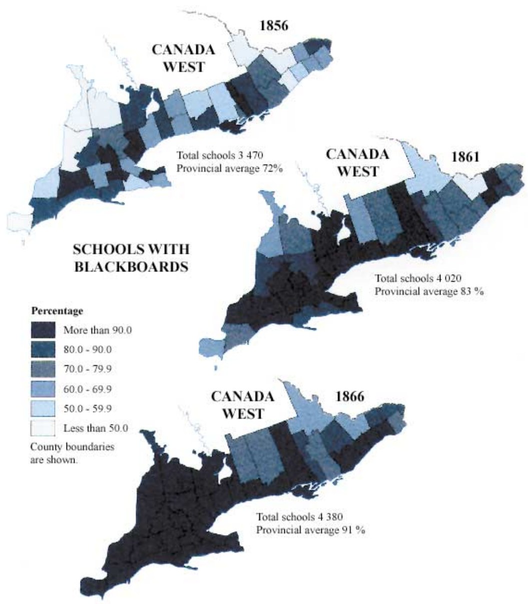
Apart from sketches on drafting tables, an idiosyncratic technique used in automotive design is tape drawing (Figure 3). Tape drawing is the art of creating sketches on large-scale, upright surfaces using black photographic tape. It offers several fundamental advantages over freeform sketching with pencil, given the large size of these sketches. It's difficult to draw, freehand, straight lines and smooth continuous curves at this scale. Physical aids such as rulers and french curves would assist the process; however, they would also have to be large, which unfortunately makes them unwieldy for upright use. Drawing with tape, on the other hand, facilitates the generation of perfectly straight lines and—due to the slight elasticity of the tape that allows it to be deformed—smooth, continuous curves. A problem inherent in this medium is that the tape has a tendency to lose its adhesion and eventually fall off the drawing surface. Also, it's difficult to save and reuse a tape drawing because the Mylar sheet on which it's created is originally stretched onto a wall. Once it's unstretched and rolled up, the original tape drawing is distorted.

Sketches, blueprints, and tape drawings are all 2D representations of the automobile being designed, which is ultimately a physical 3D object. To experience and evaluate a design more completely, designers create 3D clay models of the design. These models typically range in size from quarter to full scale. Once created, they serve as powerful artifacts that facilitate discussion and allow for interactive modification. They also let designers and management get a true 3D feel of the car's design. It's important to grasp the fidelity of these models, some of which are finished such that from a distance they are almost indistinguishable from a real car (Figure 4b). Others—those intended as works in progress—remain interactively modifiable to refine the design (Figure 4a).

Photo courtesy of General Motors Design Center

4 **Clay models are a type of 3D large-format display. In some cases (a) they are "soft" models that are worked or sculpted, thereby forming part of the modeling workflow. Here a 3/8-scale model is being worked. In other cases (b) they are "hard" and painted with a plastic material called Dinoc to simulate the finished painted surface of a real car. Hard models are nearly indistinguishable from a real car and aid in evaluating surface quality and the overall impression of a design. They're often viewed outside in natural light, as shown here.**

To understand the value of making highly finished models, consider that automotive styling is as much about the design of light reflections as vehicle design. Hence, the interaction of the form with light is critical and cannot be evaluated on paper or without high-quality finished surfaces. Some design studios have even relocated to California primarily for the quality of the natural light. They built special "patios" onto which clay models can be wheeled for evaluation.



From the Historical Atlas of Canada, Volume II, Plate 55

5 **The introduction of blackboards into schools in Upper Canada between 1856 and 1866.**

6 **The Active Desk.**

Clay models, however, suffer from several shortcomings, including the cost and time required to create them (using large milling machines) and the difficulty in translating any modifications to the 2D media when required.

Moving to electronic displays

Computers were first used in the automotive industry in the engineering and manufacturing processes. Traditional CAD software was used to control numerical control (NC) machines. Over the past ten years, computer techniques have migrated upstream and are now used extensively in the conceptualization and styling phases of the design process. Artists with a design school background, not engineers, primarily use these computer-assisted industrial design (CAID) systems. These users represent a culture distinct from traditional computer users. Many of the technologies emerging today, including large-format displays, support the deployment of a new generation of systems better suited to artists' needs and backgrounds than the traditional workstation.

Until recently, most computer use in automotive design followed other industries in that it centered around a conventional workstation driven by a CRT, keyboard, and mouse. The uniformity of the electronic tools sharply contrasts with their counterparts in traditional media, in form, scale, and location. The new technologies, led by large-format displays, are opening up a new era in which the diversity of the technologies can match those of both the traditional media and, more significantly, the users' needs.

As a means of previewing things to come, let's look at a historical precedent. Figure 5 illustrates the introduction of large-format displays in a previous era and in a different domain, namely, the introduction of blackboards into the school system in Upper Canada in the period from 1856-1866.

The value of this example emerges when we consider the impact that this transition had on education, compared to the nature of the technological change. Also, consider that the slate preceded the blackboard. All that changed was the scale of an existing device and where it was located. After all, the blackboard and slate have the same operating system, user interface, and underlying technology. Nevertheless, this "simple" change arguably has had more impact on classroom education than the introduction of any technology since, including the introduction of inexpensive paper, the personal computer, or the Internet. (Even if you disagree, the point remains that a reasonable argument to this effect can be made. We simply want to emphasize the impact resulting from this seemingly simple change of technology.) In the auto design process, similar changes are being enabled by the introduction of large-format displays, at the appropriate location, and with the appropriate modality of interaction.

Electronic drafting table

A potential replacement for the traditional drafting table is an electronic equivalent called the Active Desk[1] (Figure 6)—essentially a drafting table with a computer image projected from the rear onto the surface. Users work on the surface with its embedded transparent digitizing tablet using a computer application, much like they would work with paper on a traditional drafting table. The large size of the projected surface allows for the large-scale gestures artists traditionally use when creating large drawings.

This respect for the traditional skills of designers could play a significant role in the acceptance of this technology. From a sociological perspective, despite the benefits, when automotive designers started using conventional workstation computers, they lost something valuable in the design studio. By its nature, the technology changed some aspects of the social interactions within the studio for the worse. For a variety of reasons, the social mores around a conventional workstation differ from those of a drafting table.

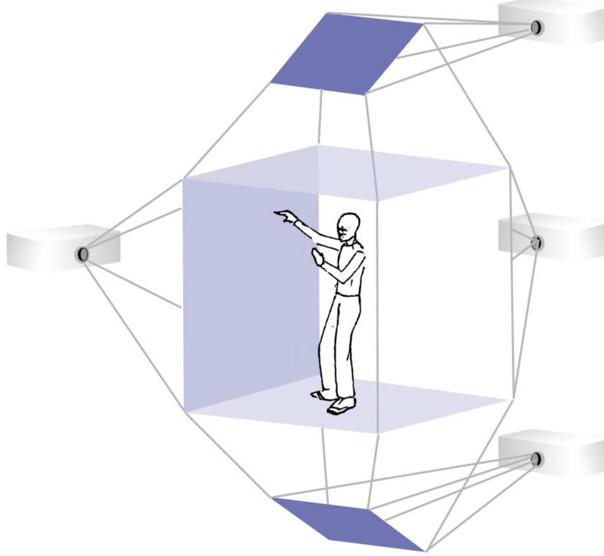
While drafting tables encourage a shared awareness of what others are working on, looking over colleagues' shoulders at their monitors has more in common with reading a newspaper over someone's shoulder—for the most part, it's socially unacceptable. Hence, the benefits of moving toward larger format drawing surfaces that are closer to drafting tables than to conventional computers go beyond simply giving a larger display surface on which to draw and view one's own work. They include recapturing some of the social and collaborative properties of the design studio that were lost during the first generation of computerization.

From a technology perspective, however, there's much room for advancement. On the hardware side, nearly all Active Desks use rear projection, with the image focused on a sheet of Mylar material on top of a transparent digitizer. This eliminates display parallax. Rear projection displays are also expensive and of limited resolution, and calibration is often cumbersome.

Photo courtesy of Pyramid Systems, Inc.

7 **The ImmersaDesk VR system, a large-format rear-projection, flat stereo display with head tracking.**

Flat-panel displays with embedded digitizers offer a potential replacement, although currently limited by size, resolution, and the parallax problem. Gas plasma displays somewhat address the size issue. The Xerox high-density displays (http://www.xrce.xerox.com/showroom/techno/flatpanel.html) promise an order of magnitude improvement over current technology. However, the user interface of CAD and drawing applications designed for the standard desktop computer and display is often not easily operable on this large-scale tabletop format. The problems include the difficulty in reaching to the extremities of the display where the traditional GUI menus and tool bars are located. Hands also tend to obscure parts of the underlying image, although this problem is common to working with traditional media on drafting tables. On the positive side, this technology allows for direct, 1:1-scale interaction between the user and the digital media. Also, familiar physical tools such as rulers and drawing templates can be used instead of abstract virtual ones.[2]



8 **Schematic of an idealized cave VR system. Tiled rear-projection stereo images appear on up to six faces of the room in which the operator works. In practice, most caves have three to four faces with projections.**

The ImmersaDesk[3] (Figure 7) better represents the 3D nature of the product being designed. It extends the Active Desk concept to display stereoscopic images rendered relative to the viewer, whose viewpoint is tracked, in real time, by a 6 degrees-of-freedom (DOF) tracker. Here, the idea is to simulate and visualize the 3D data to get a better sense of shape and form—similar to the goals of 3D clay models, although to a much lesser degree.

Caves

Increasing the level of immersion and presence that a viewer experiences is a class of systems known as caves,[4] the best-known being the Cave Automatic Virtual Environment, or CAVE (Figure 8). Rooms with multiple projection surfaces (front, sides, top, and bottom of the room) collectively display a single image that surrounds the viewer. Since viewers are inside the scene displayed, they typically experience a greater sense of presence compared to desktop displays and active desks. For example, they can immerse themselves in an automobile's interior. Although multiple people can be inside a cave at a time, the system only tracks the viewpoint of one viewer, and the displayed image is truly correct only from that viewer's point of view.

Caves also generally provide stereo-viewing capabilities through the use of LCD shutter glasses. This further increases the immersiveness of the system. Note that stereo viewing is also possible for all the technologies mentioned previously. However, in nonimmersive systems that tend to be used more casually, the added cost of putting on special glasses doesn't outweigh the benefits, and thus stereo isn't widely used.

A problem with caves is that they are located in special rooms, not in a design studio. As such, designers must make a special effort to use it, and thus caves don't form a natural part of the designers' daily workflow. Designers use caves more for evaluating form than for actively modeling, designing, or styling. Furthermore,

Photo courtesy of Fakespace Systems

9 **A stylized rendering of the Immersive WorkWall, a representative powerwall from Fakespace Systems. Such walls can present data either "flat" or stereoscopically (with the use of special glasses). Typically, they are located in special rooms with very high quality projectors so that they can be used as "electronic patios" for evaluating vehicle designs in natural-like lighting conditions.**

the display quality is insufficient for evaluating reflections off surfaces.

Powerwalls: The electronic patio

To showcase one or more full-scale digital car models, the automotive industry has begun to use powerwalls (Figure 9). Most powerwalls consist of 2 or more (sometimes as many as 6 or 8) high-resolution (1,280 × 1,024) rear projectors. The projectors overlap slightly to offer a seamless, uniformly bright projection onto screens ranging from 8 × 6 feet to upward of 60 × 20 feet. These large displays allow a group of viewers to evaluate digital car models. Here, the primary goal of the viewers is to evaluate the styling of the car and the quality of the car's surfaces by observing the light reflections of the surfaces. This emphasizes the fact that automatic styling and design is as much about design reflections (visual interaction of surfaces with light) as about vehicle design.

Although powerwalls are generally used in group settings, the renderings can only accommodate a single perspective view at a given time. Viewers at the periphery or at a different position get a slightly different view of the car. The size and resolution of these displays necessitates viewing from a distance and thus prevents detailed inspections. However, powerwalls improve upon the traditional printed renderings on corkboards by offering animated renderings (for example, a car on a turntable).

Finally, although these are computer displays, we haven't fully exploited the potential level of interactivity. This is partially because standard desktop input devices don't operate well at this scale and because the delicate nature of current powerwalls' display surfaces precludes the obvious touch-screen interface. Later, we describe an application of powerwalls with enhanced interactivity.

From a sociological perspective, some pragmatic issues can be obstacles to the widespread daily use of powerwalls. Because powerwalls are located in special rooms and not where designers do their daily work, the powerwall facilities must be scheduled. In addition, it's difficult to maintain software and hardware configuration compatibility between the powerwall computer and individual designers' workstations, and thus easily display renderings. Collectively, these factors preclude informal, spontaneous use.

Powerwalls typically display only one image at a time. To compare multiple renderings of the same car or different cars side by side, General Motors extended the powerwall concept into a virtual patio, which consists of multiple powerwalls in the same room.

The emerging generation

We've shown that the notion of using large-format displays isn't new to this industry and have established some parallels between practice in traditional and electronic media. These parallels are as interesting in what's missing as in what's present.

The most obvious gaps are in the lack of electronic analogies to things like corkboards and tape drawings. The prototype systems designed by our research group in collaboration with partners in the automotive industry will fill in some of these gaps. We demonstrated these prototypes to users and management at 10 major auto design studios located in Europe, Japan, and the United States. User feedback was critical in evolving and improving the concepts and designs.

Digital tape drawing

Despite the increasing use of computer-based design tools, one traditional technique still performed is tape drawing. As noted earlier, using digital techniques alleviates several tape-drawing problems. These include the need to eventually transfer tape drawings to CAD/CAM systems. Currently, users laboriously digitize the key curves of the tape drawing using a position sensor, then recreate those curves in a CAD package. This transfer process invariably introduces inaccuracies in the electronic version, which then must be identified and removed.

Also, since designers create multiple 2D tape drawings to represent different views (such as front and side views) of the underlying 3D vehicle, these 2D drawings must be integrated when creating the final 3D model of the vehicle. This integration requires careful alignment and matching of the primary curves of a model, a process that can also introduce errors.

The second major problem with tape drawings is the difficulty in storing and retrieving old drawings due to the material properties of the Mylar sheets on which they're drawn. Finally, the physical nature of these drawings precludes easy sharing of design information between different design studios.

Using digital electronic media to create a drawing from the start could alleviate the disadvantages of physical tape drawings. This would reduce the errors when transferring, retrieving, and storing drawings. An electronic system could also provide functionality beyond that possible using traditional media. However, most "tape artists" who use this technique are averse to using current modeling software that requires them to learn new skills unrelated to their art. We're thus faced with the challenge of designing an electronic system that will let artists easily transfer the considerable skills they have acquired in working with traditional media. Such a system must, therefore, retain the desirable simplicity, fluidity, and affordances of the physical tape-drawing process.

Our prototype digital tape-drawing system provides the functionality of laying down digital tape segments on the display and drawing surface, which is a large, back-projected screen (Figure 10). In the traditional tape-laying technique, the right hand unrolls the tape while the left hand slides along the tape as it fastens tape to the surface. To create a smooth, continuous line, designers must hold the tape taut between both hands. If the right hand is held steady while the left hand fastens, the result is a straight line; simultaneously moving the right hand in an arc while fastening with the left hand produces curves.

Our digital system preserves many of the affordances of the traditional technique. Designers use two input devices (6-DOF magnetic trackers) to provide the system with the position of each hand on the drawing surface. The right hand controls a cursor that represents the roll of tape, while the left hand controls a second cursor that represents the end of the tape. A segment of "unfastened" digital tape, represented as a polyline, always extends between the two cursors. Tape is virtually fastened onto the drawing surface by pressing a button on the left-hand tracker and moving the left hand along the unfastened tape segment toward the right hand. As with the traditional technique, holding the right hand steady results in a straight line being laid, while moving the right hand in an appropriate arc results in a curve.

This system also provides editing capabilities that resemble the traditional techniques. Balakrishnan et al.[5] provides further details on the implementation and algorithms of the system.

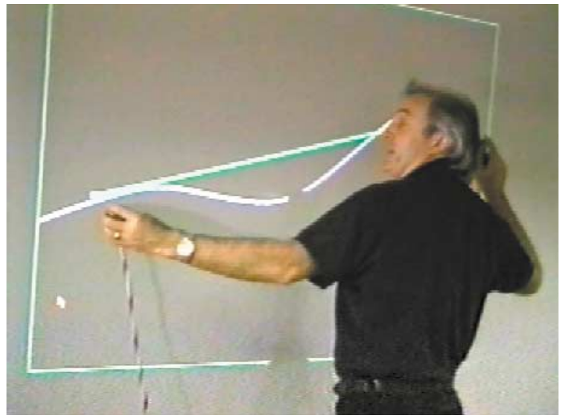
In addition to replicating the traditional functionality, our system provides several enhancements. First, artists often create tape drawings in relation to a set of engineering specifications, which may consist of blueprint drawings. Traditionally, they use these blueprints, or engineering criteria, as a background onto which they form the tape drawings. However, these engineering criteria often change during the design process. Then, artists must completely redo the pertinent tape drawings because removal of the old criteria usually distorts or destroys any tape drawings created on top of it.

As with the traditional media, our system permits engineering criteria to be loaded as a background image onto which the tape drawings are created. However, the digital media lets artists change the background engineering criteria without having to redo the entire tape drawing. Only the parts that need updating have to be changed.

A second feature lets users make the background of the application completely transparent. Artists can superimpose the digital tape-drawing application on the top of any existing CAD application, which can provide a live background onto which tape drawings can be created.

A third feature is the obvious ability to save the tape drawings in a variety of formats for direct importation into CAD packages. This eliminates the manual digitizing process required in the traditional technique.

Throughout the development of the digital tape-drawing system, we sought user feedback from tape artists at various automotive design studios. Perhaps the most important validation of the system was that tape artists could simply walk up and use our system. Within a minute, traditional tape artists were creating drawings clearly superior to that of our system developers who had multiple hours of familiarity with the system. Thus, despite some technological limitations with current tracker and display technology, the artists could transfer their skills to the new system. This indicates that we had successfully emulated their traditional interaction techniques. Balakrishnan et al.[5] provides further details on the user feedback.



10 **Digital tape drawing.**

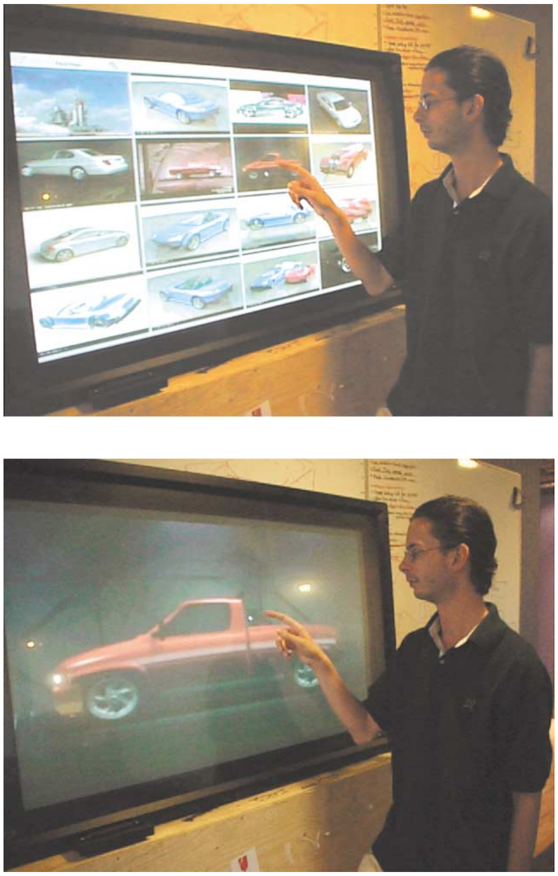
Portfolio Wall

Larger format work surfaces, such as represented by the Active Desk and the ImmersaDesk, go some way toward creating a better awareness of others' work in a studio. Nevertheless, these are intended to serve as the primary personal work surfaces for those in the design studio. The features of shared awareness still can't replace the function of the traditional wall-mounted corkboard.

One way to address this is to simply generate hardcopy renderings of computer-generated material and post them on a wall. This is what's generally done today. While this does enable the work to be communicated, it also means that many of the advantages of electronic displays are lost. For example, we cannot display animations or "turntables" of illuminated 3D models.

With the rapidly dropping prices of data projection systems as well as large flat-panel displays, it's now becoming feasible to complement physical display boards with large-format wall displays in the design studio.

The Portfolio Wall is a prototype system designed to support this kind of function. It serves as an awareness server.[6] As a first approximation, it's simply an array of about 20 to 30 images projected onto the studio wall where everyone can see them. Conceptually speaking, when designers have images or animations that they want to share, or hang on the wall, they can drag and drop them from their desktop onto one of the tiles of the Portfolio Wall. Like with a traditional corkboard, they can then work in the general ambience—they're surrounded by, and can live with, the images and concepts that they're trying to absorb. Ideas can incubate, and viewers can see how various side-by-side concepts compare, or how well they stand up over time, without having to compete for



11 The Portfolio Wall illustrating the "office" version, which is implemented using a 50-inch Plasma Panel equipped with a touch screen. This version is intended to reside in a manager's office and to afford an awareness of a project's status. Touching on a thumbnail as in the top photo expands the view, as shown in the bottom image. Simple finger gestures cause animated images to play or stop. In the design studio, the Portfolio Wall would be implemented using a large projection screen so the entire studio could view it.

valuable screen real-estate on their workstation screens.

Note that, unlike most of the computers in a studio, the Portfolio Wall isn't intended as the vehicle for primary foreground activities. Its value lies in its persistence in the background, contributing to the general ambiance of the design studio.[7]

Nevertheless, designers can interact with the Wall as a public access tool, rather than a personal one. As a consequence, interaction in the studio takes place at a distance, from wherever viewers can see the display, rather than just in front of it or in direct contact with it. Furthermore, since it's a public display, it has no owner, so anyone in the studio can see it and interact with it.

One wall interaction approach we've used is a technique adapted from a product called Cyclops from Proxima Corp. (http://www.proxima.com). Cyclops requires a personal laser pointer in combination with a few simple gestures. Lasers easily and inexpensively provide each person with a personal wireless input device. Another possibility is to use a simple pointing device like the Logitech Cordless trackball (http://www.logitech.com). Both these technologies allow for operation of the Portfolio Wall from pretty much anywhere in the design studio—either near the wall itself or from across the room.

Pointing at one of the tiled images causes it to expand to full screen. Pointing at it again causes it to collapse back to its tiled form. A stroke to the right over an image (tiled or full size) causes it to play if it's an animation. A stroke to the left causes the animation to stop.

Finally, moving the pointer to tabs at the top of the wall lets users organize tiled sets of images by project, date, person, and so on. While this may violate the concept of persistence, it provides a mechanism for retrieving previous or related work for comparison such as an important component in design reviews. In this context, the device becomes a memory prosthesis.

Even with its capacity to view full-scale images, the Portfolio Wall is still distinct from the powerwalls discussed earlier (much in the same way that a slate differs from a blackboard). The difference lies in where the unit is located, what purpose it serves, who uses it, and the fidelity of the images.

The Portfolio Wall is primarily intended to reside in a design studio for the designers' use. Powerwalls, as we discuss them, are typically far more expensive and of higher quality; they reside in specialized rooms better suited for their primary purposes, namely design reviews and evaluation by senior management.

Using an electronic Portfolio Wall rather than conventional hard copy provides additional advantages to the design process. Computer networks permit multiple instances of any display, which can be located anywhere on the network. Hence, the Portfolio Wall can enhance collaboration across studios. For example, two sites working jointly on the same project can share a common Portfolio Wall. Contributions from any location can be posted onto the wall and be immediately visible to the full team, regardless of location. This affords better awareness of what's going on at each site and reduces the potential for error.

We implemented a special case of the Portfolio Wall that exploits the potential of such networking; see Figure 11. This wall uses a networked 50-inch, 16:9 HD (1,280 × 768) plasma panel (Pioneer PDP-505HD PLP: http://www.pioneerelectronics.com/home/pdphd.htm). The panel comes equipped with a touch screen (Matisse touch panel from Smart technologies: http://www.smarttech.com/matisse/index.html).

In this form, the display should sit in the office, for example, of a design manager located outside the studio itself but needing to keep abreast of the progress of studio activities. This panel remains on the wall and in the background, but in a form better suited to the context and the more direct, personal nature of the interaction to take place.

Conclusions

The development of our applications has highlighted several issues and challenges for the future. Perhaps the overriding issue is that ultimately the story is about interaction, not displays. The displays represent just half of the equation. For the system to be of value, it's generally not enough simply to present information. Viewers must be able to create, manipulate, explore, and annotate the displayed image.

Furthermore, the display's location, who uses it, for what it's used, and how it's used are all critical in determining value. This observation likely applies to domains other than the automotive and design industries. The highly specialized nature of each use of large displays points toward the divergence of computing to a more appliance-based model rather than the convergence manifested in the current one-size-fits-all desktop workstation computing model.

These classes of displays have the potential to open up the benefits of computation to new domains of endeavor and new users. Just as the blackboard revolutionized the classroom, so can these technologies do the same for many other application areas. Note that these large display systems require different modalities of interaction, and the range of differentiation is about as broad as the range of applications for which they will be deployed. Those who have an interest in the successful deployment of such large display systems should have some concern at the relatively small amount of research being undertaken by the user interface community, relative to the importance of these technologies in the future.

While sometimes it's difficult to navigate through the ever-expanding design space of technology, it's somewhat reassuring to be reminded—as many of the examples in this article do—that the most advanced technology of all is not changing: the human being. Consequently, when in doubt, we can do a lot worse than focus on the human and work from a solid understanding of human capabilities and needs. ■

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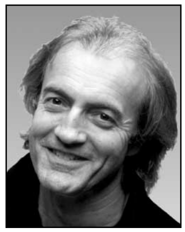

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