



Advertising on Public Display Networks

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Computing technologies permeate our everyday lives. The increasing affordability of powerful mobile devices, combined with cloud-based data storage and advances in wireless communications, have made it easier than ever for people to access information and obtain a wide range of products and services anytime, anywhere.¹ However, a key obstacle to the deployment of ubiquitous computing systems in public spaces is the question of who will pay for them.

Two online payment schemes prevail. Either users buy a product, such as an app or song, or they subscribe to a service, such as one that tailors content to passersby based on their preferences. While Internet access itself is typically a paid service, most Web-based services—e-mail, social networks, news, search engines, games, maps, and so on—as well as many apps, are free to users and thus rely on advertising.

Just as it pays for other forms of media, including free newspapers, radio, and TV, we believe that advertising—not direct sales or service contracts—will also underwrite the future ubicomp infrastructure. We envision this infrastructure beginning as public display networks and later expanding to encompass entire interactive spaces.

However, for advertising-based public display networks to become truly pervasive, using all available communication channels,² they must also provide a tangible social benefit and be engaging without being obtrusive. In many ways, public display networks must parallel the World Wide Web, blending commercial with informative content.

WHY ADVERTISING?

Advertising performs a vital function in society by conveying information about products and services, which benefits both producers and consumers. It is hard to imagine a modern capitalistic economy without it.

At the same time, people often respond negatively to advertising, especially crass efforts at manipulation. Those living in large cities see up to 5,000 ads per day,³ and many regard the proliferation of signs and billboards as a form of urban blight. São Paulo, Brazil, even went so far as to ban all public advertising in 2007.⁴

The perceived advertising glut is a product of market distortion. Ads are intended to consume our attention, but advertisers cannot be charged for accessing this scarce resource, so the market equilibrium shifts toward consuming maximal attention.

To “price in” this negative externality, city governments forbid certain kinds of advertising or require companies to purchase a license to advertise, using the proceeds to operate public infrastructure such as bus stops and toilets. These regulations often must be amended to address challenges posed by new technologies, such as digital billboards.

Table 1. Mixing information and ads: example scenarios.

Interaction type	Content presentation mode		
	Time multiplexing	Space multiplexing	Integrated
User-initiated	Full-screen advertising display that switches to a store directory upon being touched	Browsable bus timetable with ads next to the schedule	Interactive ball game with a corporate logo attached to the balls
System-initiated	Looping slideshow of various types of content including ads and information	Ads and information displayed side-by-side on the same screen	City map with embedded restaurant ads

Mixing information and ads

Public displays are conceptually similar to commercial billboards and posters, which traditionally contain little or no content besides advertising. A resulting challenge in creating public display networks is to make them attractive to viewers while at the same time catering to other stakeholders' needs.

Designers must consider two dimensions: how to present content—through time or space multiplexing, or in an integrated format—and whether the user or system should initiate interaction. Table 1 provides examples of each possible scenario.

Time multiplexing involves showing different types of content serially on a single display—for example, world and local news followed by weather forecast updates, cartoons, sports news, and advertisements. *Space multiplexing* involves presenting different kinds of content simultaneously, either in separate regions of the same display or in distinct displays—for example, restaurant advertisements next to a city map. Content and ads can also be integrated in public displays. Although in some cases legislation requires news to be clearly distinguished from advertising, ads can be embedded in other forms of content, such as an interactive game.

In *user-initiated* public display systems, users start the interaction—for example, by touching the display. *System-initiated* displays present content without the need for user interaction—for example, a looping slideshow.

Success factors

The most important factor in a public display's success is its location—in general, the more traffic (pedestrian or vehicular), the more attention it will attract. However, other guidelines are important in designing and implementing the system.

Quantifying user behavior. A recent study of user behavior around interactive public displays distinguished different phases of the “audience funnel”: people pass by a display; stop to view and react to it; engage in subtle or more direct interaction, possibly multiple times; and execute follow-up actions, like taking photos and videos.⁵

The researchers proposed the concept of conversion rate to describe the percentage of people who transition from one phase to the next—for example, the percentage

of passersby who look at the display—as a central performance measure to compare different public display deployments. Designers can analyze system requirements to improve the conversion rate and thereby encourage more interaction.⁶

Measuring advertising performance. A classic metric of advertising performance is the number of people who have “contact” with an ad, which forms the basis for what media charge advertisers. Cost per thousand (CPT) contacts then enables advertisers to determine which medium is the most cost-effective—for example, TV versus newspapers.

However, it is often more important to determine whether users engage with an ad rather than simply see it, but the advertising industry has yet to develop a common currency for user engagement; it is still struggling, for example, with the Internet's cost-per-click model. Some public display providers are already charging advertisers on the basis of novel performance measures such as duration of views and number of interactions, but more research is needed in this area.

Attracting attention. To be successful, public displays must get the attention of passersby.⁶ Designers can incorporate well-established visual techniques, such as moving and looming stimuli or motion onset, to attract viewers. User expectations also influence attention—for example, people who expect a display to be boring will ignore the content, a phenomenon similar to banner blindness on the Web.⁷ Social behavior is another factor: the honeypot effect demonstrates that people are more likely to interact with a display if others are already doing so.


Communicating interactivity. Traditional ways of communicating interactivity include calls to action, such as a sign saying “Touch me,” and attract sequences, such as a short video demonstrating the interaction. Recent research suggests that inducing incidental interaction—for example, by projecting a mirror image of passersby—is sometimes even more effective.⁸

Motivating interaction. Many factors motivate people to interact with displays, including the experience of control, curiosity and the desire to explore, freedom of choice, and the satisfaction of collaboration.⁶ Public displays should not require users to make gestures that might violate social norms—for example, kneeling or bowing.⁹

CONTENT PRESENTATION

The presentation of content on public displays is evolving, but developers have yet to fully exploit available technology. Tools used to define the appearance of displays generally appropriate software designed for other purposes—for example, many displays use a slideshow format. This unnecessarily limits the system’s capabilities. The use of Web authoring tools, such as Adobe Flash to create animations, requires designers to treat each display individually, rather than integrating it with the architectural environment. Similarly, existing content management systems make it difficult to blend context adaptivity and interactivity.

Likewise, content providers continue to adhere to the familiar but outdated TV viewing model. However, public displays and TVs are very different media. When watching TV, people are typically sitting down in a quiet, comfortable home environment for an extended period of time,



Combining visual communication channels with other output modalities, such as audio, smell, and tactile feedback, can create more powerful ads.

sometimes hours. In contrast, people observe a public display in a noisy, often crowded space while walking or driving past; unless their attention is drawn to the display, they give it only a cursory glance. Nevertheless, content providers continue to put standard 30-second TV advertising spots on public displays, with the result that many passersby arrive in the middle of the advertisement, miss the story, and leave before the punch line, never knowing what it was about.

From a media perspective, public displays are akin to traditional signage but with added Internet connectivity and interactivity. Consequently, developers should conceive displays as dynamic elements within the context of their physical surroundings. For example, displays in an airport could be synchronized with lighting and other computer-controlled functions to temporarily convert the entire space into a walk-through advertising spot.

In addition, combining visual communication channels with other output modalities, such as audio, smell, and tactile feedback, can create more powerful ads. For example, a heater could be used in conjunction with a Caribbean travel ad to convey warm, sunny weather, or a fan and salty smell could complement an ad for sailing gear.

To realize such innovative experiences, advertising agencies and display providers will need to collaborate with computer scientists in fields ranging from human-computer interaction to image processing to game design.

SENSING THE USER

Integrating various technologies with public displays can help obtain information about passersby as well as enable user interaction.

Touch technologies

Many public displays are already equipped with touch technologies to create interactive surfaces. For example, resistive touchscreens consist of two flexible sheets coated with material that can register the precise location of a touch as the sheets are pressed together. Capacitive touchscreens apply a small voltage to a conductive coating to create an electrostatic field; when a human hand, which is a natural electrical conductor, touches the panel surface, this distorts the electrostatic field, which is measured as a change in capacitance.

Optical touch technologies such as frustrated total internal reflection (FTIR) use light sensors or cameras and computer vision to detect fingers and objects on and above surfaces. State-of-the-art technologies include PixelSense (www.microsoft.com/surface/en/us/pixelsense.aspx), which integrates IR sensors with an LCD display.

The decision of which touch technology to apply largely depends on the application as well as on the display’s location.

Optical and audio sensors

Public displays can use motion detectors, cameras, and other types of optical sensors to collect different types of data about users. This information can range from users’ location or movement to personal or even behavioral traits—for example, mood, age, or gender.

In many cases, such sensors require the use of computer vision. However, today’s cameras are so inexpensive that they can be integrated with virtually any public display, along with advanced processing and data storage capabilities.

Depth cameras can capture the distance and orientation of objects in a space by illuminating it with infrared light. Two technologies prevail. *Time-of-flight* cameras such as Mesa Imaging’s SwissRanger 4000 (www.mesa-imaging.ch/prodview4k.php) use modulated light sources in combination with phase detectors to measure how long it takes light to travel from the camera to the subject and back. *Structured light* cameras like those in Microsoft Xbox Kinect project a light pattern onto a scene; a vision system then calculates depth information from the distortion of this pattern relative to objects in the scene. It is easier to run some operations such as background subtraction with depth images than with normal camera images. The recent price decline in depth cameras has also spawned a significant number of applications, such as gesture recognition.

Public displays can also use microphones, which, like cameras, can provide low-level data requiring only minimal processing—noise level, base frequency, characterization of sound source, and so on—or high-level information, such as speech recognition. Microphone arrays can determine the location of sound sources.

Audience measurement and analysis

Advertisers and other content providers can use data obtained from sensors in public displays to quantify and analyze audience characteristics, enabling them to better tailor their messages. For example, face detection and blob tracking can reveal the number, and perhaps gender and age, of passersby. Similarly, logging interactions with various touchscreen elements can reveal users' potential interests, much like clickstreams on the Internet.

User interaction

Sensors can also facilitate various forms of indirect as well as direct interaction. For example, public displays could use radio frequency identification (RFID) or near field communication (NFC) to authenticate users with mobile phones. In addition to securing input of personal or sensitive data, like an e-mail address or password, such a system would let users interact with the display at a distance, perhaps via special mobile apps. Camera-based gesture tracking would let passersby control a representation of themselves on the screen. It is easy to imagine future displays using eye-tracking technologies to mediate user interaction.

DESIGN CONSIDERATIONS

In creating public display networks, designers can glean much from studies of how people interact with traditional signage: many lessons apply to both digital and analog displays.¹⁰ However, new technologies also require rethinking current practices.¹¹

Understanding the stakeholders

Public displays should provide value to all stakeholders involved.

Retailers and other display providers seek to satisfy their customers and disseminate information about their business and offerings. Most content providers are currently professional advertisers or the retailers themselves. In the future, however, various third parties—including event organizers, some types of service providers, and even passersby—could supply content to public displays. There is an inherent tension when the display and content provider are not the same, as both rely upon each other but have their own goals. To avoid conflicts, display designers must understand both parties' expectations and establish appropriate access control mechanisms.

VIRTUAL VENDING

Traditional advertising signage often includes a phone number to contact or a Web address through which customers can purchase a product. However, public display networks now make it possible for companies to link direct sales to advertising.

As Figure A shows, vending machines already include static ads; virtual vending devices with networked displays would enable consumers to use a mobile phone to buy certain digital items, such as apps and music, in a public space. Companies like South Korean retail chain Homeplus are already deploying such devices in select locations to enable users to purchase and arrange for the home delivery of groceries and other physical items.¹

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1. J. Strother, "Shopping by Phone at South Korea's Virtual Grocery," *BBC News*, 20 Oct. 2011.



Figure A. Current vending machines already include static ads. Virtual vending devices with networked displays would enable consumers to use a mobile phone to directly purchase certain digital items, such as apps and music, in a public space.

Designers must also consider the display's target audience: are users explicitly looking for certain information, such as directions to a store, or are they simply passing by or otherwise unengaged—for example, waiting at a bus station?

The long tail


Advertising campaigns by local businesses or even individuals will become feasible when public display networks replace traditional signage. Ad campaigns are currently limited by the baseline costs of producing, printing, and installing the ad. These costs will converge with digitization, making small-scale and ad hoc campaigns viable. Thus, for example, a grocer could advertise fruits at a lower price in the hour before the store closes.

Engaging experiences

Digital displays will allow for much more engaging, interactive experiences than traditional displays. Consider, for example, a display that lets people control an avatar with body poses, much like playing a Wii or Xbox Kinect game. By having fun, users will be more likely to pay attention to content, and perhaps draw the attention of onlookers.

Personalization and context adaptivity

Traditional factors in an ad's success include the display's location, size, and orientation. The content's relevance to the local community also plays an important role. For example, a display on a university campus is likely to attract the attention of students and hence provides a good platform for advertising student apartments.



Unlike mobile phones, public displays present designers with the choice of focusing on local advertising content or appealing to a global audience.

A major advantage of public display networks lies in the personalization and context adaptivity of advertising content to increase its impact. However, exploiting this capability can be highly challenging, as no prior knowledge can be obtained from traditional displays. Deploying sensing technologies in public spaces also raises privacy concerns.

User feedback

Public display networks make it possible to obtain user feedback in a much more fine-grained and direct way than with traditional signage. Advertisers can quickly determine whether a campaign is popular and, if not, amend or abandon it.

TRADEOFFS

There are various tradeoffs to consider in designing public displays and in crafting advertising content for such displays.

Calm versus engaging advertising

A core feature of the original vision of pervasive computing is that technology must be *calm*—that is, information must effortlessly move between the center and periphery of our field of attention.¹² By using various sensors to detect users' needs and adjusting the content accordingly, context-adaptive displays are an exemplar of calming technology. Over the years, however, researchers have come to realize that determining or even quantifying what

users want through observation alone is difficult, if not impossible. In response to this dilemma, Yvonne Rogers proposed that designers instead focus on *engaging* rather than *calming* users.¹³

We believe that ads on public displays can be calm—that is, unobtrusive—or engaging, depending on the location. For example, a calm ad might be more suitable in a quiet museum, while an interactive ad is more effective in a noisy soccer stadium. Advertising can also be calm and engaging simultaneously. For example, an ad could normally display calm, mildly flowing water and convert to an engaging minigame once somebody pays attention to it.

Privacy versus personalization

From the very beginning, protecting user privacy has been an important goal of pervasive computing. However, there is an inherent tension between privacy and personalization, as it is impossible to adapt content to individual users without knowing something about them. This poses a particular challenge for public display network designers because advertisers have an incentive to collect as much user data as possible to reach customers.

User privacy can be protected through some combination of industry self-regulation and government laws. Whatever mechanisms are used, however, protecting privacy is critical to system success: winning the public's trust requires effort because that trust is easily lost. In general, personalization is more acceptable in overt situations, such as entering a building, while private displays are needed for more discrete interactions, such as entering data.

The size of the advertising audience also comes into play. Whereas outdoor advertising is clearly public, many ad channels are private or semiprivate. TV spots usually target a group of users, and individuals receive Web as well as mobile phone ads. The decision of whether to present an ad in a public or private way becomes essential with personalization, as customized ads could violate the privacy of passersby—for example, an ad for an expensive car might suggest that the person in front of the display has a lot of money. Consequently, personalized advertising on public displays must not become deterministic; an ad should not be traceable to a particular user.

Local versus global advertising

Public displays are deployed in a specific physical locale—for example, in a historic railway station or in front of a postmodern office building. Unlike mobile phones, public displays present designers with the choice of focusing on local advertising content or appealing to a global audience. A similar problem exists for website designers, who often struggle to match dynamic ads with the page's corporate template—color, font, and so on. As display providers usually have the final say on content, this creates a potential problem for advertisers.

Persuasion versus manipulation

Public display designers can apply persuasive technologies¹⁴ to create more effective systems. As persuasion is an integral part of advertising, however, designers must be wary of crossing the line into manipulation. We believe that the use of deception, coercion, operant conditioning, or surveillance to exploit vulnerable consumers is unethical, and that a system's success will in part depend on the designer making correct value choices.

PROTOTYPE DISPLAYS

Three prototype public displays demonstrate the opportunities and challenges of this emerging technology for advertising.

Researchers in Berlin deployed an interactive shop window called Looking Glass⁸ that displayed different representations of passersby—for example, mirror images and silhouettes—and then enabled users to control their avatars in a virtual ball game by moving their bodies, as Figure 1 shows. A field study revealed that this approach significantly attracted more users than state-of-the-art call-to-action or attract sequences.

Another study compared the effectiveness of various chained-display arrangements in different real-world settings.¹⁵ As Figure 2 shows, users saw their mirror image on the displays and were encouraged to play a *Space Invaders*-type game with hand gestures. The study grouped users into active participants, onlookers, and passersby and showed that displays' form factor can strongly influence levels of public engagement.

To understand the motivations of different stakeholders sharing a public display, researchers developed Digifieds,¹⁶ a digital classified ads platform. The system provided an Android client to support the remote creation, posting, and exchange of content via mobile phone and to preserve users' privacy when inputting personal information, such as an e-mail address. Figure 3 shows a typical display. A study of the system, deployed for six months in Oulu, Finland, indicated that both content providers and users were interested in locally relevant information—community news and events, local sales and job offers, and so on. Although concerned about privacy, users felt sufficiently confident in the system's protective mechanisms to share sensitive data in a public space.

Rapid advances in display technology are accelerating the digitization of advertising in public places. The deployment of networked computers with large public displays will ultimately create an entirely new ubiquitous communications infrastructure, driven largely by advertising, that will transform public spaces and how people interact in those spaces.

To attract passersby, display providers will likely offer a



Figure 1. Looking Glass used an interactive ball game to engage passersby.



Figure 2. Interactive displays' form factor can strongly influence levels of public engagement.



Figure 3. Digifieds, a digital classified ads platform, demonstrated that both content providers and users are interested in locally relevant information and that under the right circumstances users are willing to share sensitive data in a public space.

mix of useful information and ads, and system designers will seek to create more engaging, interactive experiences. At the same time, the conflicting interests of stakeholders force tradeoffs with respect to privacy protection, context adaptivity, personalization, and other issues. The solutions to these tradeoffs will significantly impact the future appearance of our cities. **□**

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