Enhancing Accessibility and Engagement for Those with Disabilities

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Pervasive computing technology can enhance quality of life for those with disabilities by providing access to timely information and helping them to navigate their environment independently. Three research projects focusing on different impairments demonstrate the importance of including target users in the design and implementation of an accessibility system.

As pervasive computing devices increase in quantity and capability, they offer abundant new opportunities to help users, especially those with disabilities, in various environments. For example, the University of Maryland's Project Sidewalk (sidewalk.umiacs.umd.edu) is collecting information about accessibility problems in Washington, DC, and other cities from volunteers who virtually explore neighborhood streets and then using that data to "improve city planning, build accessibility-aware mapping tools, and train machine learning algorithms to automatically find accessibility issues."

In general, pervasive computing technology can enhance quality of life for those with disabilities by providing access to timely information and helping them to navigate their environment independently. In this article, I describe three research projects that focus on people with different impairments: deafness and hardness of hearing, blindness and low vision, and autism. In each case, including target users in the design and implementation of the accessibility system has been critical to its success.

LOCATION-INDEPENDENT SOUND AWARENESS FOR THE DEAF AND HARD OF HEARING

UbiEar[1] is a system that notifies those who are deaf or hard of hearing (DHH) about important sound events through their smartphone. To determine what types of sound events to detect and to guide their design, the researchers surveyed 60 DHH students from 10 to 26 years of age. The researchers found that the system should detect four social sound events (doorbell ringing, knocking on door, people crying, people coughing) and five early warning sound events (fire

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alarm, smoke alarm, kettle boiling whistle, microwave oven warning, and police siren). In addition, it needed to work in any location, report sound events with minimal delay and few errors, consume minimal battery power, and require very little user input.

UbiEar classifies sound events using a lightweight convolutional neural network (CNN). Training occurs in the cloud to preserve battery life, while sensing, sound detection, data processing, and sound recognition occur on the mobile device to minimize delay. The system optimizes each computation step on the device to reduce battery load. For example, it uses adaptive sensing to put the microphone to sleep when no sound of interest is detected.

The researchers developed a prototype user interface to learn what sounds students wanted UbiEar to detect and what types of notifications they wanted to receive. They then conducted a second user study with 86 DHH students and found that most of them wanted information on the same sound events from the initial survey conveyed through a mixture of notification mechanisms, including a flickering screen and flashlight notifications, with the ability to personalize these.

The researchers evaluated UbiEar use by the 86 students over 2 days with more than 10 million audio clips from their own collection (including 60,000 that were synthesized with different background noises), along with relevant audio clips from two other online datasets. The researchers found that the system achieves high accuracy (over 90 percent) for the nine acoustic events, and performs better than other baselines including a generic CNN, a deep neural network, a random forest classifier, and an AdaBoost model. They also found that over a 10-hour usage period, UbiEar only drains the phone battery by 16 percent. After the 2-day deployment, the students reported medium to high satisfaction with respect to notification delay and accuracy of the detected sound events.

UbiEar provides a great example of how work at the intersection of pervasive computing and accessibility can profoundly impact people with disabilities. The researchers had to consider both system engineering challenges, such as limited battery life, and the target users' needs throughout the design process to meet their goals. With this mobile technology, people who are DHH can become more aware of potentially important social and early warning sound events in almost any environment.

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PROXEMIC AUDIO INTERFACES FOR VISUALLY IMPAIRED ART ENGAGEMENT

I recently completed a project with Meredith Ringel Morris and Neel Joshi of Microsoft Research in collaboration with two artists.[2] As with UbiEar, our goal was to create a novel technology that delivers information to users with an impairment, in this case blindness and low vision, in an accessible format. However, we also aimed to enhance their engagement with the environment—in particular, museums.

People who are blind or have low vision have fewer opportunities to visit museums and have a fully accessible experience. They must go during scheduled accessible tours (which typically occur infrequently, such as once a month), walk through the museum with a sighted friend or guide, or learn a new audio guide technology. To address this problem, we wanted to create a more accessible way to explore artwork. Similar to the UbiEar team, we consulted with stakeholders to inform our design—in our case, people who are blind or have low vision, artists, and museum staff. Based on these interviews we decided that, to create an aesthetically satisfying experience, we needed a technology that could verbally describe a work of art as well as convey emotion and mood.

After exploring various interfaces that could support such an experience, we opted to create a proxemic audio interface. Proxemics is a theory introduced by anthropologist Edward T. Hall in the 1960s that people place themselves at a certain distance from others by relationship type. Visual proxemic interfaces have adopted this concept by increasing the level of detail or information about a target object as a person moves closer to it. However, previous research had not explored proxemic audio interfaces.

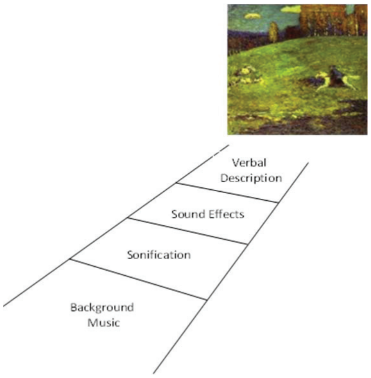

Figure 1. Eyes-Free Art was a prototype proxemic audio interface for museums that increased detail about a work of art (in this case, Wassily Kandinsky's *The Blue Rider*) in four zones as one moved closer to it: from background music to a sonification of the work's colors to sound effects related to objects in the piece to a verbal description of it.

We designed a prototype interface called Eyes-Free Art using a Microsoft Kinect that increased audio detail about a work of art in four zones as a person moved closer to it: from background music to a novel sonification of the work's colors to sound effects related to objects in the piece to a verbal description of it (Figure 1). Users could hear more details by moving their body and hands. We implemented this interface for five paintings with various colors and objects, and conducted a lab study with 13 blind and low-vision people. The subjects appreciated the interface's interactivity, but their feedback also led us to make several changes. These included ensuring that the transitions in the audio presentations between zones were smoother and, in contrast to visual proxemics interfaces, moving the detailed verbal description to the most distant zone to provide more context for the rest of the experience.

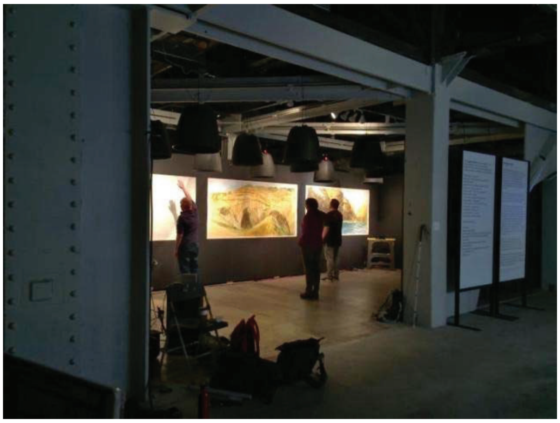

Figure 2. *The Oregon Project* was an interactive art installation inspired by Eyes-Free Art that used Kinect-based proxemic audio interfaces and various sound recordings to engage visually impaired as well as sighted patrons.

Following our lab study, we collaborated with artists Keith Salmon and Dan Thornton to create an accessible interactive art installation called *The Oregon Project* with multiple paintings that numerous people could explore simultaneously (Figure 2). Four Kinects tracked people in the room, and parabolic speakers delivered the audio presentations. Before entering the room, the visitors heard a detailed verbal description of *The Oregon Project* by the artists. As one moved closer to individual paintings, audio presentations seamlessly transitioned from environmental sounds evoking the Oregon plains to paint-stroke sounds, which visitors could control with their body and arms. *The Oregon Project* was deployed at a museum in the US and in the UK. Sighted as well as visually impaired patrons commented that, through the proxemic audio interface, they become more immersed in the artwork.

SOFT HAPTIC TOYS FOR CHILDREN WITH AUTISM SPECTRUM DISORDER

The third research project focused on creating a pervasive technology for children with autism spectrum disorder to enhance engagement with their environment. Jinsil Hwaryoung Seo, Pavithra Aravindan, and Annie Sungkajun of Texas A&M University implemented a six-month design process to create soft haptic toys for autistic children who suffer from over- or under-sensory development and stimulation.[3]

Children on the spectrum actively participated in design exploration sessions, which considered different materials, shapes, and interaction modes. They preferred the softest fabrics, such as microfleece and cotton, along with animal shapes. In addition, the researchers found that vibrations were more helpful in relaxing the children during times of stress than other types of feedback such as lights and sounds.

The soft haptic toys were constructed using the LilyPad Arduino, conductive thread, and other interactive components including pressure sensors and haptic motors. After the design exploration sessions, five children with high-functioning autism created their own toys. The researchers reported that the children were engaged in the building process and happy with the toys that they had created.

CONCLUSION

All three research projects demonstrate the importance of including target users while developing a pervasive computing technology to enhance accessibility and engagement for those with disabilities. Both users and designers benefit from this collaboration, leading to a more effective and impactful system.

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