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In this forum we celebrate research that helps to successfully bring the benefits of computing technologies to children, older adults, people with disabilities, and other populations that are often ignored in the design of mass-marketed products.

— Juan Pablo Hourcade, Editor

Grand Challenges in Accessible Maps

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Digital maps such as Google Maps, Yelp, and Waze represent an incredible HCI success—they have transformed the way people navigate and access information about the world. However, there is a twofold problem limiting *who* can use these systems and *how* they benefit. First, these platforms focus almost exclusively on data about road networks and points of interest (POIs), noticeably lacking information about pedestrian infrastructure and physical accessibility. Second, because of their graphical nature and reliance on gesture and mouse input, digital maps can be inaccessible to some users—for example, those with visual or upper-body motor impairments.

Thus, at a high level, there are two key accessibility problems related to accessible maps: 1) How can we collect, validate, and integrate accessibility information about the physical world into maps? 2) How can we design digital maps to be accessible to a diverse set of users across a wide range of physical, sensory, and cognitive abilities? Active research in HCI and beyond exists in both areas, but there has been no direct effort to unite this research community.

To begin addressing this gap, we recently organized a Special Interest Group (SIG) at CHI2018 entitled “Making Maps Accessible and Putting Accessibility in Maps.” We set forth three explicit goals: First, to bring together and network scholars and practitioners who are broadly interested in accessible maps; second, to identify grand challenges and future

research trajectories; and third, to establish accessible maps as a valuable topic within HCI.

Accessibility is a broad, multifaceted topic. We assembled co-organizers from both academia and industry with varying topical expertise and regional and cultural experiences. The SIG attracted roughly 25 participants, including three telepresence robots, and interwove small-group brainstorming and discussion with large-group summary presentations. The two primary discussion topics were identifying key challenges and seeding potential solutions in the area of accessible maps. Below, we synthesize key themes and enumerate rich, open paths for future work that emerged from the SIG (Table 1).

GRAND CHALLENGE ONE: DATA COLLECTION

Accessible infrastructure has a significant impact on the independence and mobility of citizens. The problem is not just inaccessible pedestrian pathways or buildings but also a lack of reliable, comprehensive, and open information. This *lack of data* has

Insights

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- How can we collect, validate, and integrate accessibility information about the physical world into maps?
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broad, far-reaching consequences, from affecting the types of mapping tools and features that companies develop to providing transparency to citizenry about the accessibility of their cities. So the first grand challenge is about *data collection*, with key questions including: Where does the data come from? How is it collected? Who collects the data and what skills and expertise do they have? How do we account for transient problems (e.g., construction, elevator trouble)? How may emerging technologies like autonomous vehicles, precise 3D mapping via LiDAR, and high-resolution satellite imagery transform data-collection efforts?

Traditionally, city transit departments and, less formally, community organizations conduct manual street audits that assess walkability and pedestrian access. However, this data is typically not freely available, has disparate formats and limited coverage, and is not intended for end-user tools. Fewer organized efforts exist for collecting indoor or transit-related accessibility data, and there are tensions between capturing data in public versus private spaces. Regardless, these in situ methods are laborious and time consuming. Recent applications such as SeeClickFix.com and Wheelmap.org (Figure 1) enable volunteers to assess and report location-based accessibility information using smartphones, which are then viewable online. But these tools often suffer from data-sparseness issues due to low adoption and the reliance on voluntary, in-person efforts. For example, Ding et al. [1] found that

only 1.6 percent of the POIs in Wheelmap.org had accessibility data. To increase scalability, Froehlich et al. have explored remote crowdsourcing approaches using Google Street View (Figure 2) as well as automated methods using computer vision [2], but both provide fewer details than in situ physical assessments. Others have also investigated automated assessment (e.g., [3]). Though promising, this research area is in its early stages, and the aforementioned concerns about validation, maintenance, open data standards, and access continue.

GRAND CHALLENGE TWO: DATA MANAGEMENT AND OPEN STANDARDS

Related to the above, how is the collected data stored, validated, and maintained? Who has access, and what entity is charged with managing the data? How do we build trust in the collected data? How can data be fed into mapping services like OpenStreetMaps.org or commercial tools like Google Maps? Unlike with road networks, there are no widely accepted open standards describing and governing data formats for the accessibility of streets, sidewalks, and indoor spaces. To begin addressing this problem, Anat Caspi and colleagues started OpenSidewalks.com, which aims to make pedestrian ways, particularly sidewalks, first-class members of open data standards included with OpenStreetMap. However, this initiative is still emerging, and new tools need to be developed to collect and incorporate sidewalk data into OSM once the standard is finalized.

Similarly, Wayfindr.net provides an emerging open standard for audio-based wayfinding that includes POIs and landmarks relevant to navigation-based assistive technologies. Tools like NavCog, for example, are beginning to incorporate these standards to support real-time navigation applications for blind people.

GRAND CHALLENGE THREE: MODELING NEEDS AND ABILITIES

Once we have the necessary data, how can we create computational models that *accurately describe the accessibility of the physical world*? Modeling accessibility is a complex, multifaceted open research topic that requires an understanding of *who* the users are, their needs and abilities, an assessment and prioritization of accessibility barriers based on those needs and abilities, and an understanding that needs and abilities may change over time (e.g., due to fatigue)—all of which need to be codified into usable algorithms and user interfaces. Given that users will have a range of physical, sensory, and cognitive abilities (see sidebar), models will have to be parameterizable and customized via end-user UIs to meet varying needs. As initial work, two emerging prototypes, AccessScore.io [4] and AccessMap.io [5], provide interactive customized views of city accessibility and pedestrian routes, respectively, based on an end-user's reported mobility needs and preferences (Figure 3). However, their models both focus solely on mobility

IMPACT OF USER ABILITIES ON MAP INTERACTIONS

Users' varying sensory, physical, and cognitive abilities can lead to differing accessibility challenges with digital maps. *Sensory abilities*, such as vision and hearing, allow an individual to sense information about the world around them. For example, blind or low-vision users may have difficulty accessing visual map information on smartphones, kiosks, and computers, while people with hearing loss may not be able to use auditory navigational guidance. *Physical abilities* including dexterity and mobility can also impact map accessibility. For example, multitouch gestures can be difficult or impossible for some users with upper-body motor impairments, while users with a limited range of motion may have difficulty using touchscreen kiosks. *Cognitive abilities* are broad, encompassing memory, learning, concentration, decision making, and language (e.g., speech and reading). For example, a user with a language impairment may have trouble understanding textual labels or invoking speech commands. Digital-map designers and UX researchers should work toward designing and evaluating solutions for these diverse abilities and user groups.

Challenges	Key Questions
Data Collection	Where and how to collect physical world accessibility data? Who collects the data and what skills do they have? How to account for transient problems? How to make use of emerging technology like automated vehicles?
Data Management	How is the collected data stored, validated, and maintained? Who has access and is charged with managing the data? How can this data be fed into mapping services?
Modeling	How can we create computational models that accurately describe the accessibility of the physical world? How can these models be dynamically personalized to fit the needs of all individuals?
Accessible Maps	How can maps be made more accessible for various stakeholders and ability labels? How can we integrate multimodal interaction modes into our devices—tactile displays, new auditory methods—and provide alternatives to gestural interactions?
User Foci	How to include users with cognitive, literacy, and language impairments? How to broaden the scope of accessible mapping efforts outside the U.S. and Europe?

Table 1. Grand challenges and key research questions for accessible maps.

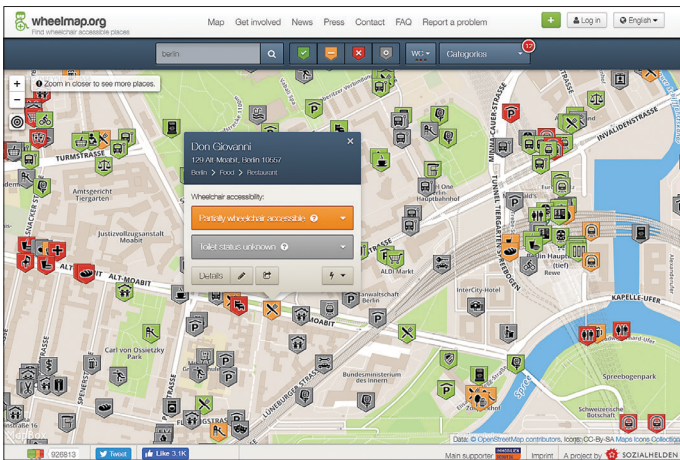


Figure 1. Wheelmap.org combines crowdsourcing for data collection and a corresponding map visualization to enable users to find wheelchair-accessible places. The map data is stored in OpenStreetMap, and the datasets are published under the Open Database License.

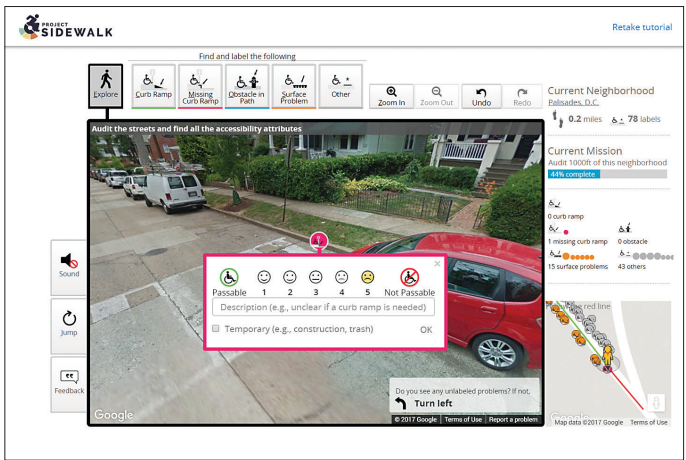


Figure 2. Project Sidewalk (<http://projectsidewalk.io>) enables anyone with an Internet connection to virtually walk through city streets and mark pedestrian-related accessibility problems such as missing curb ramps or surface problems.

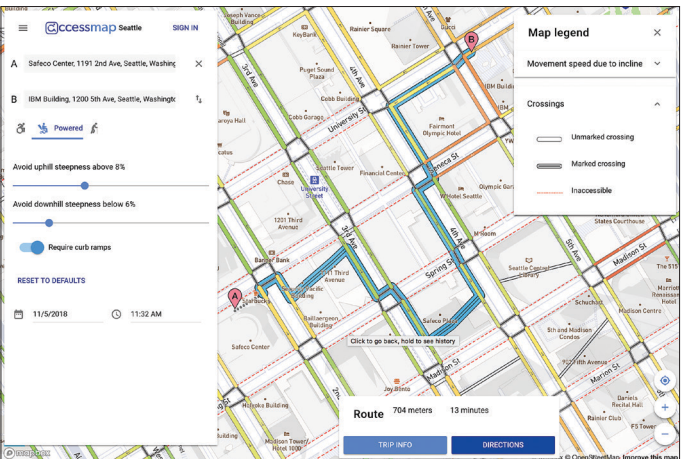
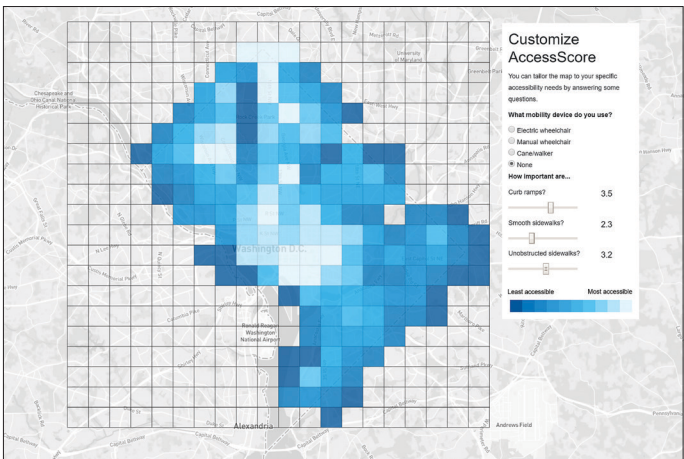


Figure 3. AccessScore.io [4] and AccessMap.io [5] provide interactive visualizations of pedestrian accessibility for people with mobility impairments. With both tools, users can select their mobility levels and weight specific physical-world properties like uphill steepness and curb ramp availability.

impairments and have yet to be extensively evaluated.

GRAND CHALLENGE FOUR: ACCESSIBLE MAPS AND APPLICATION

The data and underlying models are meaningless if a broad user base cannot access, interact with, and use them. Thus, the fourth challenge is twofold: First, how can we create accessibility-infused maps that are designed for and contain information for a broad userbase? And second, what type of applications can we and should we build that maximize value to our key stakeholder groups—be they users with impairments, caretakers, and/or government workers?

Toward the first concern, digital maps are inherently graphical and rely on gestures or mouse inputs for

interactivity, which limit their use. How can we increase the accessibility of digital maps by creating better standards and design tools, supporting alternatives to gesture-based interaction via eye tracking or one-switch interfaces, and experimenting with less traditional interaction channels like haptics and olfaction? For people who are blind or have severe low vision, there is a long history of providing tactile alternatives, with recent research and commercialization efforts focusing on adaptations for touchscreens. For example, IVEO (<https://viewplus.com/product/iveo-3-hands-on-learning-system/>) uses tactile graphics over a touch display, and the VISTE project has explored tangibles and augmented reality [6] (Figure 4). Yet many challenges remain: How do we integrate tactility into otherwise

flat smartphone screens? How can we provide real-time navigation support that is accessible to people who are blind or those with cognitive disabilities? How can we improve voice interfaces for people with hearing and/or speech impairments?

Toward the second concern, what can we—as a community—build to maximize the benefit to our user groups? How can we leverage these new sources of data to support people with impairments in their daily lives?

How can we create accessibility-infused maps that are designed for a broad userbase?



Figure 4. The VISTE project [6] (<http://visteproject.eu/>) combines tangible user interfaces and augmented reality to make maps more accessible for users with visual impairments.

How can artificial intelligence help to provide the required information or route at the right time or to take people where they need to be? To begin addressing these questions, Hara et al. introduced participatory design techniques to explore assistive, location-based technologies for people with motor impairments [7]. However, open problems remain, such as building personal pedestrian routing applications at scale, broadening use cases to multimodal travel, addressing questions that arise in urban and transportation resource planning, and finding machine-learning techniques to better model heterogeneous travelers.

GRAND CHALLENGE FIVE: USER FOCI

In preparing for our SIG and conducting background research, we observed a disproportionate focus in the accessible maps literature on users with visual or motor impairments while overlooking cognition, literacy, and language. And though accessibility is a global problem, we also found a disproportionate focus on American and European cities compared with areas in Africa, Asia, and South America. Because the layout, culture, and accessibility of cities differs significantly among regions, the accessible-mapping community needs to create stronger connections to researchers, practitioners, and potential users from these regions to better

understand unique regional needs and preferences before targeting mapping efforts in these areas.

CONCLUSION

There is a sizable community of researchers and practitioners working on accessible maps. Through our SIG at the CHI 2018 conference, we hope to energize a wider community interested in this topic. We invite interested readers to email us to engage in discussion and to follow us on Twitter (@accessiblemaps) for updates. Together we can address the five grand challenges of putting accessibility into maps and making maps accessible.

ENDNOTES

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