Interactive Visual Exploration of Physical Accessibility

Manaswi Saha
University of Washington
manaswi@cs.uw.edu

Anupam Gupta
University of Washington
anupamg@cs.uw.edu

ABSTRACT

For people with mobility impairments, street infrastructure such as sidewalks play a crucial role in navigating within cities. However, there is a severe lack of readily available tools for querying accessibility information. In this project, we worked on building a tool that visualizes the *physical accessibility* of Washington DC. The interactive prototype highlights (in)accessible areas of DC via creative use of geo-visualization techniques such as choropleths, line based street-level visualization and others, for a dataset of geo-tagged accessibility labels. The primary stakeholders of such a tool include city residents (*esp.* people with mobility impairments and caregivers), and city government officials. Secondary stakeholders include researchers and data enthusiasts. Each stakeholder group have specific design requirements from such an interface. In this paper, we focus on the primary question, "*What is the accessibility of a specific region and what are the factors influencing the accessibility of this region?*".

Author Keywords

Geo-visualization; physical accessibility; semantic zooming; visual exploration.

INTRODUCTION

Physical accessibility or street-level accessibility of a city looks at the ease with which people using different mobility aids such as wheelchairs, walkers, strollers and canes, can navigate within cities. Built infrastructure such as sidewalks have often been found to be deficient in supporting these mobility needs. Tools that support querying about accessibility will go a long way in supporting such individuals in their day-to-day trip planning needs. However, there is a dearth of tools that allows a user to explore the physical accessibility of a region. In this paper, we look into designing and developing a visual exploration tool that supports querying the city's physical accessibility.

In addition to people with mobility impairments, the other stakeholders include city government officials, urban planners, and the general public. Each group has a diverse set of needs. For example, a government official would be interested in knowing about the type and frequency of issues such that they can prioritize major issues for repairs and upgrades. Supporting the various needs of these groups is out of the scope for this paper. We focus on the common denominator across these groups, namely, *determining the accessibility of a region*.

In this paper, we present a design case study of using visualization to address the problem of exploring physical accessibility of cities. Our goal is to enable anyone to comprehend and determine the accessibility of urban regions. We visualize the dataset from *Project Sidewalk*[1], an online tool that crowdsources labels for accessibility features and problems within Google Street View (GSV)[5]. This dataset has >250,000 labels on accessibility of sidewalks in Washington DC. Each label denotes a specific accessibility attribute in the physical world such as a *Curb Ramp*, *Surface Problem*, *Obstacle in Path*, and *Missing Curb Ramp*, their geographical lat/lng coordinates and metadata (severity, associated GSV panorama, and additional notes on the labeled attribute). This data is available via Project Sidewalk's GeoJSON API (http://projectsidewalk.io/api), which we use in our system.

RELATED WORK

Geospatial visualization is a well-studied field, and has its application in diverse domains, such as for crime spotting, tracking greenery, health and others. We are looking at a specialized domain of physical accessibility of cities.

Several techniques have been proposed and used for geospatial visualization. The traditional approach is "direct depiction" of each data point on a map to extract patterns. However, with increasing dataset sizes, this approach is not scalable. An alternative approach is to create meaningful aggregates that is an abstraction of the problem at hand. And the third common approach is to use visual data mining, where useful patterns are extracted prior to data visualization [1]. We take the second approach of using aggregates for visualization. We utilize a metric called access score (described later) to aggregate accessibility of a region.

[1] http://projectsidewalk.io/

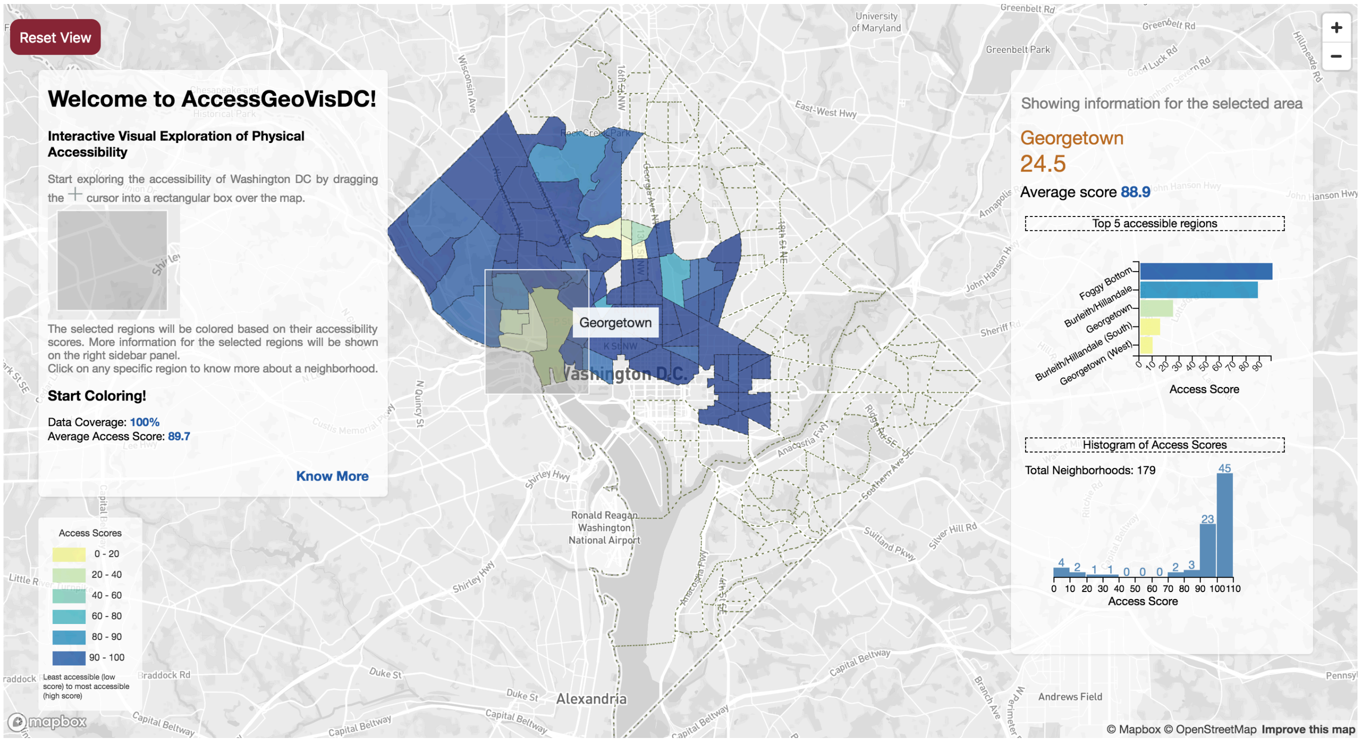

Figure 1 Visual Exploration Interface (Neighborhood Level). This illustration highlights the main *overview level* where a user can compare the accessibility of regions using a metric called Access Score. Exploration starts by selecting region(s) of interest using the brush box. Based on the selection, the right sidebar provides a detailed overview about the accessibility of the selected neighborhoods. Three main summary statistics shown are average access score of the city, top 5 accessible neighborhoods and a histogram of access scores across all neighborhoods that is currently visualized. Left sidebar provides instructions to use the tool.

Roth presents a taxonomy of interaction primitives for map-based visualization [4]. He describes twelve "work operators", namely, reexpress, arrange, sequence, resymbolize, overlay, pan, zoom, reproject, search, filter, retrieve, & calculate. In our system, we make use of overlay, pan, zoom, filter, retrieve, and calculate.

DESIGN GOALS

Prior design studies on location-based applications for accessibility [2] have provided design guidelines for such tools. They are (1) supporting at-a-glance visualization of accessibility of a city, (2) supporting street-level visualization showing curb ramps and other barriers along with the severity of the issues, (3) supporting visual inspection of locations remotely (*e.g.*, through images of locations), and (4) supporting the ability to "dive" into the accessibility data to allow for answering queries such as "*why is the region inaccessible?*". The participants express the need to evaluate the accessibility for a region by themselves.

Following these guidelines, our main visualization task is allowing a user to find the accessibility of a region and explore the factors influencing the accessibility of the region. The main questions that we want to support are "*How accessible is my neighborhood?*", "*Why does a neighborhood have poor accessibility?*", and "*Which are the most accessible neighborhoods in the city?*".

In addition to these major requirements, we also want the system to support operations that allow further exploration such as filtering based on regions of interests, and comparing regions. Finally, we want to support dynamic queries for filtering regions.

VISUAL EXPLORATION SYSTEM

Based on the aforementioned design goals, we developed a geo-visualization and exploration system called *AccessGeoVisDC* that allows a user to interactively explore the accessibility of region(s) of interest. The tool relies on a measure called *Access Score*, a model that takes the accessibility attribute labels (such as curb ramps, surface problems, and obstacles) as parameters to give a score between 0 and 1. This score is visualized on an interactive map in different forms. To facilitate exploration, we follow the visual information-seeking mantra of *overview first, zoom and filter, then details-on-demand* [7]. Based on this approach, the user interactively drills down from the coarse-grained *city level* down to the fine-grained *street level*. This exploration is supported by various interaction primitives that we will discuss later. Figure 1 shows the interface at the top most city level.

Figure 2 Street Level. In this illustration, the streets are colored based on the corresponding access score. Street are segmented from one intersection to another. Hence, a single street may have different access scores (as seen in the image).

Visualization Design

The system has three visualization levels: (1) *Neighborhood level*: Shows an at-a-glance visualization of all the neighborhoods at the city's zoom level *i.e.*, the whole city is visible on the screen, (2) *Street level*: shows the accessibility of streets for a selected neighborhood, and (3) *Feature level:* shows the accessibility based on raw features for a street or a set of streets. This is the finest granularity level of accessibility. The features include curb ramps, missing curb ramps, surface problems and obstacles.

At the neighborhood level (Figure 1), a choropleth is used to visualize the accessibility based on access scores. This level supports the task of both getting a high-level sense of accessibility as well as allowing for comparison of accessibility across regions. Based on past literature [3] demonstrating the effectiveness of Viridis colormap [8], we used this gradient scale for coloring neighborhoods and streets based on access score. A coloring metaphor is used to deal with small data retrieval and dynamic queries. Brushing allows the user to select region(s) of interest to know more through summary statistics shown in the right sidebar panel. Three main summary statistics are shown: top 5 accessible neighborhoods within the selected area, average access score of the city, and a histogram of access scores across all neighborhoods that is currently visualized.

At the street level (Figure 2), color coded lines are used for the visualization. The dashed line strokes are used to represent a street. The right sidebar shows the average street score for the selected neighborhood, and the label counts for this region. The street level visualization enables the user to identify specific reasons for a region to be (in)accessible.

Finally, at the feature level (Figure 3), the labels from the dataset is shown for the selected street/region color coded by the type of the label (e.g. *Missing Curb Ramp vs Surface Problem*). At this level, a user is allowed to visually inspect each label to evaluate the accessibility of a location through images (this feature is under development).

To move between these levels, we use an approach called **semantic zooming** [6] that displays different representation of the same data (here: accessibility) across different zoom levels. To move from the neighborhood to street level, a user needs to click on a region to zoom into that region. To move from street level to feature level, a use can either view all the labels for the region with a button click, or by clicking on a specific street to see labels for only that street (this functionality is also under development). Hovering is enabled over all the neighborhood areas and bar graphs to learn more about the scores for each. Finally, we use the brush interaction to draw rectangular boxes over the map for selecting regions to explore/compare. Based on the selection, information for these regions is updated on the right sidebar.

Implementation

We implemented the system using HTML/CSS and JavaScript libraries namely, mapbox-gl and d3. The tool queried data from Project Sidewalk APIs to acquire access scores for neighborhoods and streets, and the features for the region(s) of interest. The tool is available online at https://cse512-18s.github.io/sidewalk-a11y-geovis/.

RESULTS AND DISCUSSION

To test our system, we conducted an informal over the shoulder observation with random users (mostly graduate students). We asked them to explore the accessibility of the city using our tool. Since this was an informal usability testing scenario, most users were mostly exploring and learning more about the tool. Once familiar, they started to see patterns and make inferences about the accessibility of a region through the visualization. For example, one user was reasoning about a neighborhood's accessibility based on the access score visualization and acknowledged that "yes, Georgetown does have poor accessibility" based on personal experience. We also received feedback on certain aspects of the tool for future enhancements such as being able to click on the bars (from the sidebar) and to highlight the corresponding region in the map.

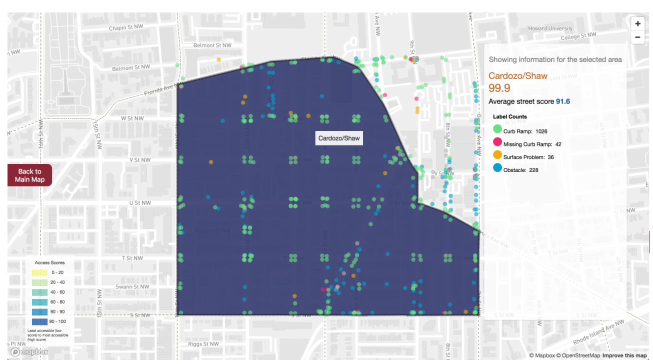

Figure 3 Feature Level. Illustration shows the different types of label types from the dataset that directly influences the accessibility of a neighborhood.

In terms of feedback, most of the users liked the street level visualization especially the textured visual appearance. Finally, some users weren't aware of physical accessibility and what it meant. This work allowed them to have a better comprehension about urban accessibility, which was our secondary goal (being able to engage the general public).

FUTURE WORK AND CONCLUSION

We built a visual exploration tool for physical accessibility, that allows a user to interactively analyze the accessibility from different views such as at the city, neighborhood or the street level. Based on an access score, the accessibility is visualized in different forms depending on the zoom level (*semantic zooming*). Different types of interaction primitives allow for varying levels of exploration.

This prototype serves as an initial proof-of-concept system. We envision expanding the current simple visualizations e.g., supporting remote inspection of accessibility at the feature level. We also want to explore other geo-visualization techniques, and study the effectiveness of each in the context of accessibility.

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