Auditory Display of Spatial Data

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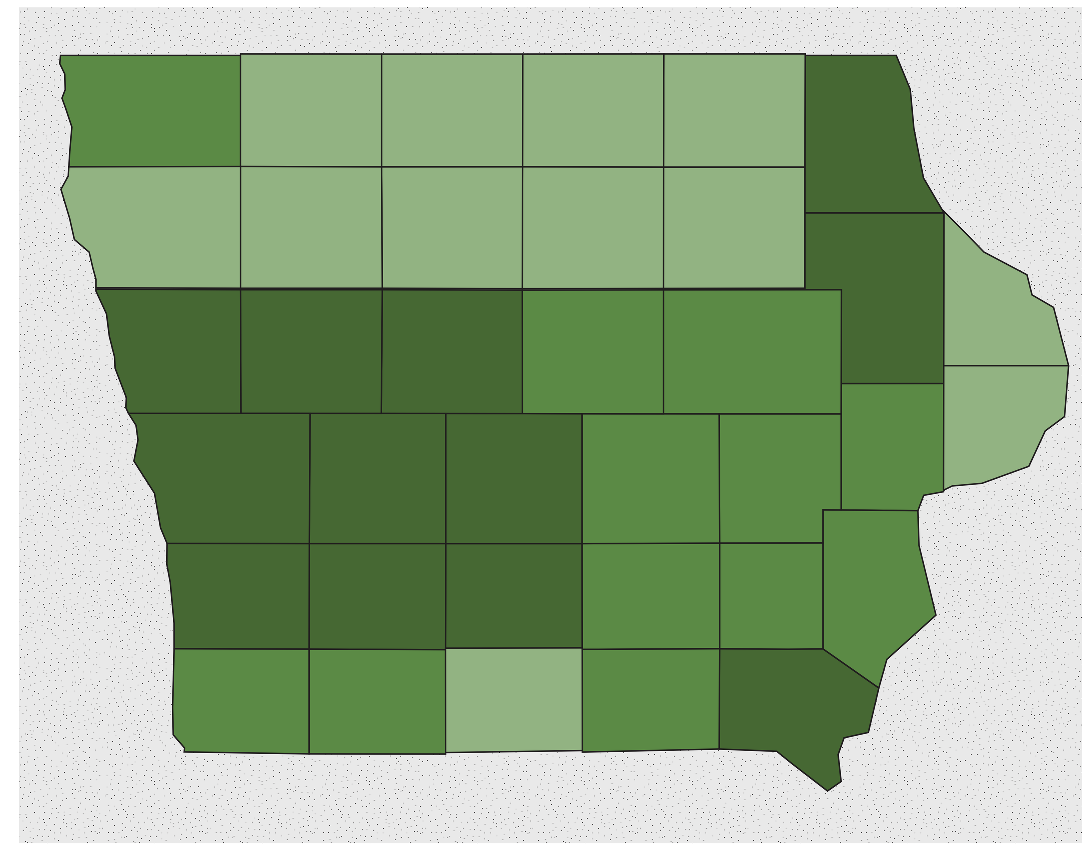
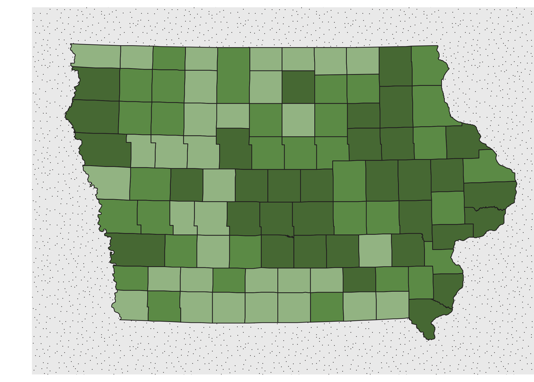
Introduction

Maps are a popular and effective way to communicate spatial data and information. Cartographers have developed numerous techniques to graphically represent maps, and auditory displays also hold potential to convey spatial information. Auditory interfaces have the potential to increase the volume of information that can be communicated and to improve accessibility of digital information.

The minimal geographic information system (mGIS) is an application developed to improve access to spatial data for people who are blind. The mGIS uses a combination of proprioceptive and auditory feedback to convey location within the display and attributes of map content, respectively. Moving a stylus across the tablet, users hear an auditory representation of the spatial data. Spatial analysis functions are available in the application menus, which are accessible through text-to-speech. A visual component of the display is also included to support work with sighted and low vision collaborators.



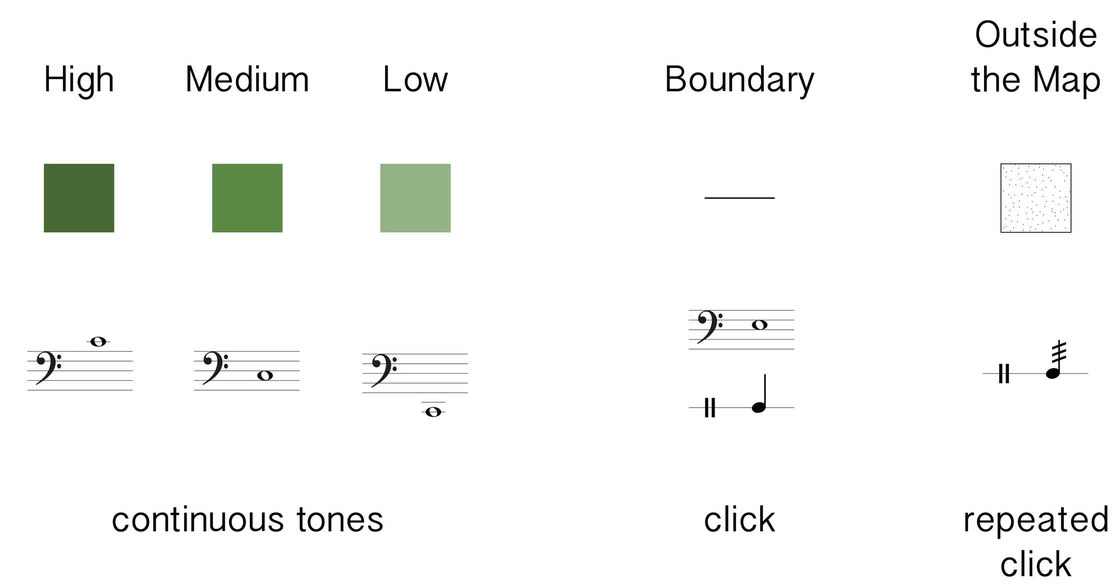


The counties of Iowa (above) were chosen as a basis for the test data because they have very regular shape. The geometry was simplified (left) for the initial audio display and to control the complexity in the Region Lab.

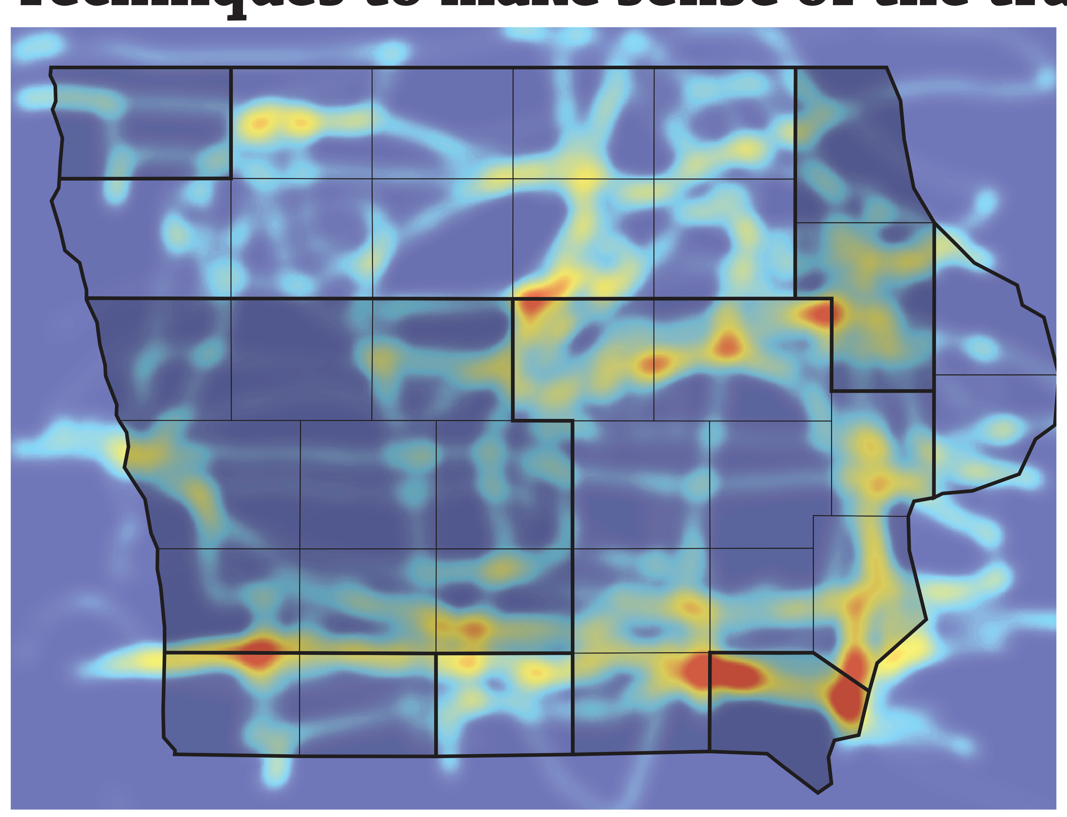
Continuous tones and a single hue sequential color scheme represent three levels of (fictitious) population density.

A fourth frequency represents boundaries when the stylus is within 10 map units (3 mm). Transition across a boundary is symbolized with a short click.

The area outside the map produces a continuous series of clicks.

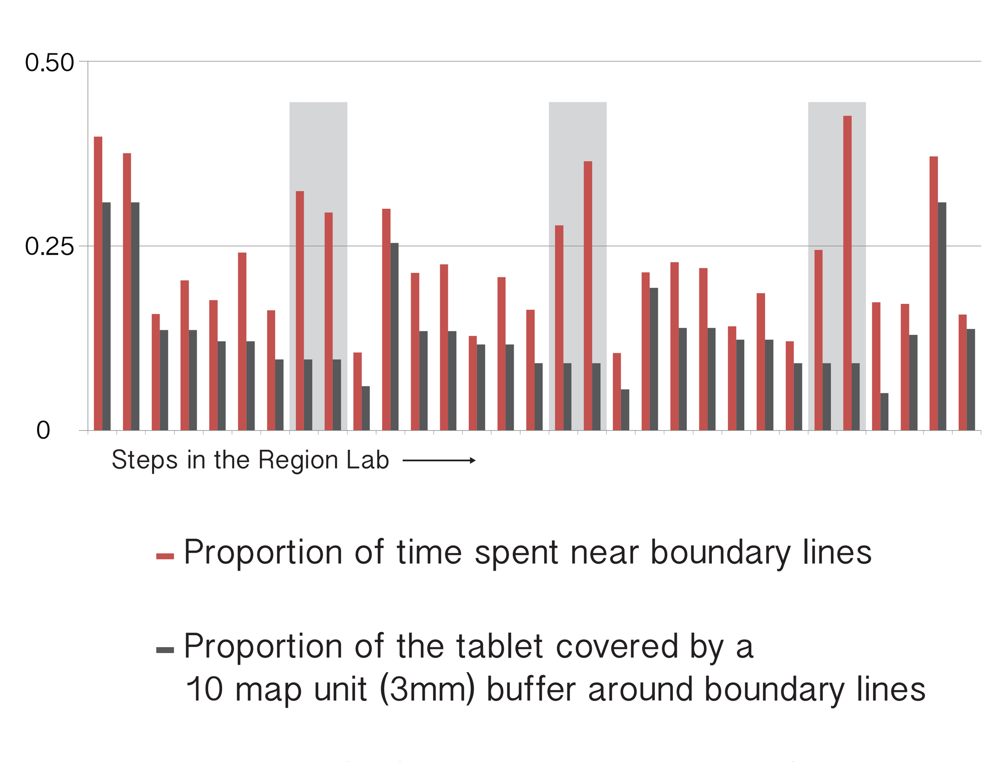


Techniques to make sense of the traces



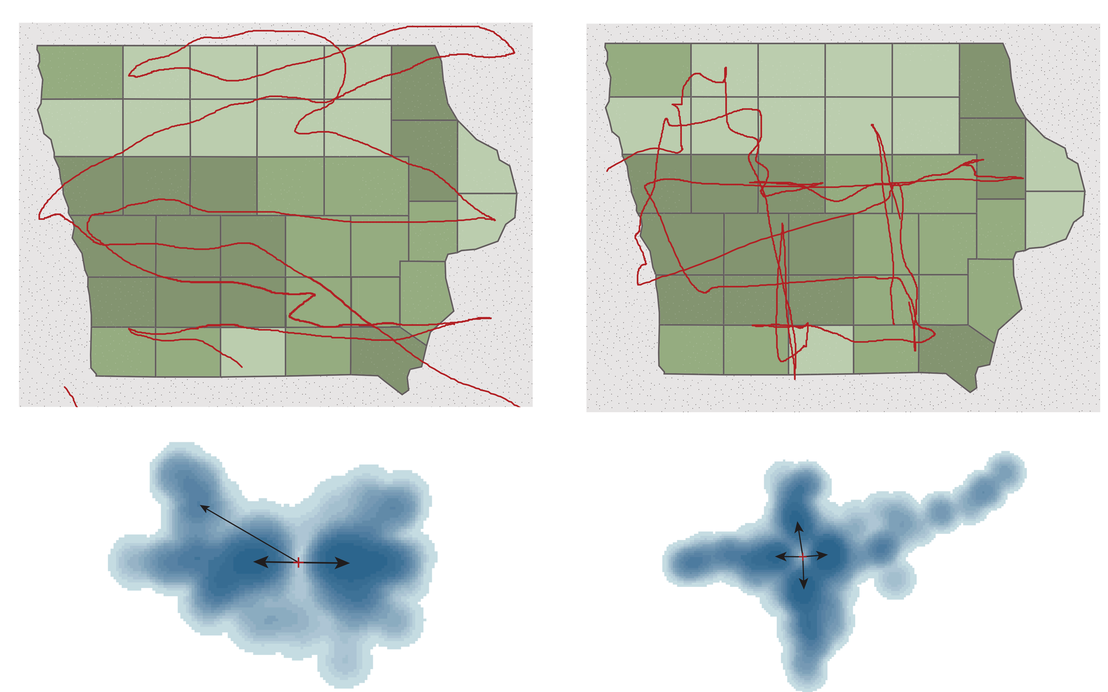
Areas of Interest

Points sampled from the stylus indicate locations that the users visited during exploration. Peaks in a kernel density computed from these points (shown in red) highlight areas of concentrated activity and suggest areas of interest that are specific to the map content.



Task Dependence

Participants spent a disproportionate amount of time within 10 map units (3mm) of boundary lines compared to the percentage of the tablet area covered by that buffer. This observation suggests that participants were able to perceive the border symbol, and the extent to which participants focus on borders is task dependent. While neither of these findings is surprising, both are important to interface design and usability.



Strategies

The interface did not constrain the direction of stylus movement, but strong trends were observed. Two example traces illustrate strong horizontal (left) and combined horizontal and vertical (right) scanning strategies used during map exploration.

The blue density plots represent direction of movement as position around the origin (marked with a red cross) and speed as distance from the origin.

Several techniques help quantify the patterns in stylus movement that were observed during behavioral testing. Empirically identifying areas of interest (above left), objectively classifying scan strategies based on movement direction (above), and determining context dependencies (left) all help inform interface design decisions and guide development of training materials.

Acknowledgements

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Region Lab

In our research, we are trying to identify successful strategies for interacting with spatial data in an auditory display. The Region Lab is an educational intervention that breaks down the concept of region into a series of actions available as GIS functions: classification, proximity, cluster, and boundary. For each action there were four phases: explore, search and select, execute the GIS function, and verify the result.

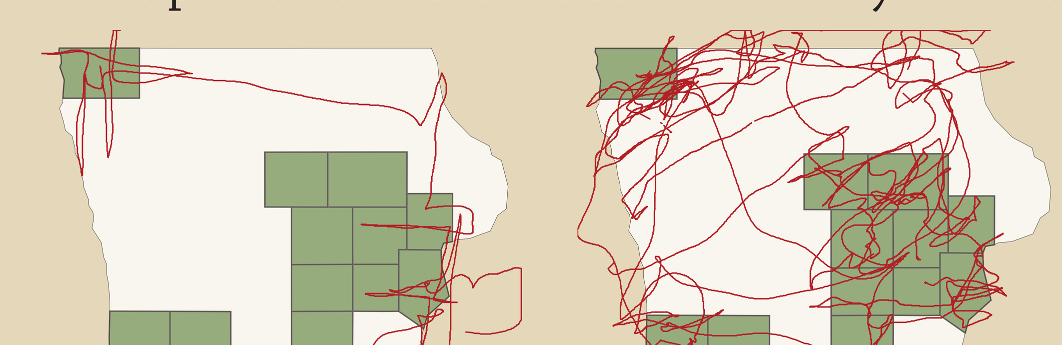
1 Explore

After filtering the display to show only counties with medium population density, participants were asked to explore the map.

Traces of stylus movements during exploration reveal that some participants adopted a time efficient strategy that used a systematic scan pattern and provided moderate coverage (left). Some participants covered a large proportion of the map extent but spent more time (center) while others covered only a limited area (right).

2 Search and Select

Participants were asked to select a county that has no similar neighbors.



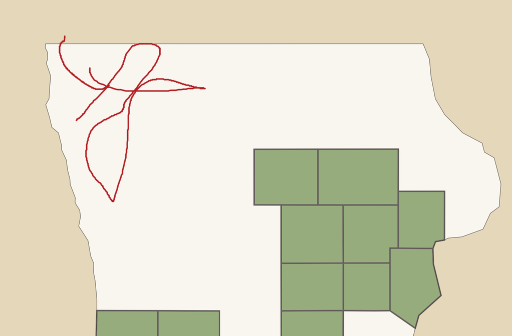
Traces of stylus movements suggest that some participants used border crossings to check the topology of the counties (left). Other participants spent more time and produced traces that appear less systematic (right).

3 Execute Spatial Analysis Tool

Tools to perform spatial analysis were available through the application menus and accessible through text-to-speech (JAWS).

4 Verify the Result

After executing the spatial analysis tool (e.g. *proximity*), participants were asked to verify that the county with no similar neighbors had been removed from the display.



This example trace shows strong fidelity to the location of map elements even after they have been filtered out of the display.

Several participants were able to return to locations described in the instructions. This suggests that they had formed a mental representation of the spatial arrangement.

While there were strong individual differences in the way participants approached the problems, there were trends among the successful strategies. By determining which strategies lead to better performance, explicit instructions to teach those strategies may improve performance among users who struggled to complete the Region Lab.