Towards Fully Accessible Data Visualisation

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Data visualisation is increasingly important
Statistics thrives on visualisation, diagrams are everywhere
  - starting in elementary school
  - in everyday publications: newspapers, magazines
  - in the workplace
People with visual impairments are often excluded from accessing crucial information
Allow VI users to become creators not just consumers of visualisations
Motivation and Aims

Bring together

- Jonathan’s work on tactile graphics in R
  - Jonathan is blind and a statistics professor
  - Needs to create meaningful diagrams himself
- My work on web accessible STEM diagrams
  - End-to-end workflow for (some) STEM diagrams, using image analysis, semantic enrichment and a web interaction model

- Can we generate web accessible data visualisations?
- Can we support working VI statisticians/students directly?
Overview

- Accessible diagram problem
- Type of data visualisations
- General navigation model
- Workflow interaction model
- Demo
- Conclusions
Diagram Accessibility: The Past

- Learning and reading material in Braille, tactile graphics, ...
- Textbooks audio recorded by expert readers, allowed for independent study
- Use of models, tactile prints, swell paper, etc. in class
- All this is already gives VI readers a considerable disadvantage
- But it gets worth with modern material
Most content is in electronic form
Anyone can prepare material
Information is ephemeral
More and more moving to the web
Content is more and more geared towards impressive visualisations

Thread: Danger that the accessibility gap widens
Opportunity: The Web is ubiquitous
Web Accessible Diagrams

Leverage power of web applications and assistive technology

- Embed information and data into a diagram
- Interactive exploration of content
- Speech generation for Screen readers
- Synchronised highlighting and magnification

This talk is about statistics

But we also have other STEM diagrams, e.g., chemistry, physics, . . .
Not necessarily Discrete Data!
But a “discrete” presentation of data
Examples: Histograms, Boxplots
Continuous Data Graphs

- Not necessarily Continuous Data!
- But a “continuous” presentation of data
- Examples: Time series, scatter plots
System Background

**R** programming language and software environment for statistical computing
- efficient manipulation of statistical data
- plethora of visualisation options

**BrailleR** Extension to turn R graphics into tactile diagrams
- Tactile graph components
- Braille translation of text

**DIAGcess** Javascript library for screen reading and interactive exploration of SVG diagrams in any browser
- combines annotated SVG with an XML navigation structure
R offers a number of different renderers
  - many produce SVG, some even good SVG
  - we chose gridSVG which generates highly structured SVG
  - already provides considerable semantic grouping

Compute semantic information to explain the diagram
  - Start with R model that contains all statistical data
  - Generate speech annotations for diagram elements
Creating a Navigation Structure

- Generate Abstraction Graph for navigation and explanation
  - Represent diagram as multi-layered graph
  - multiple layers of abstraction
  - “fit” XML to SVG via element ids with three element types: active, passive, grouped
- Graph structure serves as bases for interacting with diagram
- Very simple navigation model: down/up, right/left
Navigation Model (Boxplot Example)

- **top level summary**
  - **title**
    - **title**
    - **sub-title**
    - ... 
  - **x axis**
    - **label**
    - **tick 1**
    - ... 
  - **y axis**
    - ... 
  - **data content**
    - **data element 1**
    - Additional details 

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**Boxplots for Ozone**

- Months: 5, 6, 7, 8, 9
- Data content: 
  - Boxes represent data distribution across months.
Navigation Example

boxplot

- median
- lower quartile and upper quartile
- lower whisker and upper whisker
- outliers
  - outlier 1
  - ...
  - outlier n
Accessibility Support

- **Screen Reader Support:**
  - Generate speech output from XML annotations
  - Display of speech output using subtitling

- **Low Vision/Learning Disability Support:**
  - Highlighting of inspected components
  - Optional zooming and magnification of components
  - Changing contrast, colour configurations
Example: Exploring a Histogram

- Initial top level summary
- E.g. “Histogram of Ozone” or verbose
- “Histogram showing 9 bars for Ozone over the range 0 to 150 and Frequency from 0 to 30.”
First level exploration of 4 major components

- Title: “Histogram of Ozone”
- X axis: “X axis Ozone ranges from 0 to 150”
- Y axis ...
- Data content (summary)
Example: Exploring a Histogram (cdt.)

- Next level: Diving deeper into components to get more details
- E.g. for data content:
  - Explore every bar separately
  - E.g., “Bar 4 at 70 with value 15” or verbose
  - “Bar 4 between x values 60 and 80 with y value 15 and density 0.00647”
Navigating Continuous Data

- Apply the same navigation model on the data component
- Split continuous curve (recursively) into intervals
- Exploit discontinuities if possible
- Otherwise rewrite SVG diagram to allow navigation of partial curves
Support typical workflow for a working statistician in R

Recurring process of model refinement by
- data generation and manipulation
- data inspection and visualisation
- adaptation of the data and modification of the current statistical model

Replace canvas based by browser based visualisation

Automatically open and shift focus to browser tap

Combined with work in accessible environment like Shell, Emacs, etc.
Evaluation

- Expert evaluation
  - Feedback from 10 power users
  - Exclusively positive
  - People want to get involved

- User Study
  - 12 non-expert users
  - Generally very positive
  - Demand for Braille output and sonification

- User study with audio tactile diagrams in July
Conclusions & Future Work

- Work should aid with learning, teaching and employment
- Extending to more types of diagrams
- Adding sonification for recursively exploring continuous curves
- Demonstrates transferability of navigation model
- Fits into ongoing work of making STEM diagrams accessible
References

- BrailleR available via CRAN in R

Web References

- Demo:
  - https://zorkow.github.io/BrailleR/www/
- BrailleR package:
  - https://github.com/ajrgodfrey/BrailleR
  - https://www.r-pkg.org/pkg/BrailleR

- Chemistry examples:
  - https://progressiveaccess.com/chemistry

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