Navigating the Aural Web
Augmenting Access for the Blind

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... and many others... (10+)
Lab and Project Background

- 5 years of basic human-centered research in the area of aural user interfaces, with emphasis on Human-Computer Interaction (HCI)
- Work supported by 3-year ($400K+) NSF grant award on ‘Navigating the Aural Web and Google Faculty Research Award ($40+)
- As part of a broader research line on aural accessibility for the blind and the visually impaired (BVI), in collaboration with Prof. Mannheimer and Palakal, also supported by $300k of funding from NSF and Google.
- Over 20+ graduate and undergraduate students involved
  - 20+ publications, 4+ system prototypes, 3 PhD dissertations completed
  - 5 user studies completed (all IRB approved), 2 provisional patent filed with IURTC
  - 15+ local and regional exhibits and presentations

More info on Dr Bolchini’s HCI research lab: [http://mypage.iu.edu/~dbolchin/](http://mypage.iu.edu/~dbolchin/)
Lab and Project Background

- Foundational work for our new Indiana Center for Accessibility Informatics Research (iCAIR)
- Basic HCI research findings applied to *both* BVI and sighted aural scenarios
- Possible thanks for the collaboration with BVI advocates, users and research participants at the:
  - Indiana School for the Blind and Visually Impaired
  - BOSMA enterprises
  - EasterSeals CrossRoads
Modelling User Experience Architectures
The traditional notion of web page is a highly-visual concept. It conveys rich visual cues to guide users, at various levels, to:

- **Understand the purpose and topic** ("Oh, it’s an eCommerce site")
- **Poke around to be surprised** ("what’s new and interesting here?")
- **Quickly determine relevance** ("This is not the page I was looking for")
- **Glance at organization** ("This is a ‘product’ page")
- **Examine the message** ("It’s about the new MacBook Air")
- **Scan to find details** ("Let’s see the product specifications")
But most of this is not available during “aural browsing” with screen readers...
And if we remove from our experience the visual semiosis...
What remains is... navigation
Navigation Modelling

- Navigation (a non visual concept) scaffolds the user experience by enabling the movement across dialogic units of the information architecture.
Modelling the Aural Navigation Experience ... from Human Dialogues

- Navigating Aural, Human-Human Dialogues

- Very fluid dialogue “moves” to master navigation complexity
  - *Cata-fora* {gr.: bringing forward; lat.: pro-posing}: moving forward in the dialogue, anticipating items of conversation
  - *Ana-fora* {gr.: bringing up, as in prior/higher}: moving backward in the dialogue, referring back to items in the conversation
But, when it comes to aurally navigating the web (e.g., through TTS, with screen readers), the navigation moves are still flattened to the low-level (visual) page mechanics, thus quickly becoming inefficient and unusable...
BVI experience with the Web

Screen reader

<option value="search-alias=mobile">Cell Phones & Accessories</option><option value="search-alias=lawngarden">Patio, Lawn & Garden</option>
Navigating with Screen Readers

- **Screen readers** “read aloud” the page code that renders what is displayed on the screen.

- Resilient but rudimentary “reading strategy”: line-by-line code reading order, with ability to move up/down.

- Provide great “access”, but far from offering a “usable” experience:
  - Misses the rich user experience afforded by visual semiotic.
  - Aural order does not follow relevance of items.
  - Difficult orientation (inter-page and intra-page).
  - Afraid to miss important details.
  - Needs to continually scan “noise” to detect relevance.
  - Takes a long time to find details of interest.
Our Research Challenge

What can reconstitute the fundamental traits of an appropriate navigation for screen reader users, so that the “aural browsing” experience can become more fluid, efficient and effective?
Specific HCI contributions in this space

Codify, demonstrate and validate aural navigation design principles for:

- Accelerating screen reader navigation with Guided Tours
- Dialogue-inspired, semantic back browsing
- Moving From Screen Reading to Aural Glancing
- *Screenless access: reducing mobile device friction to support gestural aural browsing (initiated, in progress)*
Our methodological approach

- Human-centered, model-driven, empirical design research
  - Formulate general hypotheses about user-centered principles that can fundamentally improve the user experience
  - Prototype testable manifestations of these ideas for demonstration
  - and –crucially – for internal and external empirical validation with users
  - Feedback into augmenting generative theories (e.g., outlooks that inform understanding and design approaches)
Inter-Page Navigation

Index Navigation

- Common navigation pattern that supports browsing a collection of items
- Provides links of full detail page for each collection item
- A classic case of “cataforic” structure, which pervades every content-rich interactive system
Index Navigation

- Common navigation pattern that supports browsing a collection of items
- Provides links of full detail page for each collection item
Guided-tour Navigation

- Pattern that links content pages of a collection sequentially
- Enables users to browse content pages one by one through next and previous commands
Guided-tour Navigation

- Pattern that links content pages of a collection sequentially
- Enables users to browse content pages one by one through next and previous commands
- Index can be combined with guided in “mixed” solutions, where both patterns co-exist
An aural fact-finding scenario...

Problems with Index structures in Aural Navigation

On BestBuy.com, a screen-reader user is looking for a laptop with 4 USB ports.

The list of over 200 laptops provides the model name, brand, picture, price, and memory for each product. The user clicks on the first laptop of the list, explores its detail product page, and finds out that it has only 3 USB ports.

The user goes back to the list page, scrolls down the page, selects the fourth laptop, and sees that it has only 2 USB ports. Not the one s/he is looking for.

This process is repeated several times. Resorting to search, a results list of various products pops up, and the user is left to sift through a long list of items as above.
Characterizing the Problem Space

Task Domain

A curated collection of items relevant to a user’s fact-finding need. *For example, a catalogue of laptops*

Aim

The target information that the user is seeking. *For example, a laptop with 4 USB ports*

Cue

The key, sought after information element of the aim that user knows. *For example, the sought after number of USB ports of a laptop.*

Scent

The index-level information that may or may not match the cue. *For example, the number of USB ports of each laptop*
Potential and limits of Indexes

- Indexes work best when they convey necessary hint or scent
- Scentless indexes are still manageable by sighted users
- However, a scentless index likely imposes highly inefficient navigation for the scree-reader users (recursive move from index to detail and back)
- Especially with over 20 list items it becomes cumbersome
Opportunity

If we bypass lists, how would guided tour support screen reader users during fact finding?
User Study at ISBVI

- 11 Blind and Visually Impaired participants from ISBVI
- 3x2 controlled, within-subject experiment design with two independent variables
  - Navigation pattern (different prototype variants generated):
    - index
    - guided tour
    - mixed pattern
  - Location of the task aim:
    - First half: within 1-15 items
    - Second half: within 16-30 items
Examples of User Tasks

- **Ecommerce - Task #1**: Find a cellphone (Domain) that was released in June 2010 (Cue – missing from index). Then, find what methods one can use to refill the minutes (Aim).

- **History of the web - Task #2**: Find the world renowned researcher (Domain) who was born on January 30, 1925 (Cue – missing from index). Then, find which organizing principle (Aim) he or she has implemented in his or her lab.
Results:
Savings in Aural Navigation Efficiency (Time on task)

Items: 1↔15 out of 30
Time on Task (Seconds)

- Index: 325.90 (5.43 min)
- Guided tour: 192.80 (3.21 min)
- Mixed pattern: 181.70 (3.02 min)

*41% savings

Items: 16↔30 out of 30
Time on Task (Seconds)

- Index: 650.20 (10.83 min)
- Guided tour: 427.30 (7.12 min)
- Mixed pattern: 484.30 (8.07 min)

*34% savings

*26% savings
Results:
Savings in Aural Navigation Efficiency (pages traversed)
Results:
Savings in Aural Navigation Efficiency (keystrokes)

Items: 1\(\leftrightarrow\)15 out of 30
No. of Keystrokes

Items: 16\(\leftrightarrow\)30 out of 30
No. of Keystrokes
Results: Aural navigation experience (perceived navigation and cognitive load)
Interview Findings

- Overall, participants preferred mixed pattern and guided tour to index irrespective of aim location.

- Excerpted participant’s quote: “I felt like I am doing the same task repeatedly in index navigation. Listening to the same list items while going back and forth was painful.”
Interview Findings

Self-reported comments on BVI experience with Index navigation

“I felt like I am doing the same task repeatedly in index navigation. Listening to the same list items while going back and forth was painful.”
Interview Findings

“I like the way I could navigate with guided tour, it’s much better than index navigation. I remember taking lot of time to navigate using index”
Interview Findings

How BVI users understand their experience with aural navigation patterns

“Guided tours can be a good strategy for encyclopedia, which tells me my location, like four out of ten, and reads the title of next and previous items I am about to navigate. Guided tour also gave me a chance to navigate back and forth without leaving the page”
“Though I like guided tour, I’d like to see mixed pattern on all the websites”
Our work suggests that, when designing navigation for large collection of information items, **guided tours should be integrated as a complement to any index to enhance usable accessibility** for screen-reader users.

**Linearizing cataforic structures to bypass unnecessary aural navigation steps**

**Demo Web Portal:** tinyurl.com/WebNexterPortal

**Plugin:** tinyurl.com/WebNexterPlugin
Back Navigation Shortcuts for Screen Reader Users

“Back” navigation is a very common web task.

Easy to master visually...but not so easy in aural settings.
Whereas sighted users can very quickly master a long series of backtracked pages by visual scanning, backtracking with screen readers is a long and inefficient process.
In aural dialogues, we refer to prior parts of the conversations through direct, semantic pointers to topics (anafora).

Current back navigation instead forces users to backtrack pages, instead of meaningful units of dialogues.

It would be as if in our dialogues we would keep backtracking in syntactic, rather than semantic units.
Opportunity

- Leveraging the conceptual structure of content-intensive web applications
- We introduced and validated two back navigation strategies that gets aural navigation closer to the anaforic moves of human dialogues:
  - Topic-based back
  - List-based back
Traditional back

# back steps = # visited pages
Traditional back

# back steps = # visited pages
and listen to each one of them
Topic-based “Back” Navigation

**Traditional back**

# back steps = # visited **pages**

**Topic-based back**

# back steps = # visited **topics**
List-based “Back” Navigation

Traditional back

# back steps = # visited pages
List-based “Back” Navigation

Traditional back
# back steps = # visited pages
List-based “Back” Navigation

Traditional back
# back steps = # visited pages

List-based back
# back steps = # visited lists
Controlled User Evaluation at ISBVI

- 10 participants

1. Training on Topic-based
   - 5 participants
   - 45 min

2. Training on List-based
   - 5 participants
   - 45 min

Aural Navigation Strategy Tasks
- T: Traditional back
- TB: Topic-based
- LB: List-based

- 5 participants
- 2 tasks
- Navigation and Cognitive Effort Questionnaire

Post-test Interview

**KEY:** T: Traditional back; TB: Topic-based; LB: List-based
Welcome to Webtime!

This website raises awareness about the history of World Wide Web to the blind and visually impaired high school students. You could easily browse people, technologies, ideas, places and news related to the history of the web.

Do you know...

**who is William English?**

William "Bill" English is a computer engineer who contributed to the development of the computer mouse while working for Douglas Engelbart at SRI International’s Augmentation Research Center. Learn more about English

**what is Content Rating?**
Time-on-Task & No. of Backtracked Pages (Topic-based Back)

* $p < .05$ | 40%

Time-on-Task (Sec.)

- Traditional: 60.87 ± 5.30
- Topic-based: 36.47 ± 2.10

* $p < .05$ | 60%

Number of Backtracked Pages

- Traditional: 5.30 ± 0.5
- Topic-based: 2.10 ± 0.2
Keystrokes for Backtracking (Topic-based Back)

*\( p < .05 \) | 67%

Average number of backtracked pages = 5.30

Average number of backtracked pages = 2.10
Time-on-Task & No. of Backtracked Pages (List-based Back)

- Time-on-Task (Sec.): 53.03 ± 6.06 sec for traditional, 11.08 ± 1.00 sec for list-based.

  *$p < .05$ | 79%

- Number of Backtracked Pages: 6.06 ± 7.00 for traditional, 1.00 ± 1.00 for list-based.

  *$p < .05$ | 83%
Keystrokes for Backtracking (List-based Back)

*\( p < .05 \mid 85\% \)

- **Traditional**
  - Average number of backtracked pages = 6.06

- **List-based**
  - Average number of backtracked pages = 1.00

**Graph**

- Bar graph showing the number of keystrokes for backtracking.
- The traditional method has an average of 16.67 keystrokes, with a significant difference (\( *p < .05 \) | 85\%).
- The list-based method has an average of 2.22 keystrokes.

**Bar Chart**

- Vertical axis: Keystrokes for Backtracking
- Horizontal axis: Method (Traditional vs. List-based)

<table>
<thead>
<tr>
<th>Method</th>
<th>Keystrokes for Backtracking</th>
<th>p-value</th>
</tr>
</thead>
</table>
| Traditional  | 16.67                      | *p < .05*
| List-based   | 2.22                       |         |
Conclusion

- Topic-based and list-based back resulted in **significant enhancements in both navigation efficiency and effectiveness** for screen reader users, and can be used as a supplement to current back mechanisms.

- Topic-based and list-back back support a view of aural navigation that operates at a **higher level of abstraction** than page-to-page browsing.

**Topic Based Back Portal:** tinyurl.com/TB-Back

**Topic Based Back Portal:** tinyurl.com/List-Back
Glancing at a web page is crucial for navigation ...
But screen reader strictly “serialize” such intra-page activity...
Intra-page aural mechanics

- With screen readers, it may be difficult to *quickly identify* the available sections of a page (even using page headers).

- Even when users know the relevant page sections are there, there is currently no efficient navigation mechanism to access that section quickly (without knowing its specific label...)

- “Skip to main content,” “list of links” on the page, or “searching” attempts to support more direct access.
Towards Aural Glancing

What could be *one possible* aural equivalent for “glancing at a page” using current screen reader technologies?
Our approach

To explore aural glancing:

- In a user study, we identified key page-level navigation problems that screen-reader users face while browsing a complex site.

- Through a crowd-sourcing system, we prioritized the most relevant sections of different page types necessary to support basic tasks.

- We introduced DASX, a navigation approach that augments the ability of screen-reader users to “aurally glance” at a complex page by directly and quickly accessing at any time the most relevant page sections.
Key Themes from User Observations (at BOSMA)

- Even simple pages pose navigation problems
- Rigid access to different page types hampers navigation
- Fear of missing crucial information
- Little tolerance of navigation mistakes
- Difficulty to distinguish sections and overloaded pages
- Difficulty in re-finding information
- Shortcuts like ‘Skip to Content’ are not always optimal
Sighted and Aural Navigation Performance by Page Type

Search and Compare Task

Select and Checkout Review Task
How can a group of “important” page sections be determined, given the variety and richness of modern websites?
Crowd Ranking Portal

- To quickly rank different page sections
- Web designers can instantly
- Web designers who can directly flag (in HTML and CSS) highly-relevant sections of the page at design time.
Crowd Ranking Portal

Color coded sections: to be ranked (blue); ranked (green); select section (red)

Subtask on each page to solicit page-specific section rankings

Turkers simply drag and drop the numbers on the sections based on their ranking order preference

Displaying ranked sections. These ranking preferences can either be reorganized or deleted

Text box soliciting Turkers’ opinion on why they choose that specific ranking order

Drag up and down to rearrange the ranking or click on the X to delete a section ranking. You can also click on the names to see the section it corresponds to:
1. Shop by department
2. Search
3. Search listings
4. Account options
5. Related searches

Rationale for Ranking
Why did you order the section in this way?

SAVE NEXT
## Crowd Ranking Portal

### View all ranks

Average of all the ranks:


<table>
<thead>
<tr>
<th>Important</th>
<th>Image Id</th>
<th>Avg. Rating</th>
<th>Admin Rating</th>
<th>Change Admin Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Menu</td>
<td>1.8</td>
<td>1</td>
<td>Change</td>
</tr>
<tr>
<td></td>
<td>Books</td>
<td>2</td>
<td>2</td>
<td>Change</td>
</tr>
<tr>
<td></td>
<td>Electronics and Computers</td>
<td>3</td>
<td>3</td>
<td>Change</td>
</tr>
<tr>
<td></td>
<td>Movies, Music</td>
<td>3.2</td>
<td>4</td>
<td>Change</td>
</tr>
</tbody>
</table>

Showing 1 to 4 of 4 entries
<table>
<thead>
<tr>
<th>Page Type</th>
<th>Crowd-based ranking (most important sections first)</th>
<th>No. of screen-reader actions (Keystrokes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>Search</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Shop by Department</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Top Menu</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Account Options</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Recommended Sections</td>
<td>4</td>
</tr>
<tr>
<td>Search Results</td>
<td>Search Listings</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sorting Options</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Shop by Department</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Search</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Item Menu</td>
<td>18</td>
</tr>
<tr>
<td>Item Description</td>
<td>Item Summary</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Product Information</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Customer Reviews</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Customer Questions</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Cart Options</td>
<td>6</td>
</tr>
<tr>
<td>Added to Cart</td>
<td>Product Summary</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Checkout Options</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Customers Also Bought</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Financing</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Recommended Sections</td>
<td>6</td>
</tr>
<tr>
<td>Checkout</td>
<td>Shipping Address</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Order Summary</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Product Summary</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Payment Method</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Shipping Speed</td>
<td>22</td>
</tr>
</tbody>
</table>
Aural Glancing with DASX

- A novel navigation approach for instant, on-demand access to relevant sections.
- Augments screen-reader navigation with simple, high-level vocabulary of commands to “aurally glance” at a page by quickly invoking and browsing the most important sections available.
Aural Glancing with DASX

- What’s there (Ctrl+Shift+W): Reads the top-priority, five main sections of the page.
- Get me going (Ctrl+Shift+I): Reads the one, most important function on the page (e.g., “Add to Cart” for shopping site, or it goes to the product page of the first item in a list)
- Go (Enter): Loads the desired option
Aural Glancing with DASX

Demo Web Portal: tinyurl.com/DasxPortal

Plugins: tinyurl.com/DasxPlugins
Conclusion

- Analytical evaluation (GOMS) predicts significant savings in time on tasks on various page types

- The main contribution of our approach is to suggest strategies to drastically reduce the mechanical effort of screen-reader users in navigating a complex page, thus shrinking the gap between sighted and BVI users in performing common tasks.

- Empirical evaluation studies with screen reader users at BOSMA under planning
Outlooks and next steps

- These same aural navigation strategies have been applied and evaluated also in sighted, mobile scenarios with similar results (CHI 2012, IWC2015, IJHCI2014)

- Guided tours as mobile aural flows

- Topic- and list-based back on mobile apps

- Find further applicability of these principles in new and emerging applications

- Visit our demos for trying out our prototypes and asking more questions...

- Current project: reducing mobile device friction to experience web navigation (in progress)