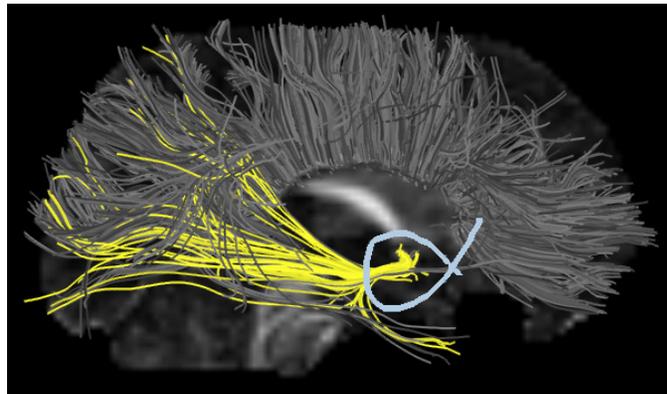

Wizard of Oz for Participatory Design: Inventing a Gestural Interface for 3D Selection of Neural Pathway Estimates

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Abstract

This paper describes a participatory design process employed to invent an interface for 3D selection of neural pathways estimated from MRI imaging of human brains. Existing pathway selection interfaces are frustratingly difficult to use, since they require the 3D placement of regions-of-interest within the brain data using only a mouse and keyboard. The proposed system addresses these usability problems by providing an interface that is potentially more intuitive and powerful: converting 2D mouse gestures into 3D path selections. The contributions of this work are twofold: 1) we introduce a participatory design process in which users invent and test their own gestural selection interfaces using a Wizard of Oz prototype, and 2) this process has helped to yield the design of an interface for 3D pathway selection, a problem that is known to be difficult. Aspects of both the design process and the interface may generalize to other interface design problems.

Keywords

Participatory design, Wizard of Oz prototyping, 3D selection, gestural interfaces, brain visualization.

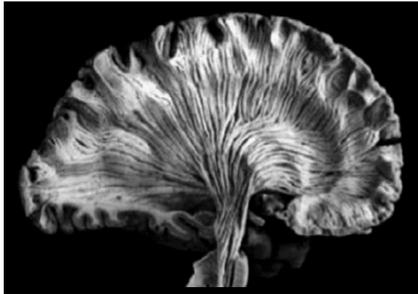


Figure 1: **A photograph of a brain dissection.** Visible in this image, the brain's white matter pathways can pass through each other and weave together in intricate ways. (Image courtesy T.H. Williams, N. Gluhbegovich, J. Jew; University of Iowa and Roy J. and Lucille A. Carver College of Medicine.)

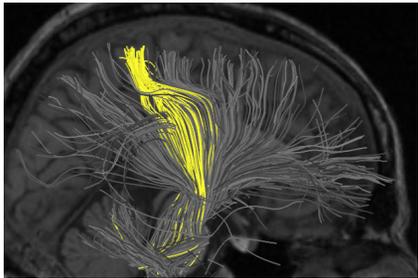


Figure 2: **Neural pathway estimates obtained using medical imaging techniques.** Cutting planes of anatomical data (background image) are used to locate the pathways within the brain. Scientists select subsets of pathways (highlighted in yellow) for further analysis.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces - Interaction styles, prototyping, theory/methods; I.3.6 [Interaction techniques]: Methodology and Techniques - Interaction techniques.

Introduction

Using medical imaging techniques, neuroscientists can estimate the locations and orientations of the brain's nerve bundles in living subjects. Each pathway estimate is a piecewise-linear curve representing a possible connection from one place to another in the brain. Unfortunately, the brain's structure is quite complex (see Figure 1), with nerve bundles frequently weaving together in hard-to-predict ways. A fundamental challenge that neuroscientists face is how to browse and analyze the complex pathways.

One way to mediate this complexity is through the use of *pathway selection*: identifying sets of pathways for further analysis (see Figure 2). As we learned during contextual inquiry with neuroscientists, pathway selection is becoming a critical subtask in scientists' everyday work. In particular, selection is necessary for evaluation of connectivity hypotheses, interactive segmentation of pathways into meaningful groups, and for the training of probabilistic connectivity models.

Existing pathway selection approaches employ cumbersome methods for manipulating 3D *regions of interest* (ROIs) with a mouse [6]. The goal of our work is to address this by designing a mouse-based gestural interface. By alternately rotating the 3D scene and drawing simple gestures on the image plane, the neuroscientist should be able to execute any desired selection operation. The gestures should be both

intuitive (match neuroscientists' mental models) and expressive (achieve a wide variety of objectives).

We present two contributions. First, we have employed a form of participatory design in which the subjects invent their own gestural interface, assisted by a Wizard of Oz [3] prototype. Second, this methodology has led to the design of a set of intuitive pathway selection tools that we hope will help expert neuroscientists to conduct their scientific inquiries. As a next step, we have begun a heuristic evaluation of our interface with usability experts, and will follow this up with a full software implementation and a longitudinal study with experts.

Related Work

Existing selection interfaces [6] use ROIs to select pathways that connect particular anatomical regions. This method is particularly powerful because it matches well with the scientist's thought process when evaluating connectivity hypotheses. However, 3D ROI manipulation is particularly difficult since the ROIs must be positioned in 3D, but commodity input devices (mice and pens) only afford two degrees of freedom. Our work seeks to overcome these problems by providing ways to interpret 2D mouse gestures as 3D selections. Instead of experimenting with tangible user interfaces [1], we have chosen to use commodity input devices, increasing our chances for adoption.

Gestural interfaces have been studied extensively for 3D modeling tasks. In SKETCH [7], Zeleznik *et al.* describe a gestural interface for 3D sketching. With Chateau [2], Igarashi *et al.* propose the value of suggestive interfaces for gesture-based modeling. Unfortunately, it is unclear how to design a simple,

static representation (*e.g.*, thumbnails) for 3D selections, and there are many possible selections corresponding to a user's gesture. For these reasons, we have decided not to pursue suggestive interfaces.

Like some other participatory design approaches [5], our design process uses prototyping as a means to involve users cooperatively in the design of the interface. However, there are two critical differences. First, our use of a gestural interface affords a wide variety of designs (gesture languages), without modifying the basic user interface (drawing a curve on the screen). This obviates the need for complex interface-invention tools. Second, our use of the Wizard of Oz method allows us to simulate complicated system behaviors even when these behaviors have not been defined *a priori* by the designer.

Phase I: Contextual Inquiry

We interviewed two neuroscientists over a three month period about their daily work. These interviews comprised more than 20 hours of observation, watching them use their own software and asking questions. For both scientists, pathway selection represented a large part of their everyday work. Using their in-house software tools that employ ROI-based selections [6], these scientists sometimes spent over an hour defining precisely which pathways to include in a selection. Most of this time was spent carefully re-positioning ROIs to capture just the right set of pathways in the selection.

While the end purposes for any particular selection varied, goals could be classified into two major phases: initial selection specification, and selection refinement. In initial selection specification, the neuroscientist would coarsely position large ROIs to unambiguously

include all of the pathways of interest, often intentionally capturing extra pathways along the edges of the selection. In the refinement phase, the scientist would introduce additional ROIs to gradually remove these extra pathways from the selection, until the selection looked right.

Phase 2: Participatory Design

The central question for our participatory design process was: what gesture language is appropriate to express the pathway selection goals of neuroscientists? Ideally, the set of gestures should be both intuitive (well-matched to neuroscientists' mental models) and expressive (can achieve a wide variety of objectives).

Initial strategy

We began to answer this question by involving users directly in our brainstorming sessions. Sitting in front of a computer with a set of pathways displayed, the author and the scientists would try to imagine realistic selection scenarios. For each scenario, we would think about the most natural way to express the intention using gestures. This initial approach turned out to be more frustrating than helpful, because it was hard for us to imagine the results of gestures. Moreover, it was hard to simulate errors in selection, and to imagine the steps it would take to resolve such errors.

Wizard of Oz Prototype

To address these problems, we created a Wizard of Oz prototype system to assist with the participatory design process, (see Figures 3 and 4). The prototype allows the user to perform core selection operations. The left mouse button rotates the entire 3D scene, while the right mouse button draws selection gestures on the image. Other keyboard shortcuts are available to add

Wizard of Oz implementation:

While the full implementation details of the wizard control panel are outside the scope of this paper, the entire prototype was implemented in two days. *Shape matching* was implemented by projecting each curve onto the image plane, and using a simple 2D distance metric to compare with the gesture. *Touch* was implemented by projecting the gesture into the 3D scene, and selecting all pathways that intersect the projected surface gesture.



Figure 3: **The Wizard of Oz control panel (hidden from users).**

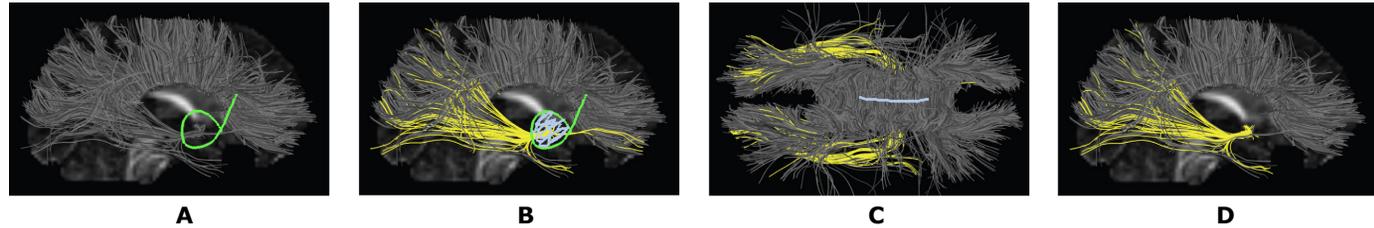


Figure 4: **A typical Wizard of Oz interaction during participatory design. A)** A subject draws a circle gesture (green) on the screen. The subject tells the wizard that he means to select all pathways that pass through this region of the cutting plane. **B)** The wizard takes over control of the system in *wizard* mode, and scribbles a *touch* gesture (blue) to select a set of pathways. **C)** After rotating the view, the wizard cleans up the selection with a second *touch* gesture to indicate the cutting plane. **D)** Finally, the wizard switches back to *user* mode, and the subject sees the results from the original viewpoint.

or remove cutting planes of anatomical data. (Neuroscientists use such cutting planes to navigate through the brain data.) Hidden from the user is a panel of controls (see Figure 3), intended for the wizard to implement the user's intention after a gesture is made. The wizard's controls include two selection tools, *shape matching* and *touch*. (See Figure 5, following page, for details.) To achieve more complicated effects, these two tools can be combined with four selection modes: new selection, add to selection, remove from selection, and intersect with selection.

Study Design

We recruited four neuroscientists and one radiologist for our study. Each design session lasted for one hour, and the author was present to act as the wizard. There was no set scenario – users were permitted to perform their own investigations. We did not want to bias the users toward any particular interface, so we had them invent their own gesture language. Therefore, the user needed to explain the intended meaning of each gesture before the wizard could implement it. Figure 4 shows an example interaction with the prototype.

Hypotheses

Based on our contextual inquiry findings, we expected the users to invent at least two selection tools: one like our *shape matching* gesture, and another like our *touch* gesture. We also expected them to invent the four selection modes (new, add, delete, and intersect).

Findings

These basic hypotheses were confirmed. Three of the five subjects invented the *shape matching* gesture to build initial selections, while all five invented the *touch* gesture as a way to refine selections. All five indicated the need for selection modes.

We also encountered several major surprises. Inspired by the presence of the cutting planes in the prototype, four of the five subjects invented a new gesturing method (see Figure 5). They drew shapes directly onto the cutting planes, telling the author that they wanted “all pathways that pass through this part of the plane.” This gesture was most useful when the subject wanted to guarantee that selected pathways passed through some anatomical landmark.

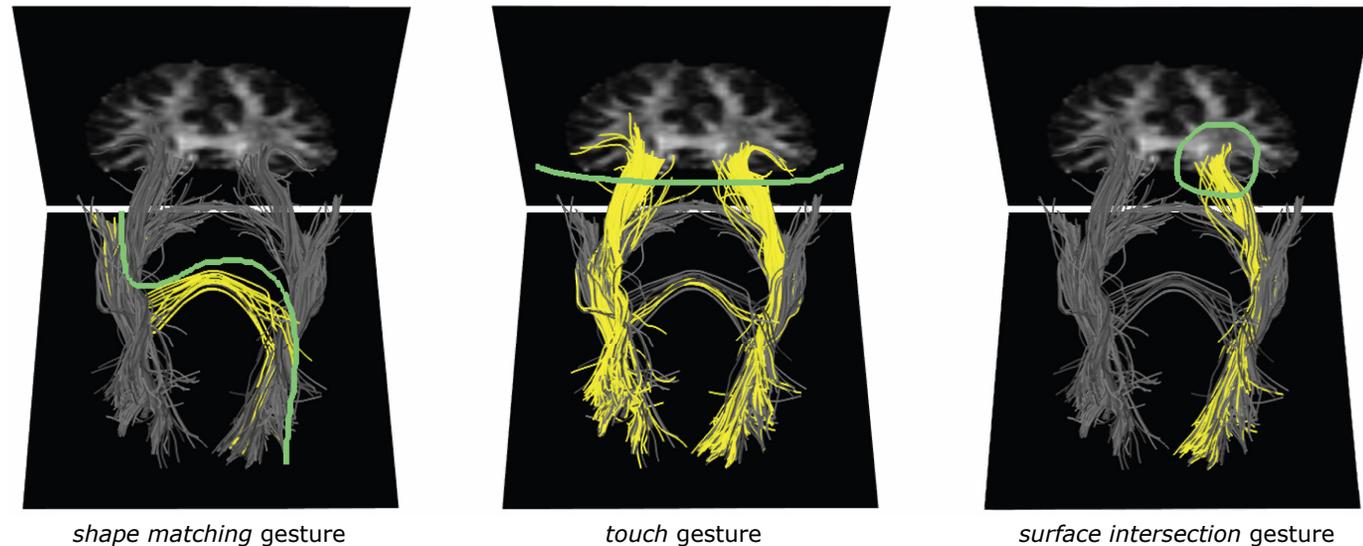


Figure 5: **Three selection gestures invented by users during participatory design:** Left: *shape matching* (selects paths that look like the gesture curve). This gesture was most useful when the paths of interest were known, but obscured from view. Center: *touch* (selects any paths that touch the gesture). This was most often used when the goal pathways were visible. Right: *surface-intersection* (selects paths that intersect the specified region on a cutting plane). Unanticipated by the author, this gesture allowed the neuroscientist to ensure that selected pathways pass through specific anatomical landmarks visible in the cutting plane data.

Mediating ambiguity: During participatory design sessions, users struggled with the ambiguity of their selection gestures. Mankoff *et al.* [4] suggest two ways to mediate ambiguity in recognition-based interfaces such as ours: repetition and choice. In our study, users seemed content to use a repetition strategy. They unanimously agreed that they did not want to be actively interrupted with a choice of selections, but they left open the possibility of a passive choice mechanism.

As in the contextual inquiry, users were most concerned with false negatives – pathways that they missed with their selection gesture. To clean up their selection, they wanted a way to easily visualize the context immediately surrounding a selection. This suggests the design of a *context slider*, allowing the user to interactively control the amount of context visible around a selection. Related to this, users also wanted an easy way to grow or shrink a selection.

Several users expressed dismay when their selection operations selected pathways on the opposite (non-visible) side of a cutting plane. Intuitively, people seem

to expect that their selection operations would only operate on visible pathways. This suggests that cutting planes would be a natural way to limit the depth extent of a selection gesture.

Significantly, neither the surface intersection gesture, the idea of a context slider, nor the depth-limiting of selections was discovered using our initial design strategy (without the use of our Wizard of Oz prototype). The use of a concrete prototype, in which we could simulate both the selection gestures and their effects, was instrumental in eliciting the kind of detailed feedback that we received.

Discussion

What enabled our Wizard of Oz strategy to work were the two selection operations we pre-built (*shape matching* and *touch*). To use a mathematical analogy, these operations are like “basis vectors” in the space of pathway selections: all pathway selections can be simulated using some combination of these operations (including scene rotations to adjust the viewpoint). We suggest that Wizard of Oz prototyping could be useful in participatory design whenever such a basis exists and can be implemented with little effort. The basis need not be intuitive, as long as the wizard user is capable of using it to accomplish any objective.

Our experiences also uncovered some challenges in using this design methodology. Users found it frustrating that some of their actions took over a minute to simulate using the Wizard of Oz controls. Moreover, some users even tried to guess how the Wizard of Oz controls worked based on differences in how long it took for each kind of action to be simulated! We could have perhaps avoided this by introducing artificial delays to even out the timing, but additional delays would have introduced further frustration.

Future Plans

To validate the interaction techniques suggested by our design process, we have begun to test our prototype using a heuristic evaluation. Once this process is complete, we will replace our Wizard of Oz prototype with a complete implementation. Since our system is intended for use with experts, we plan to conduct a longitudinal study of the system. This will require integrating our selection interface into their existing software, and then observing the use of our techniques over several months. In this study, we will also

compare the use of our system with a mouse or pen as input. Our participatory design subjects have told us that they are excited to use the interface, and they believe it will significantly improve the efficiency of many of their scientific investigations.

Acknowledgements

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