Computational Implications of Human Navigation in Multiscale Electronic Worlds

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ABSTRACT

In this work I seek to formulate a theory of the computational implications of certain factors that affect human navigation in multiscale electronic worlds. Specifically, I seek to describe the properties a multiscale world must satisfy to furnish useful frames of reference. I draw factors from three areas. First, understanding of spatial cognition in general and frames of reference in spatial cognition in particular. Second, theoretical characteristics of multiscale information spaces. Third, general attributes of users' task contexts. The ultimate goal of the work is to provide a basis for a theory of design of navigational aids. This project also seeks to provide a case study of integrating existing psychological theories with emerging theories of computational environments.

KEYWORDS

Navigation, Frame of Reference, Multiscale, Spatial Cognition, Pad++.

INTRODUCTION

Curiosity may have killed the cat, but it got Erik the Red from Scandinavia to North America and Neil Armstrong from the Earth to the Moon. Of course, while Neil knew exactly where he was going, Erik probably hadn't a clue. Nevertheless, by navigating, they both reached their goals. Erik relied on the environment to help him—ocean currents and trade winds—and used fairly simple navigational aids—lodestones, stars, birds (and probably Neil's destination, the moon). Neil had little help from the environment and depended on very sophisticated navigational aids that included complex technology and scores of humans. Had their worlds been designed to ease navigation, Neil might have gotten better support from the environment and Erik might have had more powerful navigational aids. Such design would have required understanding of Erik and Neil's cognitive abilities, the particular properties of their environments, and the special circumstances of the two journeys. More significantly, it would have required understanding how factors of these three types interact to constrain and guide what can and must be done to ease navigation.

Unlike the physical world through which Erik and Neil traveled, electronic worlds are designed and can be designed to ease navigation. To do so requires understanding the cognitive needs of the user, the navigational affordances of the electronic world, and the navigational demands of the user's task and context. In this work I seek to formulate a theory of the computational implications of such factors on navigation in multiscale electronic worlds. I focus specifically on the requirements for frames of reference. The ultimate goal of the work is to provide a basis for a theory of design of navigational aids. A secondary goal is to provide a case study of integrating existing psychological theories with emerging theories of computational environments.

By *navigation* I mean the cognitive process of determining and following a path, based on knowledge of and information in the environment. My present focus is on interactions between the cognitive processes of the navigator and the traversal characteristics of the environment, and how these influence what information can and must be provided to enable the navigator to make appropriate navigational decisions. Frames of reference are essential to navigational reasoning as they enable the navigator to conceive of and distinguish between different portions of the navigational space.

Multiscale worlds are worlds in which information exists at multiple levels of detail—from minute particulars to complete overviews. Multiscale worlds are increasingly used to manage ever-larger quantities of ever-more-complex information. Correspondingly, there is an increasing interest in spatial multiscale interfaces—interfaces that adopt models of continuous infinite scale using strongly physical metaphors such as fly-through or zooming. Addressing navigation is critical in such interfaces. Not only may the world violate expectations carried over from the physical world ("Sure you can jump over the moon, ..."), it also provides opportunities not offered in the physical world ("... just shrink the world so that you are bigger than the moon").

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In prior work, I identified the problem of *"desert fog"*—a condition in which the immediate view of the environment holds no information on which to base navigational decisions. Analysis of the characteristics of environments in which desert fog can arise and of the nature of spatial cognition, yielded the implication that desert fog is a frame of reference problem. I found that desert fog and related problems can (and must) be addressed by making a meaningful frame of reference visible or accessible to the user at all times. This may seem self-evident, but the analysis also revealed necessary properties of the needed frames of reference and suggested ways of determining what constitutes appropriate frames of reference.

In the proposed work, I continue the approach applied to desert fog. However, rather than attempting to analyze a particular navigational problem, I focus on a particular navigational need: frames of reference. That is, what properties must a multiscale world satisfy to provide the necessary frames of reference? An underlying assumption is that users can and should draw on navigational skills acquired in the physical world [4].

To understand the role of frames of reference in navigational reasoning, I draw on research on spatial cognition and linguistics. These fields describe different types of frames of reference and their roles in mental representations of large-scale spaces [3]. Frames of reference are typically characterized by how they are established, e.g., relative to the planes of the body, or fixed elements in the environment. I am exploring a characterization based on the types of reasoning a frame of reference supports, e.g., whether it orders elements.

In examining the navigational affordances of multiscale electronic worlds I make two limiting assumptions. First, I assume that the interaction metaphor is strongly physical, i.e., the world is a spatial multiscale world. Second, I limit my consideration to properties that are characteristic of, if not unique to, spatial multiscale worlds. An example of such a property is that straight lines may not be the shortest distance between two points [2]. (Zooming out—moving in scale, panning—moving in space, then zooming in—moving in scale again, is generally faster than moving along a geometrically straight line—pure panning.)

To characterize the user's task and its context I consider the goal of the task as well as its particular needs. The goal may be to find a specific item, to find an item that has certain attributes, or simply to learn about the items in the environment. The context of the task determines, in part, the spatial and temporal profiles of the task: which, and how often, different parts of the environment are needed.

After articulating a model of the roles of frames of reference in each of the three areas described, I will bring the three models together to examine interactions and emergent properties. I will then use these properties to develop a theory of computational implications. The theory itself will comprise a model of computational elements along with causal motivations. Expression of the theory will include formal reasoning as well as computational representations and expository text and images. Incremental development and testing of ideas will take place in Pad++ [1]. Anticipated approaches to validation include user testing and comparative analysis.

SUMMARY

In this work I seek to integrate understanding of the characteristics of the psychology of navigation, special properties of multiscale worlds and attributes of users' task contexts. The purpose of this integration is to develop a theory of computational implications for human navigation in multiscale electronic worlds, specifically regarding the requirements for frames of reference. The ultimate goal is to provide a basis for a theory of design of navigational aids. A secondary goal is to provide a model for integrating existing psychological theories with emerging theories of electronic environments.

I deliberately do not address affective and aesthetic factors. These are undoubtedly relevant to navigation and typically emerge early in discussions on navigation. However, attempting to understand the role of affect and aesthetics in navigation is—without the aid of a pre-existing theory of their role in learning and cognitive performance in general—itself a full research agenda.

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