A Framework for Locomotional Design: Toward a Generative Design Theory

Susanne Jul
Electrical Engineering and Computer Science
University of Michigan
sjul@acm.org

ABSTRACT
Generative design theories are needed to bridge the gaps between pure scientific knowledge, individual ("point") designs and systematic generation of viable design alternatives. This paper suggests a framework for locomotional design that uses knowledge of navigation and spatial cognition to inform design. Examples of the implications of two such pieces of knowledge are sketched out, suggesting how this framework might lead to a generative design theory.

KEYWORD
Theory-driven Design, Informed Design, Design Generation, Generative Design Theory, Design Framework, Navigation, Wayfinding, Locomotion.

INTRODUCTION
Usability engineering has become a major industry over the past two decades. Methodologies for structuring the design process help designers collect and organize information relevant to generating good designs, and evaluation techniques help designers choose among design alternatives. However, there has been relatively little focus on supporting generation of good design alternatives by informing design content systematically. Thus, designers often expend significant effort in "rediscovering the wheel" or, worse yet, fail to recognize that a wheel would solve the problem. Reinvention is costly in both time and money. Failure to recognize known design problems can also be costly in usability.

At present, information to support design generation typically takes the form of either heuristic guidelines or general rules of cognition. Heuristic guidelines specify particulars of certain "good" designs, but are sporadic and do not allow reasoning about their implications for a specific design situation. For example, "Guideline 1: It is essential that the [Virtual Environment] contain several landmarks" [10]. General rules about human cognition and perception, in contrast, are systematic and allow general reasoning about their relevance, but are often difficult to link to design particulars. For example, "The choice points of a route, at which navigation decisions are made, provide a natural segmentation of the route as represented in [long term memory]" [3].

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Generative design theory is aimed at giving the designer information that has the direct pertinence to design of heuristic guidelines, but the systematic and more general nature of cognitive rules. Design theory is prescriptive rather than explanatory [7], that is, where explanatory theory provides causal accounts of existing phenomena ("Y *is* thus because of X"), prescriptive theory provides rationales for potential phenomena ("Because of Y, Z *should be* thus"). Generative design theory differs from evaluative design theory in that it seeks to predict what design elements and characteristics will produce a desired outcome, rather predicting the outcome that a given design will produce. In human-computer interaction, evaluative theories, such as GOMS-related theories [4], predict human behavior and performance from design, rather than prescribing design from human performance and behavior as is needed from a generative theory.

The framework presented here represents the beginnings of a generative design theory of navigation. Drawn from information in the extensive literature on spatial cognition and cognitive studies of navigation, the framework focuses on the relationships between cognitive attributes of navigational performance and specific elements of environmental design. At present, only design elements that pertain to locomotion—actual movement—are examined.

A FRAMEWORK FOR LOCOMOTIONAL DESIGN
The term "navigation" is variously used to denote different activities related to the task of determining where things are and getting to them. Here, it is used to denote the overall

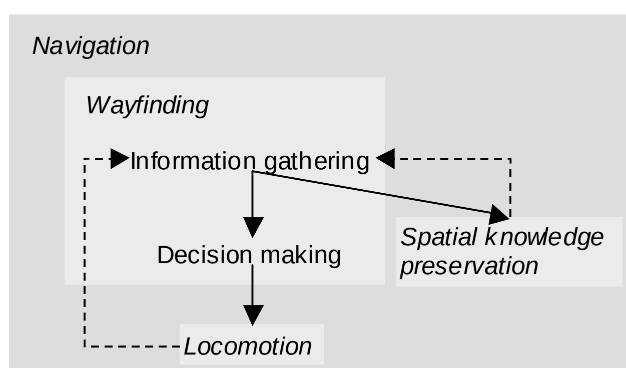

Figure 1 Present terminology. Solid arrows indicate dependencies of activities. Dotted arrows indicate feedback.

task, which is then decomposed into three subtasks (Figure 1). *Wayfinding* is the task of spatial problem-solving and decision-making, and is the central-most of the three subtasks. *Spatial knowledge preservation* is the task of transforming and storing spatial information for future use, including relating new and previously stored information. (Cognitive maps [5] are one well-studied form of such stored information.) *Locomotion* is the task of actually moving and controlling movement and is the most basic of the three navigational subtasks.

Most work related to locomotion in electronic spaces focuses on the mechanics of controlling movement, e.g., the characteristics and use of different input devices [1] or the input necessary to control complex virtual movement [6, 9]. The present work sets locomotion in the context of navigation and thus focuses on how environmental design determines what movement is necessary and, consequently, how complex navigation is.

In a navigational context, locomotional design determines what wayfinding decisions must be made, when they must be made, how much time is available to make them and how complex decisions are [3, 8]. (Wayfinding design, in contrast, determines what information is available for making decisions.) Thus a generative theory of locomotional design must prescribe locomotional design elements from wayfinding decision-making processes and performance.

Examples of Elements of Locomotional Design

Locomotional structure, the set of locations that can be reached and routes between them, is highly significant in determining wayfinding behavior and performance [5, 8]. In the physical world, design of the locomotional structure is highly limited by the laws of natural physics. However, electronic worlds impose no such restrictions and locations and routes can be designed specifically to meet the needs of the task the design is intended to support and the wayfinding task it incurs. They can even be reorganized, added or eliminated dynamically at low cost.

Thus, the first step in locomotional design is to determine what constitutes a location, what locations are necessary to the task and what connections between them are needed to complete the task. If the design goal is to minimize wayfinding overhead, the designer's objective is to keep the locomotional structure true to this task-defined structure.

Decision points, locations at which decisions are made, are another significant determinant of wayfinding behavior and performance [2, 8]. These can be divided into two types. *Branch points* are locations where routes intersect [8]. Locomotional decisions *must* be made before proceeding from a branch point. The designer must balance the number of branch points against the number of options at each branch point in the locomotional structure. *Information points* are locations at which new information becomes available [2]. The locomotional structure may create information points by revealing views of the environment, as in the physical world when a path crests a hill. Wayfinding design may create additional information points by the placement of environmental information such as signage or landmarks. The distance between information and branch point and the speed of movement control the time available to make a decision without interrupting movement.

SUMMARY

Generative design theories are needed to bridge the gaps between pure scientific knowledge, individual ("point") designs and systematic generation of viable design alternatives. This paper has laid out the shape of a framework for locomotional design that places movement in a context of navigation and thus uses knowledge of navigation and spatial cognition to inform design. The implications for design of two such pieces of knowledge were sketched out, suggesting how such a framework might lead to design theory.

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