Spatial Cognitive Engineering

The goal of spatial cognitive engineering is to design spatial information systems and services based on the principles of human communication and reasoning. It is an interdisciplinary endeavor, involving the disciplines of geographic information science, cognitive science, computer science, and engineering. A special focus is human-computer interaction based on the integration and processing of the spatial and temporal aspects of phenomena. The field of spatial cognitive engineering is motivated by the belief that useful and usable solutions to people's geospatial problems can only be found by considering the cognitive abilities and strategies people bring to the problem-solving process.

Roots: Cognitive Engineering

The term *cognitive engineering* was invented by Donald Norman in an effort to integrate cognitive and computer science approaches to the design and construction of machines. According to Norman, cognitive engineering is a type of applied cognitive science. When looking at people's interaction with different everyday things, such as telephones, faucets, and doors, one notices a discrepancy between *psychological user variables and physical system variables*. The psychological user variables comprise goals, intentions, concepts, and also spatial and cognitive abilities. During the performance of a task, a user must therefore interpret the physical system variables in the context of his or her psychological goals and translate his or her psychological intentions into physical actions on the system. The goal of cognitive engineering is to bridge the so-called gulf between execution and evaluation (Figure 1), which results from the differences between user and system states in terms of form and content. This gulf can be bridged from two sides:

1. The system designer can move the system closer to the user in terms of finding better matches to his or her psychological needs.
2. The user can bridge the gap by approximating the description of goals and intentions to the system's language. Such approximation covers different levels of outcomes and intentions.

In his account of cognitive engineering as a new discipline, Norman focused on computer design in general and the design of user interfaces in particular. A major point in the analysis was that different users may require different interfaces, even when performing the same tasks and working with the same system. He therefore advocated a *user-centered* system design, which starts with the user's needs regarding a particular problem.

From Cognitive engineering to Spatial Cognitive engineering

Spatial cognitive engineering follows the general ideas of cognitive engineering and applies them to the geospatial domain. Such application highlights important aspects that are integral to and characteristic of geospatial problem solving. Spatial cognitive engineering focuses especially on human-computer interaction regarding the *spatial and temporal aspects of* phenomena in the world. Geospatial services and systems are unique in the way they use data, which are related to locations in space (and time), and in how processing of the data with respect to these spatial locations is possible. The fact that everything is tied to a location in space and time leads to increased complexity regarding reasoning with and analysis of the data. People's questions when using geospatial tools have a spatiotemporal context. One can ask “Where is (a certain object)?” or “Where are (all objects with certain properties)?” at a given time—for example, when trying to find the nearest kindergarten for a child; or one can ask “What are the properties of (a certain area in space)?” at a given time—for example, when trying to assess the area in which to rent a house.

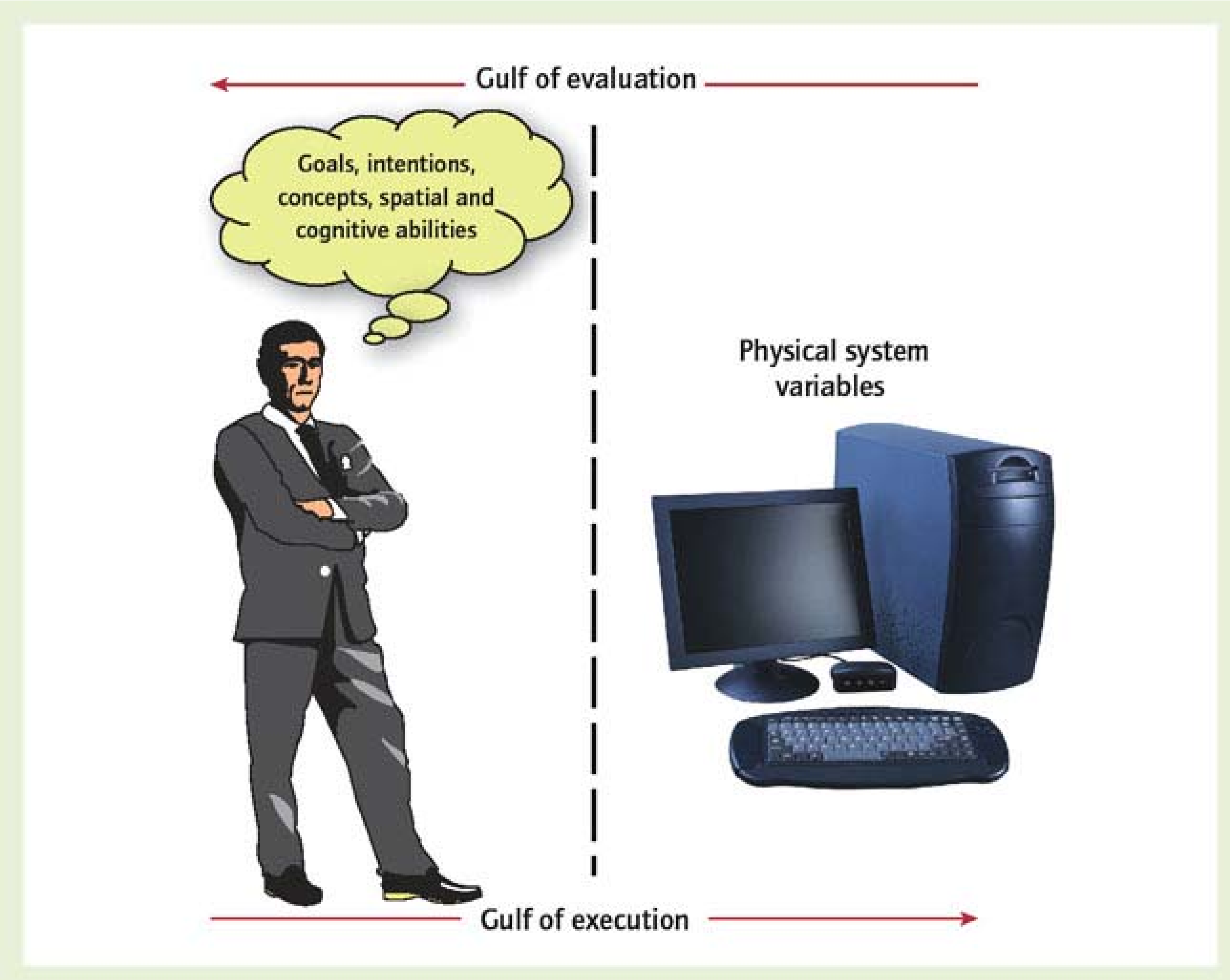

Figure 1 Discrepancy between psychological user variables and physical system variables

Source: Adapted from Norman, D. (1986). Cognitive engineering. In D. Norman & S. Draper (Eds.), User centered system design (pp. 31–61). Hillsdale, NJ: Lawrence Erlbaum.

Resolving the discrepancy between psychological user variables and physical system variables in the geospatial domain goes beyond the user-interface level:

- People use various conceptualizations of space and time, such as "continuous versus discrete" or "absolute versus relative." The particular spatiotemporal perspective in spatial cognitive engineering implies that spatial and temporal concepts need to be matched between users and systems. Take, for example, the different semantics of spatial concepts, such as location or road, depending on the user and context. Semantic heterogeneity—two contexts leading to different interpretations of the same information—can lead to erroneous decisions made by geospatial services. The results of a spatial analysis may be correct for the data model of the data set but may still not meet the user's expectations and can therefore lead to false decisions.
- Spatial reasoning and decision making in a spatiotemporal context include particularities that need to be accounted for during human-computer interaction. Spatial reasoning is about topology, distance, orientation, and shape with regard to objects and configurations of objects in space and time. Instead of doing exact calculations, people apply qualitative methods of spatial reasoning that rely on magnitudes and relative values—see, for example, the differences between wayfinding instructions as given by humans versus machines. When people perceive space through different channels, they arrive at various kinds of information, which are usually qualitative in nature. People do not move through the environment using rulers or tape measures. Spatial reasoning involves a variety of decision-making methods and choice behavior. In many cases, human decision making is not strictly optimizing in an economical and mathematical sense as proposed by the algorithms of classical decision-making theories. Several of these aspects are accounted for to various degrees during spatial cognitive engineering.

Cognitive user parameters

When dealing with the problem of considering people's spatiotemporal and cognitive strategies and abilities during their interaction with geospatial services, it is of major importance to account for people's problem-solving requirements. These requirements differ, depending on the category of user. With regard to the acquisition, mental representation, use, and communication of geographic information, it has been argued that information consumers differ in their cognitive styles, abilities, and preferences. Cognitive research helps understand how individuals and groups of people differ in their cognition of geographic information. Several case studies involving the cognitive aspects of navigation systems demonstrated the importance of taking into account individual differences among navigators, such as different abilities, preferences, and navigational styles. The importance of research on education, experience, culture, gender, and age differences has been emphasized in efforts to design better—in the sense of more *personalized*—geospatial tools.

Users can be categorized into *generic*, *group*, and *individual* with regard to their cognitive parameters, such as strategies, abilities, and concepts. The generic level comprises a general set of cognitive parameters assumed to be applicable to all people. For example, in general, people use landmarks for finding their way and for communicating wayfinding directions to others. The generic category also accounts for the fact that there are numerous cultural universals that people share. User groups are defined by common sets of cognitive parameters. The focus of analysis is on the variation of parameters across different groups. Examples are gender groups, such as all women and all men, and comparatively smaller cultural groups defined, for example, by sharing a common language. These examples demonstrate that user groups occur at different levels expressed through the number of their members. User groups are often defined for user interface design—for example, novice versus expert. Wayfinding services may distinguish between different groups of disabled (e.g., visual or hearing impaired) persons. Wayfinding instructions need to be adapted to these groups to be useful. Dealing with people as individuals puts a focus on individual variation. Every single person is treated differently. Personalization of geospatial services can go a long way; the more parameters there are that need to be adapted, the more complex it becomes.

It is useful to note that this classification forms a hierarchy (Figure 2).

All people share some cognitive parameters, but they also fall into various user groups and have their individual preferences. When using spatial cognitive engineering approaches for the design of geospatial services, a major question is, therefore, how far one can or wants to move down in this hierarchy.

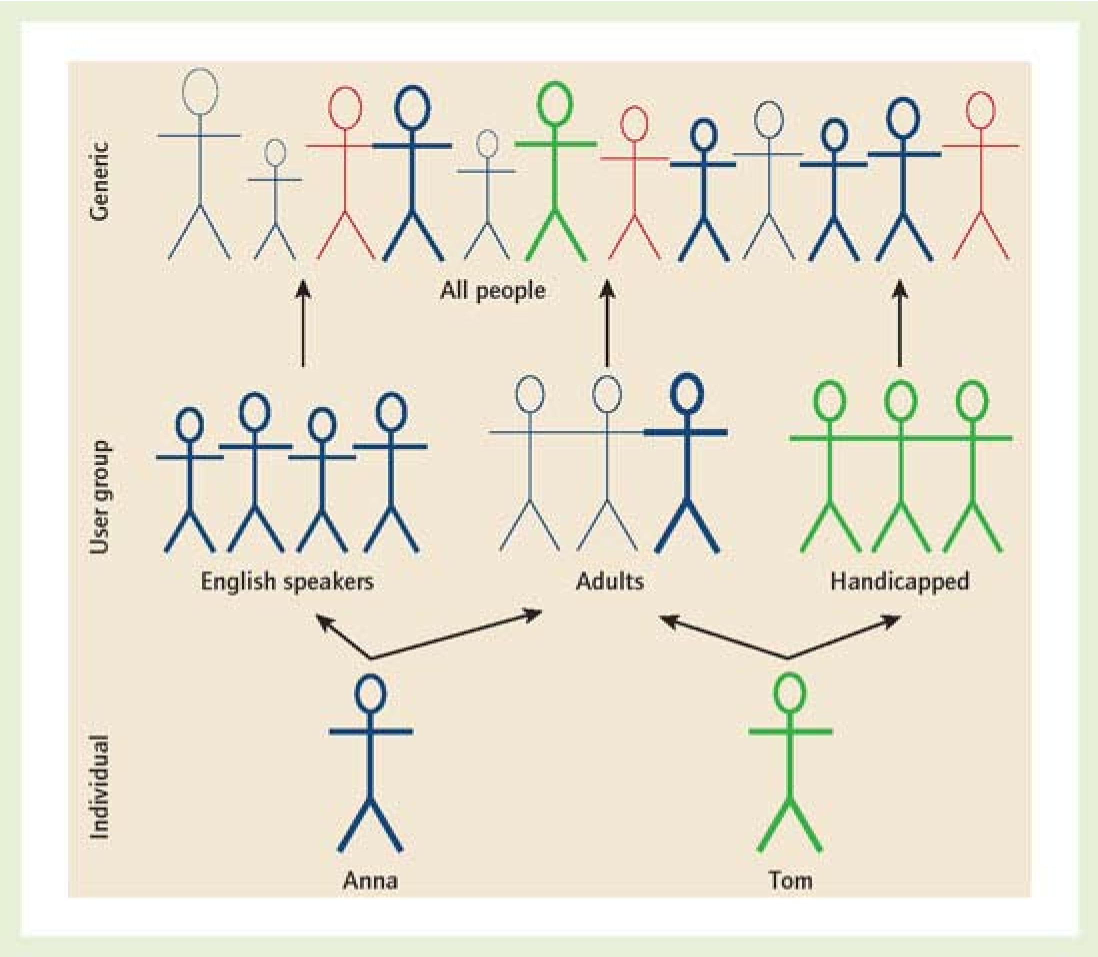

Figure 2 User categorization into generic, group, and individual

Source: From Raubal, M. (2005). Cognitive engineering for geoinformatics. Solingen, Germany: Verlag Nature &

Wissenschaft.

Applications

Spatial cognitive engineering has been applied in various areas to bring geospatial tools closer to the user, with respect to both monolithic geographic information systems (GIS) and geographic information services. Lately, research has focused on personalizing location-based services—information services that are sensitive to the location of a (mobile) user—with the goal of creating *location-based decision services,* which support people's everyday spatiotemporal decision making in a mobile context. The following selective list gives some examples of applying spatial cognitive engineering:

- Spatializing user interfaces to map the particular spatial experiences of users to various application domains: Considering how individuals understand and represent space benefits the design of GIS and facilitates user interaction with these systems.
- Designing natural-language query interfaces for GIS: Such interfaces allow users to pose their spatiotemporal questions in a more natural way.
- Developing personalized navigation services that offer wayfinding directions based on landmarks: These services also consider user preferences for the performance of spatiotemporal tasks.
- Applying cognitive design principles to cartographic maps and geographic visualizations to facilitate people's understanding and knowledge acquisition
- Designing geospatial tools for disabled people, such as global positioning system (GPS)-based navigation systems for the visually impaired

—Martin Raubal

Further Readings

Entry Citation:

Raubal, Martin. "Spatial Cognitive Engineering." *Encyclopedia of Geography*. 2010. SAGE Publications. 4 Oct. 2010. <http://www.sage-ereference.com/geography/Article_n1057.html>.