A Conceptual Framework for Exploring Movement Using a Visual Problem-Solving Approach

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Abstract.

This paper proposes a conceptual framework that summarizes a visual analysis process for exploration of movements by applying a visual problem-solving approach. The aim was to establish a logical structure, according to which visualization designers can provide users with visual analytical solutions to deal with their domain problems related to human movement.

The visual approach consists of a *user problem* and a *solution* domain (Figure 1). The first domain describes users' domain problems related to movement. The second domain describes the process of discovering patterns from data using interactive visualization solutions. *User tasks* derived from the user problems bridge the two domains. Being guided by the user task and the data at hand, the design of a visualization environment focuses on employing suitable *visual representations*, *interaction operators* and necessary *analytical functions*. The selection of visual representations focuses on questions which visualization is best suited to pursue a given task on the given input data. And the selection of interaction operators and analytical functions focuses on how to work with the data, e.g. to filter the data displayed or to add external data.

The conceptual framework was designed and revised based on literature reviews. Basic components of the approach including *movement data*, *user tasks*, *interaction tasks*, and *visualization solutions* have been discussed. We firstly summarized the properties of movement data including *space*, *time*, *moving object*, *the internal state*, *the geographic context* and *trajectory* based on a conceptual model of movement. We then identified three primitive user tasks: *identify*, *localize* and *compare*, while other user tasks summarized from literatures can be considered as compound tasks consisting of sequential primitive tasks. The user tasks can be conducted in an elementary level targeting at low-level data characteristics of data components (i.e. data values of attributes), or in a general level targeting at the pattern emerging from the data components that are treated as a whole.

Thirdly, based on the summarization of seven interactive operation taxonomies, we classified the interaction operators into eleven categories: *re-encode, arrange, coordinate, aggregate/segregate, filter, derive, navigate, query, search, select* and *enabling*. And finally four major visualization solutions were summarized: *spatial visualization, non-spatial visualization*, *visualization with aggregations* and *visualization supported by data mining methods*. Spatial visualization and non-spatial visualization are two visualization types with the focus on representing different properties of movement data. Visualization with aggregations and visualization supported by data mining methods are two ways of dealing with the data.

This conceptual framework focuses on developing the relations among movement data, user tasks, interaction tasks, and visualization solutions to form the visual problem-solving approach. The overall approach to link user problems and visualization solutions is assumed to be widely applicable. We are developing case scenarios to apply this framework. Further research also includes evaluating the usability of the proposed framework with case studies.

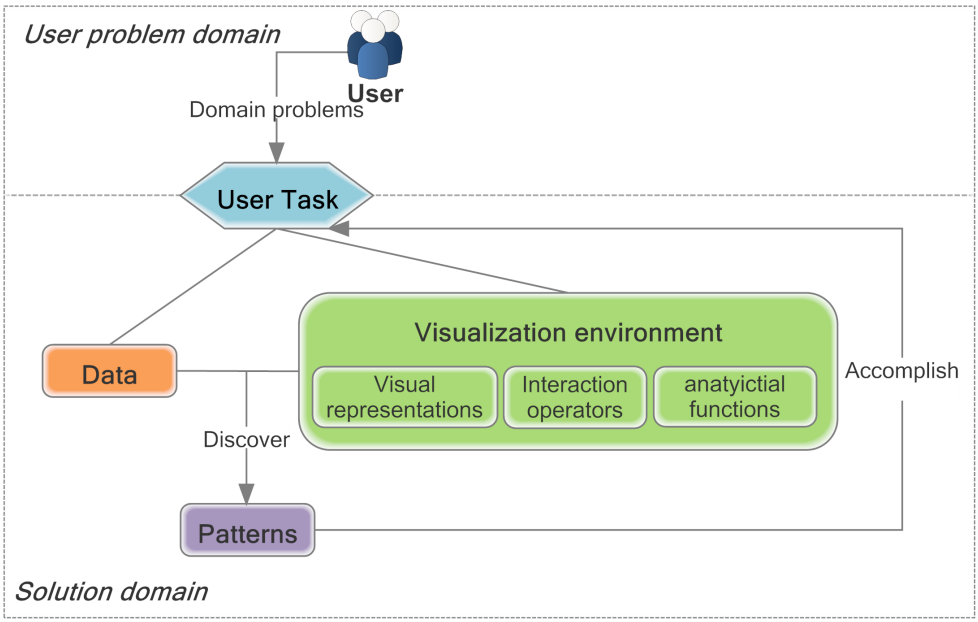

Figure 1. An approach of visual problem-solving, consisting of a problem and a solution domain. The first domain introduces user contexts, and the second domain provides discovered patterns from data in a visualization environment. The user tasks to be executed bridge the two domains

Keywords: Visual problem-solving, movement data, movement pattern, user task, interaction, visualization