The role of relevance and cognition in attention-guiding geovisualisation

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Promptly locating and easily decoding relevant information in complex geovisualisations (GV) is a major user task during decision-making in geospatial objectives. To fulfil these needs, it is favourable to formulate design principles and to establish a design methodology that realise a preservation of users' limited attentional resources. Attention-guiding geovisualisation (AGV) tends to release this cognitive workload by considering the relevance of information and the cognitive skill of attentional information processing as fundamental components of cognitive-adequate design.

In digital era, geovisualisation systems depict a high quantity of geographic data on diverse display sizes for variable applications. For instance, while mobile GVs visualise known geographic information in mobile environments on small displays to individual users with a low degree of human-computer interaction, exploratory systems reveal unknown geographic phenomena in static environments on larger desktop and wall size displays by means of intensive human-computer interactions. Despite different usage concepts users face the same rising cognitive workload in coping with the complex visual environment. Gazes of explorative users may be deviated by the representation of irrelevant geospatial objects and attentional resources of mobile users are largely affected by distractive stimuli that are located in geographic space. Still, the practical acceptability of geovisualisation systems has to be optimised.

The usefulness as one criteria of practical system acceptability is composed of utility and usability. We regard the relevance of information as an element of utility and the cognitively adequate visualisation as an element of usability. Correspondingly, to avoid a loss of utility caused by the presentation of irrelevant information we separate irrelevant from relevant data by applying relevance as a filter criterion and encode relevance values as attributes of geographical information.
To enhance the usability we adapt the design of AGV to the user's capability of visual scanning, i.e. guiding visual attention shifts to discover fixation locations for processing information while maintaining a coarse representation of the spatial properties of a geovisualisation. The design of AGV is based on relevance theory and foundations of attentional information processing. We join these aspects together and consider AGV to be favourable for augmenting the usefulness and thus the overall practical acceptability of geovisualisation systems.

AGV is treated as any kind of representation that stimulates the human working memory system through visual sensory input to process relevant geographic information. The theory of relevance and findings from cognitive neuropsychology provide the theoretical basis for our design principles of AGV in mobile and explorative systems.
First, by concentrating on guiding the visual attention to relevant information we consider the relevance of geographic information to be of prime importance for the selection of information from today's vast quantity of geographic information. The attention-guiding design as an interconnecting artefact between the computational filtered information and the user's limited cognitive workload is based on the theory of cognitive relevance. Thus, only geographic information that unifies small effort (fast localisation and information decoding) and high effect (e.g. generating inferences) is processed. Second, we attract notice to the biological centre-surround mechanism that is implicated in figure-ground segregation and consider this capability of attentional processing as the main foundation of our design methodology. Visual attention as one category that describes the efficiency of mental processes is part of information processing and contributes to mnemonic processes. Hence, attention is involved in selecting information, facilitating the storing and retrieval of information, and monitoring executive

activities (e.g. decision making) by minimising responses to visual distractors, and maximising processing of salient features.

A basic challenge of AGV is to allow users a fast locating (*where*) and easy decoding (*what*) of relevant information by implementing graphical variables that are appropriate for guiding attention and encoding information. Accordingly, we consider variables that provide high neural response in cortical areas along the 'where' and 'what' processing pathways of the sophisticated neural network of visual information processing. We believe that stimulating these sensory signals processing pathways causes the release of the sensory signal converting system, i.e. the working memory system that is fractionated with respect to visual 'where' and 'what' information. The working memory system plays a crucial role in converting sensory input to generate stimulus-driven motor output like generating eye movements or activating finger muscles to click or move a mouse button.

To exemplify, we consider Bertin's set of variables and MacEachcren's extensions to them to be more or less effective for visualising ordinal data like the order of relevance. We relate these variables to a neurocognition-based classification of attributes and appropriate values depending on their property to guide attention. Based on this classification and a review of neurocognitive literature we propose further potential variables and relate all variables to functions of visual cortical areas.

By considering computational and user's properties of information processing we present a design approach of AGV that consists of the following steps: (1) relevance is assessed based on the user's query, (2) relevant geospatial objects are filtered and (3) the filtered and ranked objects are visualised with attention-guiding attributes. The evaluation of AGVs was conducted with a computational visual attention model that is based on the centre-surround mechanism and that predicts gaze paths and fixations. This model has been successfully validated against experimental evidence for visual search tasks and has served as a promising pre-evaluation method for eye-tracking studies.

Armed with the above mentioned attribution we finally propose possible evaluations methods of graphical variables and design principles with the goal to establish a scientific testable taxonomy of graphical variables. 'Scientific testable' is used for placing emphasis on the need of empirical evidence to include a graphical variable in a contemporary taxonomy grounded on relevance theory and cognitive research.