USER-CENTRED HUMAN-COMPUTER INTERACTION IN CARTOGRAPHIC INFORMATION PROCESSING

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1. Background and requirements of cartographic interaction

Computer interaction, animation and multimedia have changed cartography to a tremendous extent. This phenomenon requires new developments in cartographic theory and methodology. Especially interaction has influenced cartographic information processing decisively. Map-making and map-using have become one single and integrated process. The user is able to process and visualise data according to his or her needs. It is no longer the best map that dominates cartographic information processing, but rather it is the interactive process of creating and using a map.

Bearing this in mind, it is demanded of cartographers to create interactive cartographic visualisation systems that help users to meet their requirements and needs (Knapp 1994, Lindholm and Sarjakoski 1994, Medyckyj-Scott 1994, Nyerges et al 1994, Mackaness 1995, Guo 1997, Keller and O'Connell 1997, Dransch 2000). Investigations regarding computer interfaces have demonstrated that more than 60 percent of users' problems with human-computer interaction arise from the fact that interfaces are not adjusted to the users' tasks (Preim 1999). With regard to this, the main question is: what sort of interaction is necessary and useful for the user.

At present, cartographic interaction can be characterised as being mainly dominated by technique and data; what kind of interaction is possible with computer technique and what sort of interaction can be done with the data. Additionally, cartographic interaction is directed predominantly at map-making, the user can change colour, classification or scale etc..

However, interactive cartographic information processing consists of two integrated parts: map-making as well as map-using. Cartographic interaction should support both. Further, cartographic interaction should be targeted at the task the maps are used for instead of at technical possibilities.

Cartographic interaction, which is related to tasks and their map-making and map-using processes, requires a full investigation of map application. It needs a description of the tasks maps are used for and of the way in which they are used. “Know the users and their tasks” should become the main idea in the design of cartographic interaction.

The idea of user-centred, task-oriented computer interaction is also included in the ISO-Standard which defines the usability of human-computer interfaces:
„Usability is the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments.
Effectiveness is the accuracy and completeness with which users can achieve specified goals.
Efficiency is the accuracy and completeness of goals achieved in relation to resources expended.
Satisfaction is the comfort and acceptability of using the system.“
(ISO CD 9241-11.4, Version 8.8, Mai 1993. Source: Macaulay 1995, in R. v. d. Schans 1997)

2. Concepts in Human-Computer Interaction

At present, in the field of human-computer interaction, two main concepts exist to create user-centred interfaces. One of the concepts is founded on cognition theory, the other concept depends on activity theory.

The cognition based concept embodies the idea that humans and computers are both information processing systems; they are “equal” components. According to this hypothesis human information processing is the decisive issue when defining human-computer interaction. It has to be examined and be transposed to computers and their interfaces. (Grey et al. 1997, Kaptelinin 1997)

On the contrary, the concept of activity theory treats computers and humans as different components. Computers are artefacts which are used by an acting person to perform action in order to reach an intended goal. In this approach, the point of interest is the human’s activity and the application of artefacts. Accordingly, the design of computer interfaces requires a full investigation of human activity and its determining parameters. (Bodker 1990, Bannon, Bodker 1991, Rasmussen 1994, Nardi 1997, Kuutti 1997)

The concept of activity theory goes beyond the cognition approach. It regards not only the internal cognitive aspects of activities but also external elements that direct human activity. For that reason, it has been used in this work to develop a theoretical and methodological framework for modelling user- and task-oriented cartographic interaction.

For a better understanding of the theoretical background, the main ideas of activity theory are elaborated in more detail in the following:

- Human activities are always initiated by and directed to a specific goal. The goal determines and structures each activity. Cognitive plans of action which consist of activity goals, subgoals and sequences of actions (conscious) and operations (unconscious) guide the activity. On the other hand, the activity and its result effect the action plans. Consciousness and activity are an indivisible unit: You are what you do. Consequently, the acting persons are predominantly characterised by their knowledge of action instead of by very individual skills and characteristics.

- An activity is a process in which actions are planned, executed and evaluated. The actions are performed with the help of artefacts. The acting person's mental plan of action has to be executed by means of the artefact. For that reason, artefacts have a particular significance: They are mediators between the intended goal and the activity's result. The artefacts' properties and characteristics decisively influence the way in which an activity can be performed and also the quality. They also determine if the goal can be fulfilled at all. Artefact and action stand in a strong relationship to each other. The artefact's properties determine the action; the action, conversely, defines the artefact's properties. Therefore, if one component of the relation changes, the other has to change, too. A modification to the artefact necessarily results in a modification of action and vice versa.

- Activities are always inextricably linked with a certain situational context. The context shapes the action goals, it defines the community of persons who are involved in the activity and their roles, finally it determines the rules that effect the activity. The context influences *what* an acting person has to do and *how* the person has to do it. (It is important to realise that the situational context does just *influence* the action, it does not *determine* it. This is the significant difference between behavioural and activity based idea.)

3. Activity theory and cartographic human-computer interaction

From activity theory's point of view, interactive cartographic information processing which includes map-making as well as map-using can be described as follows: Interactive cartographic information processing is an activity that is initiated by and directed to a spatial goal e.g. way finding or route planning. The activity is performed by a person according to his or her action plan using interactive maps as artefacts. Cartographic activity is bound up with a certain situational context that defines the acting person's role and the work directing rules e.g. obligatory work organisation, mandatory map based procedures, or map design instructions (Bollmann 1996, Schans v.d. 1997, Heidmann 1999, Müller 2000, Dransch 2000).

Interactive cartographic information processing is a process in which a person's plan of action, that is derived from a spatial goal, has to be executed by means of the interactive map. Norman (1986) has examined activity processes with physical artefacts and has described the importance of "gulfs" that have to be overcome during this process. The first gulf, the "gulf of execution", has to be bridged when the mental action plans are to be executed by the artefact. The second gulf, the "gulf of evaluation" has to be crossed when the activity's result is evaluated against the intended goal.

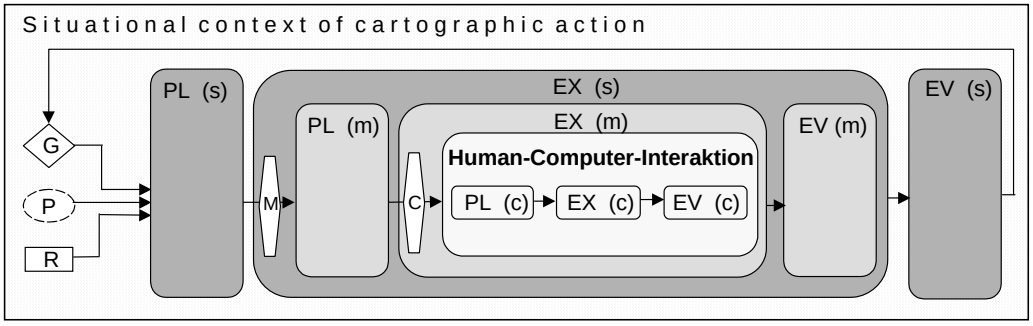
Cartographic information processing with interactive maps deals with an artefact that is split into two components: the map (and the database) and the computer with its interface. Both artefacts are in a hierarchical relation: The map is used to execute actions related to the spatial based goal, the computer is applied to perform actions related to the map. Because of the bipartite artefact the gulfs of execution and evaluation have to be overcome twice. The spatial based action plan has to be transferred to the map, the map based action plan has to be transposed to the computer. The gulfs have also to be bridged during the result's evaluation: The computer-action's result has to be evaluated in the map context and finally in the spatial context.

The activity "cartographic information processing" is successful only when the gulfs between spatial goal and map, as well as between map and computer, can be bridged without any problem. This is possible when the properties and characteristics of the artefact, i.e. the interactive map, are adjusted to the activities and action plans that have to be fulfilled.

The given framework indicates the strong interdependence between activity and cartographic interaction. Figure 1 depicts this framework in a graphic model; it shows the relations between the activity's situational context (i.e. acting persons, spatial goals and rules), the activity's process and the artefacts map and computer interface.

4. Modelling user-centred cartographic human-computer interaction

With regard to the interdependence between activity and computer interface, modelling user-centred cartographic human-computer interaction requires a full investigation of cartographic activities and their influencing parameters. "The most important issue in developing an interactive system is to accommodate the computer system's work processing to the user's thinking and work situation" (translated after Preim 1999). For that reason, all requirements derived from activities in a certain situational context have to be analysed and modelled.



G = spatial Goal, P = acting Person, R = Rules
PL = Planning the action, EX = Executing the action, EV = Evaluating the action
(s) = spatial based, (m) = map based, (c) = computer based

Fig. 1: Framework of situational context, cartographic action, and human-computer interaction

The analysis is involved with:

- the spatial action goals and subgoals of a specific situational context
- the sequences of actions to reach theses goals,
- the acting persons and their roles,
- the maps used and
- the influencing rules.

This data can be collected by means of observation, interviews, think aloud records, and also by evaluation of working material.

Furthermore, it has to be analysed in which way the changing artefact, the full interactive map, would or should alter the activity. According to activity theory, a modification of the artefact causes inevitably a modification in the activity. This relation is to be considered when designing the new artefact, the interactive cartographic visualisation system.

On the basis of the analysis' results the necessary cartographic human-computer interaction can be modelled. The map based actions which are required to reach a specific goal are to transpose in computer based actions. Figure 2 shows the process of modelling activity based, user-centred cartographic interaction.

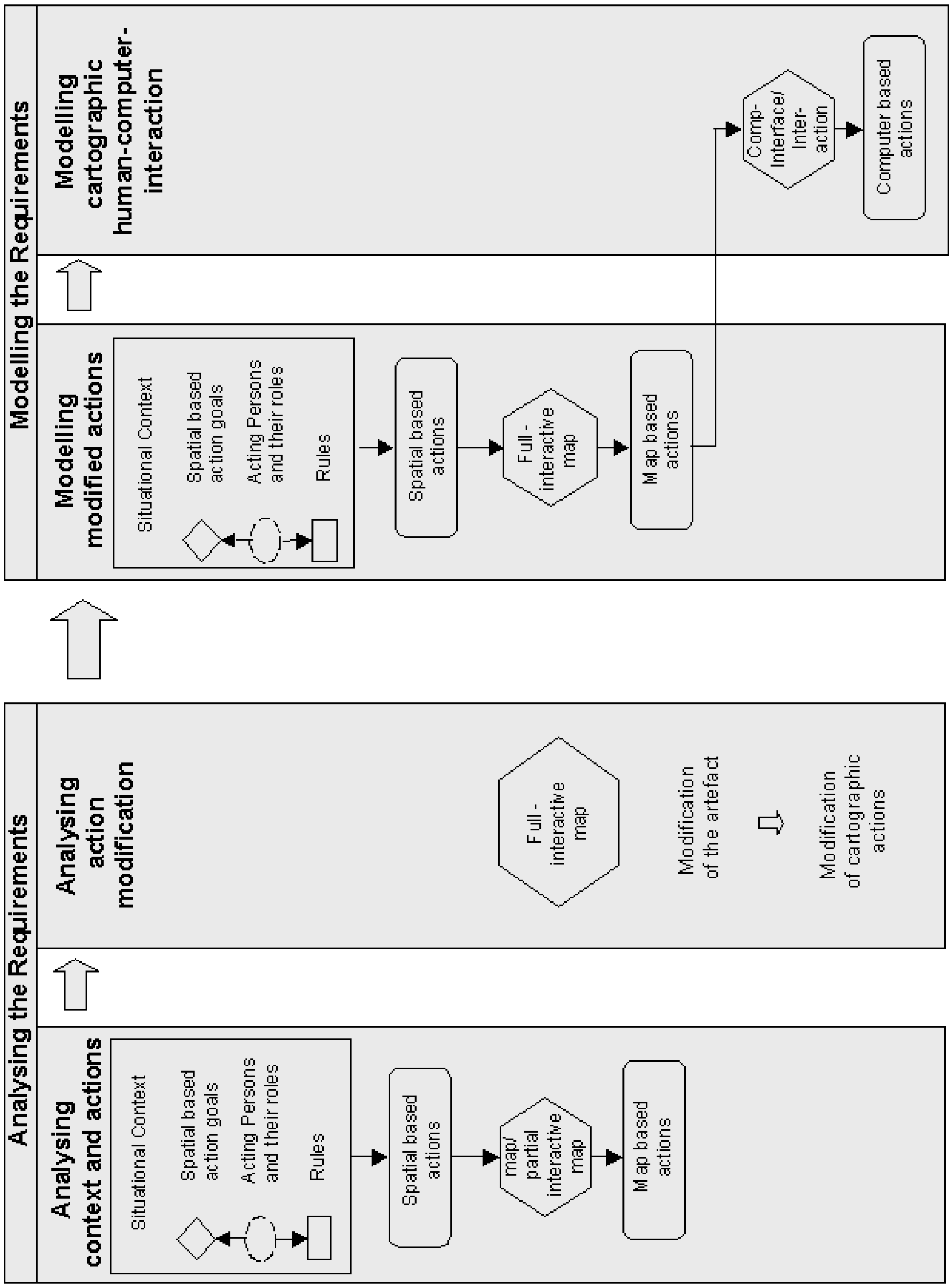


Fig. 2: The process of modelling activity based, user-centred cartographic human-computer interaction

5. Conclusion

Cartographic interaction has changed cartographic information processing decisively. It is no longer the map maker who dominates this process, but rather it is the map user. The map user is able to guide cartographic information processing to his individual requirements and needs. However, this important advantage can be realised only, when the interactive cartographic visualisation system meets the users' requirements and needs; when it is targeted to user's activities and goals. For that reason, the investigation of cartographic activities and their situational context is the most significant issue when designing user-centred cartographic human-computer interaction.

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