

THE USE OF MAPS IN THE EXPLORATION OF GEOGRAPHIC DATA

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ABSTRACT

At the International Cartographic Conference 2003 in Durban, South Africa, results are presented tests with users who were asked to select or generate and then use maps and map displays in the exploration of geographical data. These tests should lead to hypotheses that may be tested in further map use research. The ultimate aim is to use the research results for the improvement of the tools for exploratory cartographic visualization, i.e. both the cartographic displays and the hard- and software used to generate these displays. This written paper does not yet contain a systematic overview of the research results. It just summarizes the research questions, the methodology applied, the task given to the test persons and the test procedure in the map use research laboratory at ITC.

1. INTRODUCTION: MAP USE IN EXPLORATORY CARTOGRAPHY

A map is an abstraction and simplification of geographic reality to scale, obtained by reducing the amount of information on geographic reality, translating it into graphic symbols and, usually, projecting it on a flat medium (e.g. paper or the display screen of a computer system). As such, maps are very efficient means for the communication, analysis, synthesis and exploration of geographic data and information. In addition, there is no better way to provide insight into, and overview of, spatial patterns, relationships and trends.

Maps provide answers to concrete and simple geographical questions like: "Where is that supermarket?", "How do I get to the railway station?", "Where do most people live in this country?", etc. The geographical problem is a little bit more complex when users are *exploring* a geographic dataset, that is still largely unknown to them, in order to gain understanding of and get insight into that dataset. This is typically a problem with which many geo-scientists, regional geographers, physical planners, but also geography students and school children in their geography classes, may be confronted with regularly in practice. The way in which problems like this are tackled by human beings is characterized by psychologists as a *cognitive process* that is goal directed and requires effort of the brain and concentration of attention [1]. The solution is not found directly in a single step but via intermediate reasoning steps, some of which may later appear useless or false. In this way, *exploratory cartography* for geographic problem-solving may be regarded as a cognitive process in which maps are used as *tools for discovery*[2] in order to solve the problem of gaining insight into unknown geographical data. The maps are used to recognize regional and temporal patterns, trends, correlations or particular anomalies in the geographical data. There is no doubt that maps or map displays are very effective and essential tools when dealing with geographical data exploration questions (see e.g. [3]).

Before the widespread availability of computerized GISes, map libraries and paper atlases constituted some kind of exploratory cartography environment in which the user was looking for and browsing through the maps that could help him or her in solving their complex geographical problem. And, still, existing maps, be they on paper or in digital form (e.g. on diskette, CD-ROM or on the Web) may play some role in current exploratory cartography. In the past, the problem was that a lot of time and cartographic (drawing) skills were required to construct (paper) maps. As a consequence, only a limited number of maps could be made, or was not made at all, and, as a consequence, the cartographic tools were not used to their full potential. Another problem is that existing maps are just the map maker's conception of reality with, perhaps, a purpose that is not in line with the exploratory cartography objective. Such an exploratory cartography environment is essentially supply-driven and not demand-driven and the user cannot really interact, neither with the maps (certainly not if they are on paper), nor with the data. A real cartographic exploration is only possible, and this is becoming available to more and more users nowadays, if maps can be more or less adjusted to the specific needs of the users or if the maps can be generated from the raw geographical data in demand-driven ways by the users themselves with the help of cartographic visualization software tools like Esri's ArcGIS.

Since the 1950's, quite some map use research has already been executed. In the early days it was logical to do such research in order to test the effectiveness of particular cartographic symbol sets or complete maps or map series designed by cartographers for their users. The results of this kind of map use research were used to improve the functioning of maps, and it sure did! As, nowadays, there are still many maps made by cartographers for other users (like maps in school atlases, physical planning maps, road maps and maps in newspapers), this kind of testing of existing map displays (no matter whether they are printed on paper or only appear on the computer screen) may still be very useful.

Also in the context of exploratory cartography it is important to know how effective a certain map display is in answering a particular geographical question or in meeting the objective of the user. However, there are only a few examples of earlier scientific map use research in this field of exploratory cartography. A lack of research was already noted by McGuinness in 1994 [4] and by Davies & Medyckyj-Scott in 1996 [5] and since then the situation did not improve very much. Besides, and perhaps more importantly, the research that has been executed was mostly limited to the use of already existing map displays or to the use of visualization systems with only very limited cartographic functionalities. Therefore, the research into the use of maps in exploratory cartography that has been executed so far (see e.g. [6], [4], [7]) may be considered as 'supply-driven'. In this research, no attention was paid to the question whether or why the user would think of generating or retrieving a particular map at all. In other words, what has been missing altogether is research into the process that *precedes* the actual use of an existing map or map display. That is, we do not know much about when, why and how users decide to generate, to look up, to retrieve and to use a map in the process of geographical problem-solving in an exploratory cartography environment. It is this use of maps, which not only encompasses the actual use of an existing cartographic display, but also the cognitive process of finding, selecting, retrieving, adjusting or generating 'private' map displays, that is investigated in this research project.

2. RESEARCH QUESTIONS

As there has been hardly any map use research in the field of exploratory cartography, the nature of this PhD research project is rather experimental and, in essence, exploratory too. It should lead to an inventory of the factors involved and the objective of this research project is mainly directed towards the generation of hypotheses that may be tested in further map use research. The ultimate aim is to use the research results for the improvement of the tools for exploratory cartographic visualization, i.e. both the cartographic displays and the hard- and software used to generate these displays.

In order to be able to generate more specific hypotheses, this research aims at providing possible answers to research questions like:

- How do users go about in exploring a geographical dataset that is largely unknown to them? What are the successive stages in the process of geographical data exploration?
- After establishing the problem, what do they do, and in which order: formulating one or more detailed geographical questions, browsing the available data or browsing the available, existing map displays?
- Which geographical questions are formulated by the users when they are exploring a geographical dataset?
- When and how do users decide that they are in need of a map display to answer those questions?
- What do they do first: will they try to generate their own map, directly from the database itself with the help of visualization software, or will they first look for an existing map display?
- When users look for an existing map display, will they first look for an existing digital map or will they look for a paper map?
- What are the arguments on which a decision is based to consult either a paper map or an existing digital map?
- Which map type is selected to answer a particular geographical question? On which arguments is the selection based? Do users know which map type provides the best answer to their specific geographical question?
- When users generate their own map displays with the help of a visualization tool in order to find an answer to their specific geographical question, do they make proper use of the rules of the grammar of cartography? In other words, do they select the "best" way of representation?
- In which ways are users applying their visualization tools: will they try to generate with them the map displays they have in mind, or will they first try and see which defaults are offered to them by the visualization tool at hand?
- How do users read, analyze and interpret map displays in view of their particular objective? Which map use tasks do they execute?
- Which map use activities are they carrying out when executing their map use tasks?
- How do the users rate the effectiveness of the map displays in meeting their objectives? In other words, do the map displays meet their expectations? If not, what do the users do?
- What are the effects of differences in background and experience of users in exploring geographical datasets, map use and in using the visualization tool at hand? Are there any other factors that may explain differences in the use of maps in the exploration of geographical data?

In order to be able to arrive at workable answers to these research questions, it was needed to formulate a case for exploratory cartography with a concrete objective and a clearly defined group of users. As geographers most likely constitute a group of users who potentially make use of a great variety of map types, and as it is one of the research goals to investigate which of all these different map types are used in complex geographical problem-solving, it was decided to concentrate on the specific exploratory geodata analysis problem of gaining insight into the geography of an unknown region. This may be called a *regional exploratory study* and it usually constitutes one of the first stages in geographical research. Although the emphasis in scientific cartography varied over the years, such studies have always been one of the essential tasks of geographers and they were, therefore, selected as the user group for these investigations. The region that was selected for this research is the Province of Overijssel in the Netherlands (see Figure 1). In this exploratory cartography research project the concrete task for the experimental subjects was to use maps for the construction of a hypothetical cartographic model of the geography of Overijssel.



Figure 1. Location of the study area Overijssel in the Netherlands.

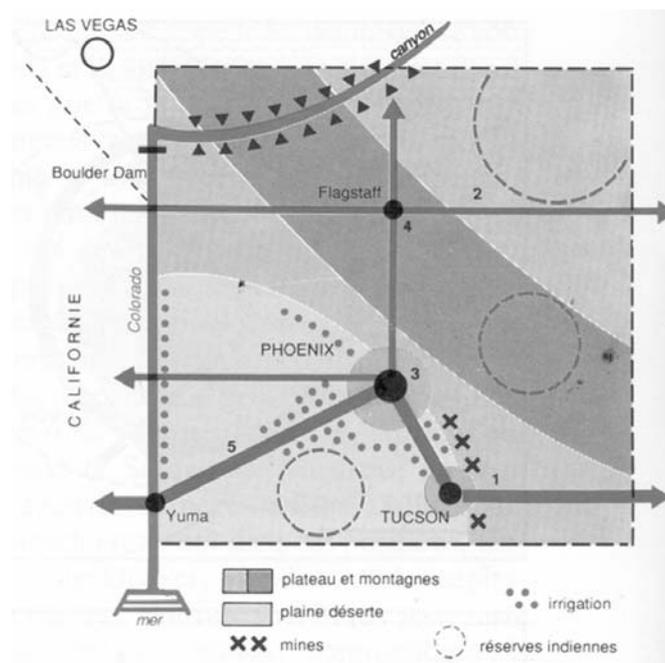


Figure 2. Graphical spatial model of the American State Arizona (source: [8]).

3. USER TASK AND INSTRUCTIONS: CONSTRUCT A GRAPHIC SPATIAL MODEL OF OVERIJSEL

The test persons were asked and instructed to construct the graphical model during the test session, with the help of Microsoft's PowerPoint software. Graphical spatial models like the one shown in Figure 2 may be very useful means to create insight in and to explain the geographical structure of regions. As such, they fit the definition of a map, as given above: "an abstraction and simplification of geographic reality". In traditional maps, however, usually the geometrical aspects of reality (bearings, distances, area relationships) are preserved as much as possible when represented to scale.

This condition was the starting-point for many research activities in, for instance, the fields of map projections and cartographic generalization. In most of the maps that are included in the database of Overijssel (see next Section) the geometrical aspects of reality have also been preserved and the real-world topography is usually also the organizational basis for the data stored in a geographical information system. But a correct geometrical representation of reality to scale is not always needed, and sometimes even not desirable, for the map -or graphical model of reality- to best meet its purpose. A famous example is provided by Beck's graphic representation of the London Underground. In it, geographical reality is deliberately distorted, but the result is one of the most effective maps ever made. Simply because future geometry cannot yet be known, and also because these maps are meant to convey rough ideas about the possible spatial organization of a large area, the graphical model concept is often also applied in physical planning maps. In the London Underground map, physical planning maps, and in the model shown in Figure 2, the geometry is not correct, but the topological relationships are preserved. And this is what matters more when structure and dynamics of a geographical region will have to be represented.

	Point	Line	Area	Network
models of the manner in which a region is subdivided				
	chief towns	adm. boundary	state, region	centers, boundaries and polygons
models of a region's infrastructure				
	node vertex	lines of communication	service, irrigation drainage area	network
models of gravity				
	satellite points	lines of gravity orbits	attraction area	preferred relationships
models of fronts of communication				
	passage point	rupture, interface	contact areas	"port" base abutment of a bridge
models of unilaterally biased movements				
	directed movement	division line	tendency surfaces	dissemmetry
models of conquest diffusion				
	point evolutions	axes of propagation	areas of extension	tissue of change
models of hierachies				
	urban pattern	dependency relationship administrative boundaries	subset	linked network

Figure 3. Table of chorèmes (source: [8]).

Brunet [8], [9], [10] provided a framework for the possible application of graphical spatial models in regional exploratory studies. He developed a sign system "with which relational models of regions can be built, stressing aspects of spatial organisation not rendered by traditional maps." [11]. Brunet's sign system consists of a limited number of fundamental models of geospatial dynamics or geospatial organisation, depending on the dimensional properties of the phenomena under consideration (points, lines, areas and networks respectively) (see Figure 3).

Brunet described these basic models of spatial organisation with the term *chorème*. The various chorèmes may be used as building-stones for the construction of a graphical model of the region under study. As Ormeling [11] also indicated, this may be done in two ways: either by producing and combining basic chorèmes "from scratch", or by departing from an actual map and arriving at a *modèle épuré*, a schematic representation, purified of all aspects that are irrelevant to the main structures or relationships within the geographical region, including geometric accuracy. In view of the fact that it could be expected that most test persons did not have experience with constructing graphical models from basic chorèmes, and that there would also be no time to learn this during the test session, the latter approach was followed in this research project. The test persons were presented with a PowerPoint design template with a simple geographical map of Overijssel on it, without geographical names (see Figure 9).

At the same time, the test persons received instructions on how they could "draw" -with the help of MS PowerPoint-basis point, line, area and arrow symbols on it, in order to construct a graphical spatial model on the basis of their selection and use and analysis of maps taken or generated from the Overijssel database (see next Section). The test persons were specifically asked not to try to produce a geometrically correct "map"; they were asked to construct a schematic graphical model, which only contains the elements that are considered to be essential for the structure of the region and in which only the topological relationships are being preserved. Usually, the test persons will gradually arrive at this *modèle épuré* after having started with a so-called *modèle localisé* [11]: a schematic map without too many geometric distortions, created by putting the first basic graphical symbols on the PowerPoint design template of Overijssel. Somewhere in the course of the process of the construction of the graphical model this given map background could be switched off.

MS PowerPoint was used as a tool for the construction of the graphical models as it is a package with simple drawing tools with which many test persons could already be familiar, as they are also present in MS Word, another member of the Microsoft Office family that is widely used and has a similar user interface. Using a more complicated graphics design package could lead to a disturbance of the cognitive process that is the actual subject of this research project: the selection, construction and use of map displays preceding the construction of the graphical model.

4. DATABASE OF OVERIJSSSEL

In order to be able to find out when and how geographers make use of maps and map displays in the process of gaining insight into the geography of the province of Overijssel it was required to collect and to make easily accessible a vast set of maps and geographical data of that region beforehand. After all, during the user tests, which are already time-consuming, no unnecessary time should be wasted on finding and retrieving the maps and/or data wanted by the subjects. At the same time, it had to be prevented that the amount of maps and data was so small that there would be a danger of 'supply-driven' instead of 'demand-driven' exploratory map use research and also that the subjects were not automatically tempted to start browsing through the materials available in order to solve their task. Of course, it is impossible to create a 'complete' set of maps and geographic data of Overijssel, but it was tried to bring together beforehand all the maps and data the subjects could most likely ask for. A vast collection of maps and geodata prevents that the research results are biased too much by the specific materials available. During the progress of the research project the collection was constantly extended and updated. In this respect, the results of pilot tests also provided useful directions.

As this research project is directed towards the possible use of maps and map displays in regional exploratory studies - and not solely towards the functioning of a particular software tool (i.e. ArcGIS) in this respect- the database of Overijssel could not be created within that selected software environment alone. In order to alleviate the inherent limitations that are present in every cartographic software tool (e.g. possible ways of cartographic representation and the computer medium for dissemination, with its limited size and rather low resolution) it was decided to also give the subjects access to existing paper maps of Overijssel as well as to existing static, interactive or dynamic digital maps created in other software environments.

At first, a database was conceptualized, consisting of the following five groups of data:

- digital geographic (attribute) data, to visualize within the ArcGIS environment
- digital topographic base map elements in formats that can be handled within the ArcGIS environment
- existing paper maps (plano, folded, or maps in paper atlases or other publications)
- existing digital maps (static, interactive or dynamic maps in different formats, ArcGIS 'Map documents' (see Figure 6), maps on CD-ROM or on diskette and Web maps)
- publications about the geography of the province of Overijssel

In order to make these items quickly and easily accessible, a metadatabase was created with MS Access. Forms were used as user interfaces for the input of the metadata (see Figure 4) and by means of search queries the wanted maps and data could be identified as well as their physical location (e.g. place of storage of loose paper maps, reference to a paper map in a publication or a specific computer directory for the digital items) (see Figure 5). For the attribute data, paper maps and existing digital maps the main search field was a classification of geographical themes into main categories and sub-categories.

Figure 4. Form for adding metadata on digital maps in the Overijssel database (construction: Nicoline Emmer).

04. Subcategory	a. Field name	b. Table name	05. Topic in English	06. Topic in Dutch	08. Location	09. Area covered	10. Mapping unit	11. Scale
POam - Age & ma	AGE0014_88	wmPOam_1988_1	Number of inhal Aantal inwoners	N:\gip\carto\Overijssel\NData\	W = Overijss	M = Municip	< 1:500.000	
POam - Age & ma	AGDF1	AGDF1_AgeDis	AGDF1_AgeDis	N:\gip\carto\Ov	Them10: Dia	W = Overijss	M = Municip	< 1:500.000
POam - Age & ma	AGDF2	AGDF2_PercM	AGDF2_PercM	N:\gip\carto\Ov	Them07: Chr	W = Overijss	M = Municip	< 1:500.000
POam - Age & ma	AGDF41	AGDF41_PercC	AGDF41_PercC	N:\gip\carto\Ov	Them07: Chr	W = Overijss	M = Municip	< 1:500.000
POam - Age & ma	AGDF42	AGDF42_PercA	AGDF42_PercA	N:\gip\carto\Ov	Them07: Chr	W = Overijss	M = Municip	< 1:500.000
POam - Age & ma	Plano21	Age compositio	Leefijdsopbouw	Them07: Chr	S = Overijss	M = Municip	< 1:500.000	
POam - Age & ma	Plano22	Age compositio	Leefijdsopbouw	Them07: Chr	S = Overijss	O = Other	< 1:500.000	
POam - Age & ma	NOTMAR_89	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	MARRIED_89	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	DIVORCE_89	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	WIDOW_89	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	NOTMAR_90	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	MARRIED_90	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	DIVORCE_90	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	WIDOW_90	wmPOam_1988_1	Marital status: i	Huwelijkse stas	N:\gip\carto\Overijssel\NData\	W = Overijss		
POam - Age & ma	AGE0014_91	wmPOam_1991_1	Number of inhal Aantal inwoners	N:\gip\carto\Overijssel\NData\	W = Overijss			
POam - Age & ma	AGE1564_91	wmPOam_1991_1	Number of inhal Aantal inwoners	N:\gip\carto\Overijssel\NData\	W = Overijss			
POam - Age & ma	AGE65UP_91	wmPOam_1991_1	Number of inhal Aantal inwoners	N:\gip\carto\Overijssel\NData\	W = Overijss			
POam - Age & ma	AGE0014_92	wmPOam_1991_1	Number of inhal Aantal inwoners	N:\gip\carto\Overijssel\NData\	W = Overijss			

Figure 5. Results of a search action on the metadatabase: three hypelinked tables with all paper maps, digital maps and attribute data on the topic selected.

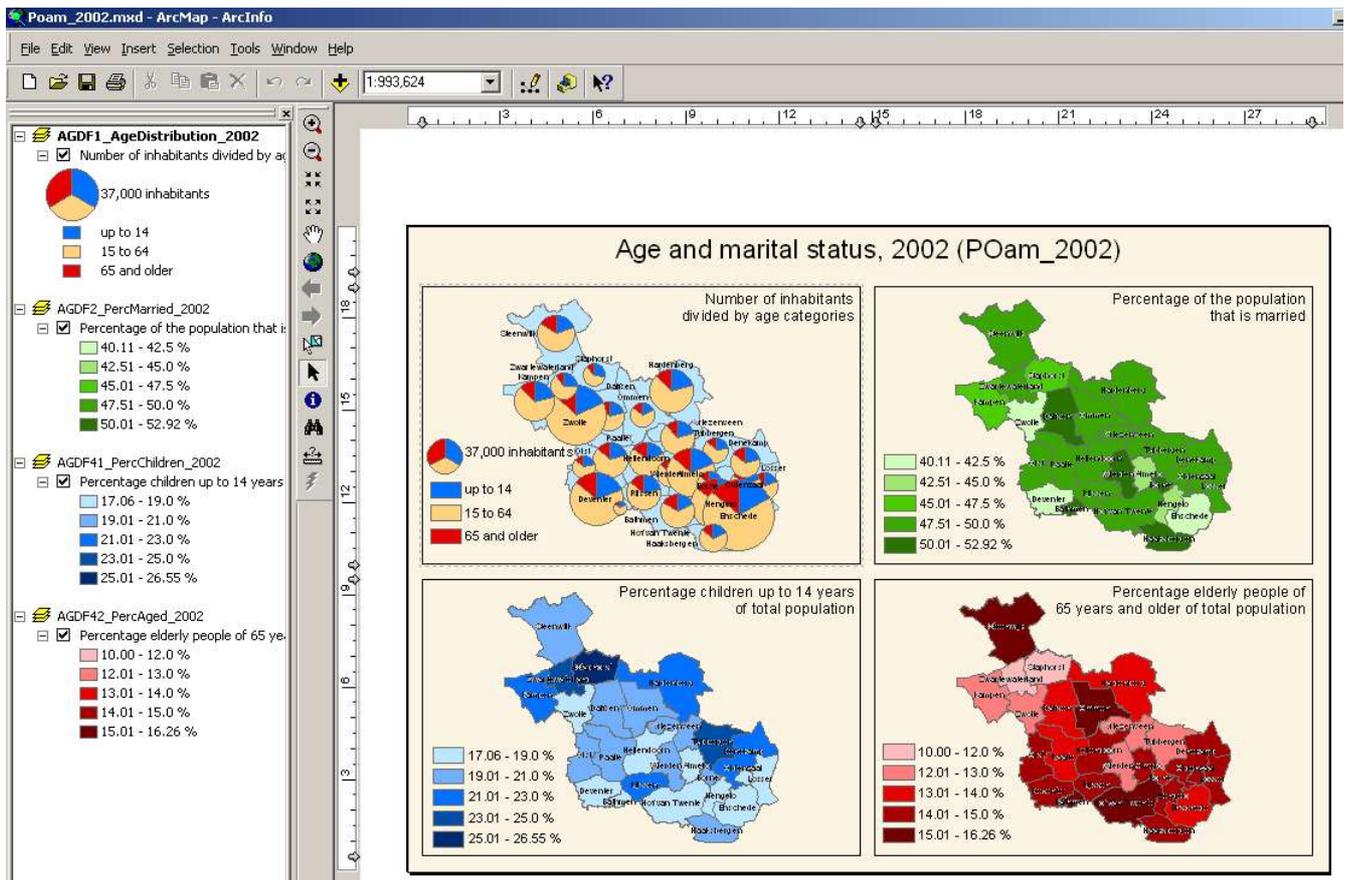


Figure 6. Ready-made ArcGIS 'Map documents' are also included in the Overijssel database.

5. RESEARCH METHODOLOGY

There are no solid scientific theories yet on the use of thematic maps in the exploration of geographical data nor on the use of cartographic or geographic visualization tools. Therefore, this research project is exploratory in nature as well and directed towards the generation of hypotheses to be tested in further research. For this kind of exploratory or inductive research a combination of qualitative research techniques centred round the so-called 'think aloud method' and leading to verbal and action protocols to be analyzed appeared to be most promising. In papers for the two previous ICA conferences (in Ottawa and Beijing) I have already reported on the general characteristics of this particular research method and its application in map use research, as well as on the procedure of setting up a model of geographical problem-solving to be tested (definition of the overall map use objective, putting up the necessary geodata, formulation of geographical questions and related map use tasks and establishment of required map use operations) [12, 13].

In this research project, the thinking aloud is recorded on videotape together with the images of the test persons interacting with the map displays generated by the cartographic visualization software and with the paper maps that are also considered to be part of the database (see Figures 7 and 8).

The changes on the monitor screen were recorded separately by means of interaction logs, but a video camera was still required; not only because of the incorporation of the use of paper maps in this research, but also because the subjects' gestures and mimics may partly betray what they think, but perhaps do not say. Possible verbalization problems while thinking aloud are also alleviated by putting the operation of the cartographic visualization software in the hands of a research assistant, who is instructed to only execute the orders of the test persons.



Figure 7. Impression of the research laboratory: the test person (left) produces a graphical model on the PC to the left. Research assistant Sven Gerhardt (right) is helping the test person to retrieve existing maps from the Overijssel database and to construct new maps from geographical attribute data with ArcGIS. All actions of the test person are recorded with the video-camera at the back and his thinking aloud is recorded with a wireless microphone.



Figure 8. Synchronization of the sounds of the thinking aloud, the video image of the test person and the changes on the monitor screens of the two PC's is obtained by recording all these inputs simultaneously with a SVHS video-recorder (bottom right) on one single video tape. The images can be combined in this way with the help of a Video Quad Unit (bottom left)

The involvement of a research assistant -not the researcher himself, in order to try to maintain scientific objectivity as much as possible- also reduced a potential bias as a consequence of differences in working knowledge by the test persons of the cartographic visualization tool applied (i.e. ArcGIS). However, such differences, for instance in knowing what kind of map displays may be supplied by the software, may still have a negative impact on the results of this research project that is first of all aiming at a demand-driven approach. Therefore, knowledge of the visualization tool applied is one of the characteristics of the test persons that was established before the actual start of the think aloud sessions by means of a questionnaire. That questionnaire also contains questions on, among other things, the knowledge of the sample region Overijssel, the experience in using map displays, with executing regional exploratory studies and the construction of graphical models and familiarity with MS PowerPoint.

In order to deal with some disadvantages of the think aloud method [see 12], the think aloud session with some of the subjects was followed by letting them watch and listen to the video recordings and interaction logs and ask them to comment in retrospect as well. This commentary is again recorded and transcribed into verbal and action protocols for later analysis. Finally, in this research project the execution of the geographical problem-solving task also led to results or products that could be analyzed: hypothetical cartographic models of the region of Overijssel (see Figure 9). By means of separate, but synchronized, interaction logs, the interactive construction of these models is registered as well.

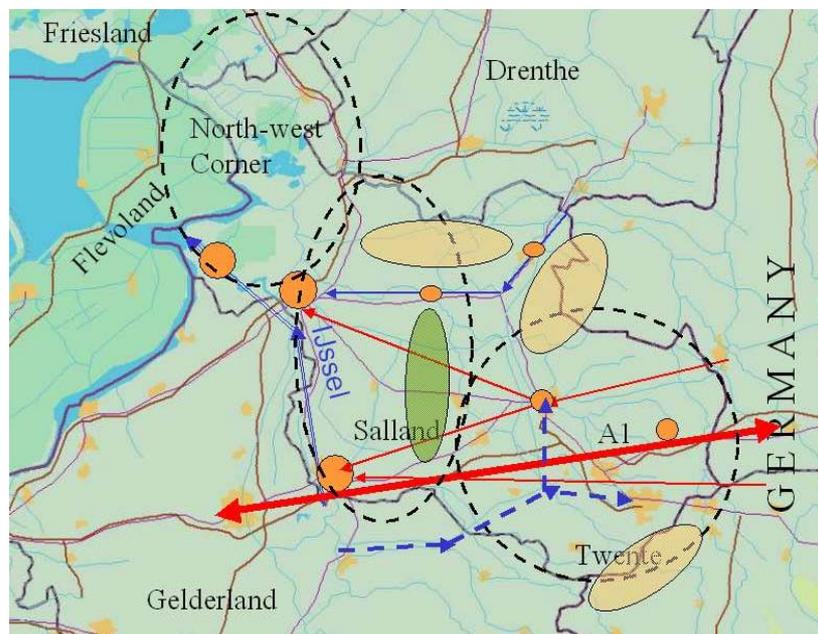


Figure 9. Graphic model of Overijssel, produced by one of the test persons on the base map (derived from [14]) provided.

6. CONCLUSION

At the time of writing this paper there were not yet sufficient results available to be able to formulate new hypotheses on the use of maps in the exploration of geographic data. However, the first pilot tests demonstrated the suitability of the research methods and techniques applied. Some interesting cognitive processes were discovered and will be shared during the conference in Durban. And, of course, the pilot tests were also used to improve the test procedures and the instructions for the test persons. For example, it appeared that the first test person was concentrating far too much on the construction of the graphical model and by far not enough on the selection, construction and use of maps and map displays that were supposed to be the basis of this model and the prime object of this research. It also proved to be wrong to already inform the test person -at the moment of the invitation to participate- of the task to be executed: making a model of the main geographical characteristics of Overijssel. The first test person used the time in between the invitation and the actual test to already start thinking about the contents of the model and, as a consequence, immediately started to draw a model during the test and only looked at the first map after more than 10 minutes (and then just for confirmation). It also demonstrated -as could be expected in an exploratory map use research project- that the results are only limited in situations where the geographical data to be explored are not completely unknown to the subjects. These outcomes have led to a more careful selection of test persons. The research done with these test persons leads to models of geographical problem-solving that could become invaluable means for the development and construction of more effective tools for exploratory cartographic visualization.

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Biography

Dr Corné van Elzakker studied human geography with cartography as main subject at Utrecht University. In 1981 he lectured for 8 months in the Cartography Department of Utrecht University. In the remaining 22 years of his career (one year before and since the period in Utrecht) he was (and still is) employed by ITC (International Institute for Geo-Information Science and Earth Observation) in Enschede, the Netherlands, and executed a great variety of tasks in the fields of education, research, consulting and management and administration in the Cartography and Geovisualization knowledge node. His current position is Assistant Professor and Portfolio Manager Education in the Department of Geo-Information Processing. His main research interests are in the field of map use (currently doing a Ph.D. research project into the use of maps in the exploration of geographical data). Corné van Elzakker chairs the Working Group on Map Use of the Netherlands' Cartographic Society and is a member of the Maps and the Internet Commission of the International Cartographic Association.