Map Use Tasks in Regional Exploratory Studies

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Abstract

In order to be able to build effective tools for cartographic exploration, a clear distinction should be made between the overall objective of that exploration, the various questions or map use tasks that have to be solved and the actual map use activities that are executed to deal with these questions. When map use tasks and map use activities are combined into matrices, one for every map display required, a model of geographical problem solving emerges, that can be tested in user research. This procedure is worked out here for the example of a regional exploratory study with the overall objective of gaining insight into the geography of an unknown region.
Keywords: exploratory cartography, user research, map use tasks, map use activities, regional exploratory studies

Introduction

Exploratory cartography involves the interactive cartographic visualization of unknown geodata by an individual user in order to stimulate the visual thinking, which should lead to a better insight in, and overview of, these geodata. *User research* is required to improve the effectiveness of the software tools that are applied in exploratory cartography, as well as the map displays that are generated with these tools.
Such user research will only lead to successful results if it is based on a thorough *task analysis*. Andrienko & Andrienko (2000) have already tried to make a general classification of user tasks for exploratory spatial data analysis. However, making such a complete and overall classification is very difficult, if not impossible, as the analytical tasks, their relative importance and the possible orders in which they are executed (task scenarios) may differ considerably, because of differences in the overall objectives of the spatial data exploration. It is clear, for instance, that task scenarios will differ when a user is exploring a spatial dataset in order to find a suitable place to live or when he / she is doing that in order to gain insight into the geographical aspects of the results of elections.

Besides, some confusion may be created when reference is made to user tasks in the context of geodata exploration with the help of map displays. When mention is made of map use tasks in literature, quite often the geographical questions and map use actions executed to deal with these questions are mixed up (see e.g. Kraak & Ormeling, 1996, pp. 204-207). In order to be able to arrive at a proper model of geographical problem-solving (that may be tested in user research and could be the basis of software development) user questions and actions will have to be unravelled. Therefore, a distinction is made here between the overall *objective* of the spatial data exploration (the main "task" of the geodata explorer), the various analytical or geographical (sub-)*tasks* that are or have to be executed to meet that overall objective and the map use *activities* that are undertaken during the execution of these tasks.

The purpose of this paper is to work out this distinction for an exploratory geodata analysis problem with the specific objective of gaining insight into the geography of an unknown region. This may be called a *regional exploratory study*. In order to reach that overall objective, several tasks may have to be executed in relation to the geographical questions that have to be addressed (like defining spatial relationships). And in executing these tasks for various geographical themes, users may carry out all kinds of activities with maps (like panning or zooming). A kind of *scenario* may evolve by combining

the geographical tasks and map use activities into matrices. The conclusion of this paper provides an answer to the question whether this procedure can also be used when dealing with other exploratory cartography objectives.

Overall objective: gaining insight into the geography of an unknown region

The research reported on in this paper forms part of a bigger research project (van Elzakker, 1998) in which the so-called *think aloud method* (see van Elzakker, 1999) is applied to find answers to questions like why, when and how users generate particular kinds of maps in the process of exploring geodata and whether these maps meet their expectations and supply the information they need. That research project is limited to exploratory spatial data analysis by *geoscientists* with one specific objective: gaining insight into the geography of an unknown region, in this case the Province of Overijssel in the Netherlands. In this research project, the concrete task for the experimental subjects is to construct a hypothetical cartographic model of Overijssel (a so-called *chorème* (Brunet, 1980)).

Geographical tasks in regional exploratory studies

In order to gain insight into the geography of an unknown region various geographical tasks may be executed. Without claiming completeness, in *Table 1* some of the are listed by means of verbs, in relation with the geographical questions that are addressed. These questions may be derived from geographical textbooks (as done before, for instance, by Board (1984), who made a selection of a list provided by Slater (1982)), although it is surprisingly hard to find clear and systematic overviews of the nature of the geographical questions posed by geoscientists in situations like this (van Elzakker, 1999).

Geographical questions	**Tasks**
Elementary	
What is there?	to **recognize** objects (external identification)
At a given place, what is there?	to **identify** objects (internal identification)
How much is there?	to **quantify** / **estimate** amounts
Where is that geographical object?	to **locate** an object
Intermediate	
What is near that geographical object?	to **position** with respect to other objects
What is the distance to similar/other objects?	to **define** relative / absolute distance
Why is a geographical object there?	to **explain** a location
What is the spatial distribution of that object?	to **find** order, patterns or spatial anomalies
Where are the limits of a spatial distribution?	to **delimit** a distribution
Temporal	
Has that geographical object always been there?	to **determine** changes
Have the spatial distribution patterns changed?	to **establish** trends
Which spatial processes are taking place?	to **detect** processes
Overall	
What are the influences from outside the region?	to **contemplate** spatial context
Are there relationships between spatial patterns?	to **discover** correlations / dependencies / conflicts
Which factors cause the regional structure?	to **structure** the geographic information
Can different (sub-)regions be identified?	to **regionalize**
What are the geographical characteristics?	to **obtain** insight in and overview of the region

Table 1. Map use tasks in relation with the geographical questions addressed

The grouping of the geographical questions and their related tasks into main categories in *Table 1* (elementary, intermediate and overall) is comparable to Bertin's distinction of levels of reading, way back in 1967. Bertin (1983, p. 140) and others (e.g. Ormeling & Anson, 1996, pp. 75-79) also pointed at the following successive stages in the map reading process: external identification (in the mind), internal identification (in the graphic image) and perception of pertinent (new) correspondences. These stages match up with the tasks indicated in *Table 1* with the verbs “to recognize”, “to identify” and “to discover” respectively.

Although, in doing so, there is a potential danger again of mixing up map use tasks and activities, the order in which the map use tasks are usually executed, and more or less the order in which they are presented in *Table 1*, could also be described by the map use sequence: map *reading* - map *analysis* - map *interpretation* (as done by Muehrcke & Muehrcke, 1992). In the light of the map use *tasks*, this is a cognitive process that starts as soon as a map user is confronted with a cartographic display.

In considering that cognitive process, Olson (1976) also distinguished three levels of map reading tasks (to differentiate between individual symbols, to recognize properties of symbol groups, to attach meaning to symbols / symbol groups). But these are levels in the process of relating the cartographic symbols to what they actually represent and only the highest level concerns what the symbols mean or stand for. Therefore, this is another kind of distinction than the one into levels of geographical questions, and related map use tasks, as shown in *Table 1*. In the strain of Olson, and in the terminology of Board (1984), *Table 1* limits itself to the higher order map using tasks. What is important here is to distinguish clearly the invisible, cognitive tasks, or mental constructs, listed in *Table 1* from the externally noticeable map use activities, as presented in *Table 4* further on.

Geographical data

In *Table 1*, a distinction is made between geographical questions ranging from elementary (analytical) to overall (synthetical). Indeed, it should be realised that in complex regional explorations like this, users will usually first have and want to consider various aspects of the geographical data separately. For developers of exploratory cartography tools it is also important to know, or to find out, which geodata are required by the users, and in which way or in which order they will be analysed. For this particular cartographic exploration, with the overall objective to gain insight into the geography of an unknown region, a geographic database of the Province of Overijssel has been created, structured on the basis of some main categories of geographic themes, as shown in *Table 2*.

1. Economy	7. Land use	12. Soil
2. Environment	8. Physical planning	13. Topography
3. Geomorphology / Geology	9. Politics	13. Tourism
4. Housing	10. Population	14. Traffic & transportation
5. Hydrology	11. Relief	15. Welfare
6. Landscape		16. Other

Table 2. Main categories of geographical themes for regional exploratory studies [1]

The geographical themes are divided into subcategories. For instance, the Population theme is subdivided into births and deaths (10.1), migration and commuting (10.2), number of inhabitants (10.3), density (10.4), etc. [1]. The data in the various (sub-)categories may be explored alone, or in combination. In view of the possible geographical questions with a temporal component, users may also specify the dates (years), or series of dates, for which they want to explore the data. In a similar way, users may want to explore the data at different aggregation levels (e.g. district / neighbourhood or municipality). Finally, a user may want to specify the geographical extent of the data: the region as a whole (W), just part of the region (P), or the region and its surroundings (so as to be able to put the regional data in a geographical context) (S) [1].

Map types

As stated before, *Table 1* lists the tasks that start as soon as a map user is confronted with a cartographic display. But it should be realized that, in exploratory cartography, actual map use is preceded by another stage that may be called map *selection*. For in regional exploratory studies first the need for (a) map(s) will have to arise and, thereafter, (a) certain map(s) sought, selected or generated from a spatial database. What will be happening, most likely, is that a user, depending on the geographical task at hand, will make some kind of inner (mental) definition or image of the kind of map he/she thinks may help him/her. After that he/she will try to find that map or generate it from the data in the spatial database.

Another important goal of this research project is to find out whether the subjects are looking for the "right" map type when dealing with a particular geographic question for a particular kind of geodata. That is, if the users generate their own maps, will they correctly apply the rules of cartographic symbol design, so carefully established by cartographers in the past 30 years, and what are the consequences of an "incorrect" application of these rules? And is the user aware of all cartographic techniques and methods of representation which may be used in regional exploratory studies?

Therefore, next to knowing which geographical data are considered, and in which order, or in which combination, in the framework of this research project it is also important to find out for which types of maps geoscientists are looking first when dealing with the geographical tasks involved in regional exploratory studies. For the purpose of this particular project, a classification of *map types* has been applied that is shown in *Table 3*.

a. Topographic/geographic map	f. Dot map	k. Diagram map
b. Image map	g. Choropleth map	l. Flowline map
c. Physical planning map	h. Chorochromatic map	m. Cartogram
d. Road map	i. Isoline map	n. Prop. point symbol map
e. Tourist map	j. Statistical surface	o. Dynamic map / animation

Table 3. Map types for regional exploratory studies [1]

In addition, users will also specify a desired map *scale* in relation, perhaps, to the aggregation level ("I would first like to see a small-scale geographical map of the Province of Overijssel as a whole."). In this particular research project the following three categories of map scales are distinguished: > 1 : 250,000 (I), 1 : 250,000 – 1 : 500,000 (II) and < 1 : 500,000 (III) [1].

Above, the map selection process in regional exploratory studies is presented as being purely demand-driven (the user makes up his / her mind about the map he / she needs and, thereafter, looks for it or generates it). However, in practice the map selection process will often also be of a more supply-driven nature. That is, the user may first ask: "What maps are available?", look at them and decide whether one or more maps may be useful in view of the geographical task at hand. This map use aspect of exploratory cartography requires further investigation as well.

Map use activities in regional exploratory studies

As has been done in *Table 1* to denote geographical tasks, verbs may also be used to distinguish various user *activities* (or *operations*) with maps, undertaken to execute these tasks. And as there is a logical sequence of stages in the map use process (map reading, map analysis and map interpretation, preceded by a choice of geodata and map type), there is also a logical sequence of map use activities in regional exploratory studies and, in fact, in exploratory cartography in general.

Except for map interpretation (which is an invisible, cognitive process), the same headings may be used to group the successive map use *activities*: map *selection* (e.g. to generate a map from a spatial

database or to select from the maps available), map *reading* (e.g. to look at or click on a map) and map *analysis* (e.g. to measure on a map). In fact, there may be loops in the map use process as new maps may also be sought, selected or generated as a result of the cognitive map reading, analysis and interpretation. In a digital exploratory environment, where map displays are not of a view-only nature (like paper maps or atlases) this may often be in the form of *adjusting* the maps that are on-screen at that moment. The adjustment may be, for instance, a change of the classification method, a change of the aggregation level, a change in symbology (e.g. a change of the colours used) or a complete change of the way of representation (i.e. map type or mapping method). This is one of the key elements of interactive spatial data exploration. Finally, new maps may be drawn (or *constructed*) to present the results of the cartographic exploration. In this particular research project these maps to be constructed are of a special kind: a cartographic model of the regional structure (*chorème*) that may be considered as a hypothesis to be tested by means of further geographical studies, supported by, what may be called *analytical cartography* [2].

In summary, it is proposed to make the following main distinction between five groups of actual map use activities in exploratory cartography:

- map *selection*
- map *reading*
- map *analysis*
- map *adjustment*
- map *construction*

These main types of map use activities are operationalized by specific verbs in *Table 4*.

Stages in map use for regional exploration	**Specific map use activities**
Selection	to **select** from maps available (supply-driven)
	to **search** for existing maps (demand-driven)
	to **generate** maps from a spatial database
Reading	to **look** at the title / legend
	to **look** at the map image
	to **click** on a map symbol (to **retrieve** attribute data)
Analysis	to **measure** on the map
	to **count** symbols
	to **highlight** an object or category of objects
	to **juxtapose** map displays
	to **compare** map image with chorème
Adjustment	to **overlay** (to **add** layer(s) to a map display)
	to **switch off** a layer
	to **change** the classification method of attribute data
	to **pan**
	to **change** the level of aggregation
	to **zoom in** (make the map scale larger)
	to **zoom out** (make the map scale smaller)
	to **change** the map orientation
	to **change** the snapshot in time
	to **change** the symbology
	to **change** the mapping method = to **generate** new map
Construction	to **trace** boundaries
	to **draw** the other elements of a chorème

Table 4. Map use operations

Scenario for regional exploratory studies: matrix of geographical tasks and map use activities

The geographical tasks and map use activities presented in *Tables 1* and *4* may be combined into a matrix that shows which map use activities are involved in executing the various geographical tasks (see *Table 5*). The geographical topics analysed and the map types (and scales) selected may be considered as the third and fourth dimension to such a matrix, in the sense that a choice of data, or combination thereof, and a selection of map type / scale, or combination thereof, will most likely precede map use activities executed to deal with particular geographic tasks. Put in a more simple, two-dimensional way: the matrix of geographical tasks and map use operations may be filled up differently for different (combinations of) geographical data and for different (combinations of) map types and scales. *Table 5* just shows a possible example with respect to the use of a dot map, showing the spatial distribution of population in the Province of Overijssel. This is just one of the many different map displays that would normally be used in regional exploratory studies. For each map display (that will receive a unique code number, in this example: 8) another map use matrix may be drawn up. Together, the many different map use matrices constitute a kind of task scenario for regional exploratory studies. It should be realized, however, that in complex exploratory cartography, like these regional exploratory studies, the various matrices in the task scenario will, most likely, appear in random order and, sometimes, in repetitive loops. In this respect, one important factor is that users will want to juxtapose different map displays (in this example the dot map is juxtaposed with imaginary map no. 4, showing e.g. the natural areas) in order to discover relationships between spatial patterns or to explain them. Most likely, also the order in which the map use activities are executed within one matrix will often be random.

These orders of dealing with matters in regional exploratory studies are one thing that should be investigated in user research projects. In doing so, *Table 5*, together with the other map use matrices combined into the task scenario for regional exploratory studies, could also be considered as the hypothetical model of geographical problem-solving that should be validated in research experiments with actual users. As stated before, in the experimental research project for which this paper has been written, such a model is tested by means of a combination of research techniques centred round the think aloud method, but other research methods could be applied as well (van Elzakker, 1999). The realistic task scenarios that result from such user research may then act as guidelines for the further design and development of software tools for regional exploratory studies.

Conclusion

So far, most map use research executed, also in exploratory cartography, is of a supply-driven nature, in the sense that in most experiments subjects are asked to solve geographical problems with the help of existing map displays or with the help of existing cartographic visualisation tools with particular, sometimes limited, functionalities and a given database (van Elzakker, 1999). The procedure that is presented in this paper is different in that it does not start from an existing map display or from an existing visualisation tool with existing functionalities, but from the overall objective and the more detailed geographical questions of the user. In doing so, the cognitive map use tasks are clearly separated from the operational map use activities. The resulting matrix, or, usually, set of matrices, may be considered as a hypothetical task scenario, or model of geographical problem-solving, that could be tested by means of experimental user research.

In this paper, the procedure is illustrated with the example of a cartographic exploration with the overall objective of gaining insight into the geography of an unknown region. This is a task that is so complex and comprehensive that it will only be simpler to apply the same procedure for less complicated objectives of exploratory cartography (e.g. exploring the geographical aspects of the results of elections). The way in which the model of geographical problem-solving will come into

Map display no.:	**8**																			
Geodata	Theme(s)										**10.3**									
	Year(s)										**2000**									
	Aggregation level										**-**									
	Geographical extent										**W**									
	Map use tasks																			
	Map		*Elementary*				*Intermediate*					*Temporal*			*Overall*					
	map type	scale	recognize	identify	quantify / estimate	locate	position	define distance	explain location	find pattern	delimit distribution	determine changes	establish trends	detect processes	contemplate context	discover correlations	structure information	regionalize	obtain insight
Map use activities																				
Selection																				
select																				
search																				
generate	**f**	**II**																		
Reading																				
look at title/legend			#		#															
look at map image				#		#	#			#										
click																				
Analysis																				
measure								#												
count					#															
highlight						#				#										
juxtapose with map no.: **4**							#		#					#		#				
compare with chorème							#		#							#	#			
Adjustment																				
overlay							#		#							#				
switch off layer																				
change classification										#										
pan																				
change aggregation level																				
zoom in									#	#										
zoom out									#	#					#					
change map orientation										#										
change snapshot in time												#	#							
change symbology																				
Construction																				
trace boundaries											#									
draw elements chorème																	#	#	#	

Table 5. One of the matrices (analysis of spatial distribution of population by means of a dot map) in a task scenario for a regional exploratory study

existence will be the same (definition of the overall objective, putting up the necessary geodata, formulation of geographical questions and related map use tasks and establishment of required map use operations) but the task scenario may consist of less matrices and the matrices themselves may, perhaps, be smaller and less complex. Application of the proposed procedure, including the testing of the models of geographical problem-solving in user research projects, should eventually lead to more effective tools for cartographic exploration. These tools will not only be more effective in view of the map displays that may be generated, but hopefully also in terms of the required data and the way they are structured in the database. And this is the result of map use research that now is and should be more comprehensive than just testing the effectiveness of a certain cartographic display.

Notes

1. The letter and number coding applied here is used in the example shown in Table 5.
2. Analytical cartography is one of the types or goals of map use that may be positioned in the so-called 'map use cube', originally conceived by MacEachren. Other types of map use, identified by MacEachren & Kraak (1997) next to analysis, are exploration, synthesis and presentation.

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