HOW TO VISUALISE SPACE AND TIME IN "MODERN" MAPS?

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ABSTRACT:

Nowadays it becomes more and more important to combine spatial information with time related information. In a project (master thesis) with the State Office of Criminal Investigation (LKA) of Lower Saxony we have developed a map server based on the open source CartoWeb system which especially can visualise time related information. The LKA of Lower Saxony has the problem how to provide their investigators with 2D maps which presents information about when, where, how fast, how long, or the encounter of something occurs? These online maps have to be derived automatically from a database which stores observations of suspects and information about sites of crime. First solutions of this master thesis to present the duration, speed, and encounter of observed objects or persons in 2D maps have shown that standard visualisation techniques of map servers or geoinformation systems reach their limits. Based on these experiences we have started to investigate the possibilities of connecting modern visualisation techniques with standard geoinformation systems to overcome such problems.

1. INTRODUCTION

1.1 Motivation

Visualisation of spatiotemporal data becomes more important, especially regarding geographical aspects of criminal investigations. All times the evaluation of the crime rate in respect to their spatiotemporal distribution is of primary interest for the public security. This is the case for regional and nationwide criminal activities from pilferage up to organized crime. Up to now the visualisation of the spatiotemporal distribution of crime rates is an important strategic issue for the fight against crime. The reason why this geographical approach for criminal investigations is rarely used in practice is the high manual effort to produce this kind of maps.

Regarding this problem the State Office of Criminal Investigation (LKA) of Lower Saxony initiated a project (Rademacher, 2006) together with our institute to automate the production and distribution of situation maps and maps for the visualisation of the movements of observed objects or persons. Therefore a web map server (WMS) was designed and implemented. This WMS is now in use in the intranet of the LKA.

1.2 Aims

The aim of the project was to investigate how one can extend an open source web map server (chapter 2) with the capability to analyse and visualise spatiotemporal data in 2D maps. Therefore typical motion patterns were investigated and described (chapter 3). The main focus in this project was on the possibilities to create graphical representations of these motion patterns, which should be fast and intuitive to understand.

2. WEB MAP SERVER

A Web Map Server (WMS) provides a service via the internet defined by the OGC (2006), which is an international standard for producing maps dynamically of spatially referenced data.

All OGC conformal WMS have to be able to handle the following requests (Figure 1):
- getCapabilities
- getMap
- getFeatureInfo

The response on the getCapabilites request is an XML document, which describes the interface (possible method calls) and additional meta data of the WMS. The result of a getMap request is a map as a raster graphic. The getFeatureInfo request is optional and returns additional information about selected areas in the map.
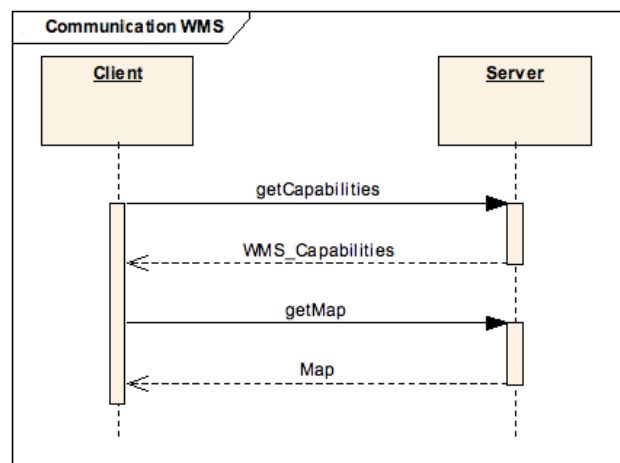

Figure 1. WMS communication schema (Rademacher 2006)

2.1 Architecture

The LKA intranet WMS (Figure 2) is based on the open source software CartoWeb (2006). The core of the CartoWeb system is a UMN map server. The spatiotemporal data is stored in a PostgreSQL database with PostGIS extension. The system was extended with an administration tool to support all LKA relevant issues and a first prototype for motion pattern detection

and visualisation. Topographic maps and airborne images as background information are provided by an external WMS of the land survey administration of Lower Saxony (LGN).
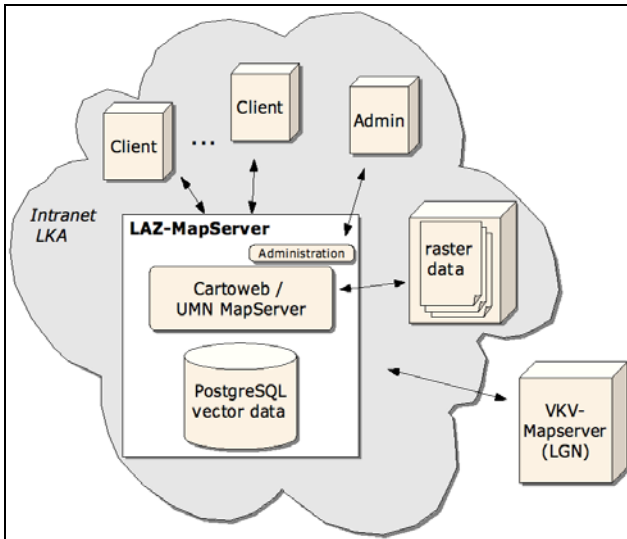

Figure 2. LAZ-MapServer architecture (Rademacher 2006)

2.2 User interface

The graphical user interface (GUI) of the LAZ WMS is based on a template provided by the CartoWeb software package. The functionality of the GUI is to allow the user to select a project from a list of available projects. Every project has the same interface (Figure 3). The web interface allows standard operations for zooming, panning, querying, printing and selection which kind of layers should be displayed. Figure 3 shows only the main entry interface for a selected project.
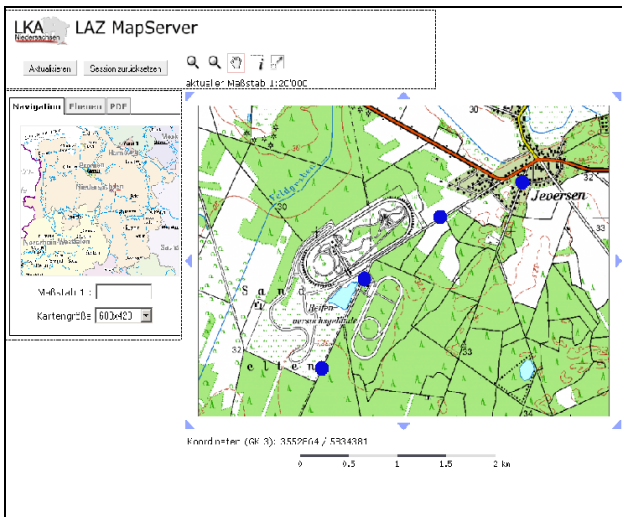

Figure 3. LAZ web interface (Rademacher, 2006)

3. MOTION PATTERNS

As more and more technologies like GPS, RFID, and radio transmitters are available the amount of available moving object data is also increasing. The automatic analysis of such data is called spatiotemporal data mining (Roddick et al. 2001). In general one can subdivide the analysis of spatiotemporal data in two groups:

- Spatiotemporal behaviour of a single object. Some times also called geospatial lifelines (Laube et al. 2002).
- Spatiotemporal behaviour of a group or cluster of objects (Sester and Anders 2005).

It should also be mentioned that in general the objects which are investigated in a spatiotemporal data analysis can be points, lines, or regions.

3.1 Types of time patterns

The analysis of time behaviour (also called trend detection) of a single entity can be classified in the following way (Han and Kamber 2001):

- *Long-term trend*: A formal characterisation of a time dependent curve over a long time interval. It is a kind of generalisation of the time behaviour.
- *Cyclic variations*: Changes over the time which occur in certain periods
- *Seasonal variations*: Cyclic variations which depend on the season (period of one year).
- *Irregular or random variations*: No regular formal description of a time dependent curve can be found or the time dependent behaviour can be described by a stochastic process.

Considering groups of entities (clusters) Miller and Han (2001) define the following patterns:

- *Follows*: One cluster shows the same behaviour like another cluster, but with a certain time delay.
- *Coincides*: One cluster shows always a specific behaviour if another cluster shows a different specific behaviour. This can happen immediately or with a certain delay.
- *Parallels*: Two different clusters have the identical behaviour at the same time.
- *Mutates*: One cluster is splitting up in different clusters or the cluster changes its characteristic (shape). It is also possible that different clusters merge together to one cluster.

The combination of these general types of time patterns with spatial behaviour leads to a large number of possible spatiotemporal patterns. In the following we concentrate on a specific subset of these patterns, which are the patterns of singular moving point objects.

3.2 Pattern types of moving point objects

This project puts the focus on four motion patterns which are defined in (Laube and Imfeld 2002) and (Laube et al. 2002). In (Gudmonsson et al. 2004, 2007) a detailed complexity analysis for the detection of these motion patterns is given. These following four motion patterns (Figure 4) are of relevance for data of moving point objects, which is captured by the LKA.

3.2.1 Flock
The *flock* pattern describes singular moving objects, which are moving close together to form a single group. This group is then moving together in the same direction until the objects in the group are moving away from the group. In (Gudmundsson et al. 2004, 2007) *n* objects belong to a group at a certain time if all these objects are inside a circle with a predefined diameter.

3.2.2 Leadership

The *leadership* pattern is an extension of the flock pattern. One object in the flock (the leader) moved already in the direction of the flock before the flock pattern occurred. One can say that all other objects are following this leader object.

3.2.3 Convergence

The *convergence* pattern describes the situation that some objects are at the same location without changing their own direction. The objects do not have to be at this location at the same time.

3.2.4 Encounter

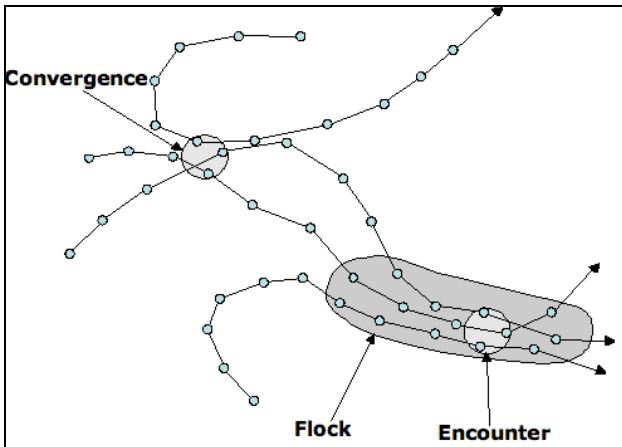If the convergence of some objects occurs at the same time then this is called an *encounter* pattern.

Figure 4. Motion patterns defined in Gudmonsson et al. (2004)

4. VISUALISATION OF MOTION IN MAPS

One main question in this project was: It is possible to create graphical representations of motion properties and patterns, which are fast and intuitive to understand. In the LAZ WMS project some prototypes were implemented to visualise the above described motion patterns: convergence, encounter, and flock. But additionally it was also important to visualise the following motion related properties:

- *Speed*: How fast was someone moving?
- *Direction*: In which direction was someone moving?
- *Duration*: How long was someone at a certain place?
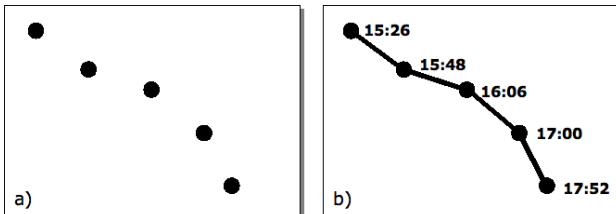
4.1 Speed and direction

Figure 5. Simple representation of an object trajectory

The very simple way to display a motion path is to display the measure points of the path (Figure 5a), but this is only useful to display simply the occurrence of some events. The direction and speed is not visible in such kind of representation. If we connect the measured points of the trajectory by a line and write the time at every point then the direction of the motion is unambiguous (Figure 5b). But still we can not easily recognise the speed of the motion. Of course it is possible to determine the speed by the map scale and the time difference between two points, but this is not fast intuitive.
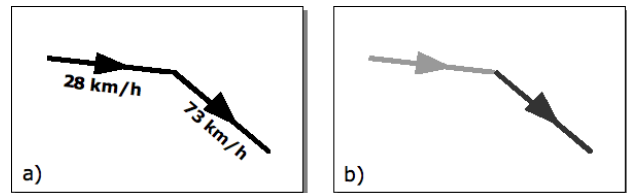

Figure 6. Visualisation of direction by a symbol and speed by text or colour

A better solution for speed and direction is the combination of symbols. One can use an arrow symbol for the direction and a text label for the speed (Figure 6a and 7). But if there is not enough place for the text labels then a colour representation for the speed would be better (Figure 6b). The colour representation is better especially for small scale maps. If the trajectory points are very dense then the text labels would not be readable anymore (Figure 8).

Figure 7. Representation of speed by a text label, but without direction information
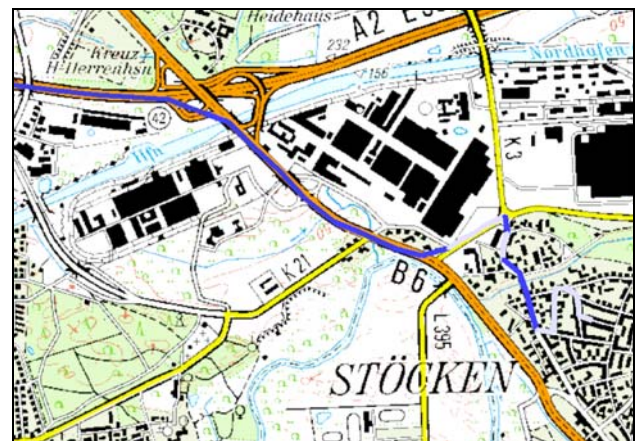

Figure 8. Colour coded representation of speed (e.g., the higher the speed the darker the blue)

Another possibility to display speed and direction is the usage of a direction symbol whose size is related to the speed. Figure 9 shows an example for this case. In our opinion this is the best

technique to display speed and direction in a fast and intuitively readable way. The drawback of this approach as well as the colour coding approach is that a map legend is needed to quantify the speed depending on the colour or size of the symbol.

Figure 9. One symbol for speed and direction: The larger the arrow the higher the speed

4.2 Duration

For criminal investigation it is also important to see where and how long something occurs. We call this property duration. For the visualisation of the property duration one can use the same techniques (text, colour or size) like for speed (Figure 10).
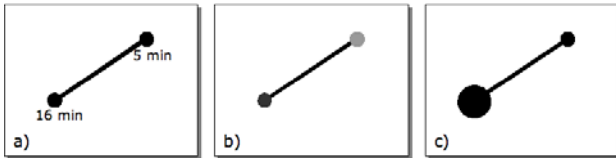

Figure 10. Duration of an event visualised by text a), colour b) or size c)

Figure 11 shows an example for the duration visualisation by symbol size. A map legend which quantifies the duration depending on the symbol size is needed.

Figure 11. Map example for the duration visualisation by size (the larger the circle the longer the duration)

In general it is possible to combine the visualisation of speed, direction and duration, but in small scale maps it can lead to overlapping symbols. A more detailed description of problems is presented in chapter 5.

4.3 Convergence, Encounter and Flock

In the LAZ WMS project the visualisation of the convergence and the encounter pattern was implemented. Both patterns are based on a circle criteria (Gudmonsson et al. 2004, 2007) therefore we display these patterns by such detected circles. To distinguish between the convergence and the encounter pattern the related circle strokes have different styles. Convergence is displayed by a dashed circle stroke and encounter is visualised by a solid circle stroke (Figure 12).
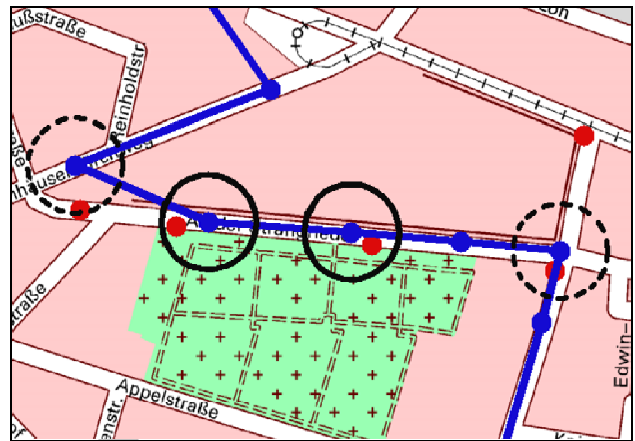

Figure 12. Convergence (dashed circle) and encounter (solid circle) pattern between blue and red events

The flock pattern is not implemented yet, but it is intended to visualise flocks by a buffer (Figure 13). The usage of different stroke types, symbols, or colours for the related trajectory sections have also to be investigated.
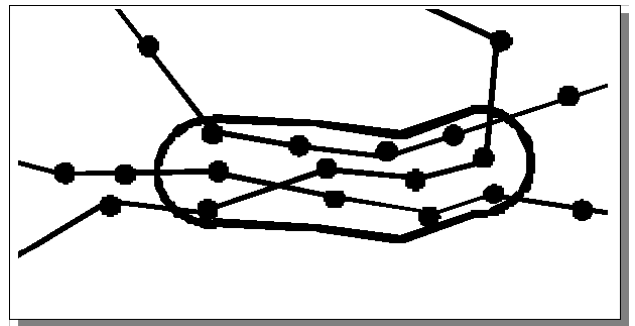

Figure 13. Flock pattern visualised as a union of circle buffers

5. OPEN PROBLEMS

From a cartographic point of view the result of this project is that a lot of problems have to be solved. One main issue is that the render capabilities of the used WMS is not sufficient for high quality maps. For an appropriate visualisation of motion information we think that dynamic map symbols are needed. A dynamic symbol can change its visualisation in a smooth continuous way (size, colour, pattern, etc.). For this purpose we think shader technologies of actual graphic cards or ray tracing programs would be the right choice. We want to mention also that current available commercial GIS software do not offer such enhanced render capabilities, too.

The missing render capabilities are not the only problem to be solved. The visualisation of moving objects has also shown that one has to think about extending map generalisation algorithms, which do not only take the geometry into account, but also the time relevant issues.

If we consider map simplification the question arise: How do we generalise the speed information of a given trajectory if we want to display it in a certain small scale map? If we use for example the Douglas-Peuker algorithm to reduce the shape complexity of the trajectory then the derived speed information from the remaining sample points would not be correct in general. In the same way we have to investigate time related issues for enhancing, displacement, and aggregation. All these operations have to be taken into account if one simply want to combine many motion related properties of a trajectory in a single map. As already mentioned in chapter 4.2 if we have dense sampled motion trajectories then overlapping of symbols can already occur in large scale maps.

Another issue is that we have to apply map matching algorithms to the motion trajectories because of accuracy differences in the position measurements, like in car navigation systems. We have to introduce also artificial trajectory points if the sampling rate is to low to fit the trajectory to the map geometry. In Figure 12 we can see that the motion path of an observed car does not follow correctly the map street geometry, because the sampling was to low.

6. CONCLUSION

The LAZ WMS project for the LKA in Lower Saxony has shown that open source software can be used successfully in a public administration. In former days paper maps were produced and distributed to all LKA offices in Lower Saxony. Nowadays every user in the LKA can produce his own maps by the implemented WMS just on demand.

From the point of view of a cartographer there is still much to do to improve the visual impression and readability of motion related maps. As a main result of this project we see the following two major research topics, which should be investigated in the future:

- Development of dynamic complex map symbols based on ray tracing techniques and special shader programs for actual graphic hardware.
- Extension of map generalisation approaches by taking time relevant issues into account.

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