

# Data and Task Characteristics in Design of Spatio-Temporal Data Visualization Tools

Natalia Andrienko, Gennady Andrienko, Peter Gatalcky  
Fraunhofer Institute for Autonomous Intelligent Systems

Sankt Augustin, Germany  
<http://www.ais.fhg.de/and/>



ICA Vis London 11.09.2002

## Introduction

- Many papers about space & time
- The problem: “How to make computers (or, more specifically, GIS) understand temporality and handle time-related information?”
- Theories formalizing human’s understanding of time and (spatio-)temporal reasoning (Allen 1984, Galton 1987, Egenhofer and Al-Taha 1992, Cohn et al. 1998, Frank 1998).



ICA Vis London, 11.09.2002



## Introduction

- Different frameworks, methods, and data structures for internal representation and operation of spatio-temporal data in GIS (Langran 1992, Peuquet 1994, Worboys 1998, Wachowicz 1999)
- We focus primarily on another problem related to space, time, and computers: “How to make computers support a human analyst in visual exploration of spatio-temporal information?”

## Introduction

- Techniques & tools: Tobler 1970, ... , Kraak et al. 1997, Blok et al. 1999, Fredrikson et al. 1999, Harrower et al. 2000, Oberholzer and Hurni 2000, Slocum et al. 2000, ...
- Most utilize animation ... how to compare time moments ? (see demo)
- No systematisation of problems and problem solving available!

## Our Objectives

- Support exploratory data analysis and decision making by interactive maps and other visualization-based techniques
  - Make our tools accessible and usable by a wide community of users by providing automated visualization design and an intelligent guidance
- ⇒ Knowledge about interactive data analysis in spatial and temporal context needed!
- ⇒ Classical books (Bertin, Tufte, etc.) describe only paper-like graphics
- ⇒ Approach: Design and experiment ...

## Typologies of data and tasks

- Data. Three major components: space (*where*), time (*when*), and objects (*what*) (Peuquet 1994)
- Spatial objects: discrete (points, lines, polygons) and continuous (rasters) (MacEachren 1995)
- Attributes: nominal, ordinal, and numeric (Bertin 1967/1983)

## Typologies of data and tasks

Spatio-temporal phenomena, types of changes:

- existential changes: appearing, disappearing, reviving of objects or/and relationships
- changes of spatial properties of objects (location, size, shape)
- changes of thematic properties, i.e. values of attributes

(Blok 2000)

## Possible questions about data

- *when + where* → *what*: Describe the objects or set of objects that are present at a given location or set of locations at a given time or set of times
- *when + what* → *where*: Describe the location or set of locations occupied by a given object or set of objects at a given time or set of times
- *where + what* → *when*: Describe the times or set of times that a given object or set of objects occupied a given location or set of locations

(Peuquet 1994 )

## Reading levels (Bertin)

- elementary, intermediate, and overall

Koussoulakou and Kraak (1992):

3 types of questions \* 3 levels of reading =>  
9 different tasks

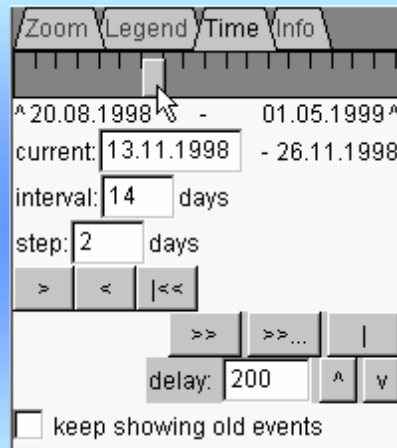
All questions: query, describe

Where is comparison task ?

## Our approach

1. Consider different types of data
2. Design analytical tools for problem solving (taking into account known dimensions of task classification)
3. Generalise and formalize the knowledge base
4. Create an intelligent system guiding users in problem solving

## Time manager

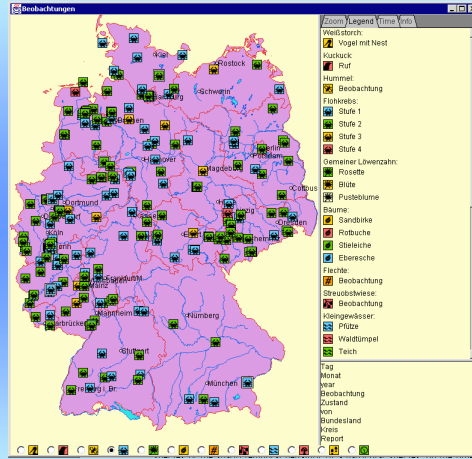


- *instant view*: the map represents the state of the world at a selected moment
- *interval view*: the summary of events, movements, etc. that occurred during a selected interval

## Tool design: examples

- existential changes: visualization of instant events
- changes of spatial properties of objects: visualization of moving objects
- changes of thematic properties, i.e. values of attributes

# 1. Existential changes



# Analytical questions

- Elementary (time) level
  - What species and in which states were observed at the moment  $t$  around the location  $l$  / in the area  $a$ ?
  - Where was the species  $s$  (in the state  $s$ ) observed at the moment  $t$ ?
  - When was the species  $s$  (in the state  $s$ ) observed around the location  $l$  / in the area  $a$ ?

## Analytical questions

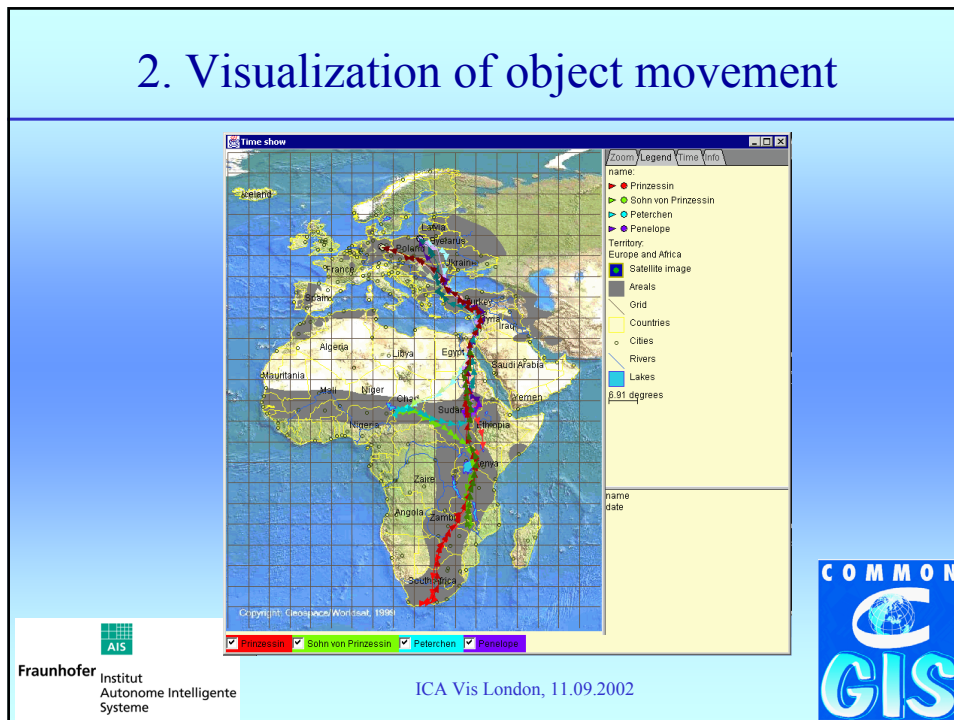
- Intermediate/overall (time) level
  - How did the variety of species observed at the location  $l$  / in the area  $a$  / over the whole territory change over time?
  - How did the spatial distribution of observations of the species  $s$  change over the time?
  - What is the spatio-temporal behavior of the species  $s$ ?

## Operations:

- Selection of time moments (time manager)
- Focusing on locations/areas (map zooming)
- Selection of a particular species
- Access to information about a particular observation (lookup)
- Observing changes over time



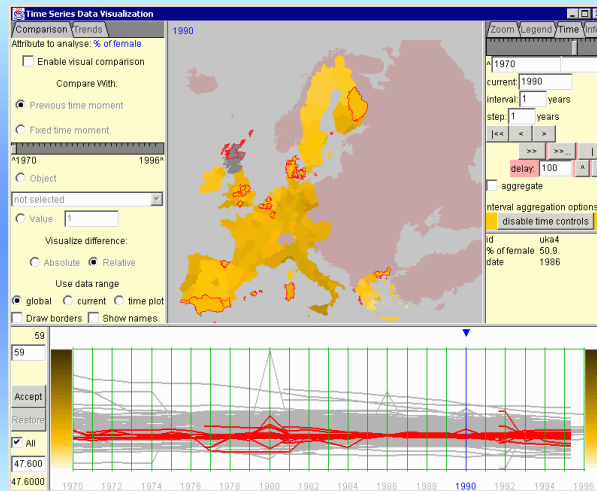
## 2. Visualization of object movement



## Analytical questions

- Where was each object at a selected moment  $t$ ?
- When did a particular object  $o$  visit the location  $l$ ?
- How long did it stay at this location?
- How did the positions of objects change from moment  $t_1$  to moment  $t_2$ ?
- What were the trajectories of the objects during the interval  $[t_1, t_2]$ ?
- What was the speed of movement during the interval  $[t_1, t_2]$ ?
- How did the speed of movement change over time or with respect to spatial position?

### 3. Changing thematic data



### Analytical questions

“Local” tasks:

- What is the value of the attribute at moment  $t$  in area  $a$ ?
- How does the value in  $a_1$  differ from that in  $a_2$  at moment  $t$ ?
- How did the value in area  $a$  change from  $t_1$  to  $t_2$ ?
- How does the change in  $a_1$  from  $t_1$  to  $t_2$  differ from that in  $a_2$ ?
- What is the trend of value change in  $a$  over interval  $[t_1, t_2]$ ?
- How does the trend in  $a_1$  over interval  $[t_1, t_2]$  differ from that in  $a_2$ ?

“Global” tasks:

- What was the spatial pattern at moment  $t$ ?
- How did the pattern change from  $t_1$  to  $t_2$ ?
- How are the changes from  $t_1$  to  $t_2$  distributed over the territory?
- What is the trend of pattern change over interval  $[t_1, t_2]$ ?
- How do the “local” trends vary over the territory?

## Operations

Different comparison modes:

- to the values for the previous time moment
- to the values for a selected fixed moment,
- to the value for a selected object
- to a constant reference value

Detecting local trends, compare trends:

- time-series plot

## Conclusion

- questions an analyst is likely to be concerned with are greatly related to the characteristics of data under analysis
- different sets of exploratory techniques are needed for different types of spatio-temporal data
- development of interactive visualization tools must be data- and task-driven

Typology of tasks is missing