Geo-visualization for the analysis of spatial time series: filling gaps in the task space coverage

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Task-aware {geo-} visualization

- Users apply {geo-} visualization tools in order to find answers to their questions about data
- Tool designers should anticipate the questions (tasks) to properly support finding answers
  →Task analysis should precede tool design
- The variety of possible tasks typically requires combination of several tools
- By task analysis, we can detect “gaps” (missing tools) in the current state-of-the-art
  →Define directions for further research

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What tasks are possible?

- Task = target (unknown information) + constraints (known information); defined in terms of data components
  - →Tasks depend on the data structure and properties of the components
    - →Task analysis can only be done for a specific dataset or a class of datasets with the same structure and properties
- Example: spatially referenced time series = space (set of places) + time (set of moments) + thematic attribute values (a single numeric attribute)

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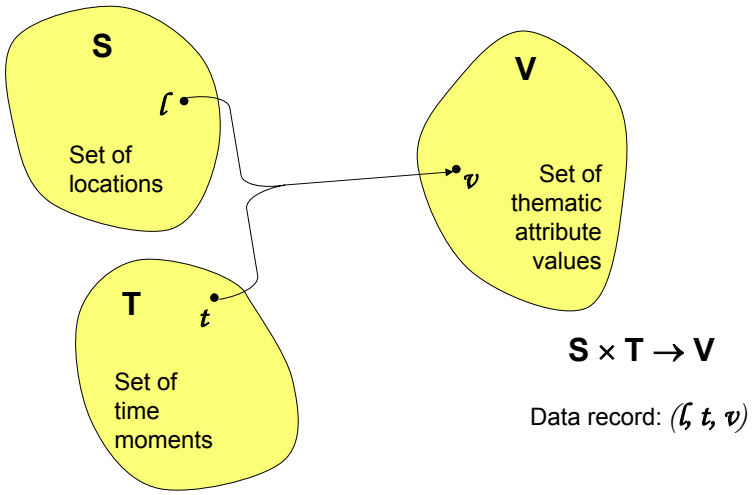
General structure of spatial time series (in terms of set theory)



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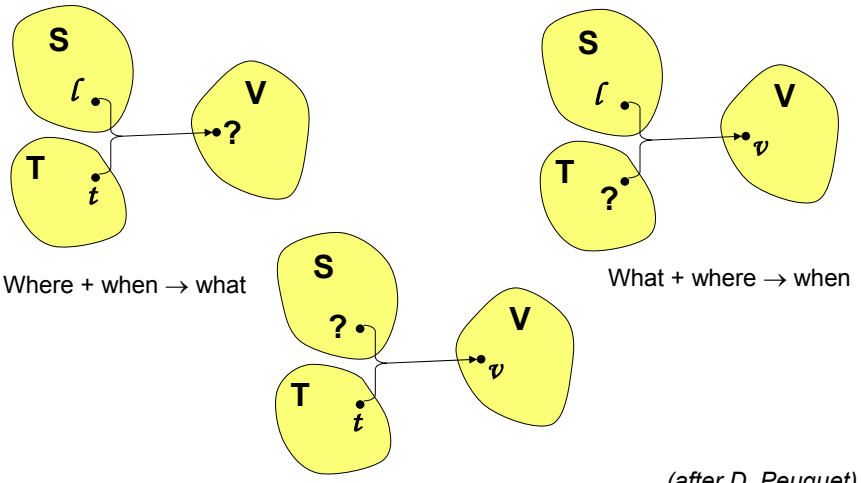
Task types (elementary)



Where + when → what

What + where → when

What + when → where

(after D. Peuquet)

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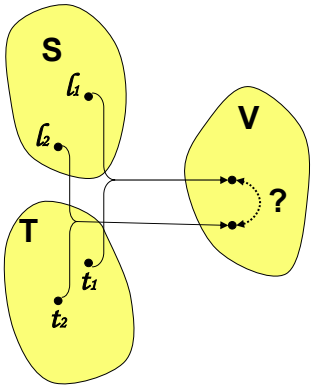
Comparison tasks (elementary)



How is the value at (l_1, t_1) related to that at (l_2, t_2)?

<u>Most typical comparison tasks</u>

•**Same time, different places:**
At the time t, how does the value at location l_1 differ from that at l_2?

• **Same place, different times:**
How did the value at location l change from time t_1 to time t_2?

• Relation type: same, different, greater than, less than, …
• Relation metrics, e.g. difference, ratio, distance

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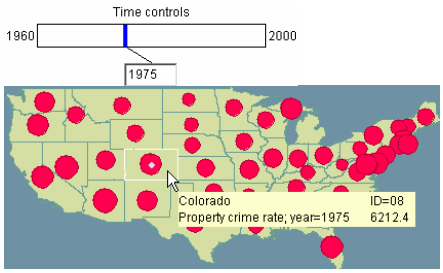
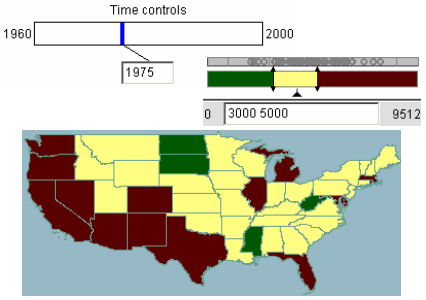
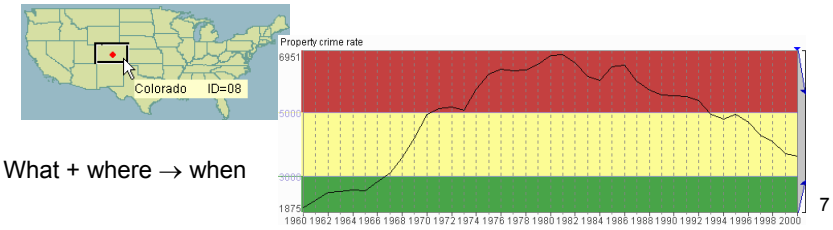
Support to elementary lookup tasks



Where + when → what



What + when → where



What + where → when

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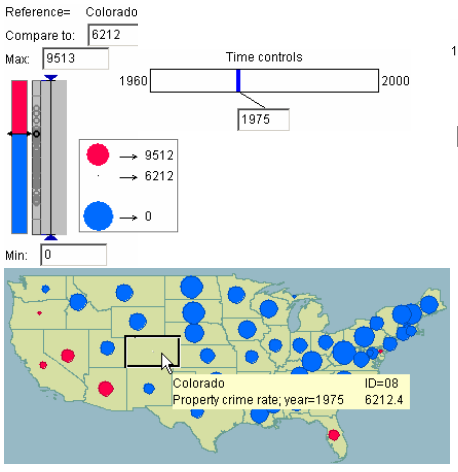
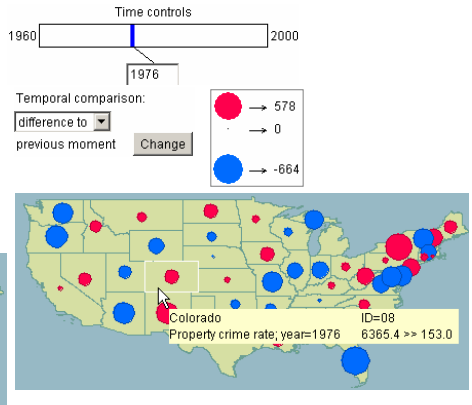
Support to elementary comparisons



Same time, different places:
At the time t, how does the value at location l_1 differ from that at l_2 ?



Same place, different times:
How did the value at location l change from time t_1 to time t_2?

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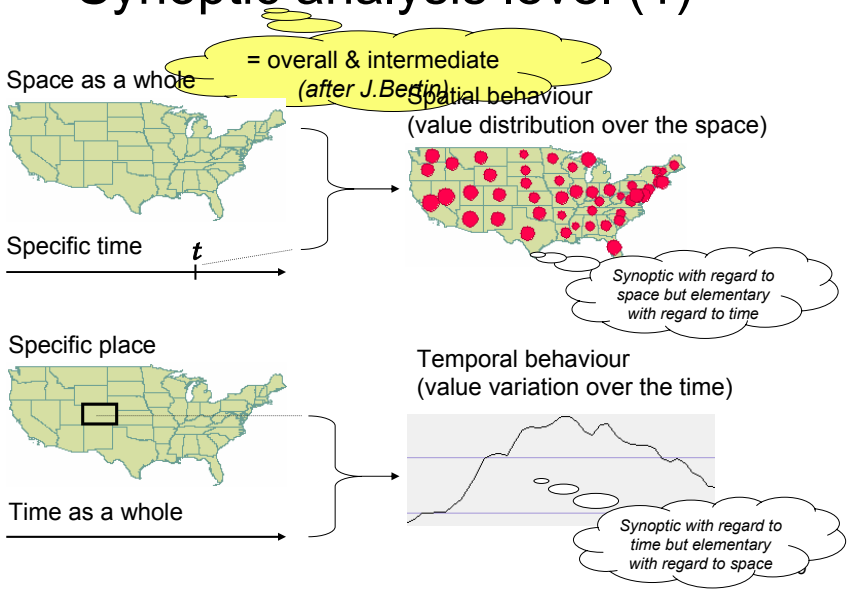
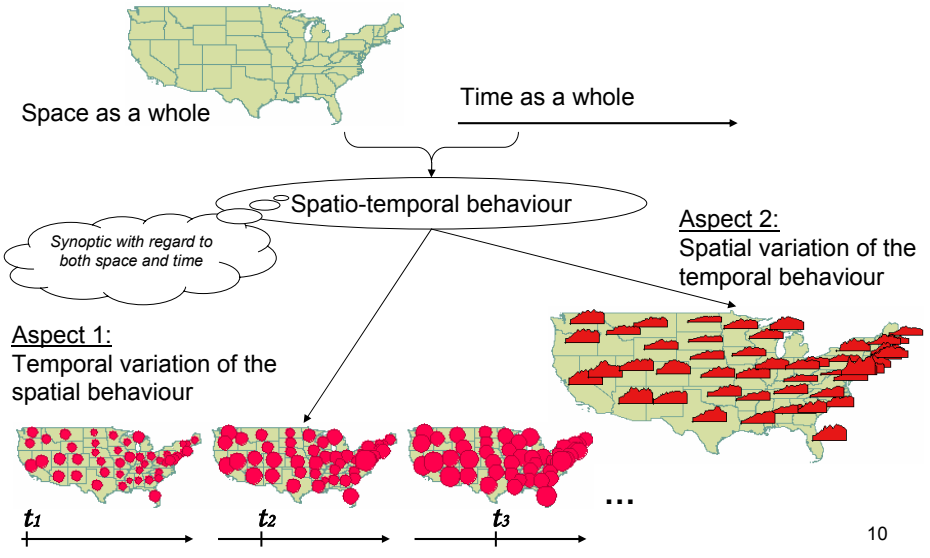
Synoptic analysis level (1)



Synoptic analysis level (2)



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Semi-synoptic ("hybrid") tasks

- At moment t, how were the values distributed over the whole space?
- At place l, how did the values behave over the whole time?
- At what time moment were the values distributed over the space in the given manner?
- At what place did the values behave over the time in the given manner?
- Compare the spatial behaviours (distributions) at moments t_1 and t_2
- Compare the temporal behaviours at places l_1 and l_2

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(Fully) synoptic tasks

- What was the spatio-temporal behaviour over the whole space and time?
  - How did the spatial distribution pattern develop over time?
  - How are the temporal behaviour patterns distributed over space?

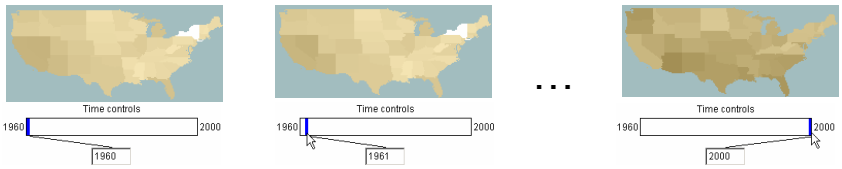
And also:

- Compare the spatio-temporal behaviours in 2 or more parts of the space
- Compare the spatio-temporal behaviours on 2 or more time intervals

(synoptic comparison)

Following: what tools can support synoptic tasks? 12

Animated map (map + timeline)



✓ How did the spatial distribution pattern develop over time?
✓ At moment t, how were the values distributed over the whole space?
✓ At what time moment were the values distributed over the space in the given manner?

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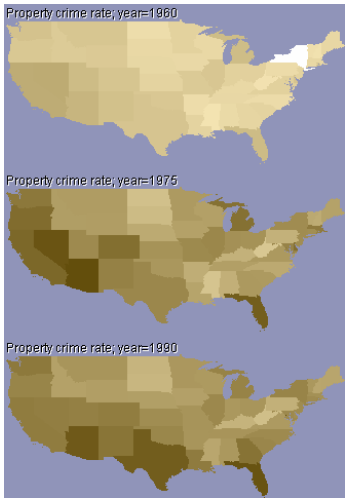
Multiple maps



✓ Compare the spatial behaviours (distributions) at specified moments

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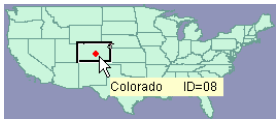
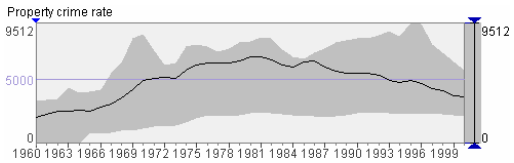
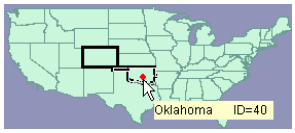
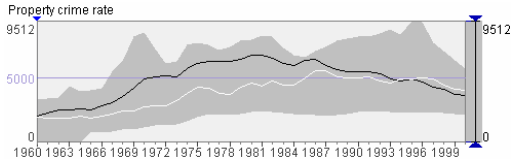
Map + time graph





✓ At place l, how did the values behave over the whole time?





✓ Compare the temporal behaviours at places l_1 and l_2

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Gaps?

- How are the temporal behaviour patterns distributed over space?
- At what place did the values behave over the time in the given manner?

Requirements to a supporting tool or tool combination:

- Support seeing all temporal behaviours at once
- Support seeing the temporal behaviours in the space context
- Support detecting behaviours with particular features (and noticing what sorts of features exist in the data)

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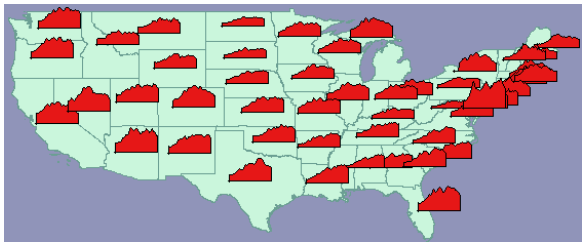
Is this the tool to fill the gap?



- The diagrams are perceived as separate entities → the map must be scanned and cannot be grasped as a single image
- Absence of ordering complicates seeking for specific behaviour patterns
- Diagram overlapping is a serious problem

– seeing all behaviours at once

✓ seeing the temporal behaviours in the space context

– detecting behaviours with particular features

– noticing what sorts of features exist in the data

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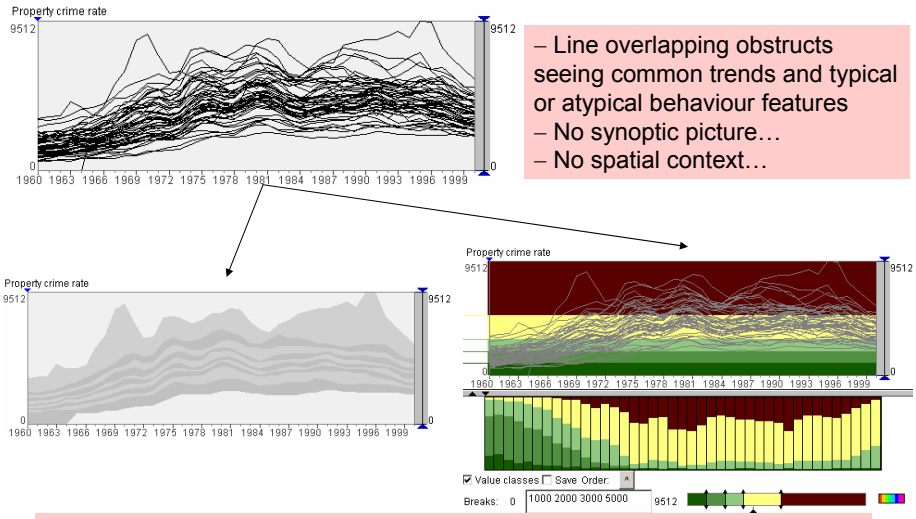
Seeing all behaviours at once



– Line overlapping obstructs seeing common trends and typical or atypical behaviour features
– No synoptic picture…
– No spatial context…

Aggregation produces highly synoptic views… but hides everything individual

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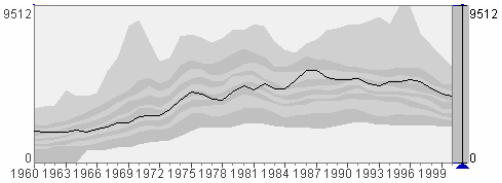
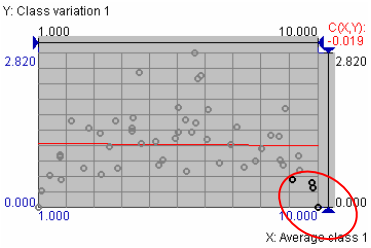
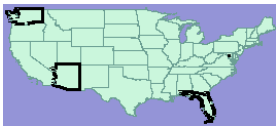
Back to the space and individuals



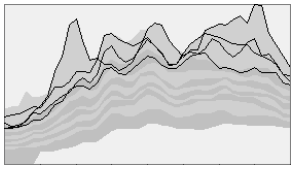
1. Obtain simple counts for every behaviour:
   - Number of times in each class (quantile)
   - Average class, variance
   - Number of "ups" and "downs"

2. Visualise the counts on an appropriate display linked to a map

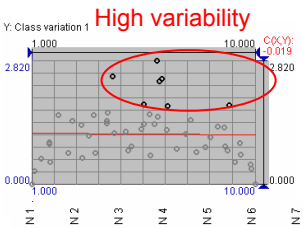


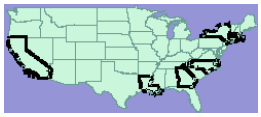


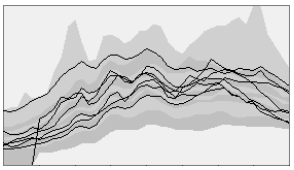
E.g. detect places & behaviours with the highest values and low class variance

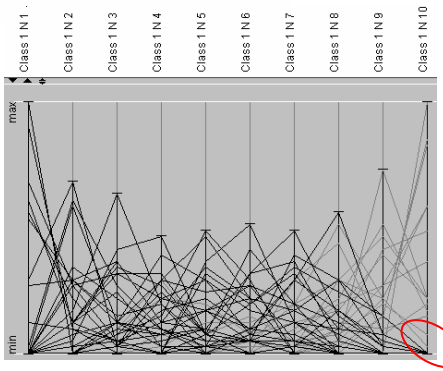


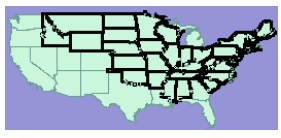
A few more examples…











Never in class 10

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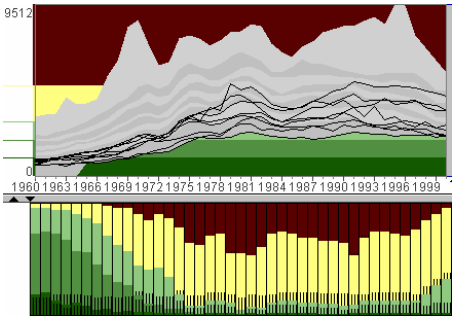
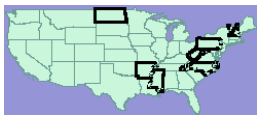
Enhance the other aggregation





The lowest values in 1960: where they are and how they behaved further?

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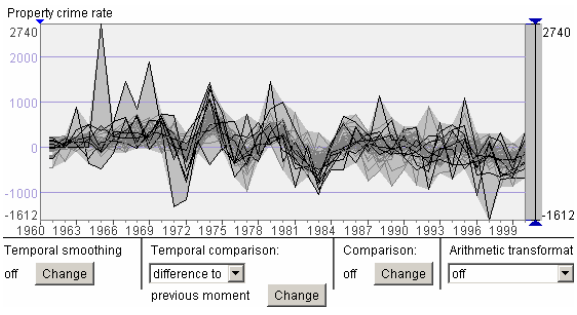
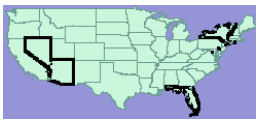
Detect behaviours with extreme rises or drops





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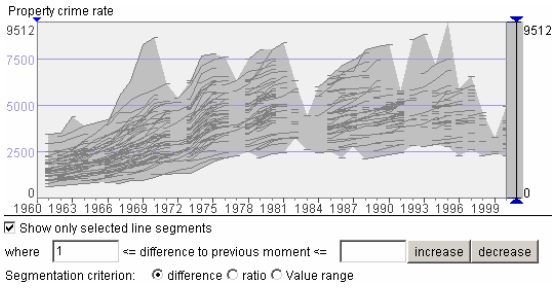
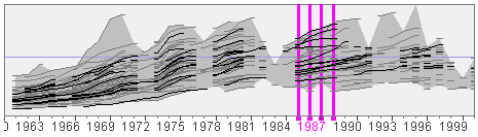
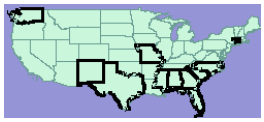
Detect behaviours with continuous increase







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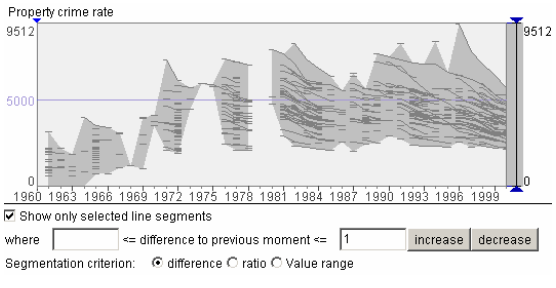
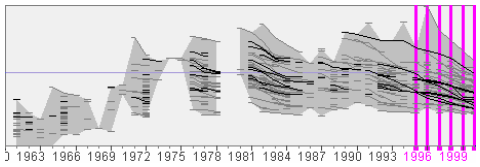
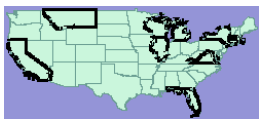
Detect behaviours with continuous decrease







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What did we achieve?

- ✓ See what sort of features are present among the individual temporal behaviours
- ✓ Detect and locate behaviours with specific features of interest
- ✓ Thereby explore the spatial distribution of the temporal behaviours
- ✓ Have a highly general view of all the temporal behaviours at once
- – However, the spatial context is provided only for a selected subset of the temporal behaviours

Let's try to go further!

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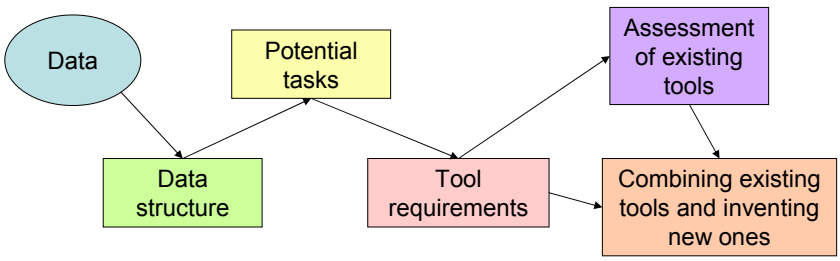
Conclusion

- Tool design (in particular, map design) should base on task analysis!



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To Learn More:

International Cartographic Association
Commission on Visualization

- Software: http://www.commongis.com
- Papers, tutorials, on-line demos: http://www.ais.fraunhofer.de/and
- Book to appear:

N. and G. Andrienko

"Exploratory Analysis of Spatial and Temporal data. A Systematic Approach"

(Springer-Verlag, ≈ end 2005)

A theoretical framework for linking tasks, tools, and principles of data analysis

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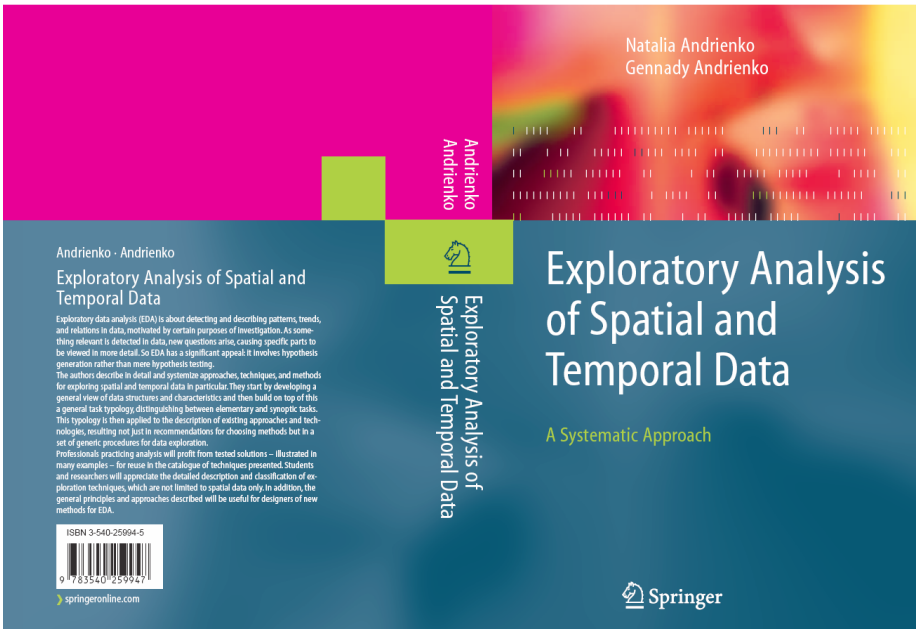

In press, to appear ≈ end 2005

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- ECML/PKDD'05 Workshop on "Mining Spatio-Temporal Data", Porto, Monday, 3.10.2005
- ✓ at 16th European Conference on Machine Learning (ECML'05) and 9th European Conference on Principles and Practice of Knowledge Discovery in Databases (PKDD'05)

  http://www.di.uniba.it/~malerba/activities/mstd/

  Deadline: 25.07.2005 (full paper)
- Special Issue of "Journal of Intelligent Information Systems" after the workshop

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