A Temporal Focus + Context Visualization Model for Handling Valid-time Spatial Information

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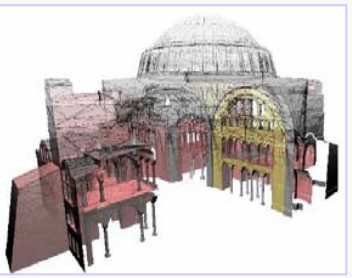
1.Context and Motivation

- Information Systems supporting critical application domains of modern societies.
- Concerning information management accross the time:
  - Alphanumeric and spatial informations systems have provided solid and robust solutions for managing the most recent state of information.
    - undesired complexity and performance problems;
  - Spatio-temporal informations systems **seamlessly manage all the states of information**, regarding temporal evolution (including most recent state);
    - valid-time (and sometimes transaction-time) temporal dimension(s).
    - continuous change or discrete change;
    - historic-temporal data or predictive data;

2.Problem Definition

- Concerning spatio-temporal informations systems:
  - The visualization of spatio-temporal information which is directly supported by spatio-temporal information systems raises interesting issues.

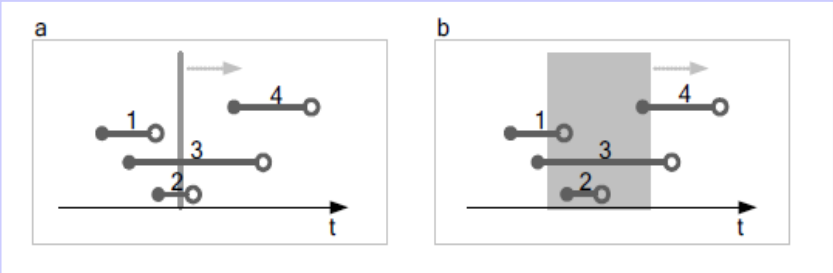
valid	name	capital	boundary
[1025-1040)	Poland	Gniezno	Polygon: (ExteriorRing: LineString: ((580.0, 198.0)
[1040-1150)	Poland	Cracow	Polygon: (ExteriorRing: LineString: ((585.0, 239.0)
[1150-1250)	Poland	Cracow	Polygon: (ExteriorRing: LineString: ((565.0, 245.0)
[1250-1350)	Poland	Cracow	Polygon: (ExteriorRing: LineString: ((550.0, 244.0)
[1350-1450)	Poland	Cracow	Polygon: (ExteriorRing: LineString: ((533.0, 239.0)
[1450-1596)	Poland	Cracow	Polygon: (ExteriorRing: LineString: ((571.0, 199.0)
[1596-1650)	Poland	Warsaw	Polygon: (ExteriorRing: LineString: ((692.0, 65.0)
[1650-1795)	Poland	Warsaw	Polygon: (ExteriorRing: LineString: ((726.0, 136.0)
[1918-1939)	Poland	Warsaw	Polygon: (ExteriorRing: LineString: ((605.0, 211.0)
[1945-forever)	Poland	Warsaw	Polygon: (ExteriorRing: LineString: ((586.0, 215.0)
[1198-1250)	Czech Kingdom	Prague	Polygon: (ExteriorRing: LineString: ((591.0, 334.0)
[1250-1350)	Czech Kingdom	Prague	Polygon: (ExteriorRing: LineString: ((644.0, 371.0)
[1350-1450)	Czech Kingdom	Prague	Polygon: (ExteriorRing: LineString: ((603.0, 370.0)
[1450-1550)	Czech Kingdom	Prague	Polygon: (ExteriorRing: LineString: ((603.0, 370.0)
[1550-1621)	Czech Kingdom	Prague	Polygon: (ExteriorRing: LineString: ((603.0, 370.0)
[1918-1939)	Czechoslovakia	Prague	Polygon: (ExteriorRing: LineString: ((660.0, 383.0)
[1945-1993)	Czechoslovakia	Prague	Polygon: (ExteriorRing: LineString: ((660.0, 383.0)
[1993-forever)	Czech Republic	Prague	Polygon: (ExteriorRing: LineString: ((587.0, 369.0)
[1940-1945)	Slovakia	Bratislava	Polygon: (ExteriorRing: LineString: ((587.0, 369.0)
[1993-forever)	Slovakia	Bratislava	Polygon: (ExteriorRing: LineString: ((587.0, 369.0)
[1143-1200)	Portugal	Guimaraes	Polygon: (ExteriorRing: LineString: ((82.0, 610.0)
[1200-1250)	Portugal	Coimbra	Polygon: (ExteriorRing: LineString: ((83.0, 611.0)
[1250-1598)	Portugal	Lisboa	Polygon: (ExteriorRing: LineString: ((80.0, 607.0)
[1640-1900)	Portugal	Lisboa	Polygon: (ExteriorRing: LineString: ((80.0, 607.0)
[1900-forever)	Portugal	Lisboa	Polygon: (ExteriorRing: LineString: ((80.0, 607.0)
(25 rows)			



- How to meaningfully view time-evolving information from spatio-temporal recordsets ?

2.Problem Description | Common visualizations

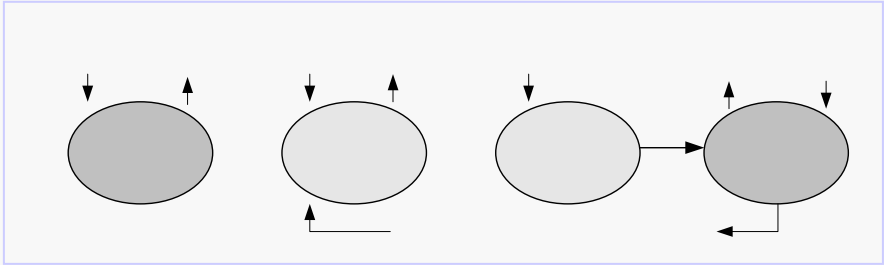
- Instant-based visualizations (a) of chronological evolutions **focus on one instant at a time**.
- A visualization that provides **the same highlight to all records** (b), despite their valid-time, can display spatiotemporal inconsistencies.



- These visualizations disregard temporal features besides focus intersection such as:
  - How much of the record span intersects the focus?
  - Is the record span intersecting the focus begin, the focus end or both?
  - What does exist in the immediate past or immediate future, regading the focus?

3.The Temporal Focus+Context Visualization Model

- The proposed model is based on concepts from InfoVIS such as Focus+Context and Fisheye.
- However these well-known techniques **are applied to time rather than more typically to attributes or space.**
- At the filtering step of the visualization pipeline a Temporal Degree of Interest (TDOI) is calculated for each data element. TDOI is based on:
  - **user requirements**, describing temporal constraints and corresponding degrees of interest;
  - **The valid-time of each record in the recordset**;
- At the mapping stage:
  - **TDOI values are mapped into graphical properties required for rendering the spatiotemporal data**;



4.The Temporal Degree of Interest

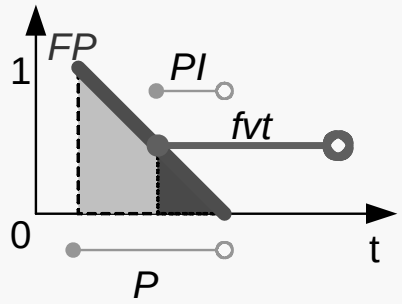
$$TDOI = f(P, vt, FC, FP)$$

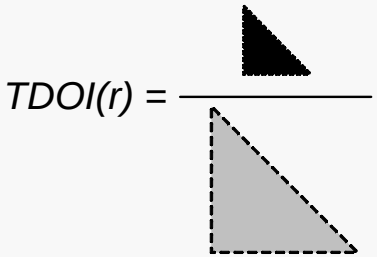
$$fvt = start(vt) = [i_{r.start}, i_{r.start} + 1[$$

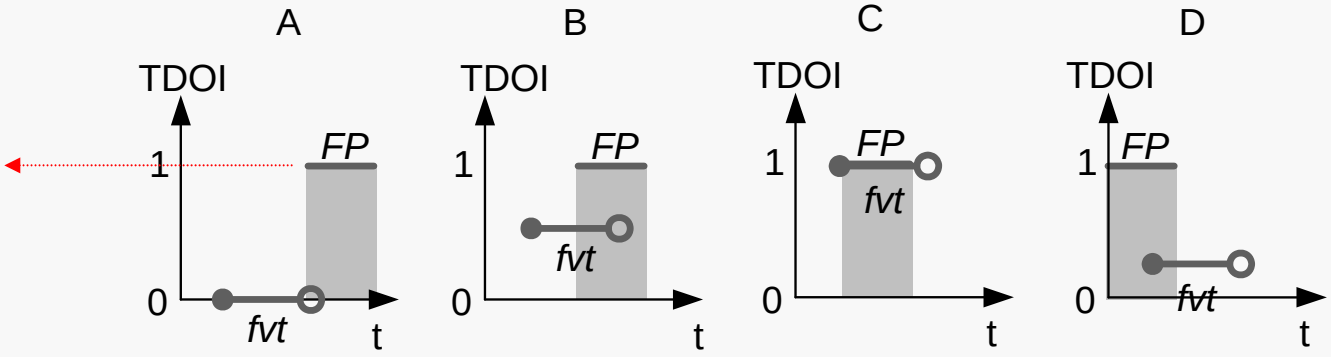
$$PI = fvt \cap P$$

$$TDOI = \begin{cases} FP(PI_{r.start}), PI_{r.stop} - PI_{r.start} = 1 \\ \dfrac{\int_{PI_{r.start}}^{PI_{r.stop}} FP(t).dt}{\int_{P_{start}}^{P_{stop}} FP(t).dt}, PI_{r.stop} - PI_{r.start} > 1 \end{cases}$$

4.The Temporal Degree of Interest







6.Tests and results

- POLITICAL HISTORY OF EUROPE
  - Showing instants (12secs), periods (24secs) and all the data (19secs)
  - The use of FC function (16secs)
  - Using F+C and large P (21secs)
- THE CONSTRUCTION OF HAGIA SOPHIA
  - The construction (1) (2) (18secs)
  - The construction constant FP, descending ramp FP (1) (2)
  - Multiple TDOI functions (1) (2)

7.Conclusions

- Traditional visualization techniques provide limited support, regarding visualization of spatiotemporal data which is directly supported by spatio-temporal information systems.
- In the previous context, the proposed temporal F+C visualization model provides means to visually represent spatiotemporal data (vt+3D) as answers to user's questions expressed in the form of requirements (FC, P, FP).
- This is acheived through the calculation of a Temporal Degree of Interest for each record (filtering step).
- TDOI values are used in mapping functions (mapping step) to:
  - Display data in the temporal context as well as in the temporal focus.
  - Control graphical properties that visually enhance the temporal features of spatiotemporal data;
  - As TDOI is based on user requirements, user's question are also answered graphically.

7.Conclusions

- By carefully configuring the TDOI functions
  - more data can be compressed onto the same visualization, while maintaining readability.
- Future work will encompass:
  - dealing with the *transaction time* simultaneously with *valid time*;
  - identifying issues that result from the application of the model to moving-object databases
  - Study of the best techniques to define mapping functions for concrete application domains.

8.Thank you

Questions:

- Regarding the use of transparency in a mapping function, what do you consider to be the correct visual clues to remove ambiguity of two overlapped rendered data elements with 0 <= TDOI < =1?
- One of the graphical properties manipulated through TDOI is the color. Based on semiology or on non-photorealistic rendering, what are the best strategies to use colour to represent data about the past or the future regarding a particular time?
- How to address valid time AND transaction time dimensions, simultaneously, in graphical representations of temporal evolutions comprising movement and change?