

Interactive Temporal Focus+Context Visualization of spatio-temporal urban data models

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Objectives

- The current work:
 1. Explores visualization possibilities of spatio-temporal urban datasets:
 - Through visual analysis, answer questions about spatio-temporal urban objects, concerning their temporal features and relationships

 2. Further develops work on the Temporal Focus+Context Visualization Model
 - Reported on [Agile 2008 Workshop on Geovisualization of Dynamics, Movement and Change](#);

 - Published at *A Temporal Focus + Context Visualization Model for Handling Valid-time Spatial Information*, Alexandre Carvalho, A. Augusto de Sousa, Cristina Ribeiro, Emília Costa, Special Issue of Information Visualization (2008), volume 7, pages 265–274, Palgrave MacMillan, doi:10.1057/palgrave.ivs.9500188, 2008.

 3. Relies on effective spatio-temporal database management

Spatio-temporal data management

- **Conceptual, representational and data model**
 - Bitemporal-conceptual Data Model (BCDM)
 - Snogdrass tuple time stamping representational data model
 - Gadia weak snapshot-equivalence between information contents
 - Implemented data model based on part of CityGML (construction)
- **Language: ATSQL2 + Oracle Spatial**
 - Instant and interval operators (Allen)
 - Valid time and transaction time dimensions supported
 - Temporal functions and operators (temporal coalesce...)
 - Sequenced and non-sequenced semantics
 - Backward and temporal backward compatibility

Spatio-temporal data management: spatio-temporal queries

■ Querying data:

- `validtime`
`select * from coordinategeometry`
`where partid = 'Floor';`

- `validtime period [1200-1500)`
`select * from coordinategeometry`
`where partid <> 'Floor';`

- `validtime`
`select * from coordinategeometry;`

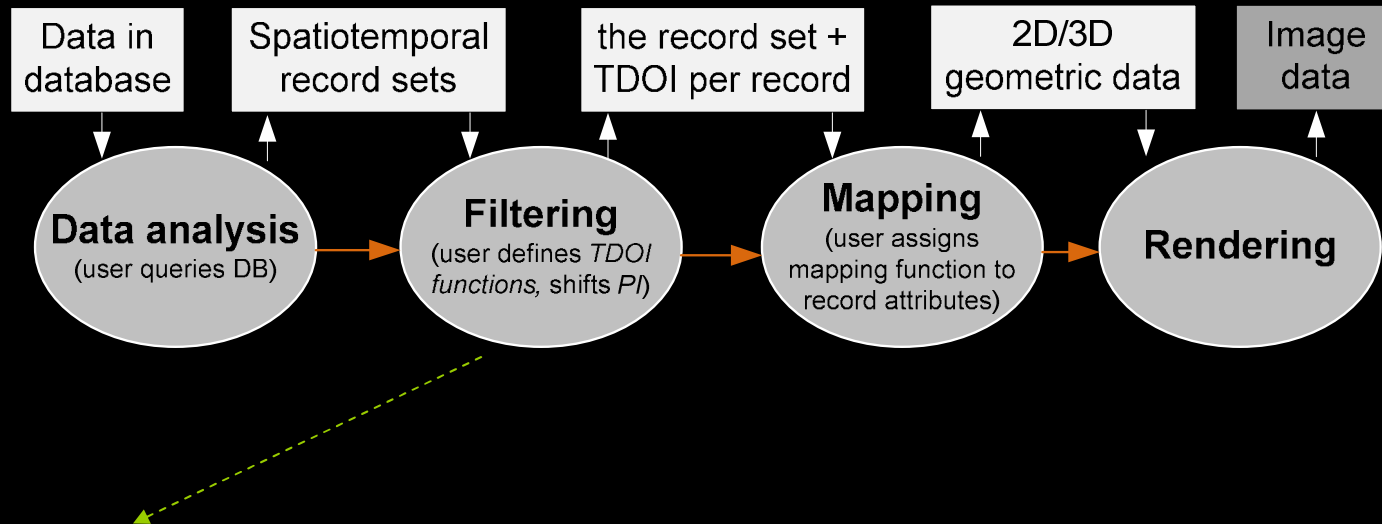
- `select * from coordinategeometry;`

Example of a spatio-temporal record set used in the visualization experiments

199 rows:

validtime	BUILDINGID	PARTID	MODEL	ROWID
[1190/01/01 - forever)	1	House8_Roof	oracle.sql.BLOB@16dcbc9	AAAI8AATAAAD2kAAA
[1180/01/01 - forever)	1	House8	oracle.sql.BLOB@15e3974	AAAI8AATAAAD2kAAB
[1410/01/01 - forever)	1	House9_Roof	oracle.sql.BLOB@10e0904	AAAI8AATAAAD2kAAC
[1160/01/01 - forever)	1	Road2	oracle.sql.BLOB@721e92	AAAI8AATAAAD2kAAD
[1500/01/01 - forever)	1	House10	oracle.sql.BLOB@35047f	AAAI8AATAAAD2kAAE
[1290/01/01 - forever)	1	House3_Roof	oracle.sql.BLOB@ba372f	AAAI8AATAAAD2kAAF
[1280/01/01 - forever)	1	House3	oracle.sql.BLOB@17d1b24	AAAI8AATAAAD2kAAG
[1510/01/01 - forever)	1	House10_Roof	oracle.sql.BLOB@810768	AAAI8AATAAAD2IAAA
[1610/01/01 - forever)	1	House13_Roof	oracle.sql.BLOB@10d7792	AAAI8AATAAAD2IAAB
[1710/01/01 - forever)	1	House58	oracle.sql.BLOB@1254e47	AAAI8AATAAAD2IAAC
[1610/01/01 - forever)	1	House59	oracle.sql.BLOB@317b1d	AAAI8AATAAAD2IAAD
[1590/01/01 - forever)	1	House22	oracle.sql.BLOB@89b953	AAAI8AATAAAD2IAAE
[1510/01/01 - forever)	1	House32	oracle.sql.BLOB@1e6258e	AAAI8AATAAAD2IAAF
[1750/01/01 - forever)	1	House50	oracle.sql.BLOB@abab54	AAAI8AATAAAD2IAAG
[1790/01/01 - forever)	1	House39_Roof	oracle.sql.BLOB@7d32cf	AAAI8AATAAAD2mAAA

The Temporal Focus+Context Visualization Model

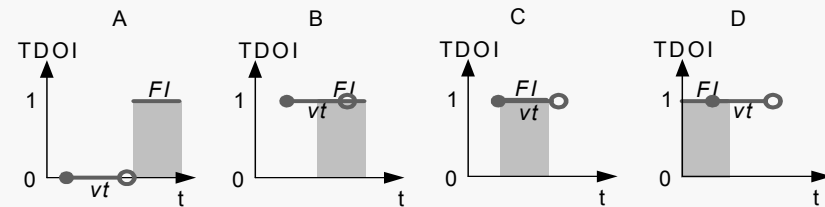


- Based on concepts from InfoVIS: **Focus+Context** and **Fisheye**.
- Addresses TIME instead of space
- Through the model a Temporal Degree of Interest (TDOI) is calculated for each record, where:
 - $1 \geq \text{TDOI} \geq 0$
- User defines *interests in terms of* TDOI functions. ----->
- Each TDOI function is defined by:
 - A time period corresponding to an interval defined by its extents, designated by Period of Interest (PI);
 - A function of interest (FI) (for instance, constant, linear, etc.) that describes the TDOI behavior for that time period.

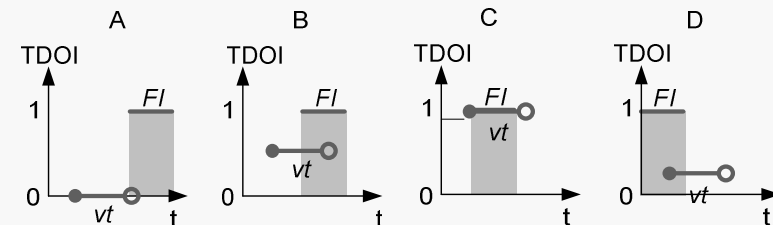
Filtering: TDOI calculation modes: maximize and relate

- In maximize mode:** The TDOI value for a record does not take into account how much the record *valid time* intersects the period of interest of a TDOI function.

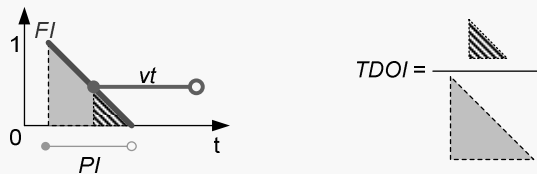
- Rather it assigns the maximum value of the part of the TDOI function that is being intersected by the record *valid time*.



- In relate mode:** The TDOI value for a record takes into account how much the record *valid time* intersects the period of interest of a TDOI function.



Smaller *vt* of records also generate smaller TDOI.



Mapping stage: TDOI controls graphical variables

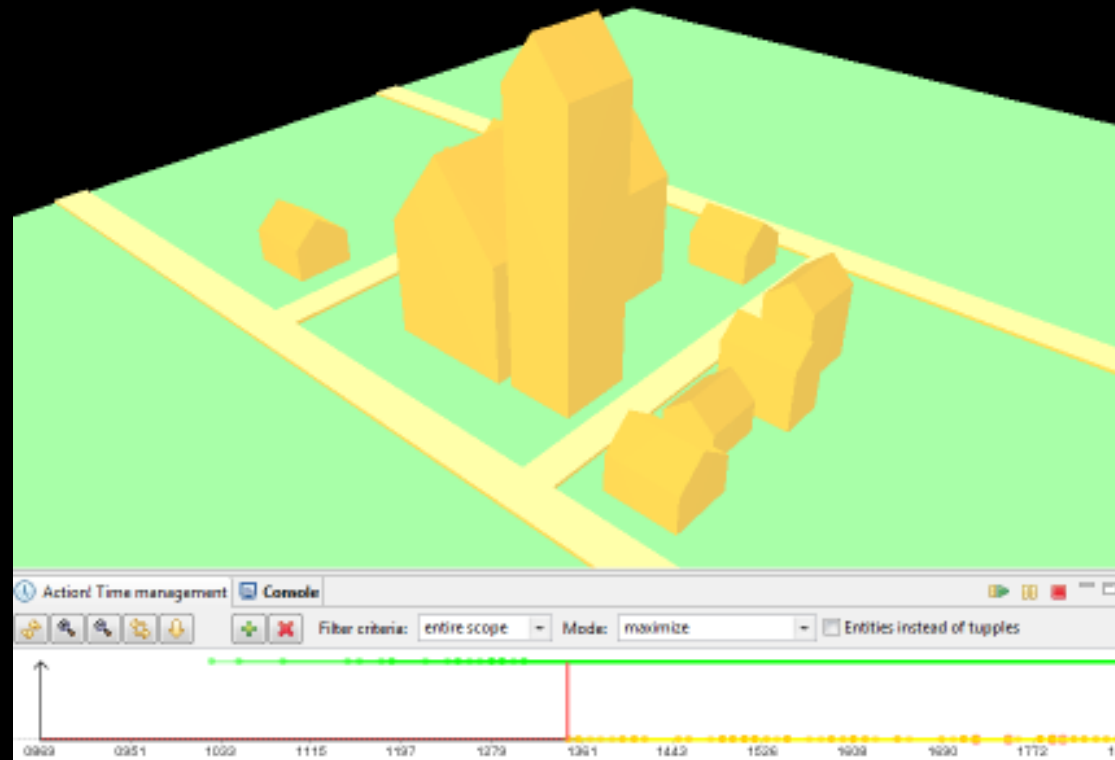
- Considering the following visualization possibilities, the control of three graphical variables has been experimented.
- Per urban object:
 - **Alpha channel level** (direct map of TDOI to Alpha).
 - For TDOI = 0 -> renders transparent.
 - -> renders intermediate alpha states.
 - For TDOI = 1 -> renders opaque.
 - **Blur level:** map TDOI to a value of blur in the representation of objects.
At the boundaries:
 - For TDOI = 0 the object gets a maximum of blur, hence defocused;
 - For TDOI = 1 object becomes completely focused.
 - **Pseudo-color:** map TDOI to the index of a palette of colors
 - Color blends with the representation of the object.

Visualization of spatio-temporal urban data models

- Experiments performed with the Temporal Focus+Context Model aim at visually answer for the following questions:
 1. *What urban objects exist at specific time instant?*
 2. *What urban objects exist over a specific time period?*
 3. *What urban objects exist over two distinct time periods?*
 4. *What is the relation of an urban object with a time period?*
 5. *What is the temporal relation between two urban objects?*
 6. *What objects exists in a near past and near future?*
- During urban planning analysis:
 - the answer to these questions provides a higher degree of decision support (awareness of present and past and possible futures)

Question 1: What urban objects exist at specific time instant?

- Get a snapshot of urban datasets at a particular instant.
For this purpose:



$\{PI=<a \text{ particular chronon}>;FI=1\}$

Question 2: What urban objects exist over a specific time period?

- Retrieves a snapshot of the urban dataset from a particular time period.
For this purpose:
 - TDOI function is $\{PI=<a \text{ time period}>; \text{selected FI}=1\}$
 - In TDOI *maximize* mode, all objects intersecting PI have TDOI = 1.
 - The mapping function:
 - TDOI mapped into alpha pseudo-color
 - TDOI mapped into pseudo-color

Question 2: What urban objects exist over a specific time period?

See flash video [question2a.swf](#) and [question2b.swf](#) for better illustration.

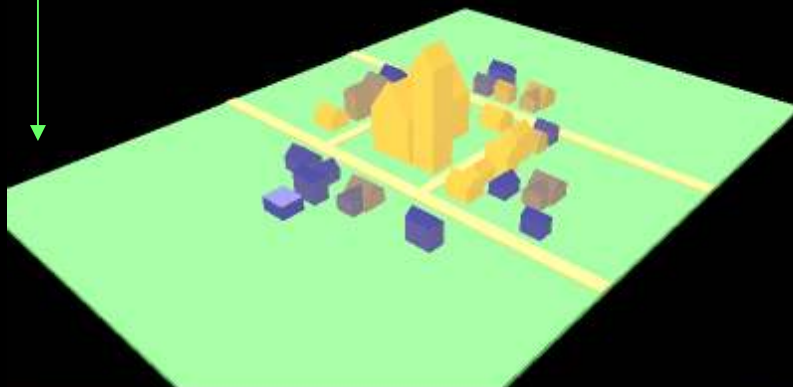
Color palette used:



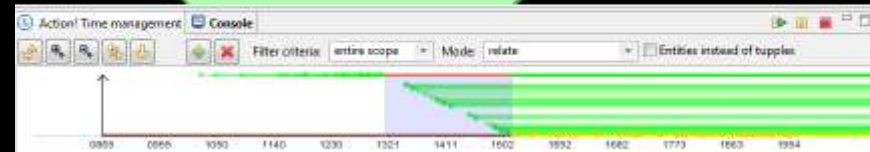
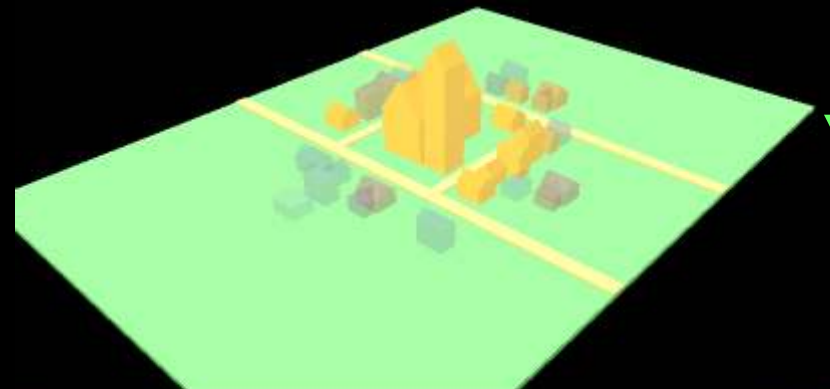
← TDOI *maximize* calculation mode
TDOI mapped to color and alpha



TDOI *relate* calculation mode
TDOI mapped to color only



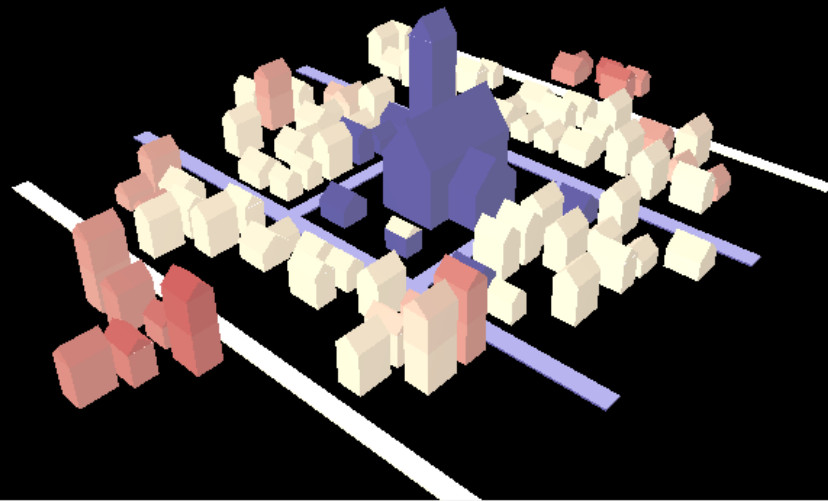
TDOI *relate* calculation mode
TDOI mapped to color and alpha



Question 3. What urban objects exist over two distinct time periods?

- **Result (two data sets):**

See flash video [question3.swf](#) for better illustration.



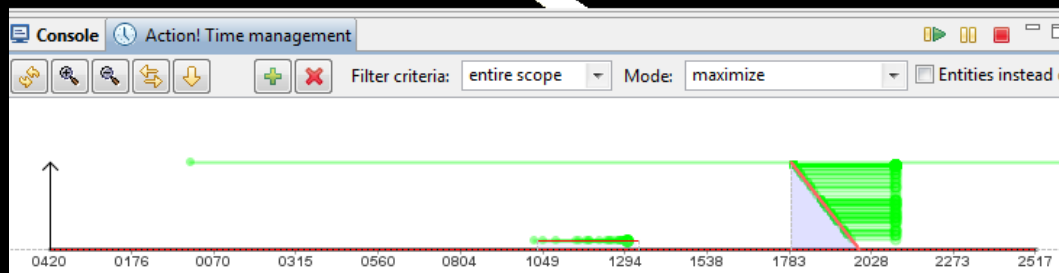
#1 `validtime period [1000-1300]
select * from coordinategeometry
where partid <> 'Floor';`

Color palette used:



#2 `validtime period [1800-2100]
select * from coordinategeometry
where partid <> 'Floor';`

Color palette used:



#1

#2

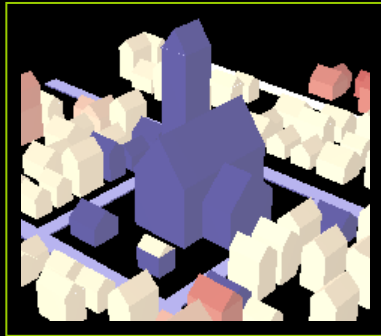
TDOI *maximize* calculation mode
TDOI mapped to color

*Blue buildings are from [1000-1300]
Other buildings are from [1800-2100],
where:*

*red are newer
white are older buildings.*

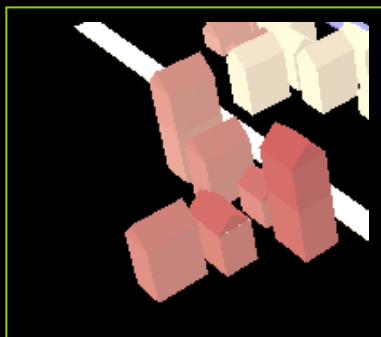
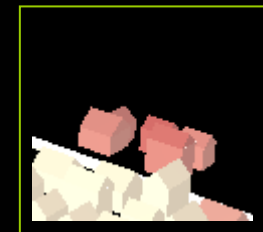
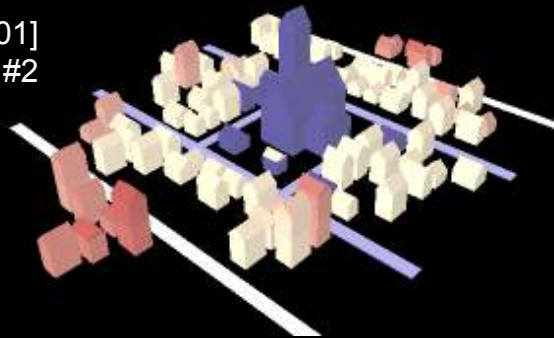
Question 3. What urban objects exist over two distinct time periods?

- On the previous result:



Red depicts recent buildings from period [1800-2001]
TDOI based on function #2

White depicts older buildings from period [1800-2001]
TDOI based on function #2



Red depicts recent buildings from period [1800-2001]
TDOI based on function #2

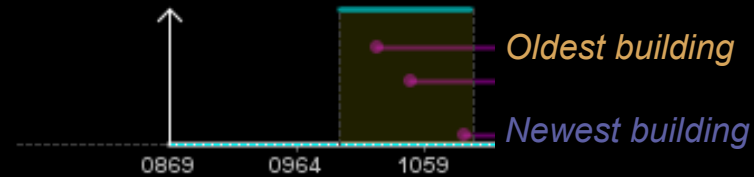
Question 4: What is the relation of an urban object with a time period?

- This question concerns the ability visually retrieve one of the following results:
 - *Urban object fully exists over the time period;*
 - *Urban object partially exists over the time period;*
 - *Urban object does not exist over the time period.*
- For this purpose we have experimented with:
 - TDOI function is {PI=<a time period>; selected FI=1}
 - TDOI *relate* mode.
- The mapping functions:
 - TDOI mapped into alpha and pseudo-color.

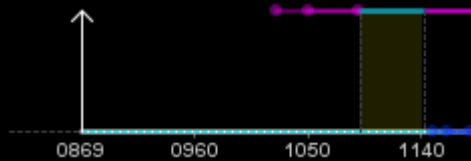
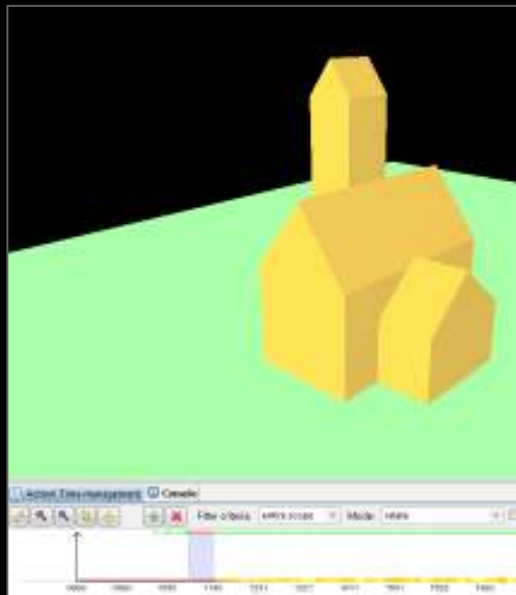
Question 4: What is the relation of an urban object with a time period?

- Result:

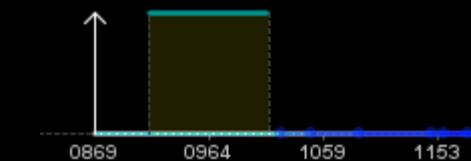
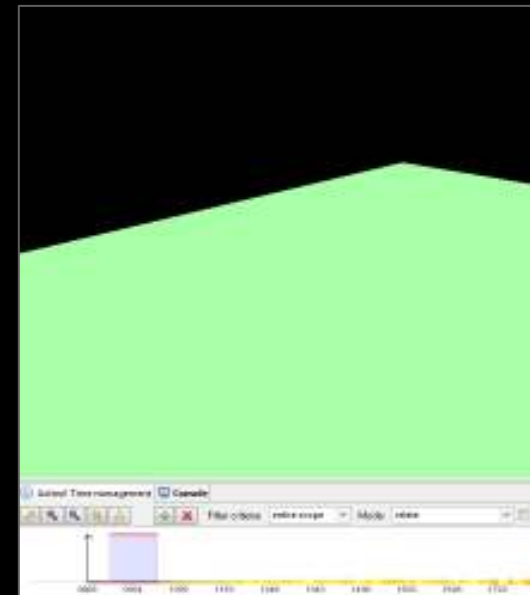
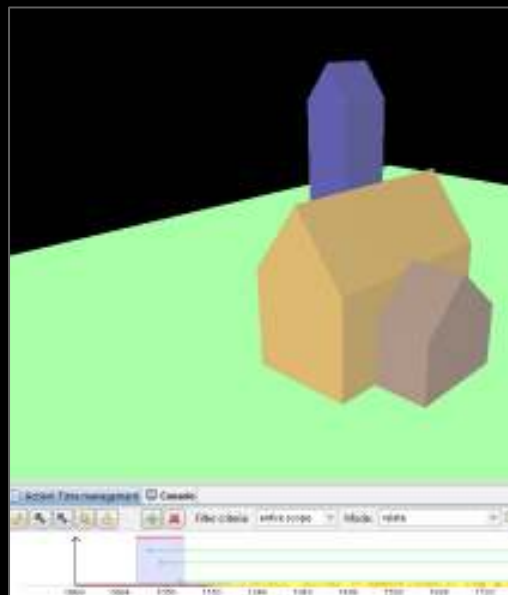
Color palette used:



Object vt partially exists over PI



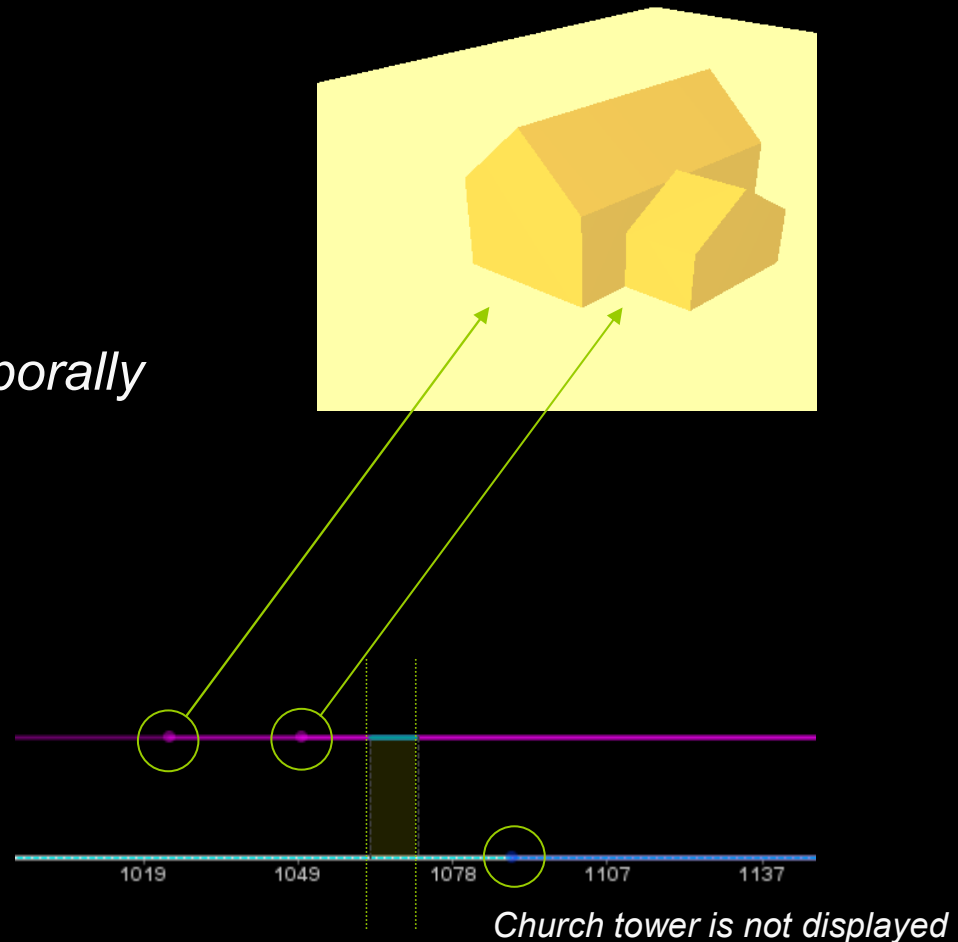
Object vt fully exists over PI



Object vt does not exist over PI

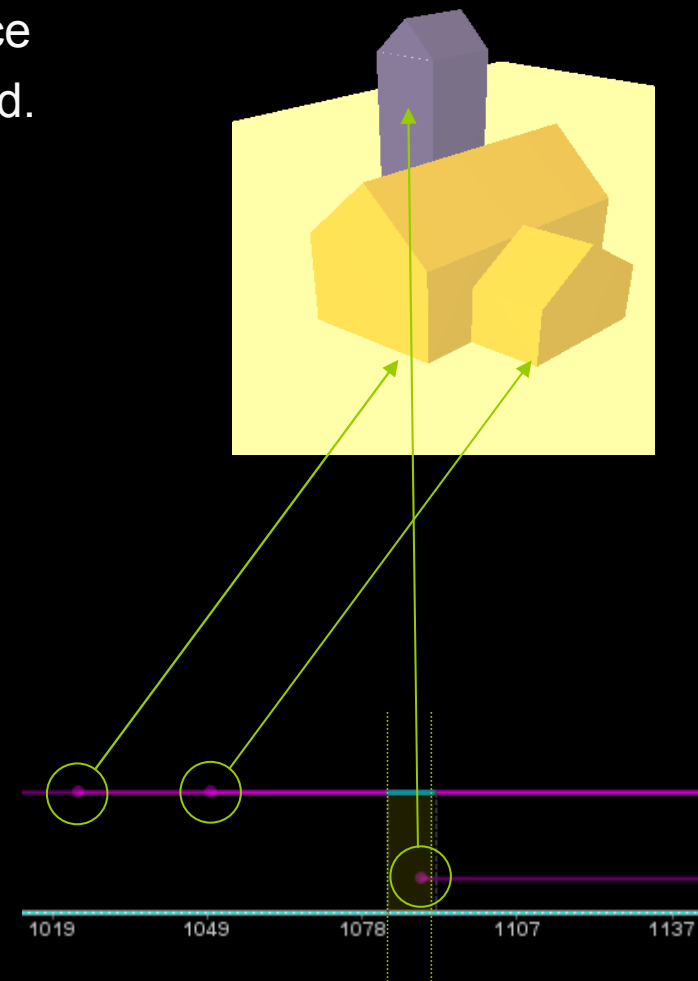
Question 5: What is the temporal relation between two urban objects?

- Given a TDOI function, temporal relations between objects can be depicted in the visualization.
- 1° - the time periods don't temporally overlap
- 2° - the time periods fully temporally overlap



Question 5: What is the temporal relation between two urban objects?

- 3° - *the time periods partially overlap:*
 - Order (object A precedes B or vice versa) can be graphically depicted.



Color palette used:

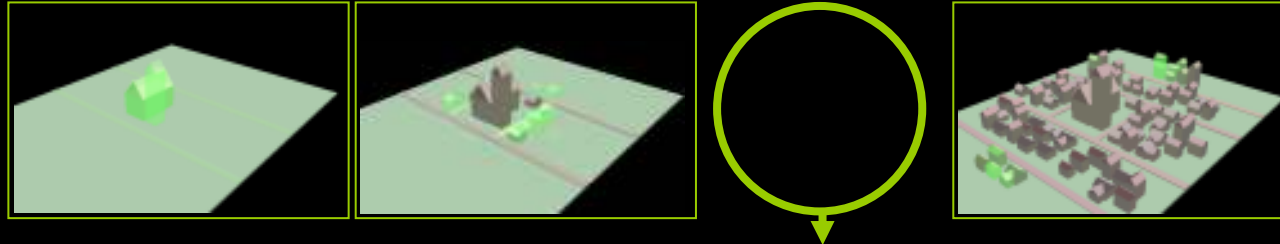


Question 6: What objects exists in a near past and near future?

- It requires a dynamic visualization of results, where PI is slided (automatically or by user intervention) across the timeline. *Here:*
 - *Span of PI -> retrieval of objects from the past or the future.*
 - *Selection of FI -> behavior of TDOI increase/decrease.*
- $\Delta TDOI = TDOI_{(k)} - TDOI_{(k-1)}$, is calculated for every change k of PI.
- The mapping function experimented transforms :
 - TDOI into alpha and blur values.
 - $\Delta TDOI$ into pseudo-color, where:
 - Positive $\Delta TDOI$ -> constant green hue.
 - Negative $\Delta TDOI$ -> constant red hue.

Question 6: What objects exists in a near past and near future?

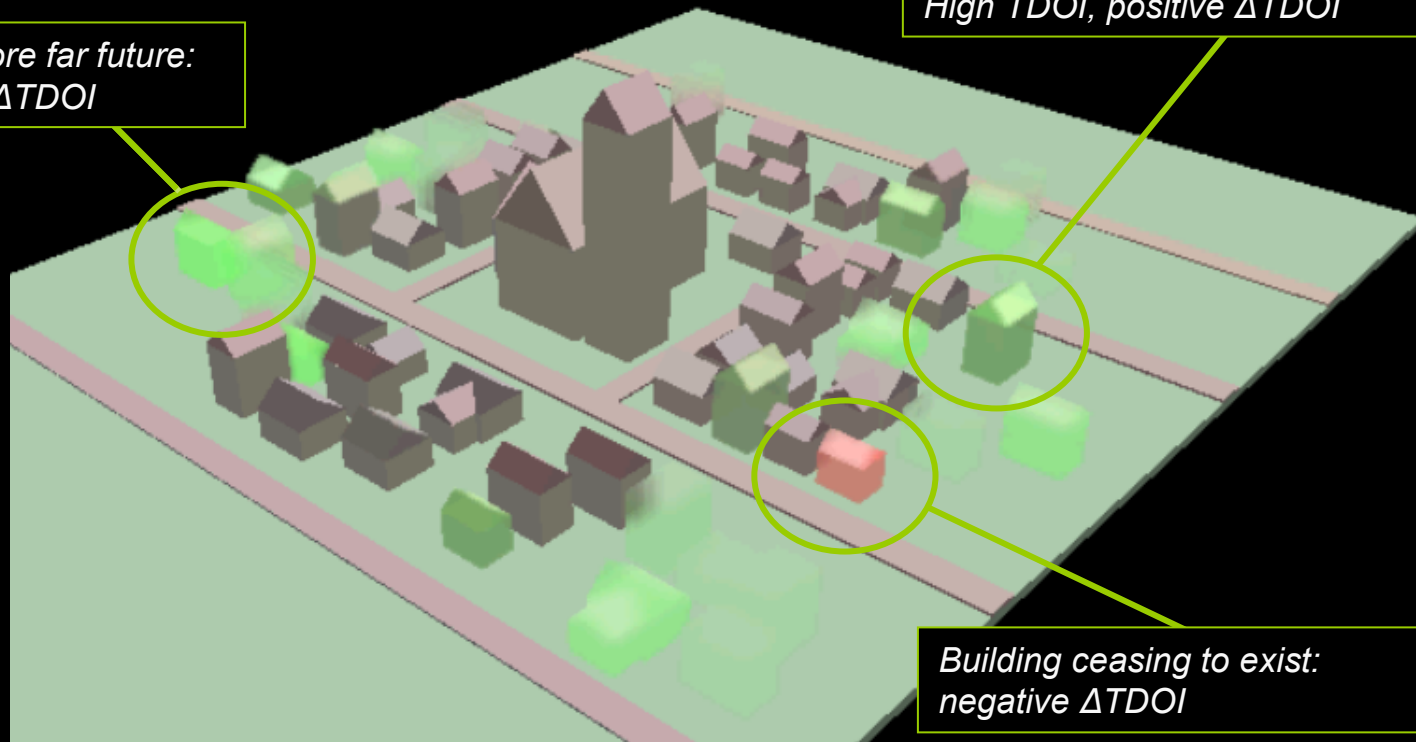
See flash video [question6a.swf](#) for better illustration.



User slides PI from past to future.

Buildings from a more far future:
low TDOI, positive $\Delta TDOI$

Building from a more near future:
High TDOI, positive $\Delta TDOI$

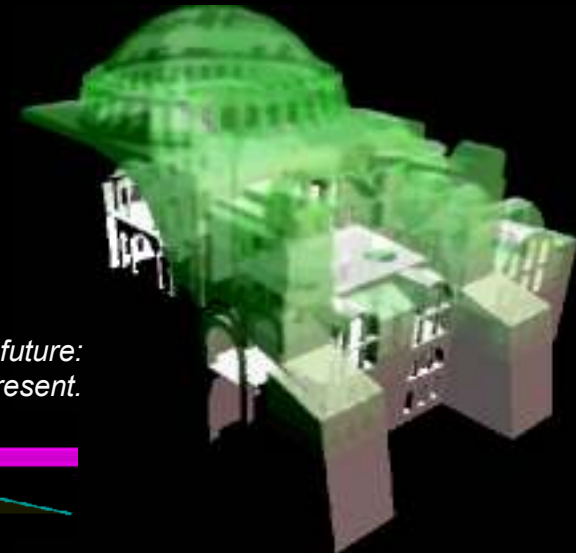
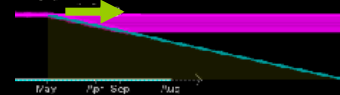


Building ceasing to exist:
negative $\Delta TDOI$

Question 6: What objects exists in a near past and near future?

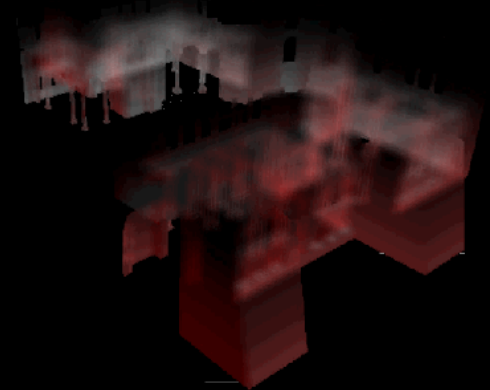
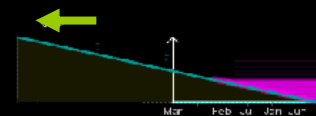
- Order of sliding matters in the visual interpretation of results:
 - By sliding *PI* into the future...
 - Green depicts a valid time from future that is becoming present.
 - Red depicts a valid time from present that is becoming past.
 - By sliding *PI* into the past...
 - Green depict a valid time from past that is becoming present.
 - Red depict a valid time from present that is becoming future.

PI slid towards the future:
Objects from future becoming present.



See flash video [question6b.swf](#) for better illustration.

PI slid towards the past:
Objects going back to the future.



Conclusions: general

- The work presented a method for spatio-temporal visualization of urban objects retrieved from a spatio-temporal database management system.
 - Relies on Temporal Degree of Interest (user + valid time data)
- Regarding visual analysis of spatio-temporal urban datasets:
 - Questions are raised addressing problem in visualization of spatio-temporal features from urban objects.
 - For each of the questions we present:
 - How to use the Temporal F+C Model in order to visually answer the question;
 - The experimented strategy that concerts TDOI into graphical properties used in the display of the urban objects
 - The visual results achieved, based on urban test scenarios.

Conclusions: mapping

- Regarding the mapping of TDOI into graphical properties for rendering the urban objects:
 - Pseudo-color seems suitable for rendering temporal features: carefully choose colors!
 - Alpha channel: ambiguities....
 - Blur + alpha seems to reduce ambiguities problem as “inside” of objects gets defocused;
 - The combined use of blur + alpha + pseudo-color seems suitable for rendering changes in TDOI.

