Time in GIS and Geographical Databases

SIE 510 GIS Applications

January 29, 2009

Motivation

- Current GIS representations assume the present or one point in time, but more often we are interested in how things change with the passage of time
- History provides an important cognitive basis for information retention and accumulation
- Need to maintain currency without losing history
- Need for the analysis of change and patterns of change through time

Representational Issues

- **State based view**
  What is/was/will be the state of an entity at any particular time?
  - What was the alignment of Route 1 through Belfast in 1975?
  - What is the position of Taxi 349 now?
  - What are possible positions of the vehicle 10 minutes from now?
- **Change based view**
  What changes have/are/will occur?
  - Where have increases in cancer cases occurred?
  - Is the hurricane accelerating?
  - What number of house sales is projected for this neighborhood in 2009?

Representing Time and Change

To support changed based queries

- Need to be explicit about change and methods for representing change
- Notion of change as an event or collection of events

Representing Time and Change

Event: Change in the state of one or more locations, entities, or both

Location view **Entity view**

Types of Change

- movement
- shape change
- attribute change

Importance of identity

Change patterns

- **Continuous** – going on throughout some interval of time
- **Majorative** - going on through most of some interval of time
- **Sporadic** - going on intermittently over some interval of time
- **Unique** – occurring only once

- Occurring **irregularly** in time
- Occurring **regularly** in time – cyclic, periodic
- Occurring **gradually**
- Occurring **suddenly**

Time data types

Need representational forms for time as well as space

- Time points
- Time intervals
- Temporal elements (sets of intervals)

Linear view

Time line as a finite sequence of **chronons** – equal sized indivisible units

Branching time

Allows representation of alternate versions

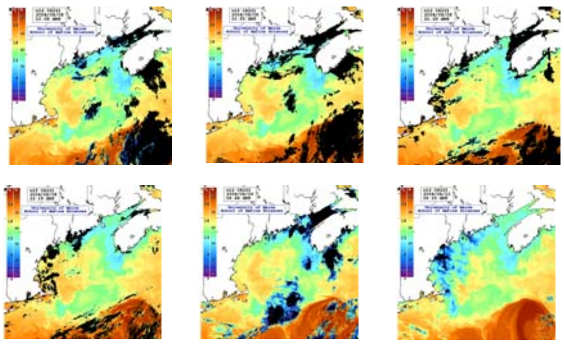
Spatio-temporal representations in GIS

Snap-shot model

Records a world state map S_i for given point in time t_i

Spatially registered time series (time series of spatial fields)

Time series of spatial fields



http://www.gomoos.org/buoy/satellite.html

Spatio-temporal representations in GIS

Snap-shot model

Records a world state map S_i for given point in time t_i

Spatially registered time series (time series of spatial fields)

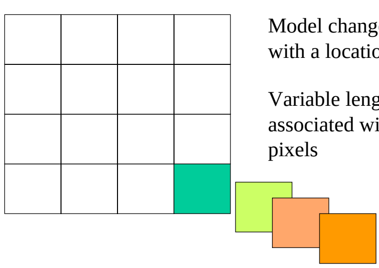
Limitations

Data accumulation and redundancy

Change is implicit between snap shots, a short lived change or event can be missed

Exact timing of an event does not correspond with the snap shot

Location based models



Model change as associated with a location

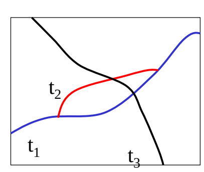
Variable length lists are associated with individual pixels

e.g. changing land use types

Records a new value and the date/time of the change

Entity based models

- Related to entities rather than locations
- Track changes in geometry over time
- Use of amendment vectors - Langran



Can represent asynchronous change to entities

With multiple spatial and aspatial change occurring, maintaining identity becomes an issue

Time based representations

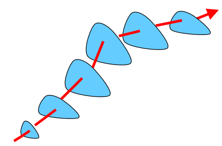
- Time as the organizing dimension
- Change stored as sequence of events through time
- Stored in time sequenced order
- Changes explicitly stored by time
- Supports time based queries
- New events easily added

Event based Data Models

- ID
- Type (event taxonomy- controlled vocabulary)
- Temporal footprint – (temporal data type - interval)
- Spatial footprint – spatial data type or ***f(s,t)***

Type dependent attributes

- Intensity – ***f(s,t)***



Characterization of events

Basic categories of change

Attribute Change	Shape Change	Movement
No Change	**No Change**	**No Change**
Nominal Class Change	**Scaling**	**Translation**
Interval, Ratio	Regular expansion	**Rotation**
Increase	Irregular expansion	
Decrease	Regular contraction	
Peak	Irregular contraction	
Trough	**Deformation**	

Extensions of change categories from Claramunt and Thériault (1995)

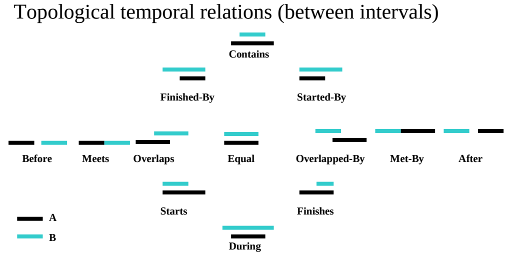
Spatio-temporal characterization of events

What are expected behaviors of events in space and time

Spatial Behaviors \ **Temporal Behaviors**	deterministically repeat	irregularly repeat	random
feature bound	Tides Moon phases	Lake turn over	Floods
region constrained	penguin march	Leaf drop Hurricanes	Avalanches
random			Storms Disease epidemics

Temporal relations

- May want to retrieve entities on the basis of temporal relations or examine the pattern of events
- Temporal metric relations – based on temporal distance
- Topological temporal relations (between intervals)



Time in Databases

A database models and records information about a part of reality termed the miniworld

A temporal database records time varying information

- **Valid time** of a fact – the collected times when the fact is true in the miniworld

  If a database models different worlds, database facts may have several valid times (one for each world)

  Captures time varying states of the miniworld

- **Transaction time** of a database fact – time when the fact is current in the database - insertion to (logical) deletion

  Can be associated with any database entity

  Captures time varying states of the database

Time in Databases

- Recording both transaction time and valid time is essential to many applications – **bitemporal database**
- Applications that demand accountability or traceability rely on databases that record transaction time
- Need support for temporal data modeling, database design and temporal query languages that operate on temporal databases

Instead of just a current value, need sequence of previous values – a history

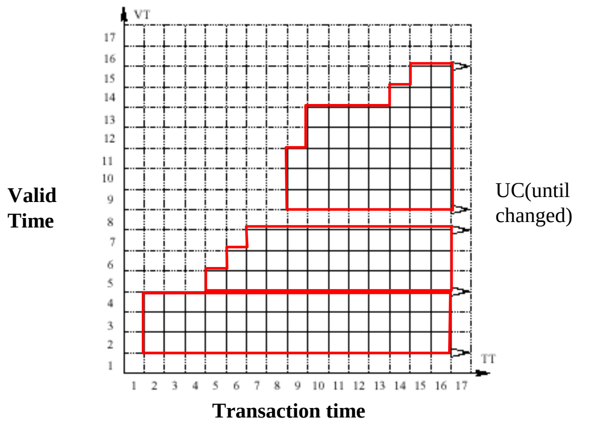
For tracking, need to decide how history will be accessed

Is a history log sufficient or does the entity need to be recreated for an earlier date

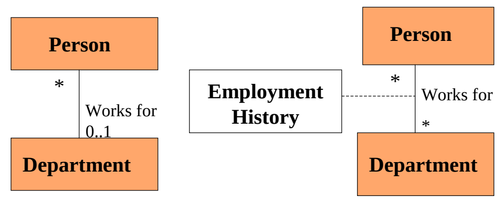
Bitemporal Database Example

Customer 101 rents video T1234 on February 2 for 3 days. The tape is returned on the 5^{th}. On the 5^{th} customer 102 rents tape T1245 with an open ended return. The tape is returned on the 8^{th}. On the 9^{th} customer 102 rents tape T1234 to be returned on the 12^{th}. On the 10^{th} the rental is extended to include the 13^{th} but the tape is not returned until the 16^{th}

CustomerID	TapeNum	T
C101	T1234	$\{(2,2), (2,3), (2,4), (3,2), (3,3), (3,4), \ldots, (UC,2), (UC,3)(UC,4)\}$
C102	T1245	$\{(5,5), (6,5), (6,6), (7,5), (7,6), (7,7), (8,5), (8,6), (8,7), \ldots, (UC,5), (UC,6), (UC,7)\}$
C102 UC(until changed)	T1234	$\{(9,9), (9,10), (9,11), (10,9), (10,10), (10,11), (10,12), (10,13), \ldots, (13,9), (13,10), (13,11), (13,12), (13,13), (14,9), \ldots, (14,14), (15,9), \ldots, (15,15), (16,9), \ldots, (16,15), \ldots, (UC,9), \ldots, (UC,15)\}$



History in an intersection table

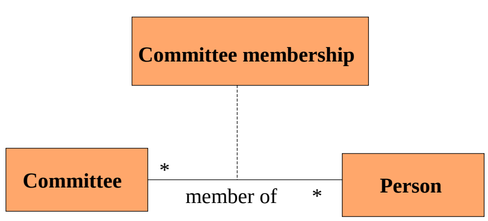


Without history

With history

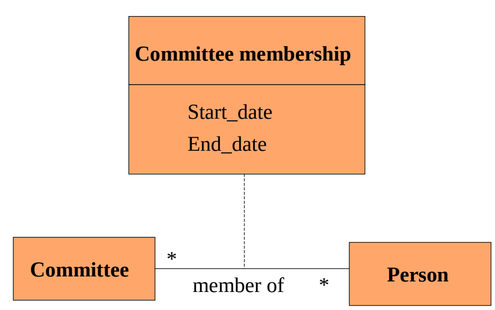
Employment History
(Emp_ID, Dept_ID)

Tracking History by Attributes



Tracks only current membership

Tracking History by Attributes



Maintaining a transaction log

Store all history about objects in one history class

```
Create table Trans-Log (
Trans_ID      Number (10) not Null
Table_Name Vachar2 (30) Not Null,
Row_ID        VarChar2 (200) Not Null,
Descr_Text   Varchar2 (2000) Not Null,
Trans_Date   Date Not Null
```

e.g. To delete a transaction, generate a delete and insert the delete statement into the transaction log

Time Series

Time data types - Elmasri and Lee 1998

- Time invariant – objects constrained not to change their values
- Time varying – objects that may change values with an arbitrary frequency
- Time series - objects that obtain values in close association with a particular pattern of time

Time Series

- Usually represented as a sequence of events
- Event as an ordered pair consisting of a temporal value and a data value
- $\{t_1, \langle data\_value_{1,1}, data\_value_{1,2}, \ldots \rangle), (t_2, \langle data\_value_{2,1}, data\_value_{2,2}, \ldots \rangle), \ldots\}$
- A time series is associated with a **calendar**
- A **calendar** provide the domain of temporal values for the corresponding time series

Time Series

Calendar defined as a tuple:
(granularity, pattern, period, start_time, end_time)

- **Granularity** – default time unit used in a calendar
- **Pattern** – a subsequence of time units expressed as a temporal element
- **Period** – the length of time interval at which pattern occurs repeatedly
- **Start_time** – the time unit for which a calendar starts
- **End_time** – the time unit for which a calendar ends

Time Series

Example Calendar

Calendar Work Hours

Granularity: Hour

Pattern: {[9,11].[13,17]}

Period:24

Start_Time 4/1/96

End_Time -

Time Series

A calendar specifies:

- Granularity of temporal values
- The pattern and period of a sequence of temporal values
- Start and end times

Temporal Value	Data Value
1/20/09	120
1/21/09	125
1/22/09	127
1/23/09	134
1/26/09	139

Closing value of stock prices based on 5 day work week and specification of holidays

ISO 8601 standard

ISO 8601:2000 Representation of dates and times, approved in 1988, updated in 2000

Defines a large number of alternative representation of dates, times, and time intervals.

Date only format

Use format like 1998-05-12, always expressing the year in full, followed by the month and then the day

Time of the day only format, international use

Use format like 14:15Z or 14:15:00Z, always expressing hours and minutes and seconds (if present) each with exactly two digits. Express the time as Universal Time Coordinated (UTC, formerly called Greenwich Mean Time, GMT); the appended Z letter indicates that the time is represented in UTC.

http://www.cl.cam.ac.uk/~mgk25/iso-time.html

ISO 8601 standard

Combined date and time format

Use a format where the date designation is followed by the letter T and the time of the day designation, e.g. 1998-05-12T14:15Z. Note that the standard clearly requires the use of T in this context. However, such a notation is often regarded as odd-looking, and people who otherwise use ISO 8601 might deviate from it here by using a space instead.

Period of time format

Use a format where an indication of the start of the period is followed by the slash (solidus) character / and an indication of the end of the period.

Examples:
1998-05-12T14:15Z/1998-05-13T16:00Z (time interval extending from one day to another)
1998-05-12T14:15Z/16:00Z (time interval within a day)
1998-05-12/15 (time interval from the 12th to 15th of May, 1998).

Time Zones

When an organization spans different time zones need to address how transaction information is displayed and managed

Times may also be offset by various time adjustments such as daylight savings time.

The shifts may occur differently in different time zones

Model **time zone** as a class

Then by knowing what time zone a particular time value is associated with it can be converted to a correct time using information of a time zone class