Spatiotemporal Databases & Moving Object Languages

query languages for moving objects databases
Spatiotemporal Databases

Both Geo spatial and temporally referenced

Why?

- Environmental Change
- Transportation
- Demographics
- Governance/Administration
Moving Object vs Change over Time

- Moving objects
  - Vehicles
  - People
  - Animals

- Changes over Time
  - County borders
  - Forest growth
  - Ice coverage

Moving Objects Changing Over Time

- Moving Wild Fire
- Spread of Volcanic Ash
- Traffic patterns
Three Stages of Complexity

You are designing a GIS database to track a vehicle in the city.

- **Static (non-temporal!)**
  - Single snapshot Eg. Car in one place at one time

- **Snapshot**
  - Periodic snapshots. Eg. Traffic cameras

- **Object lifelines**
  - Track changes to state. Eg. Record each new street

- **Events, Actions and Processes**
  - Track events themselves. Eg. Acceleration, Turns
Times in Databases

- Smallest Unit is a **Chronon** or **Tick**
  - If you store D/M/Y, you can't query by hour
- Store as instant (point in time)?
  - Or maybe time intervals?
- Branching time
  - Model what-if scenarios or possibilities
- Cyclical time
  - Repeating stuff like seasons
- Data type
  - Real numbers? Integers?
Valid vs. Transaction Time

Which type do you need?

- **Valid Time**
  - The time the event occurred
    - Maybe multiple valid times
    - Dinosaur lived 230 million years ago
    - Dino discovered 20 years ago
    - Dino acquired by museum 1 year ago

- **Transaction Time**
  - A timestamp in the DB when inserted/modified
  - Dino discovery recorded in database
Moving Objects Databases-definitions

Data abstraction

moving point - only time-dependent position
- eg. cars, trucks, airplanes, ships, mobile phone users

moving region - also time-dependent shape and extent
- eg. forest fires, oil spills in the sea, armies, epidemic diseases, and hurricanes

Database perspectives

Location management perspective
- maintain locations; query the current and expected near future positions and relations

Spatio-temporal data perspective
- the complete histories of movements are represented
Modeling and Querying Current Movement
– the MOST Model and FTL Language

Strategies:
  a. Store a motion \textit{vector} - a position as a linear function of time
  b. Database is updated if the \textit{deviation} exceeds the threshold
  c. Assumptions on object classes and \textit{spatial attributes}
  d. Contains the object - \textit{Time}, yields the current time at every instant

Dynamic Attributes
A standard data type but changes its value automatically over time
\textit{eg.} \textit{value}(A, t) = A\textunderscore value + A\textunderscore function(t - A\textunderscore updatetime). \( t \geq A\textunderscore updatetime \)

Representing Object Positions
\textit{loc}(route, startlocation, starttime, direction, velocity, uncertainty)

Semantics of Queries, Query Types
Database \textit{state}: a mapping (associates each object class with a set of objects of appropriate types, and the \textit{Time} object)
Database \textit{history}: an infinite sequence of states
\textit{eg.} \textit{Q}(Ht, t). \( \text{instantaneous query} \)
\textit{Q}(Ht, t), \textit{Q}(Ht+1, t + 1), \textit{Q}(Ht+2, t + 2), \ldots \( \text{continuous query} \)

The Language FTL
\textit{RETRIEVE <target-list> FROM <object classes>}
\textit{WHERE <FTL-formula>} \textit{until, nexttime, always, eventually\_within\_c...}
Modeling and Querying History Movement
– Spatio-temporal Data Types(1)

**Important Abstractions:**
Geometries in spatial databases change continuously over time
- \textit{Point(position relevant)}, \textit{Line(connections)}, \textit{Region(extents relevant)},
- \textit{Partition(subdivisions)}, \textit{Network(graph structure)}

**Spatio-temporal Data Types:**
- \textit{moving point} and \textit{moving region} visualized (2D/3D + time)

**Example Operations and Queries**
- \textit{Trajectory, traversed, deftime, intersection, atinstant, val, duration}
  - \texttt{eg.SELECT count(*) FROM cars AS c, weather AS w WHERE duration(deftime(intersection(c.trip, w.area))) > 1800}

**Goals in the Design of Types and Operations**
- Closure of type system; Genericity; Consistency between
  - nontemporal and temporal types; Consistency between nontemporal and temporal operations

**Abstract and Discrete Model**
- Abstract models: mathematically simple, elegant, and uniform, but
  - not directly implementable.
- Discrete models: more complex and heterogeneous, but can be implemented.(a finite representation)
Modeling and Querying History Movement
– Spatio-temporal Data Types(2)

**Operations:**
1. Design operations for nontemporal types.
2. Use lifting make them all time dependent in a way consistent with the static definition.
3. Add specialized operations for the temporal types

**Implementation:**
- sliced representation
- temporal function
- simple function
- unit

**The Structure of The Type System**

```
int
real
string
bool
point
points
line
region

moving(int)
moving(real)
moving(string)
moving(bool)
moving(point)
moving(points)
moving(line)
moving(region)

range(int)
range(real)
range(string)
range(bool)

periods
```

*eg.*
- change position in discrete steps --> set of points
- move continuously --> a curve line value
Further Work and Applications

1. Moving Objects in Networks
   A network is modeled as a set of routes and junctions between routes
   \( gpoint, gline, moving(gpoint) \) and \( moving(gline) \)

2. Spatio-temporal Predicates and Developments
   The framework first allows one to obtain basic spatio-temporal
   predicates by aggregating a static topological relationship over all
   instants of a time interval
   \( Cross := Disjoint \rightarrow meet \rightarrow Inside \rightarrow meet \rightarrow Disjoint \)

3. Uncertain Trajectories
   \( PossiblySometimeInside \) \( SometimesPossiblyInside \)
   \( PossiblyAlwaysInside \) \( AlwaysPossiblyInside \)

Key Applications

Query languages (first kind) - current and near future movement
   gas stations, hotels, parcel delivery services, air traffic control

Query languages (second kind) - history of movement
   movements of animals, deforestation of the Amazon rain forest
Thank You!