MADALGO
CENTER FOR MASSIVE DATA ALGORITHMICS

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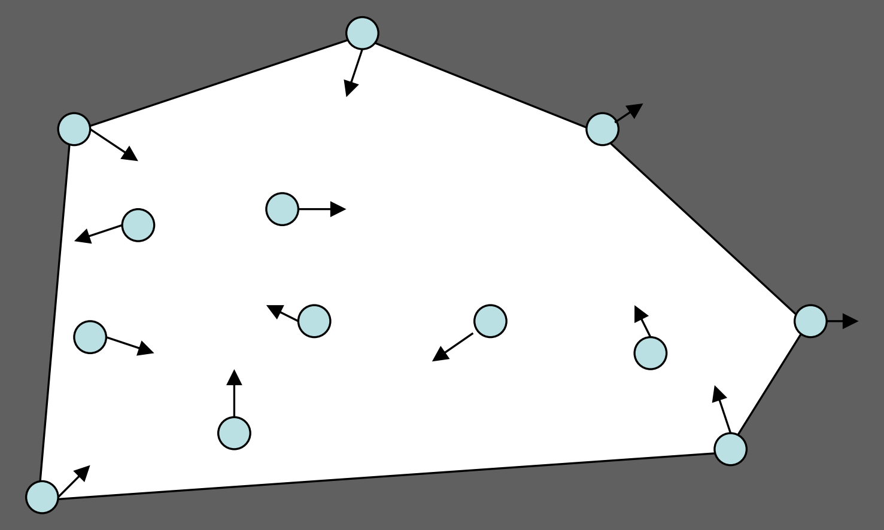
Kinetic Data Structures

Motivation

Motion is ubiquitous in the physical world and due to recent advances in sensing and tracking technology, motion data is becoming more and more available in a variety of areas:,mobile communication, geographic information system, air-traffic control, and so on. It is not surpising, therefore , that it is necessary to store, analyze, and create or manipulate motion data. As a result , modeling moving objects has become an important area of study in many areas of computer science such as computation geometry, databases, graphics, wireless netwroks, ...

Geometric study of moving objects

Simulate system of continuously moving objects and efficiently maintain discrete geometric attributes of objects such as the convex hull of moving points.



Two main approaches

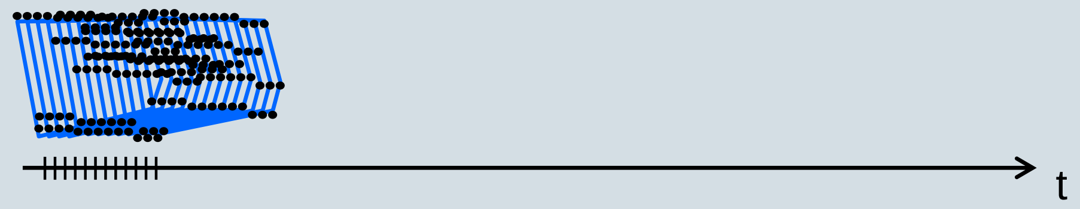
- Time sampling
- Kinetic data structures

Time Sampling Approach

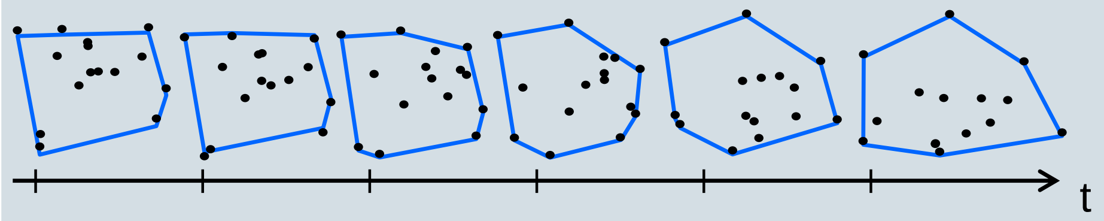
- Choose fixed time step .
- Update the positions of moving objects at each time step.
- Update the data structure with the new positions of objects.

How to choose time step?

- Oversampling:

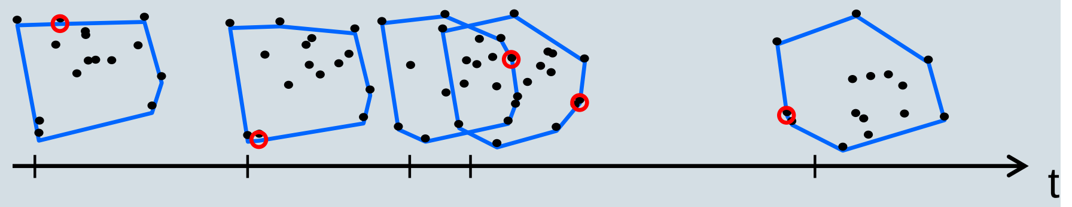


- Undersampling



Kinetic Data Structures

- Combinatorial changes occur in irregular patterns.



KDS consists of two parts

- Combinatorial description of the attribute.
- A set of certificates—elementary test on the input objects—with the property that as long as the outcome of the certificates do not change, the attribute does not change.

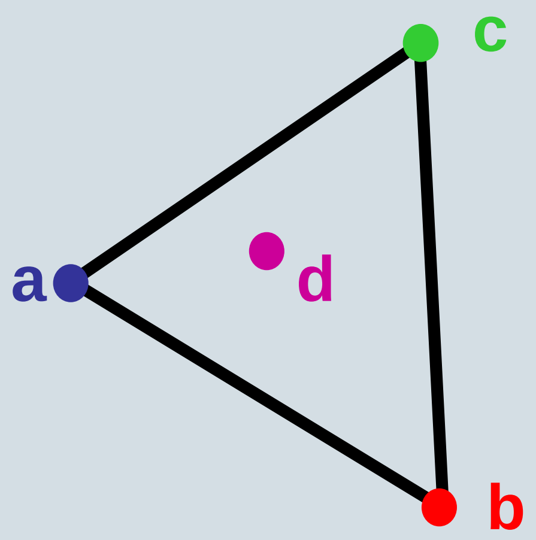
Structures

- Proof of correctness of attribute (certificates)
- Priority queue (event queue)

Assumptions

- A simple model for motion: each object follows a known flight plan with rational parameters.
- Certificates are algebraic; failure is next largest root.

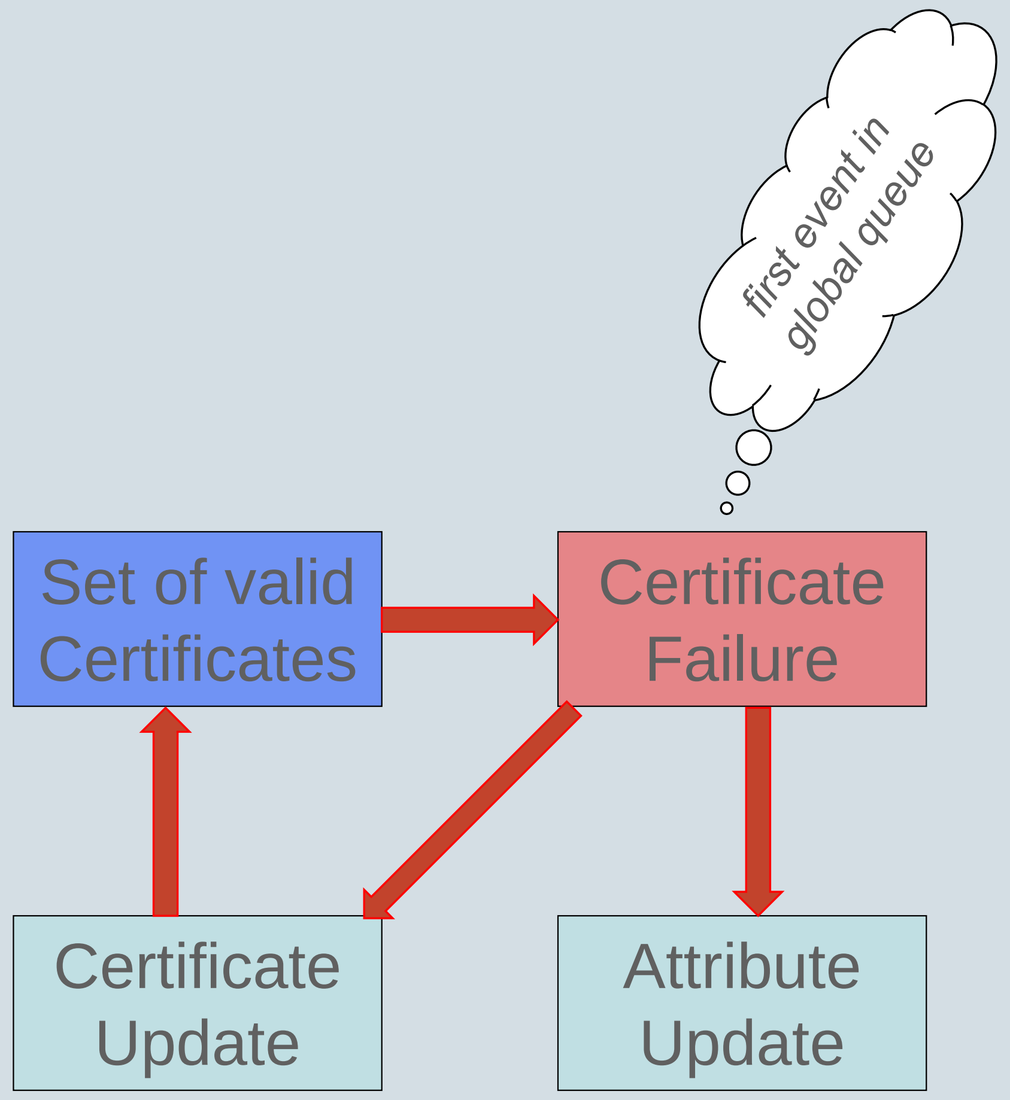
Example



Certificates

a is to the left of bc
d is to the left of bc
b is to the right of ad
c is to the left of ad

KDS Framework

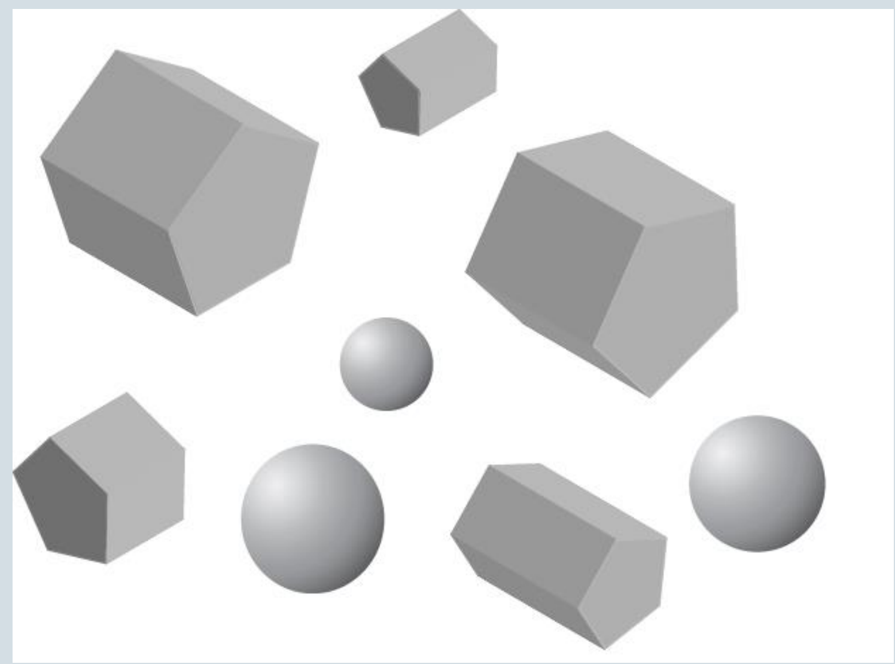


KDS Properties

- **Compact:** if it uses little space in addition to the input.
- **Responsive:** if data structure invariants can be restored quickly after the failure of a certificate.
- **Local:** if it can be updated easily if flight plan for an object changes.
- **Efficient:** if the worst-case number of events handled by the data structure is small compared to some worst case number of external events.

Collision Detection

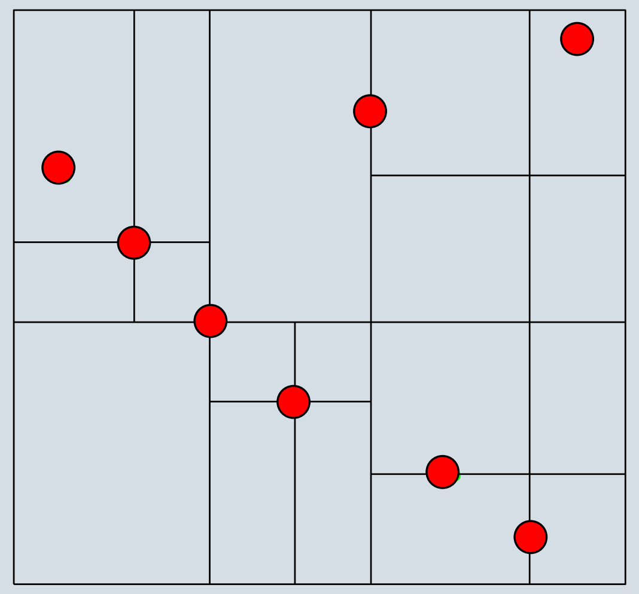
Kinetic methods can be applied to collision detection problem which is a basic problem arising in all areas of geometric modeling involving objects in motion— motion planning, computer-simulated environments, ...



Query Data Structures

Kinetic method can be used to maintain a QDS in order to quickly answer queries involving objects in motion:

- What are the points currently inside a given region?
- What is currently are nearest point to a given query point?



Rank-based kd-tree is efficient to answer above queries.

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