Spatio-temporal access methods

Tong Jia

Xiangyu Li

Yongyi Liu

Contents

Indexing the past

Multi-dimensional structures

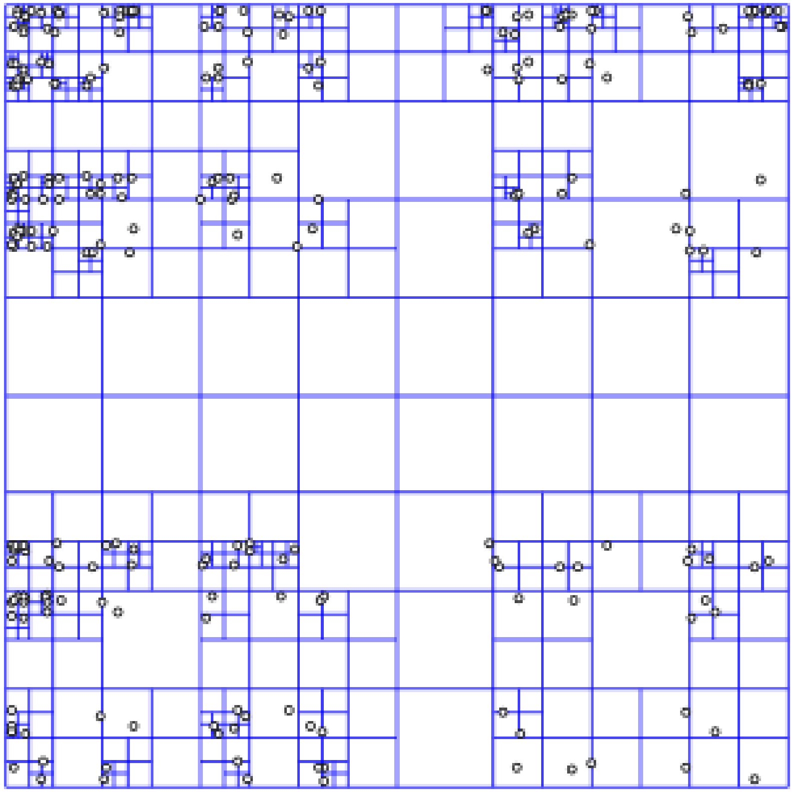
Tong Jia

PH-Tree (PATRICIA-hypercube-tree)

- A multi-dimensional data structure
- Extends both the Quad-tree and the PATRICIA-trie
- Optimize the search performance and the space utilization
- Indexing large amounts of multi-dimensional data.

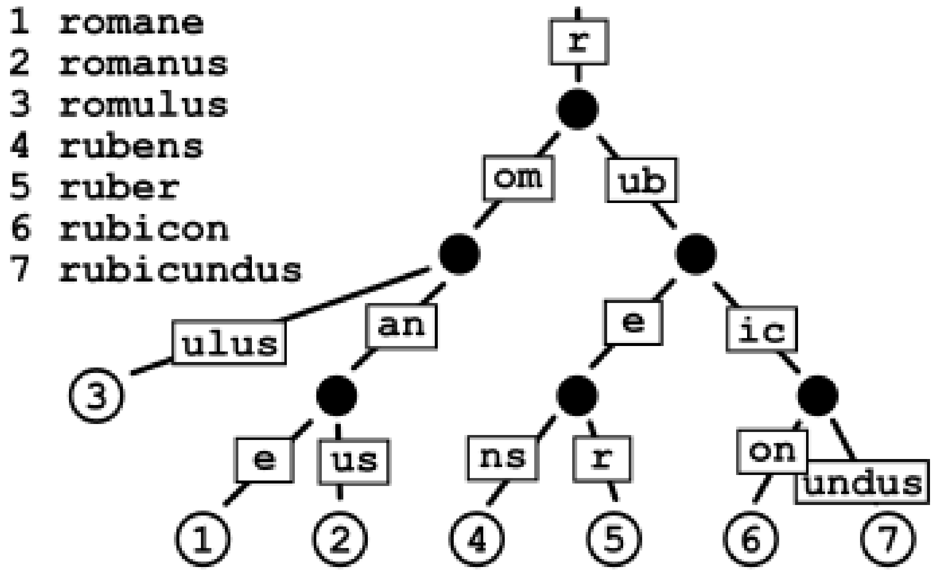
Quad-tree

- Efficiently store data of points on a two-dimensional space.
- Each node has at most four children.
- Rarely used outside 2D or 3D problems



PATRICIA-Trie (prefix tree)

Radix Trie



- Trie: strings are stored in a prefix-sharing method--Much more space efficient than storing each key individually.
- PATRICIA trees are radix trees with radix equals 2
- In general, any kind of data can be stored in such a tree by taking the bit representation of the data

PH-Tree

- k-dimensional object
- Partitions the space across all dimensions at any given node.
- Serializes the attributes of the indexed objects using binary representation.
- Can be seen as a hyper-cube of size 2^k
- Is essentially a quadtree that uses hyper-cubes, prefix-sharing and bit-stream storage.

Advantages

- Makes access virtually independent of the order.
- Reduce the number of nodes in the tree
- The maximum depth is independent of k and equal to the number of bits in the longest stored value.

Advantages

- No need for rebalancing because it’s ubalanced.
- Stable with respect to insert or delete operations.
- This is useful for concurrency when stored on disk--limits the number of pages that need to be rewritten.

1D PH-Tree

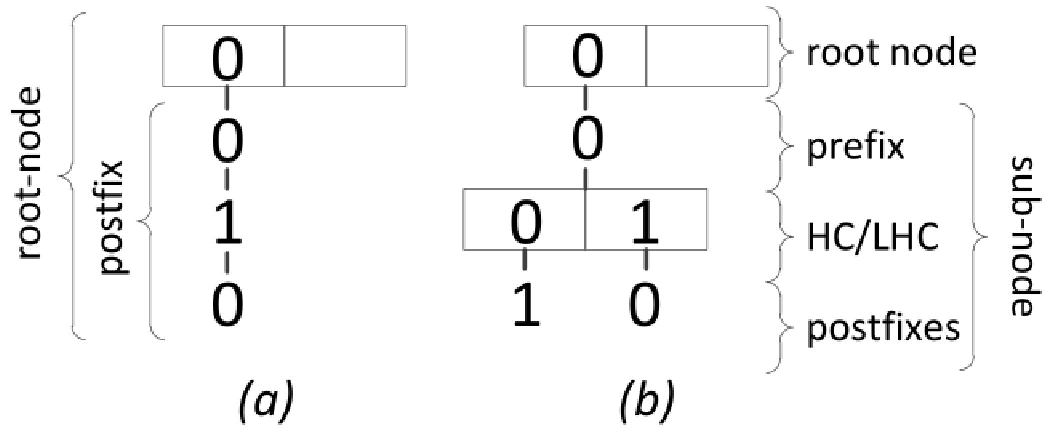


Figure 1: A sample 1D PH-tree with one 4-bit entry (a) and two 4-bit entries (b)

- resembles the binary PATRICIA trie.
- The value is stored in its binary representation as a bit-string.
- The first bit is stored in the root node.(In the 1D-case, all entries starting with a 0 can be found below the left box, all starting with a 1 can be found below the right box.)
- The depth of the trees is thus limited to 4.

1D PH-Tree

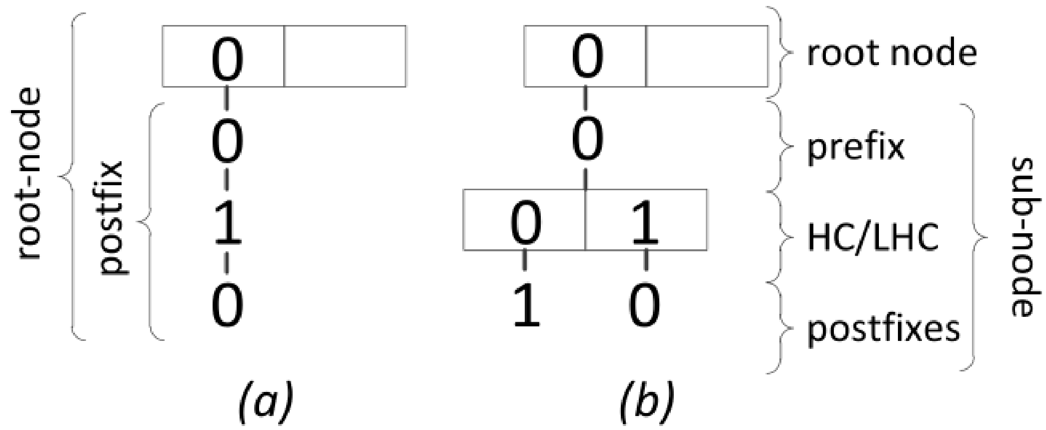


Figure 1: A sample 1D PH-tree with one 4-bit entry (a) and two 4-bit entries (b)

- Entries that are attached to an array field without further sub-nodes, such as the 010, are called a **postfix**.
- A second value 0001 has been **added** to the tree in Figure1b.

2D PH-tree

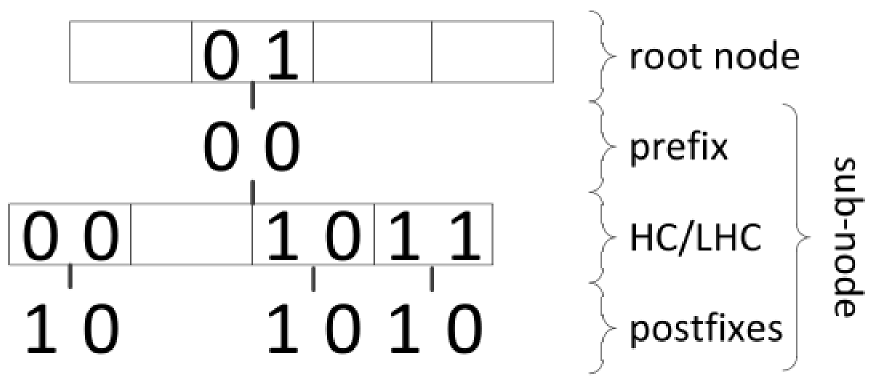


Figure 2: A sample 2D PH-tree with three 4-bit entries: (0001, 1000), (0011, 1000), (0011, 1010)

Indexing the current

Xiangyu Li

Challenges

- Frequent Updating

Challenges

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  - Locating -> Top-down
  - Deletion -> Merging
  - Insertion -> Splitting

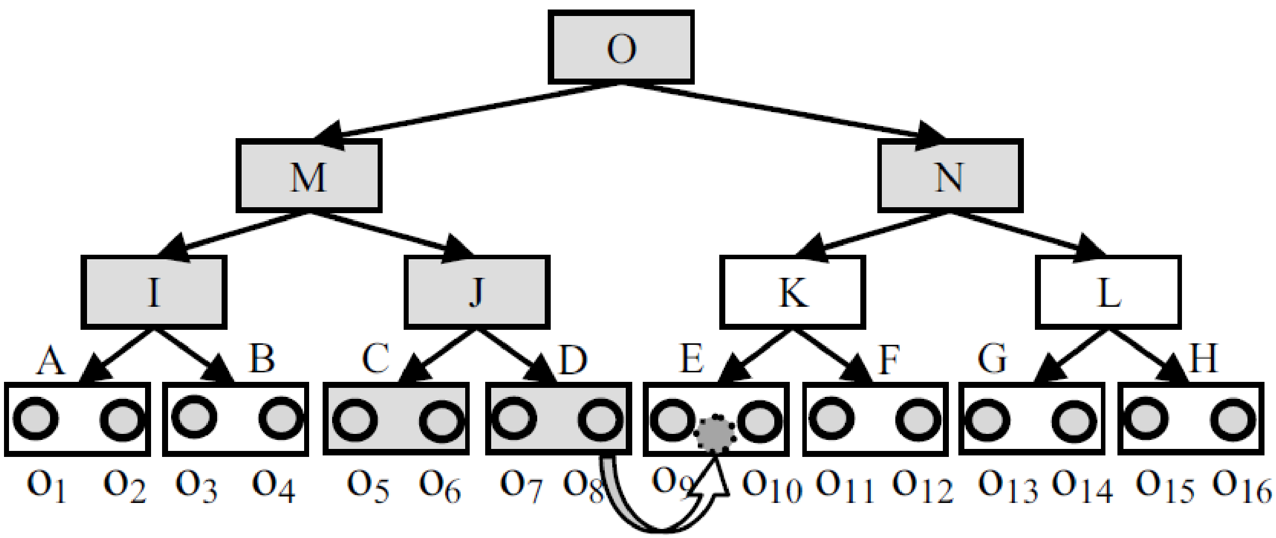

Fig. 1 An Example of Location Update

Challenges

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- Inefficient -> Real-time Response

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  - Insertion -> Splitting
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- Caching -> Reduce I/O cost -> Real-time Response
- **1. RUM+-tree**(R-tree-based)
- **2. DIME(**Disposable Index for Moving Objects**)**

RUM+-tree

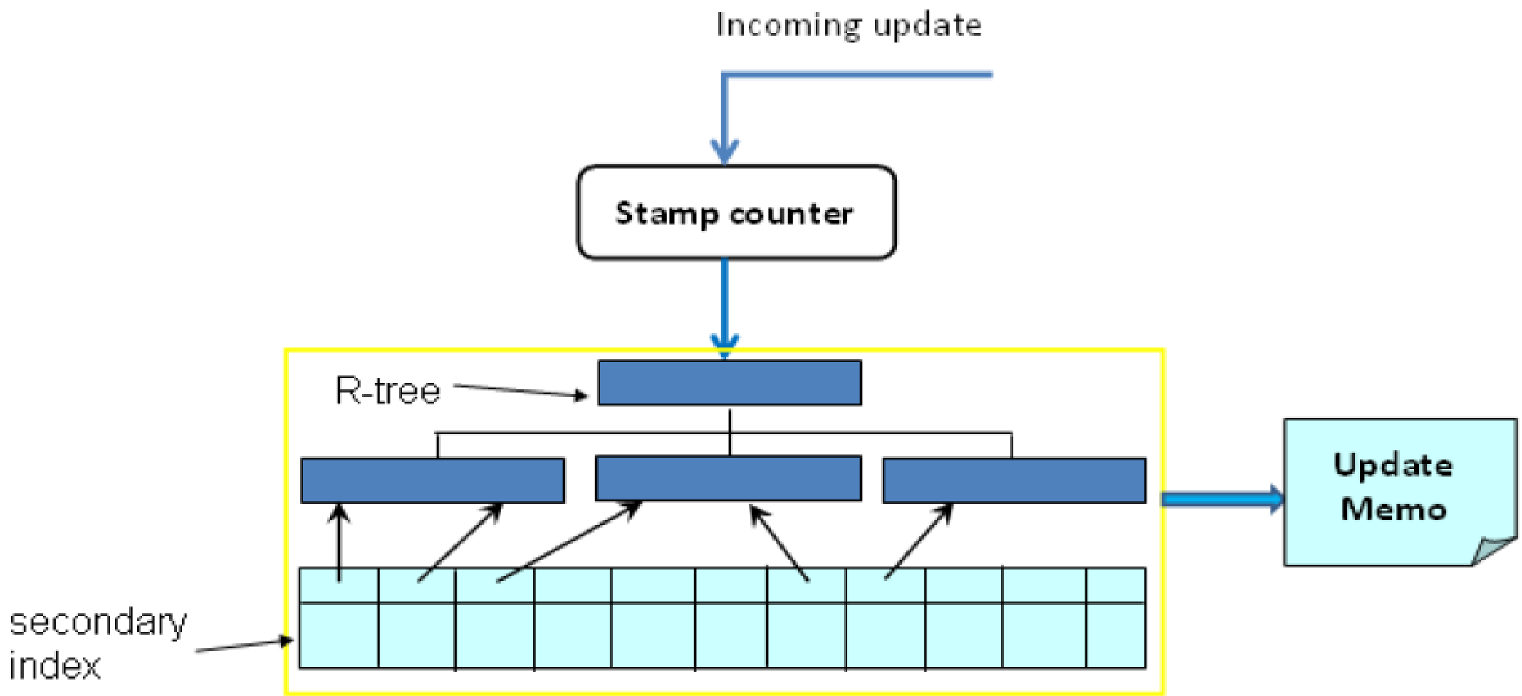


Fig. 2. Structure of RUM+-tree

- Hash Table(with Obj ID) + Update Memo

RUM+-tree

- Hash Table(with Obj ID)
- -> directly locate objects

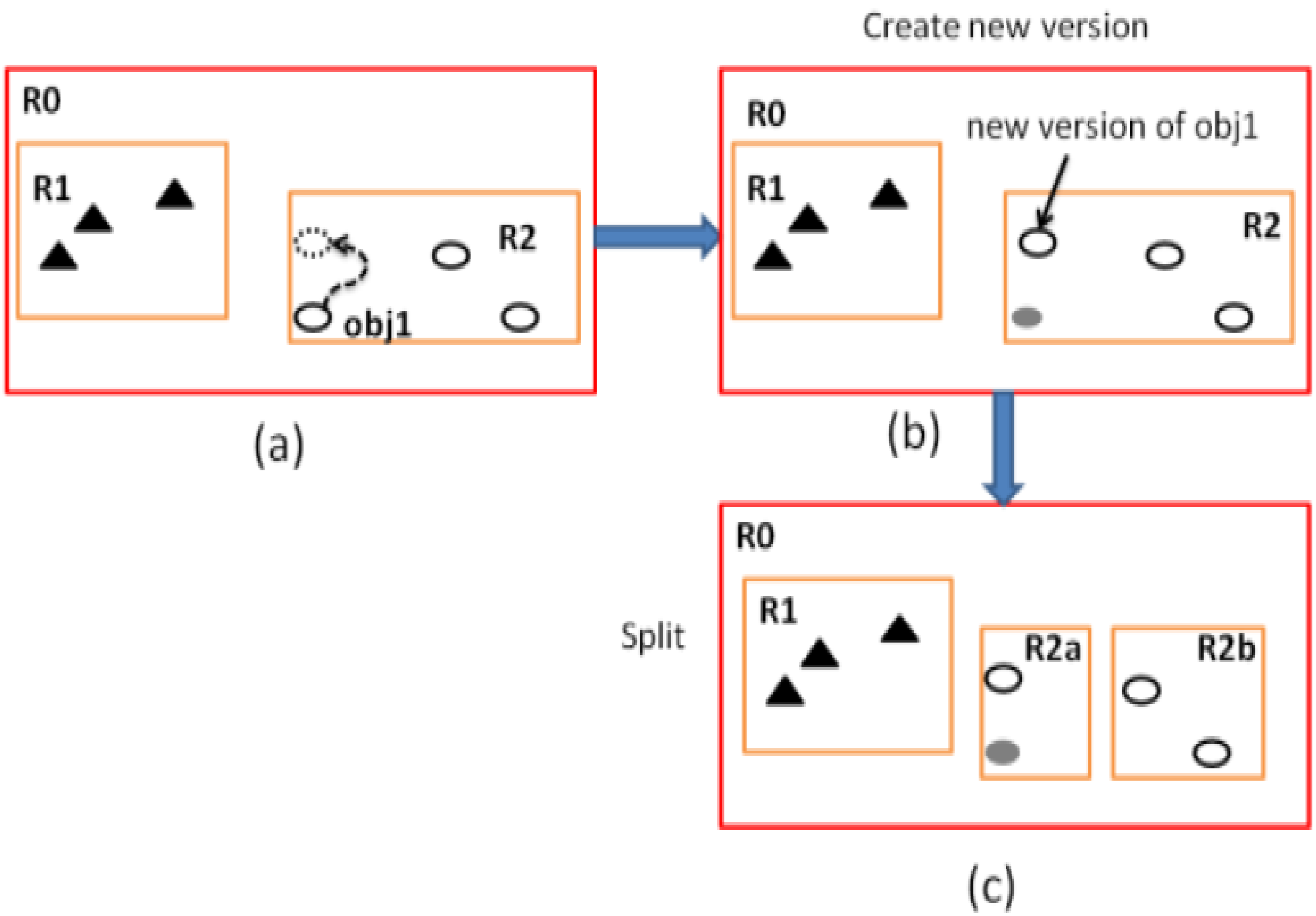
- Update Memo
- -> cache the costly modification

RUM+-tree

- With Update Memo
- Update:
  - Cheap one -> do
  - Costly -> cache

Lazy Update + Batch -> Avoid Frequent split/merge

RUM+-tree



Create new version
R0
R1
R2
obj1
(a)
R0
new version of obj1
R1
R2
(b)
Split
R0
R1
R2a
R2b
(c)

RUM+-tree

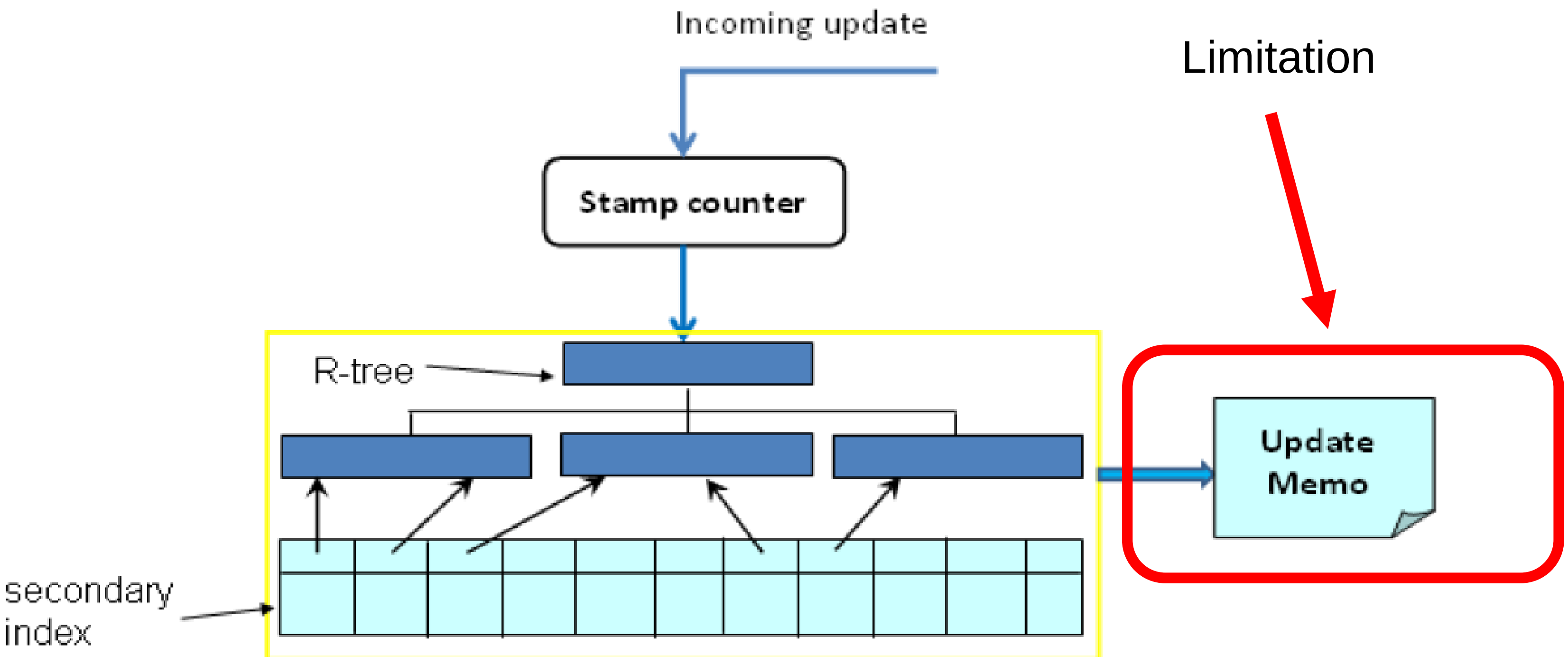


Fig. 2. Structure of RUM+-tree

DIME: Disposable Index for Moving Objects

- Do not modify the index at all!

DIME: Disposable Index for Moving Objects

- Do not modify the index at all!

- Modify the index ->
- Detach a whole chunk of the index

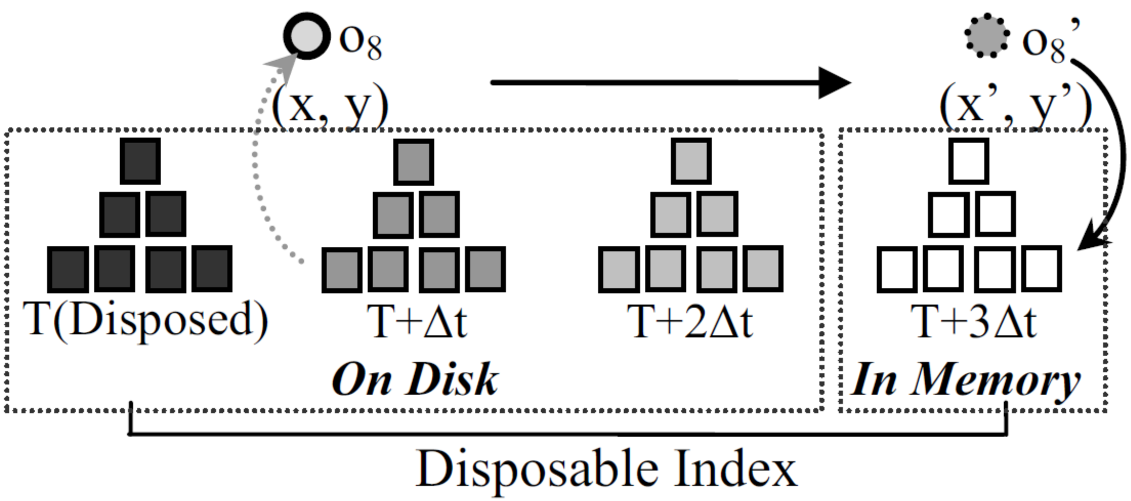


Fig. 2 Location Update on Disposable Index

DIME

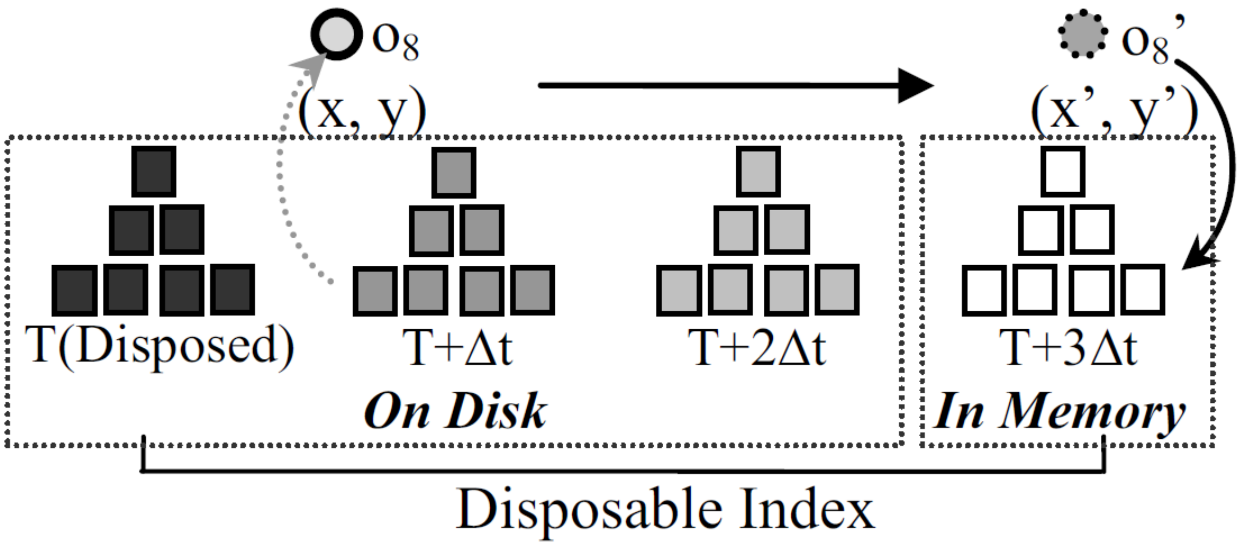
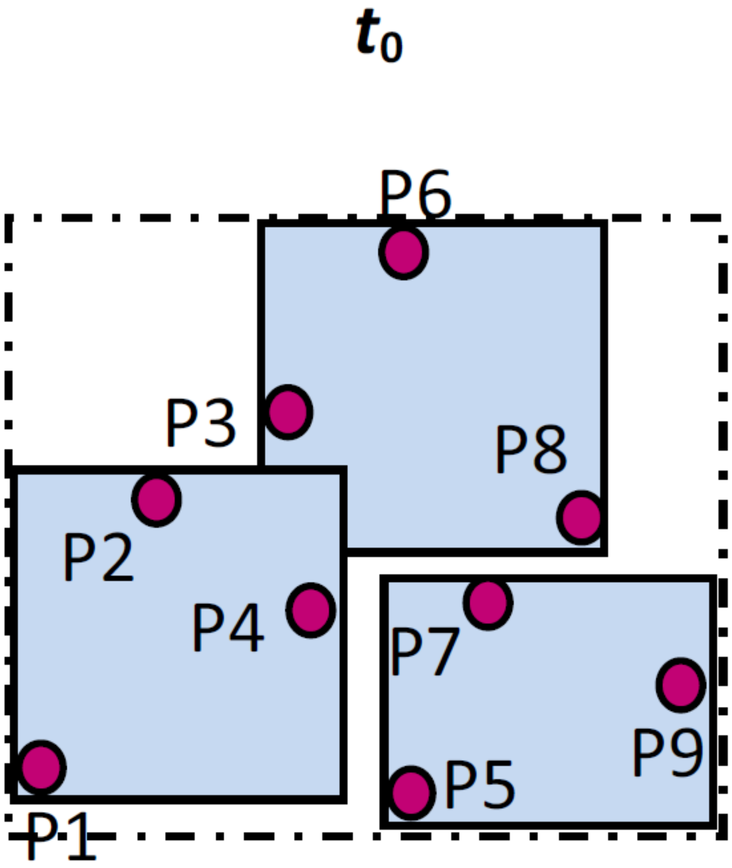


Fig. 2 Location Update on Disposable Index

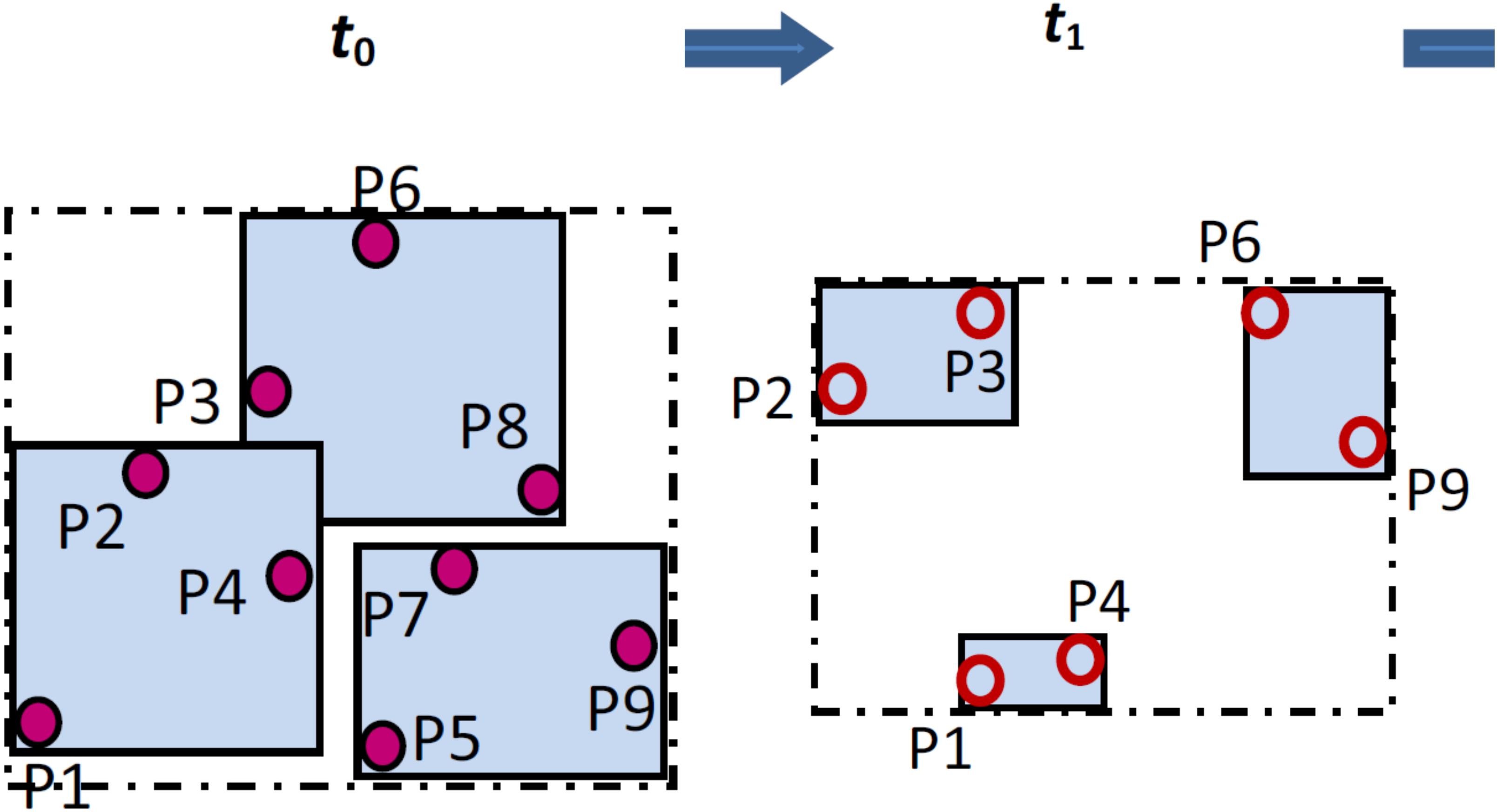
TABLE I. TERMS AND NOTATIONS

Concept	**Expression**	**Description**
Maximum time interval	Δt_{mn}	Maximum time interval for moving objects to update locations
Phase	$\Delta t = \Delta t_{mn}/n$	Time interval to construct an indexing component
Component	C_t	Indexing component constructed by timestamp t
Lifetime	$Lt = (n+1)*\Delta t$	Time period from constructing an indexing component to disposing it

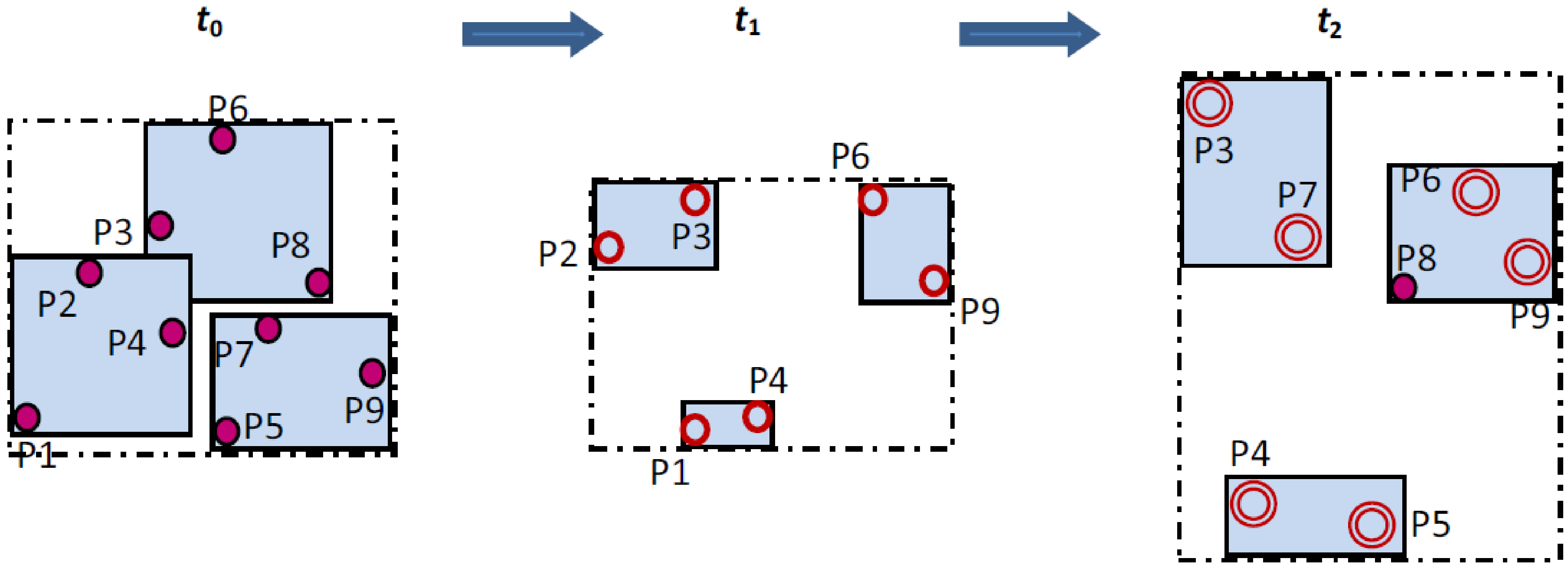
DIME



DIME



DIME



- n equals to 2.
- At t2, the components of t0 need to be disposed

Indexing the Future

Yongyi Liu

Indexing the Future Based on Underlying Road-Network

“Predictive Tree: An Efficient Index for Predictive Queries on Road Networks”

Challenges

-functional limitations

1.distance measure

2.training data

3.flexibility

-performance deficiencies

The implementation system

-iRoad Sytem Architecture

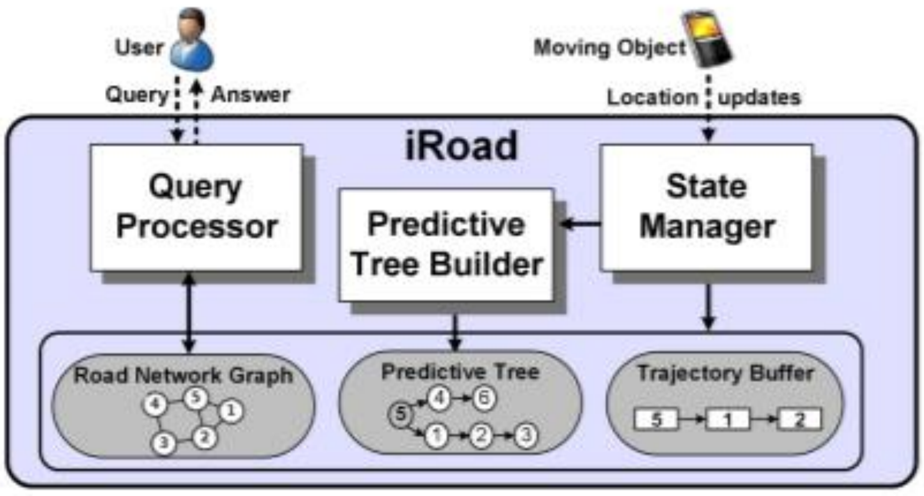
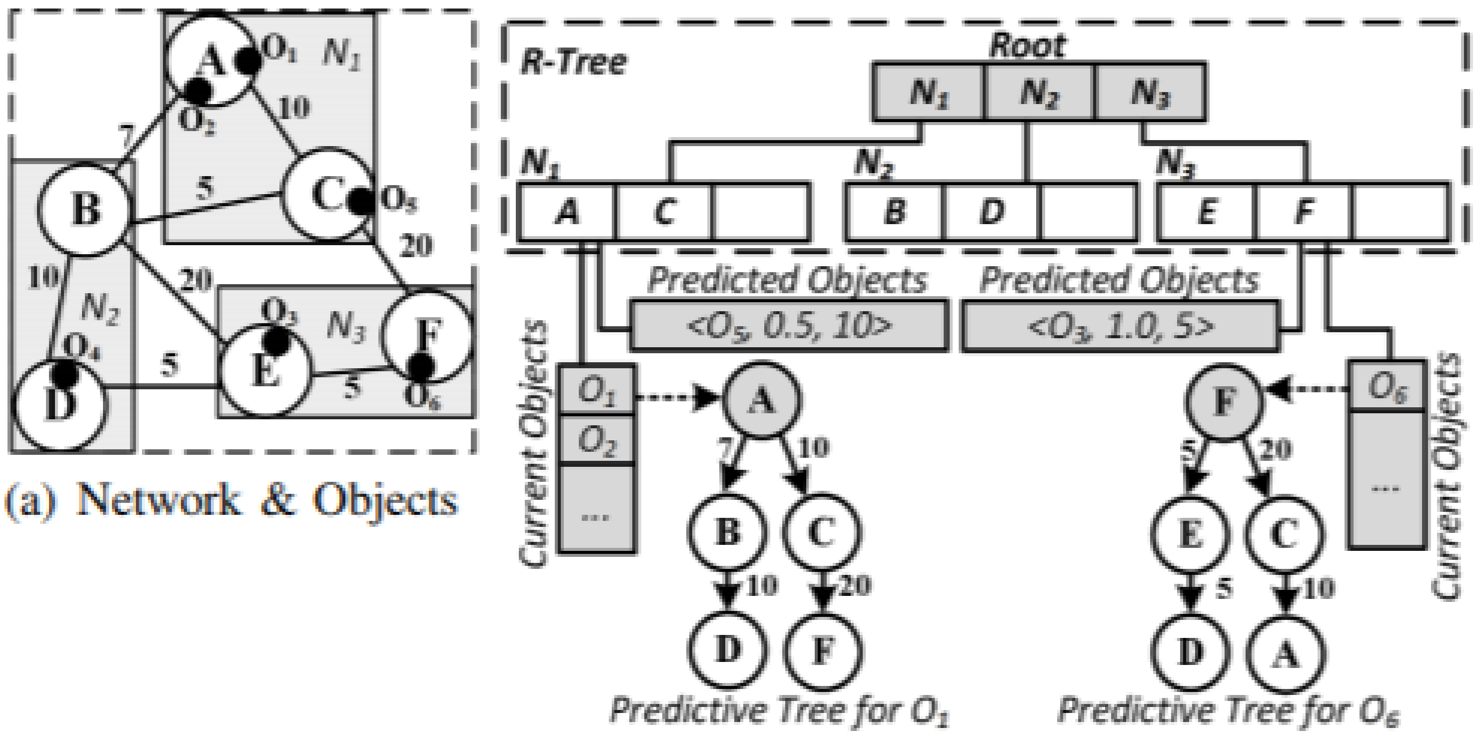


Fig. 1. iRoad System Architecture

State Manager: R-tree , trajectory buffer , predictive tree

Predictive Tree builder:the moving object's trajectory buffer, the moving object's current predictive tree, the tunable parameters

Query processor



(a) Network & Objects

(b) Predictive Trees Integrated With R-Tree

Fig. 2. Example Of The Proposed Index Structure

Predictive Tree Construction

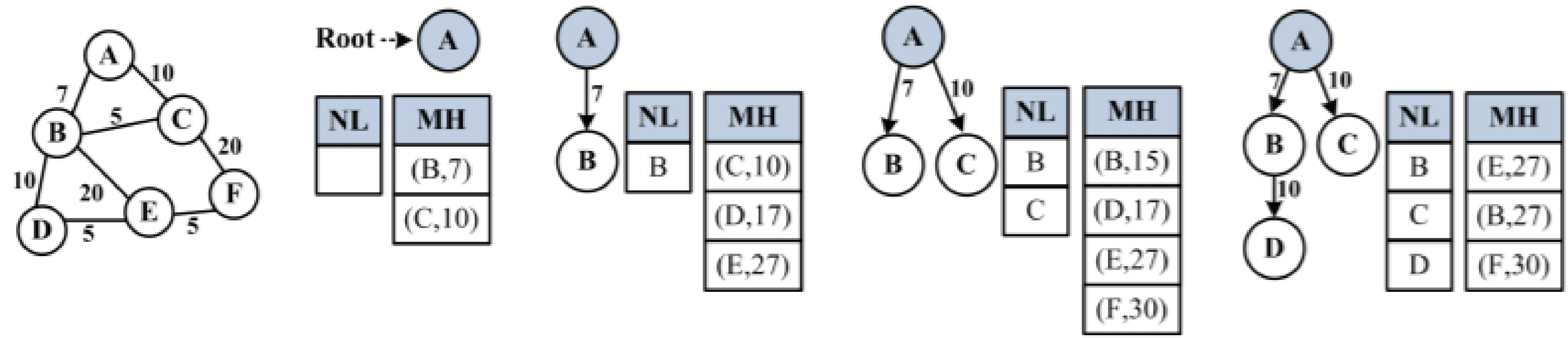
- **Initialization**

visited nodes list: record nodes processed so fa

min-heap:order the nodes based on distance to the root

- **Expansion**

continuously pop the root from the min-heap and expand the predictive tree



(a) Road Network (b) Initialize Tree (c) Expand B (d) Expand C (e) Expand D

Fig. 4. Example of Constructing And Expanding The Predictive Tree Started At Node A.

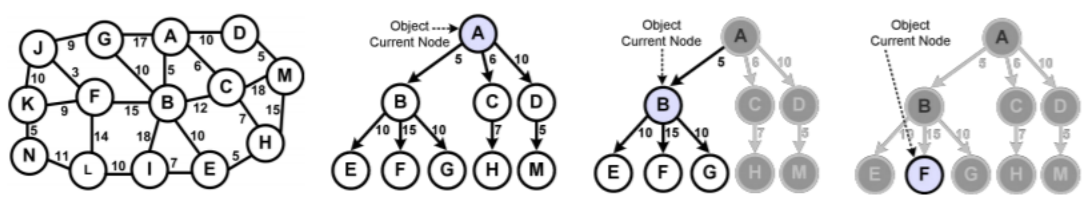
Initialization

Expansion

Predictive Tree Maintenance

Main Idea:

update the root and prune the unnecessary part



(a) Given Road Network (b) Trip Start (c) Tree Pruning (d) No More Children

Fig. 5. Demonstration Example For An Object Trip And Predictive Tree Maintenance

basic query and extensions

- predictive point query

  -to find out the moving objects with their corresponding probabilities that are expected to be around a specified query node in the road network within a future time period

extension to range queries, aggregate queries, KNN