Continuous Monitoring of Nearest Neighbors on Land Surface

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Outline

VLDB '09

- ☑ Motivation
- ❑ Related Work
- ❑ Preliminaries
- ❑ Surface Index based Approach
- ❑ Performance Evaluation
- ❑ Conclusion and Future Work

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Motivation

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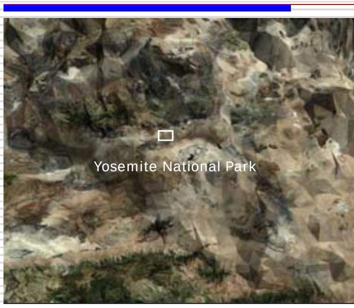

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Motivation

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Motivation

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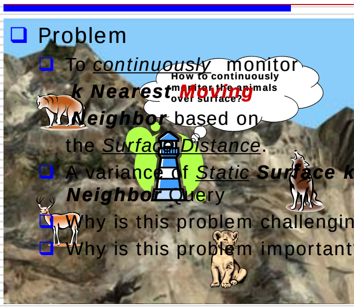

- ❑ Problem
  - ❑ To *continuously* monitor ***k Nearest Moving Neighbor*** based on the *Surface Distance*.
  - ❑ A variance of *Static **Surface k Nearest Neighbor*** Query
  - ❑ Why is this problem challenging?
  - ❑ Why is this problem important?

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Motivation

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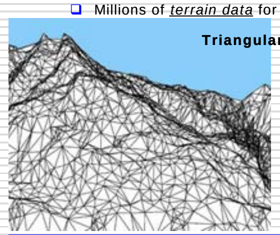
- ❑ Why is this problem challenging?
  - ❑ Huge size of surface model
    - ❑ Millions of *terrain data* for a region of 10km×10km



Triangular Meshes

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Motivation

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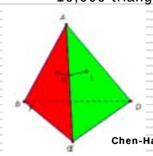
- Why is this problem challenging?
  - Huge size of surface model
    - Millions of *terrain data* for a region of 10km×10km
  - Costly surface distance computation
    - Tens of minutes on a modern PC for a terrain of 10,000 triangular meshes



Chen-Han Algorithm: O(n²)

* **Shortest paths on a polyhedron**: CHEN, J., HAN, Y., Computational Geometry 1990

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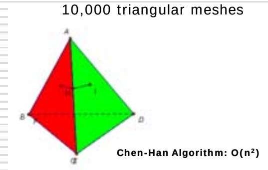

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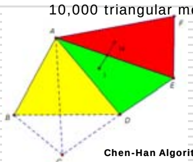
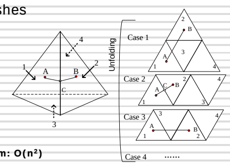


Chen-Han Algorithm: O(n²)



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Motivation

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- Why is this problem challenging?
  - Huge size of surface model
    - Millions of *terrain data* for a region of 10km×10km
  - Costly surface distance computation
    - Tens of minutes on a modern PC for a terrain of 10,000 triangular meshes
  - No efficient surface index structure for moving objects
    - Shortest Path Tree on road network can not apply
    - Existing Surface index structures are designed for static environment

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Motivation

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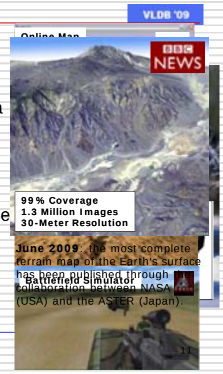
- Why is this problem important?
  - The availability of the data (imagery, elevation) of Earth surface at very high resolution
  - The quick geo-realistic rendering of terrain surface on the computer display (e.g., Google Earth™)
  - The prevalence of GPS equipped sensors



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Motivation

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Related Work

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Spatial Database
↓
kNN Query Processing
↓
Euclidean Space | Road Networks | Surface

- Conventional kNN
- Reverse kNN
- Time-aware kNN
- Visible kNN

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Related Work

VLDB '09

Spatial Database
↓
kNN Query Processing
↓
Euclidean Space | Road Networks | Surface

- Conventional kNN
- Reverse kNN
- Time-aware kNN
- Visible kNN

- ✓ NN Query: Roussopoulos et al., SIMGOD 1995
- ✓ Influences Set: Korn et al., SIMGOD 2000
- ✓ Efficient Method for Maximizing Bichromatic Reverse Nearest Neighbor: Wong et al., VLDB 2009
- ✓ Continuous NN Search: Tao et al,. VLDB 2002
- ✓ Lazy Updates : Cheema et al,. VLDB 2009
- ✓ VkNN Query: Nutanong et al., DASFAA 2007

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Related Work

VLDB '09

Spatial Database
↓
kNN Query Processing
↓
Euclidean Space | **Road Networks** | Surface

- Conventional kNN
- Reverse kNN
- Time-aware kNN

- ✓ Query Processing in SNDB : Papadias et al., VLDB 2003
- ✓ V-based kNN in SNDB: Shahabi et al., VLDB 2004
- ✓ Scalable Network Distance Browsing in Spatial Databases: Samet et al., SIGMOD 2008
- ✓ RNN in Large Graphs: Yiu et al., TKDE 2006
- ✓ CNN Monitoring in RN: Mouratidis et al., VLDB 2006

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Related Work

VLDB '09

Spatial Database
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kNN Query Processing
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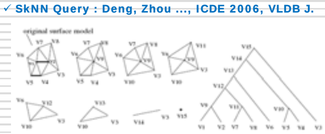
Euclidean Space | Road Networks | **Surface**

- Conventional kNN

- ✓ SkNN Query : Deng, Zhou ..., ICDE 2006, VLDB J.



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Related Work

VLDB '09

Spatial Database
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kNN Query Processing
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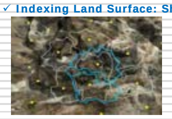
Euclidean Space | Road Networks | **Surface**

- Conventional kNN

- ✓ SkNN Query : Deng, Zhou ..., ICDE 2006, VLDB J.
- ✓ Indexing Land Surface: Shahabi et al., VLDB 2008



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Preliminaries

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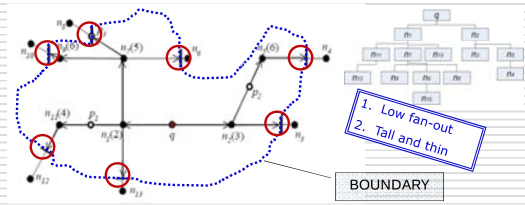
- Continuous nearest neighbor monitoring in road networks (Mouratidis et al, VLDB 06)
  - Shortest Path Spanning Tree (Dijkstra Tree)



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Preliminaries

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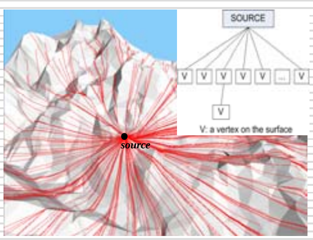
- Surface Expansion Tree (SE Tree)



- Observation 1: SE Tree is fat and short.
- Observation 2: These shortest surface paths rarely share common edges.
- Observation 3: These shortest surface paths do not cross each other.

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Preliminaries

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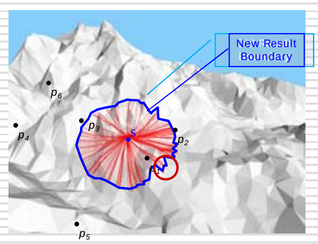
- Continuous Monitoring (k = 3)



- More incoming objects
  - Original Result Boundary contains more than k objects
  - Identify the kth object and shrink the result boundary

Preliminaries

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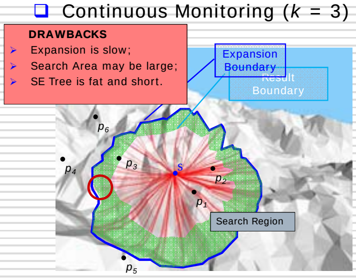
- Continuous Monitoring (k = 3)



- More outgoing objects
  - Original Result Boundary contains less than k objects
  - Compute the Expansion Boundary
  - Expand SE tree to Expansion boundary and identify the kth object inside the search area

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Surface Index based Approach

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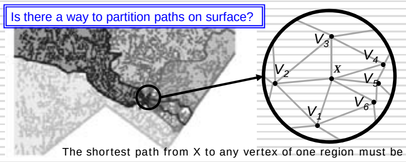
- Intuition
  - Motivated by *Partitioning* Shortest Paths on road networks
    - Scalable Network Distance Browsing in Spatial Databases: Samet et al., SIGMOD 2008 (best paper award)

Is there a way to partition paths on surface?



The shortest path from X to any vertex of one region must be inside that region.

Surface Index based Approach

VLDB '09

- Intuition
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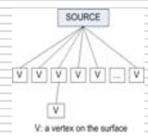
    - Scalable Network Distance Browsing in Spatial Databases: Samet et al., SIGMOD 2008 (best paper award)



Surface Index based Approach

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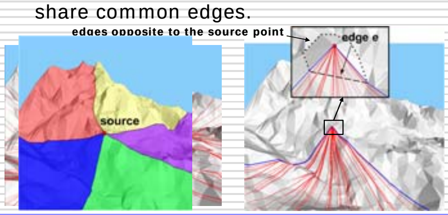
- Surface Shortest Path Container
  - Built based on the Observations that shortest paths do not cross each other and hardly share common edges.



Surface Index based Approach

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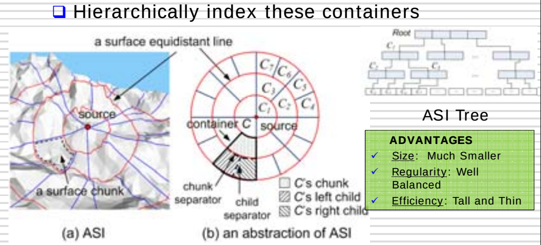
- Angular Surface Index (ASI)
  - Hierarchically index these containers



(a) ASI (b) an abstraction of ASI

Surface Index based Approach

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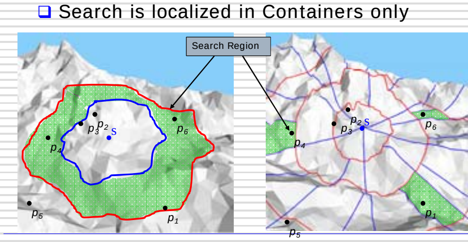
- Query Processing
  - The core is the same as using SE Tree
  - Search is localized in Containers only



Surface Index based Approach

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- More Details
  - Definitions/Properties of Containers, Equidistance Line and ASI-tree
    - Please refer to Section *5.1, 5.2 and 5.3* in the paper.
  - Constructions of Containers
    - Please refer to Section *5.1.2* in the paper.
  - Algorithms for Query Processing
    - Please refer to Section *5.4* in the paper.

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Performance Evaluation

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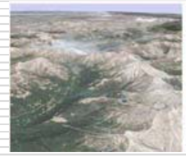
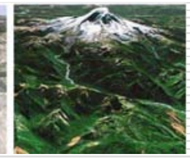
- Real World Dataset http://data.geocomm.com
  - Eagle Peak (EP) at Wyoming State, USA
    - 10.7km×14km.
  - Bearhead (BH) at Washington State, USA
    - Similar size as above.



Eagle Peak (EP)



Bearhead (BH)

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Performance Evaluation

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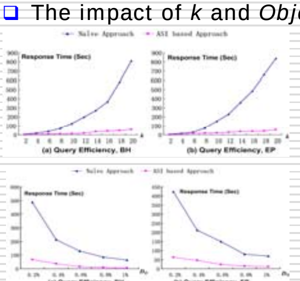
- The impact of *k* and *Object Density*



OBSERVATIONS

- The ASI based Algorithm has a much better performance .
- Response Time increases as the value of *k* increases.
- Response Time decreases as the object density increases.

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Performance Evaluation

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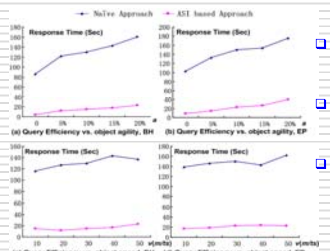
- The impact of *Object Agility* and *Speed*



OBSERVATIONS

- The ASI based Algorithm has a much better performance .
- Response Time increases as the object agility increases.
- Response Time remains almost unaffected with the object speed.

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Performance Evaluation

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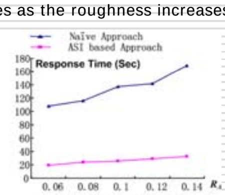
- Synthetic Dataset
  - Create terrains while varying the roughness
    - Response Time increases as the roughness increases.

(a) Roughness = 0.05

(b) Roughness = 0.1



(b) Query Efficiency vs. R_A

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- The Naïve Approach
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Conclusion and Future Work

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- Contribution
  - First study the Continuous *k*NN query on Surface;
  - Show the concept of expansion tree for land surface does not work as SE-tree suffers from intrinsic defects: it is fat and short;
  - Propose a superior approach that partitions SE-Tree into hierarchical chunks of pre-computed surface distances which overcome the above deficiency.
  - Experimentally verify the applicability of proposed methods
- Future work
  - Study the Continuous *k*NN query problem for arbitary moving query point.

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Thanks!

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