CSEG601 & CSE5601
Spatial Data Management & Application :

Continuous Nearest Neighbor Query Processing using R-tree

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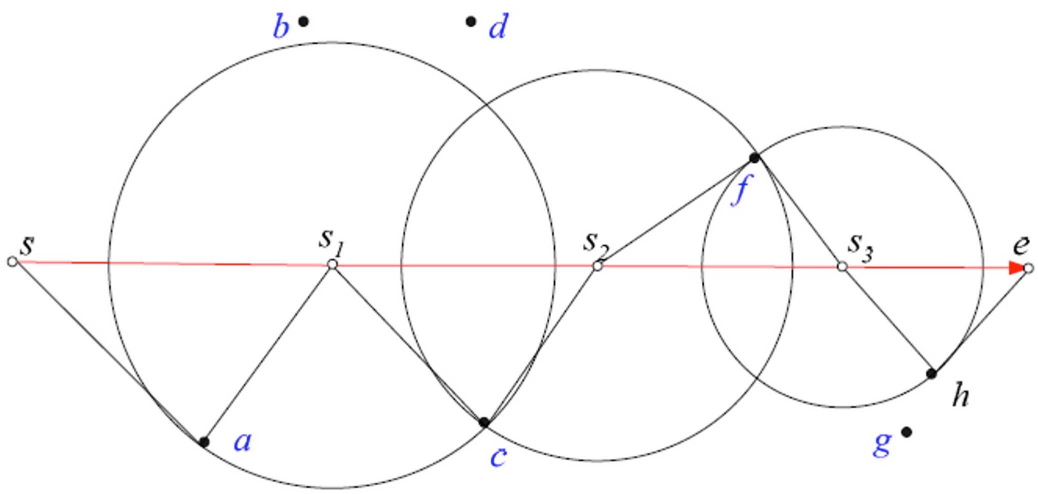
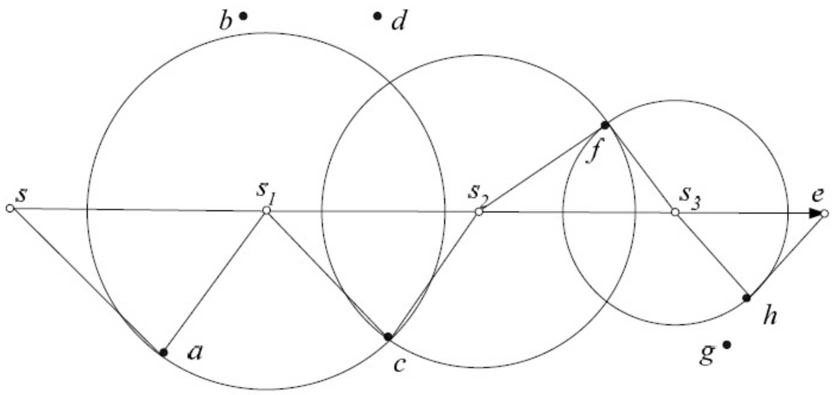
Problem: Continuous Nearest Neighbor



Data: A set of points
Query: A line segment $q=[s, e]$
Result: The nearest neighbor (NN) of *every* point on q.
Result representation: $\{s(.NN=a), s_1(.NN=c), s_2(.NN=f), s_3(.NN=h), e\}$

Goal

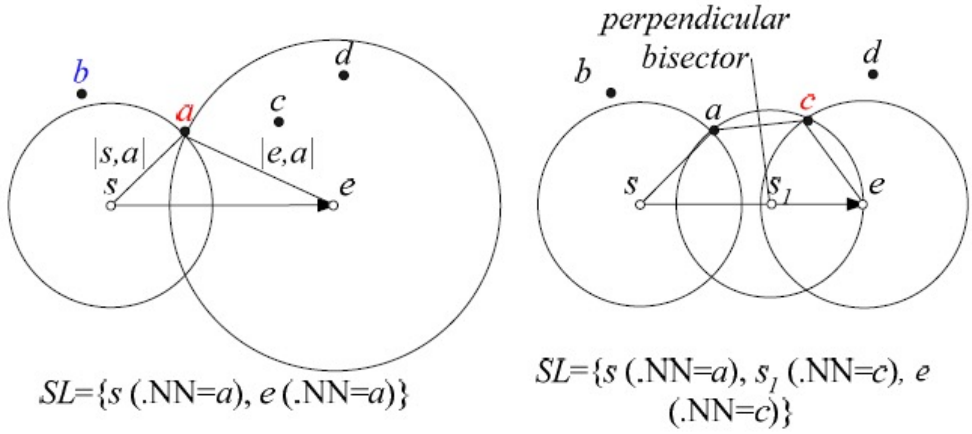


Find all *split points* s_1, s_2, s_3 (as well as the corresponding NN for each partition) *with a single traversal of the dataset.*

Term1: The set of split points (including s and e) constitute the *split list*.
Term2: The circle that centers at split point s_i with radius $dist(s_i, s_i.\text{NN})$ is the *vicinity circle* of s_i.
Term3: We say a data point u *covers* a point s if u=s.NN. E.g., points a, c, f, h *cover* segments $[s, s_1]$, $[s_1, s_2]$, $[s_2, s_3]$, $[s_3, e]$.

Lemma 1

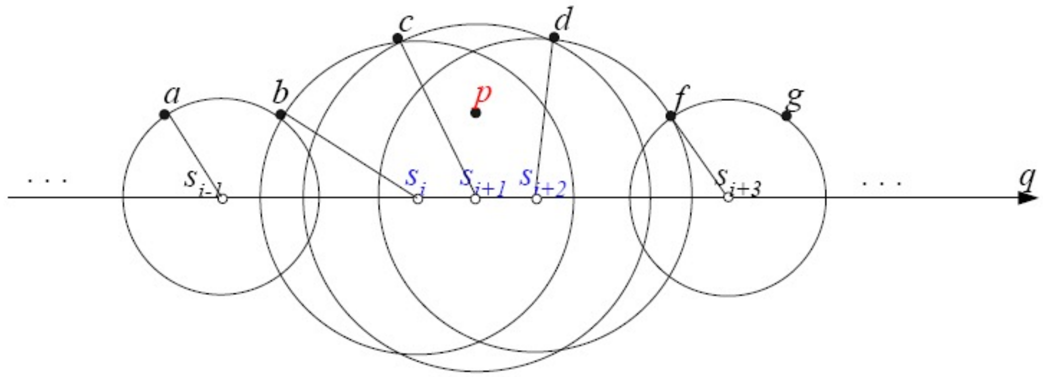
Given a split list SL $\{s_0, s_1, \ldots, s_{|SL-1|}\}$, and a new data point p, then: p covers some point on query segment q if and only if p covers a split point.



After processing a After processing c

Lemma 2 (Covering Continuity)

The split points covered by a point p are continuous.
Namely, if p covers split point s_i but not s_{i-1} (or s_{i+1}), then p cannot cover s_{i-j} (or s_{i+j}) for any value of $j>1$.



$SL=\{s_{i-1}$ (.NN=a), s_i (.NN=b), s_{i+1} (.NN=c), s_{i+2} (.NN=d), s_{i+3} (.NN=f)$\}$

Algorithm with R-trees Overview

Use branch-and-bound techniques to prune the search space.

<u>When a leaf entry (i.e., a data point) p is encountered</u>
SL is updated if p covers any split point (i.e., p is a *qualifying entry*) – By Lemma 1.

<u>For an intermediate entry</u>
We visit its subtree only if it may contain any qualifying data point – Use heuristics.

Heuristic 1

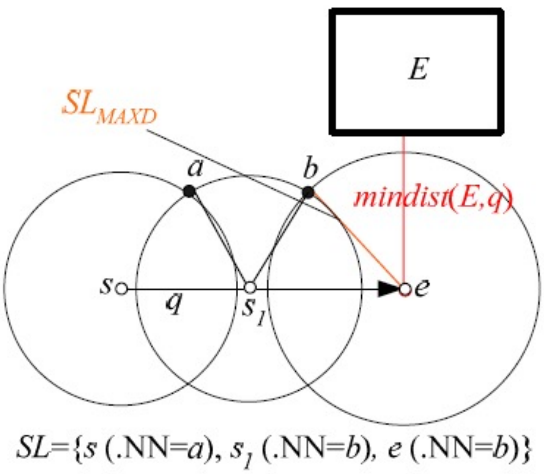
Given an intermediate entry E and query segment q, the subtree of E may contain qualifying points only if

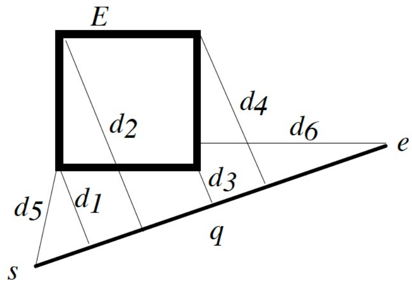
$mindist(E,q) < SL_{MAXD}$,

where

$mindist(E,q)$ denotes the minimum distance between the MBR of E and q

SL_{MAXD} is the maximum distance between a split point and its NN.



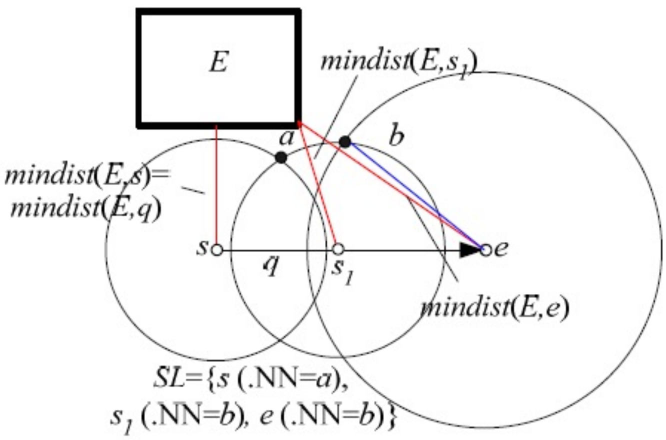


(b) Computing *mindist*

Heuristics 2

Given an intermediate entry E and query segment q, the subtree of E must be searched *if and only if*

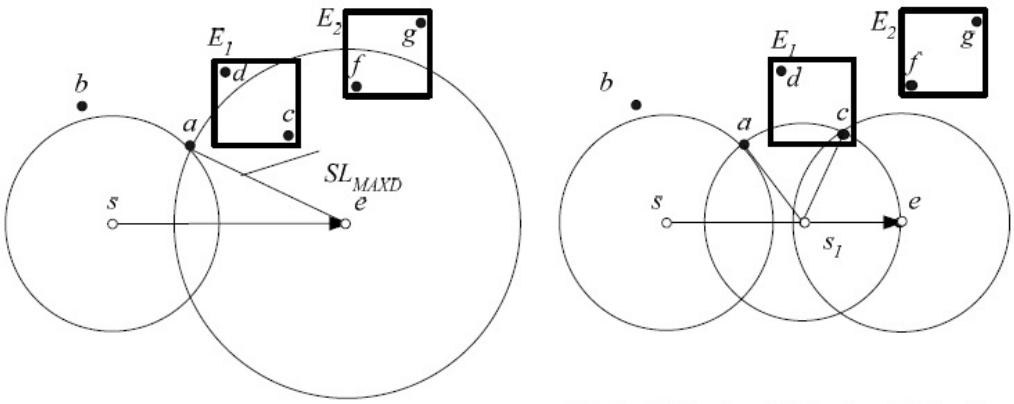
there exists a split point $s_i \in$ SL such that $dist(s_i, s_i.\text{NN}) > mindist(s_i, E)$.



Heuristic 2 requires mindist computation between E and all split points. Hence it is applied only if E passes heuristic 1, which requires only one computation.

Heuristics 3 (Access Order)

Entries (satisfying heuristics 1 and 2) are accessed in increasing order of their minimum distances to the query segment q.



$SL=\{s\ (.NN=a),\ e\ (.NN=a)\}$ Before processing E_1

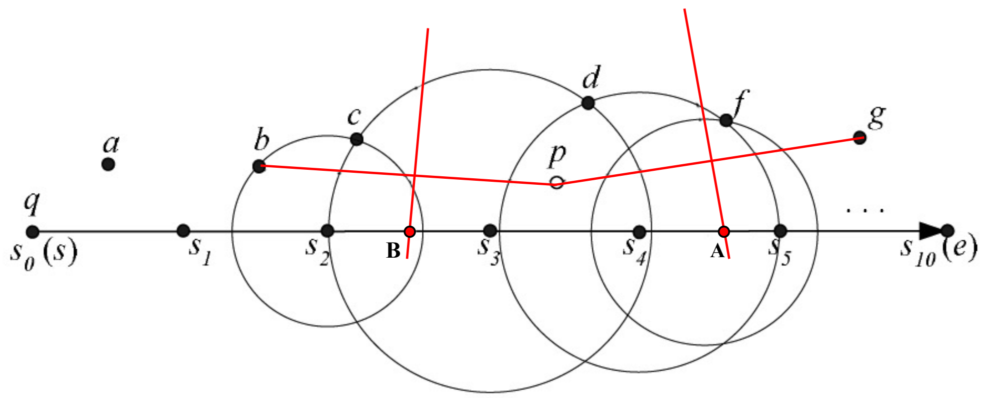
$SL=\{s\ (.NN=a),\ s_1\ (.NN=c),\ e\ (.NN=c)\}$ After processing E_1

CNN Algorithms with R-trees

- When a leaf entry(i.e., a data point) p is encountered,
  1) Retrieves the set of split points $S_{COVERS}=\{s_i, s_{i+1}, \ldots, s_j\}$ covered by p.
  2) Updates SL accordingly if S_{COVERS} is not empty
- Use binary search
  – To avoid comparing p with all current NN for every split point.

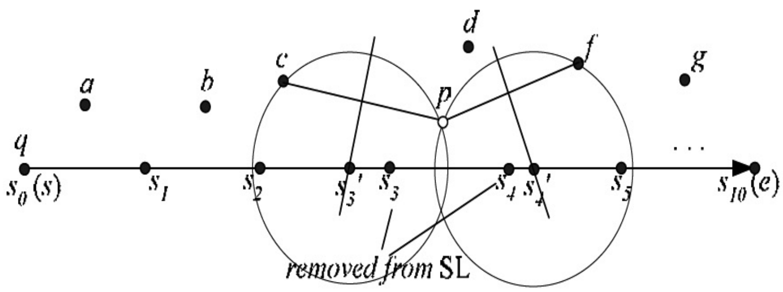
Find the split points covered immediately before and after s3.

$S_{COVERS}=\{s_3, s_4\}$



CNN Algorithms with R-trees

- When a leaf entry(i.e., a data point) p is encountered,
  1) Retrieves the set of split points $S_{COVERS}=\{s_i, s_{i+1}, \ldots, s_j\}$.
  2) Updates SL

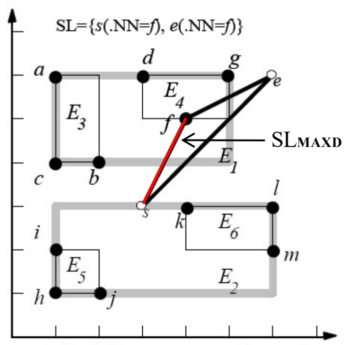


Algorithm Handle_Leaf_Entry
/**p*: the leaf entry being handled, SL: the split list*/
1. apply binary search to retrieve all split points covered by p: $S_{COVER}=\{s_i, s_{i+1}, \ldots, s_j\}$ → **Scover={s3, s4}**
2. let $u=s_{i-1}$.NN and $v=s_j$.NN → **u = s2.NN = c, v = s4.NN = f**
3. remove all split points in S_{COVER} from SL → **Remove s3, s4 from SL**
4. add a split point s_i' at the intersection of q and $\perp(u, p)$ with s_i'.NN=p, $dist(s_i', s_i'.\mathrm{NN})=|s_i', p|$ → **Add s3' at the intersection of q and ⊥(c, p)**
5. add a split point s_{i+1}' at the intersection of q and $\perp(v, p)$ with s_{i+1}'.NN=p, $dist(s_{i+1}', s_{i+1}'.\mathrm{NN})=|s_{i+1}', p|$ → **Add s4' at the intersection of q and ⊥(f, p)**

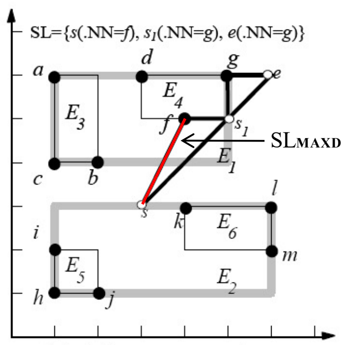
End Handle_Leaf_Entry

CNN Algorithms with R-trees

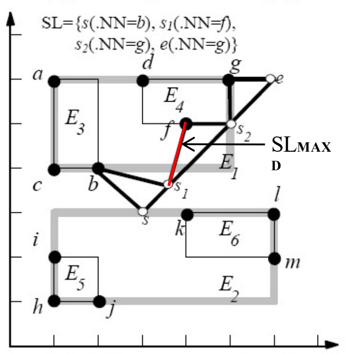
- Example of the CNN algorithm using depth-first traversal on the R-tree



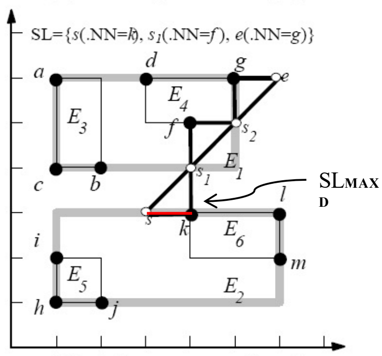
(a) After processing f



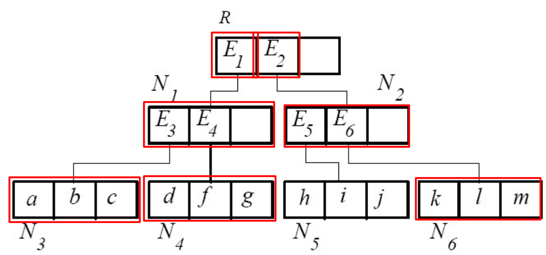
(b) After processing g



(c) After processing b



(d) After processing k



Result : {<k, [s,s$_1$]>, <f,[s$_1$,s$_2$]>, <g,[s$_2$,e]>}