Edge-Based Locality Sensitive Hashing for Efficient Geo-Fencing Applications

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Outline

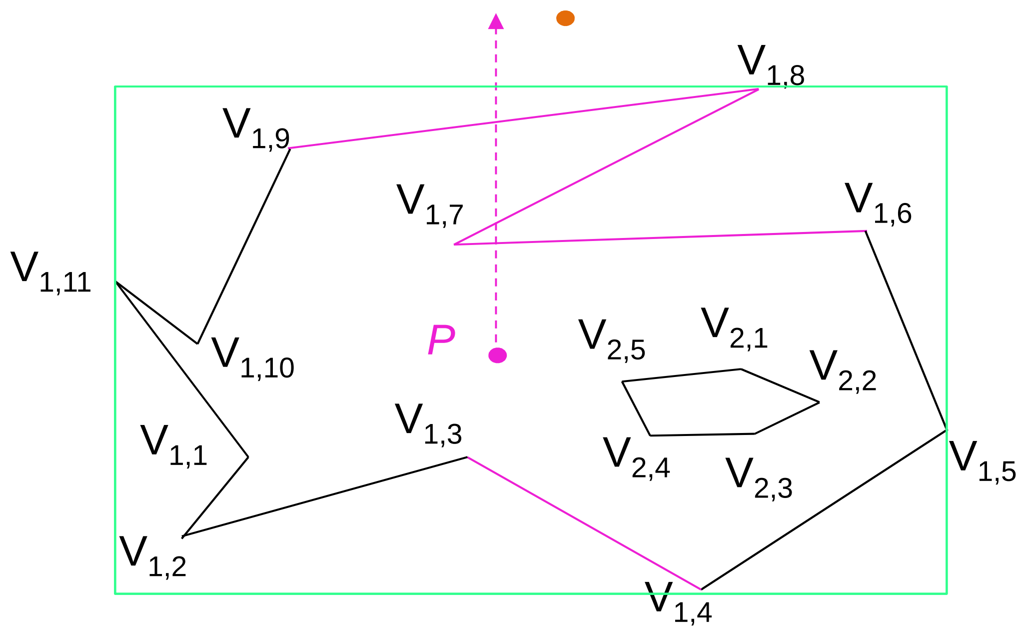
- Application and motivation of geo-fencing
  - Pairing a point with polygon: INSIDE/WITHIN
  - Crossing number algorithm and its scalability problem
- Proposed edge-based LSH algorithm
  - R-tree for pre-filtering
  - LSH for INSIDE, plus probing for WITHIN
  - Simple but effective and efficient
- Experimental results
- Conclusions

Motivation & Concepts: INSIDE

- Basis: Well-known crossing number algorithm
  - Inside **iff** number of intersections == odd
  - Requires checking each edge ⇒ inefficient

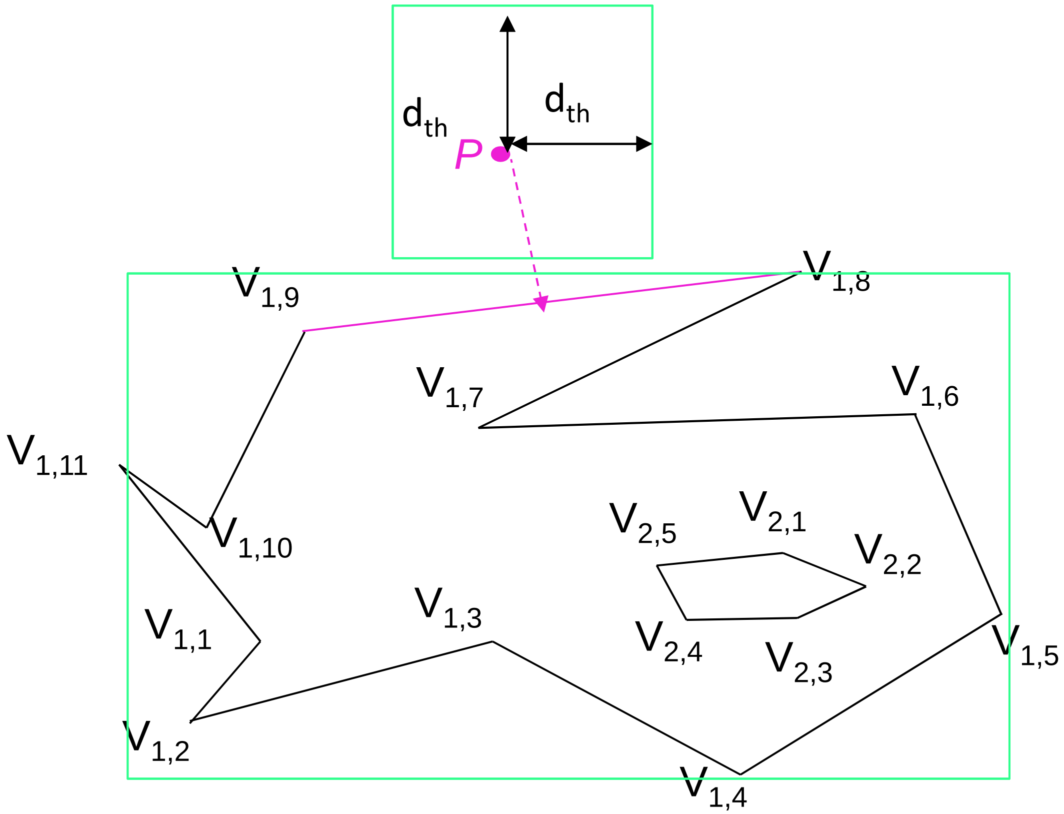
- Enhancements:
  1) Exploiting MBR for pre-filtering
  2) Locality-sensitive hashing (LSH) for further acceleration

MBR: minimum bounding rectangle

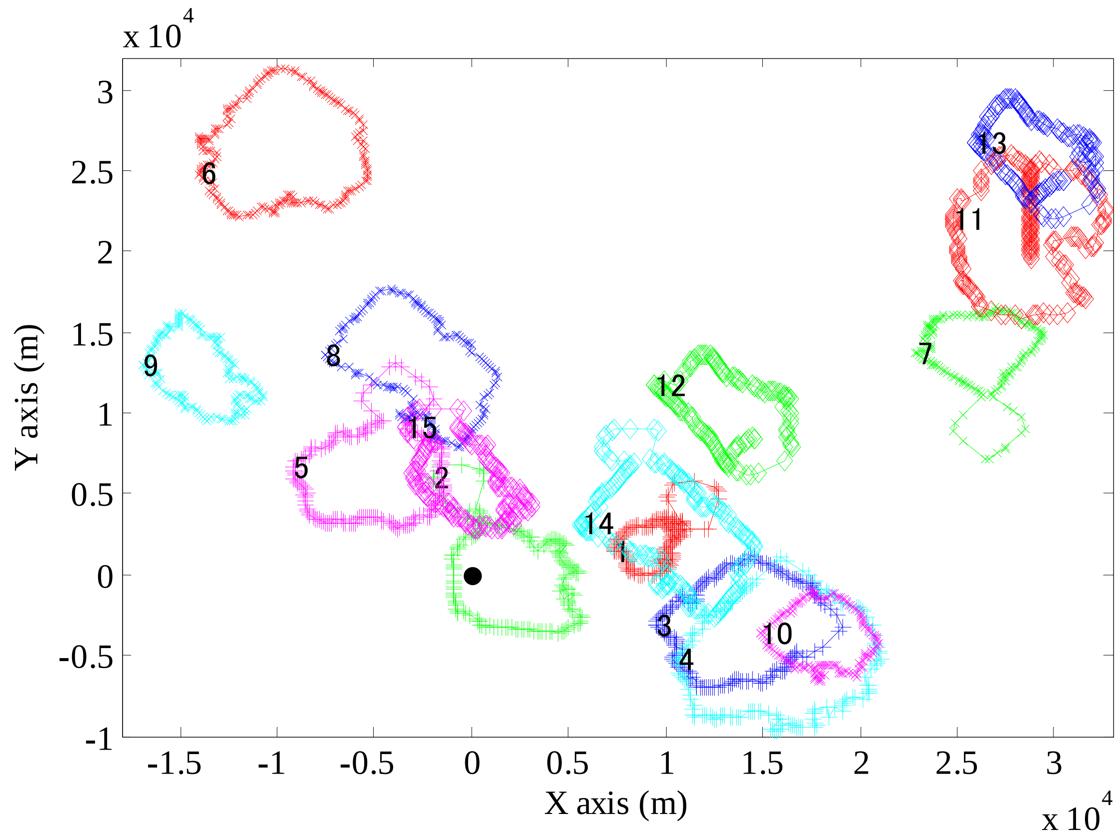


Motivation & Concepts: WITHIN

- Case: Point *P* outside of MBR but within a distance of d_{th}
  - A rectangle centered at *P*, edge length being two times d_{th}
    - If no overlap ⇒ point surely not WITHIN distance



Scalability: Polygons, Points, Edges



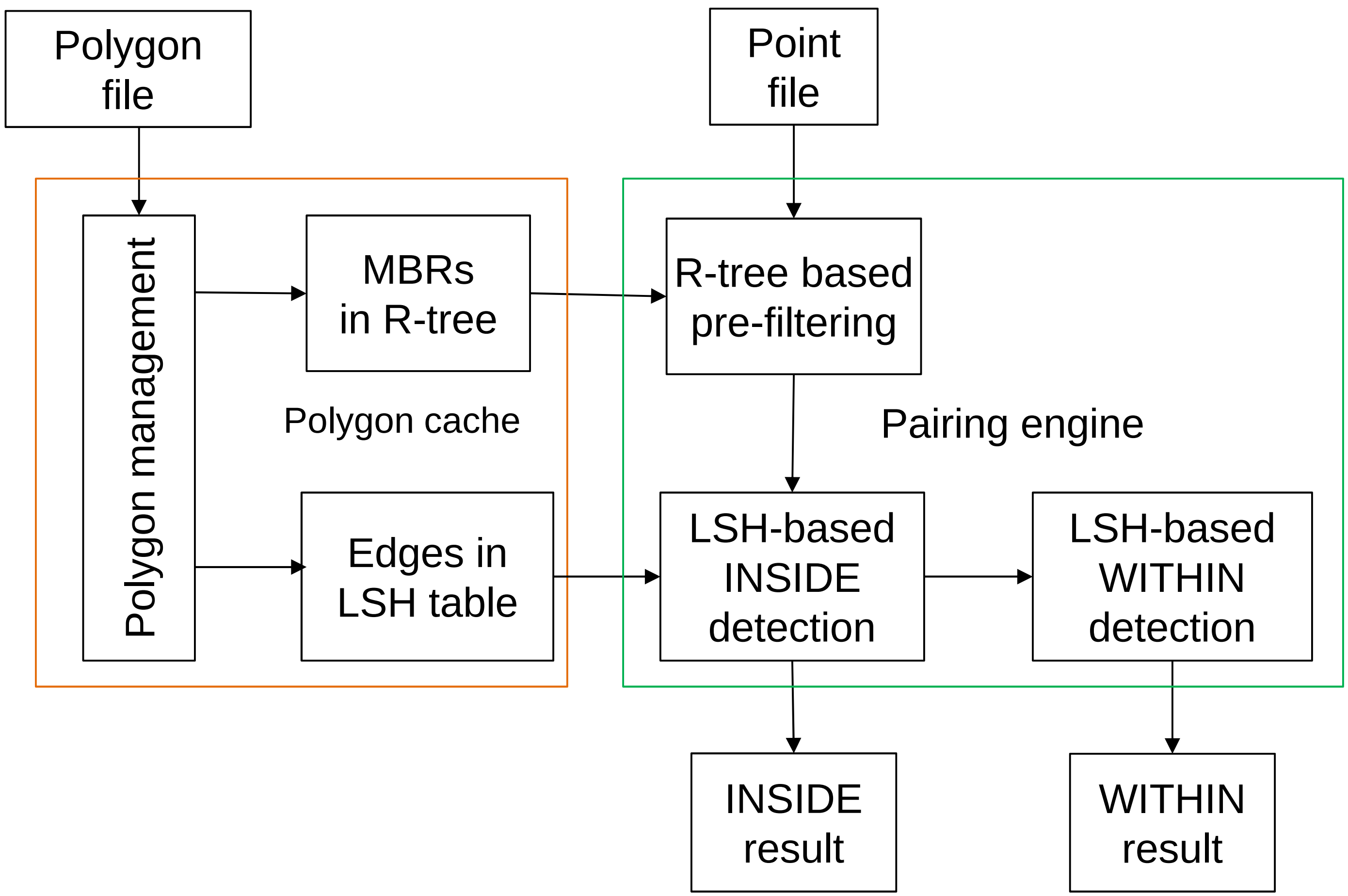
\# edges of 15 polygons

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
285	255	235	196	264	250	240	239	226	226	242	153, 15	152, 20	250	217

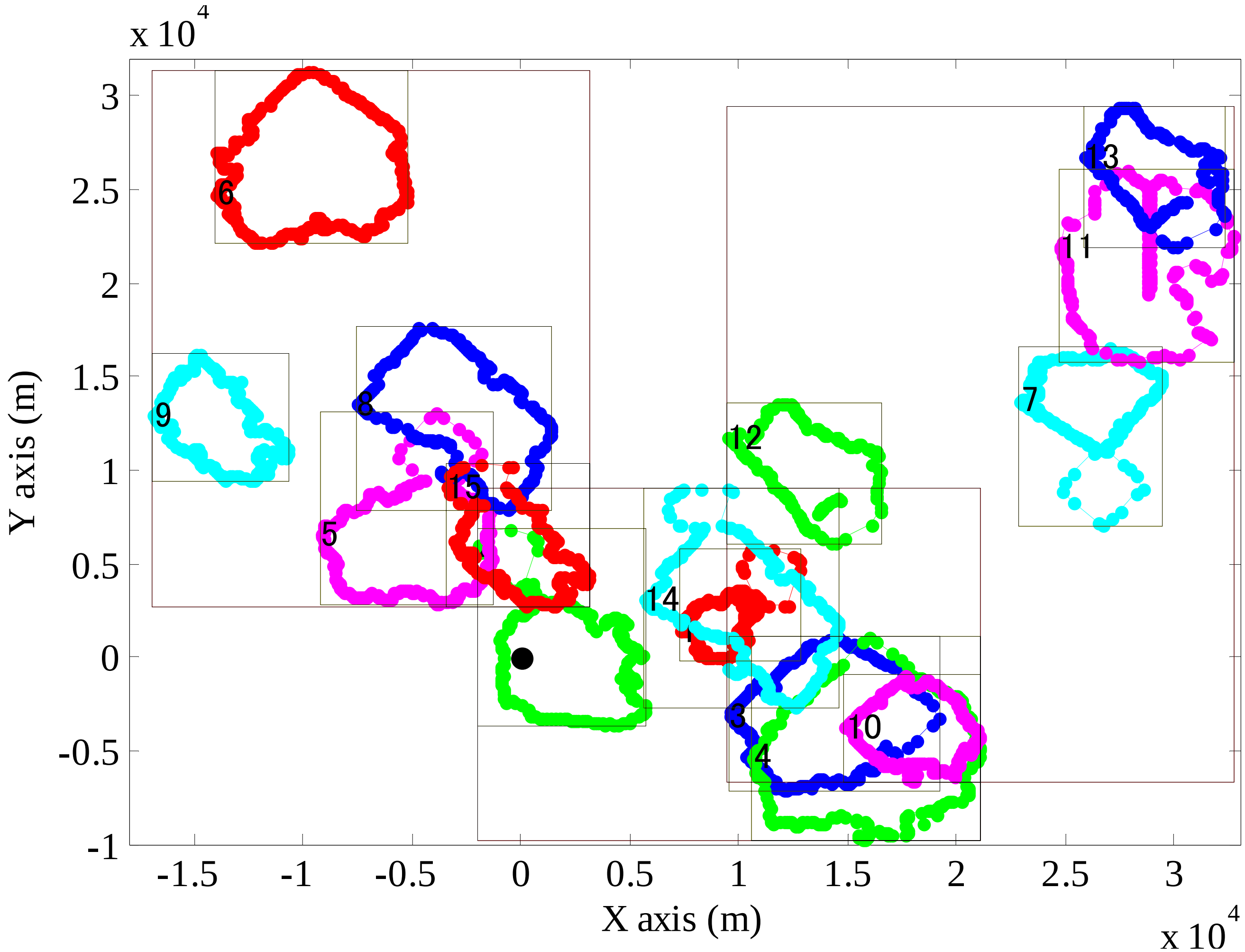
⇒ Problem: scalability with the number of edges

Efficient Geo-Fencing: Framework

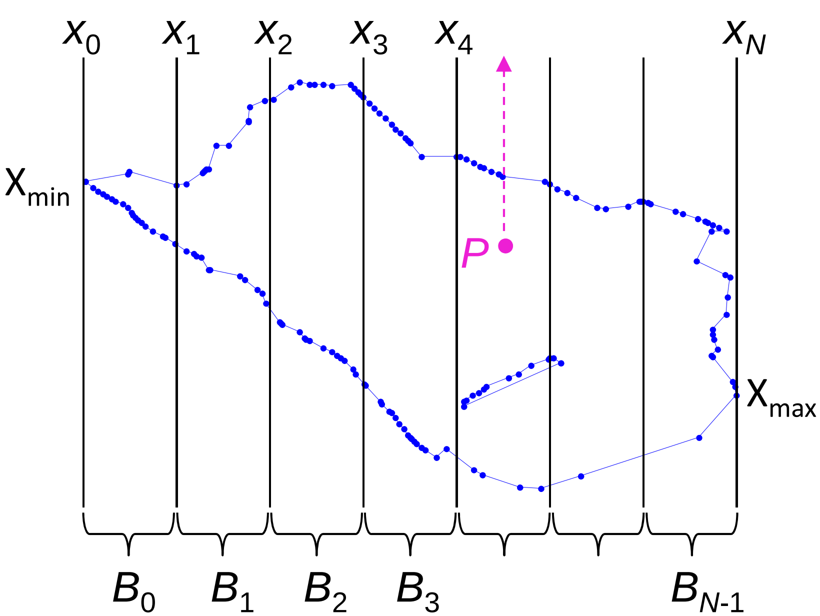
- Two stages
  1) R-tree-based pre-filtering
  2) LSH adapted to crossing number algorithm



Efficient Geo-Fencing: R-tree Based Pre-filtering



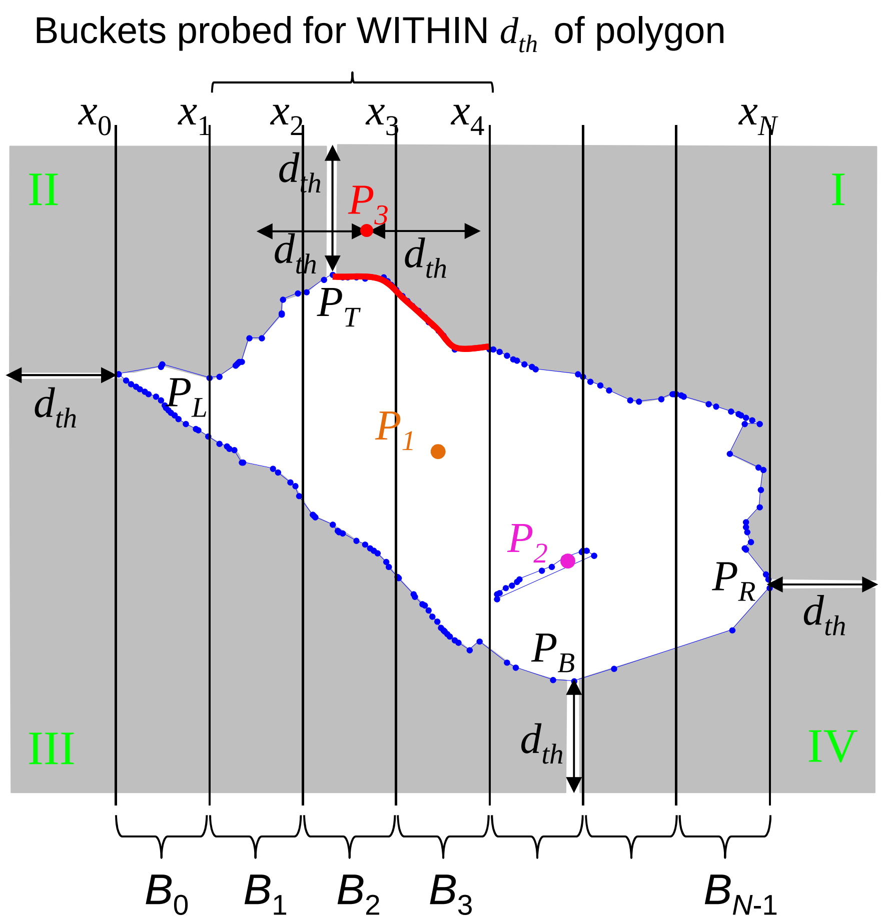
Efficient Geo-Fencing: INSIDE Detection



Hash table of edges

- A separate hash table for each polygon
- A fixed number of buckets, N, for each hash table
- Hash function
  - $T = (X_{max} – X_{min}) / N$
  - $HashKey(x) = int((x – X_{min})/T)$
- An edge (x1, y1)—(x2, y2) stored in buckets from key1 to key2,
  - key1=HashKey(x1), key2=HashKey(x2)

Efficient Geo-Fencing: WITHIN Detection



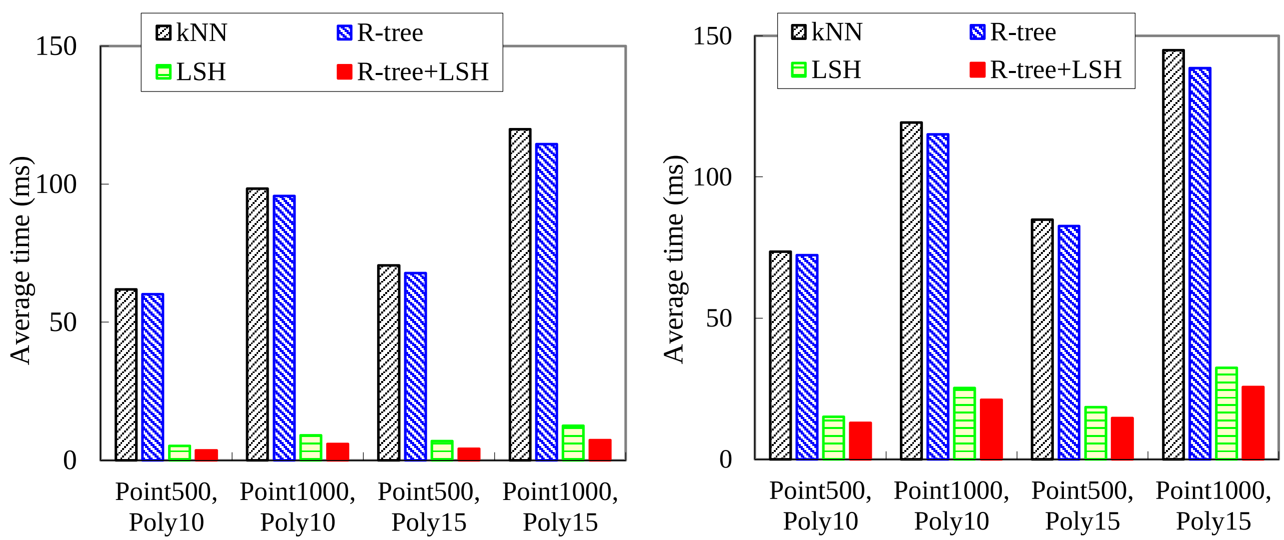
- LSH with multi-probing
  - Inside polygon • P_1
  - Inside inner ring • P_2
  - Outside outer ring • P_3
- Optimization P_3
  - Range of a point
  - Divide outer area into 4 ranges
  - Only check edge in the same range with the point

Geo-Fencing: Evaluation Setup

- Training dataset
  - Two point files: Point500 (39,289 instances), Point1000 (69,619 instances)
  - Two polygon files: Poly10 (30 instances), Poly15 (40 instances)
  - Ground truth available (different combinations of inputs and predicates)
- Two predicates
  - INSIDE & WITHIN 1000
  - Execution times without overhead (file I/O, data conversion)
  - Accuracy & efficiency (4 methods)
- Environment
  - A laptop PC (Intel Core i5 CPU, 64-bit Windows 7)

Geo-Fencing: Example Experiments

- 100% accuracy with test set
- Running time without system overhead
  - Measured via Windows **QueryPerformanceCounter()**: 100 runs
  - LSH+R-tree: Execution speed-up by 970% for INSIDE and by 370% for WITHIN



(a) INSIDE predicate

(b) WITHIN 1000 predicate

Other Optimizations

- Execution profiling showed that I/O processing required considerable time
  - Large amounts of text data needed to be read
- Therefore we applied several I/O optimizations
  - Reading data in larger blocks, not line-by-line
  - Writing pairing results in large blocks
  - Optimized number conversion: text-float to binary-float
  - Multi-threading
- Batch processing
  - Multiple points at a time, find candidate pairs for each polygon
  - Precise pairing for each polygon (CPU cache optimization)

Conclusions

- Different levels of approximation
  - Polygon as MBR: pre-filtering via R-tree
  - Edges in bucket: LSH
- LSH table per polygon
  - Compatible with R-tree
  - Fixed number of buckets, less affected by the distribution and shapes of polygons
- Simple, effective and efficient
  - 100% accuracy, high speed

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Thank You – Q&A

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