Applications of LSH

Entity Resolution

Fingerprints

Similar News Articles

Desiderata

- Whatever form we use for LSH, we want :
  1. The time spent performing the LSH should be linear in the number of objects.
  2. The number of candidate pairs should be proportional to the number of truly similar pairs.
- Bucketizing guarantees (1).

Entity Resolution

- The *entity-resolution* problem is to examine a collection of records and determine which refer to the same entity.
  - *Entities* could be people, events, etc.
- Typically, we want to merge records if their values in corresponding fields are similar.

Matching Customer Records

- I once took a consulting job solving the following problem:
  - Company A agreed to solicit customers for Company B, for a fee.
  - They then argued over how many customers.
  - Neither recorded exactly which customers were involved.

Customer Records – (2)

- Company B had about 1 million records of all its customers.
- Company A had about 1 million records describing customers, some of whom it had signed up for B.
- Records had name, address, and phone, but for various reasons, they could be different for the same person.

Customer Records – (3)

- Step 1: Design a measure ("*score*") of how similar records are:
  - E.g., deduct points for small misspellings ("Jeffrey" vs. "Jeffery") or same phone with different area code.
- Step 2: Score all pairs of records; report high scores as matches.

Customer Records – (4)

- Problem: (1 million)^2 is too many pairs of records to score.
- Solution: A simple LSH.
  - Three hash functions: exact values of name, address, phone.
    - Compare iff records are identical in at least one.
  - Misses similar records with a small differences in all three fields.

Aside: Hashing Names, Etc.

- How do we hash strings such as names so there is one bucket for each string?
- Possibility: Sort the strings instead.
  - Used in this story.
- Possibility: Hash to a few million buckets, and deal with buckets that contain several different strings.
- Note: these work for minhash signatures/ bands as well.

Aside: Validation of Results

- We were able to tell what values of the scoring function were reliable in an interesting way.
  - Identical records had a creation date difference of 10 days.
  - We only looked for records created within 90 days, so bogus matches had a 45-day average.

Validation – (2)

- By looking at the pool of matches with a fixed score, we could compute the average time-difference, say x, and deduce that fraction (45-x)/35 of them were valid matches.
- Alas, the lawyers didn't think the jury would understand.

Validation – Generalized

- Any field not used in the LSH could have been used to validate, provided corresponding values were closer for true matches than false.
- Example: if records had a height field, we would expect true matches to be close, false matches to have the average difference for random people.

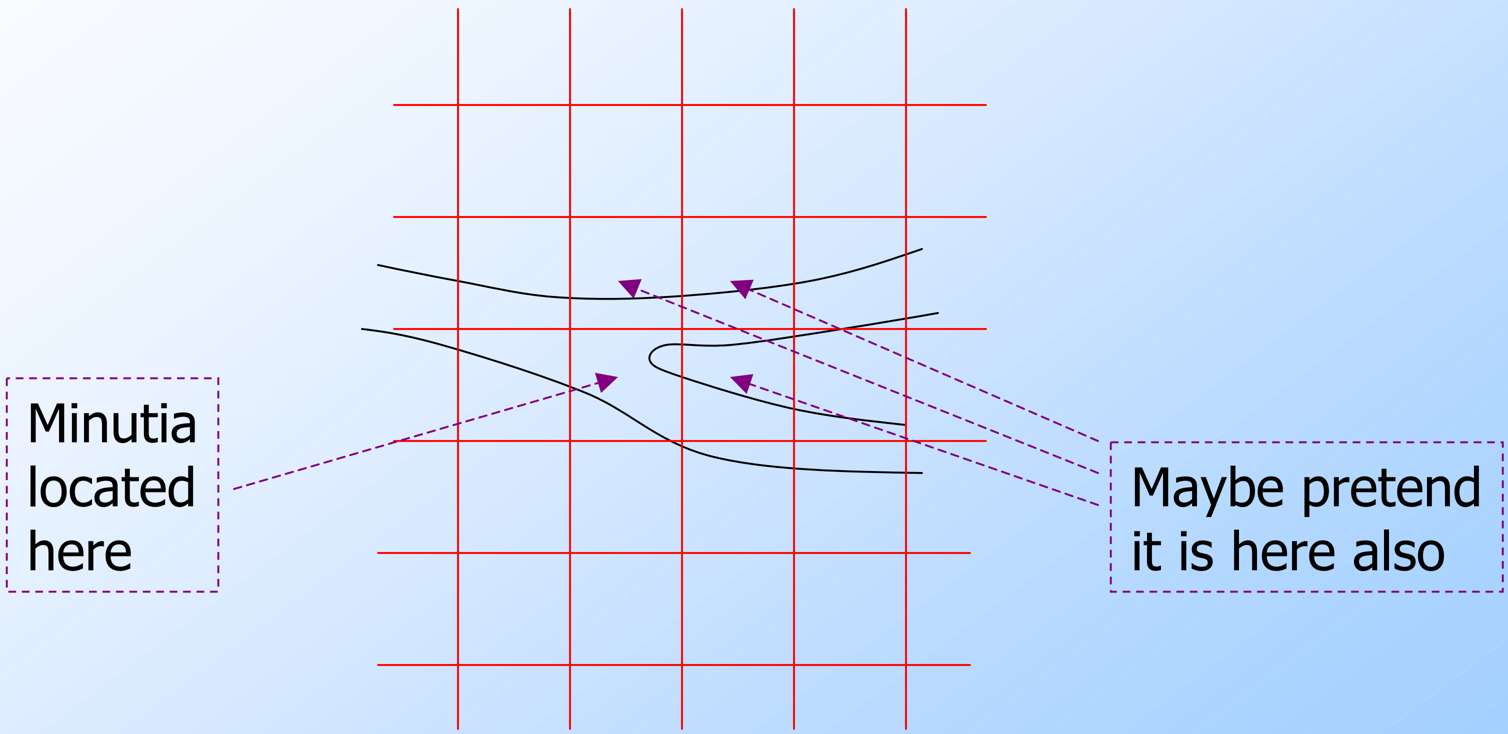
Fingerprint Comparison

- Represent a fingerprint by the set of positions of *minutiae*.
  - These are features of a fingerprint, e.g., points where two ridges come together or a ridge ends.

LSH for Fingerprints

- Place a grid on a fingerprint.
  - Normalize so identical prints will overlap.
- Set of grid points where minutiae are located represents the fingerprint.
  - Possibly, treat minutiae near a grid boundary as if also present in adjacent grid points.

Discretizing Minutiae



Applying LSH to Fingerprints

- Make a bit vector for each fingerprint's set of grid points with minutiae.
- We could minhash the bit vectors to obtain signatures.
- But since there probably aren't too many grid points, we can work from the bit-vectors directly.

LSH/Fingerprints – (2)

- Pick 1024 (?) sets of 3 (?) grid points, randomly.
- For each set of points, prints with 1 for all three points are candidate pairs.
  - Funny sort of ‘bucketization.”
    - Each set of three points creates one bucket.
    - Prints can be in many buckets.

Example: LSH/Fingerprints

- Suppose typical fingerprints have minutiae in 20% of the grid points.
- Suppose fingerprints from the same finger agree in at least 80% of their points.
- Probability two random fingerprints each have 1 in all three points = $(0.2)^6$ = .000064.

Example: Continued

First image has 1 in a point

Second image of same finger also has 1.

- Probability two fingerprints from the same finger each have 1's in three given points = $(\boxed{(0.2)}\boxed{(0.8)})^3$ = .004096.
- Prob. for at least one of 1024 sets of three points = $1-(1-.004096)^{1024}$ = .985.
- But for random fingerprints: $1-(1-.000064)^{1024}$ = .063.

1.5% false negatives

6.3% false positives

Application: Same News Article

- Recently, the Political Science Dept. asked a team from CS to help them with the problem of identifying duplicate, on-line news articles.
- Problem: the same article, say from the Associated Press, appears on the Web site of many newspapers, but looks quite different.

News Articles – (2)

- Each newspaper surrounds the text of the article with:
  - It's own logo and text.
  - Ads.
  - Perhaps links to other articles.
- A newspaper may also "crop" the article (delete parts).

News Articles – (3)

- The team came up with its own solution, that included shingling, but not minhashing or LSH.
  - A special way of shingling that appears quite good for this application.
  - LSH substitute: candidates are articles of similar length.

Enter LSH – (1)

- I told them the story of minhashing + LSH.
- They implemented it and found it faster for similarities below 80%.
  - Aside: That's no surprise. When similarity is high, there are better methods, as we shall see.

Enter LSH – (2)

- Their first attempt at LSH was very inefficient.
- They were unaware of the importance of doing the minhashing row-by-row.
- Since their data was column-by-column, they needed to sort once before minhashing.

New Shingling Technique

- The team observed that news articles have a lot of stop words, while ads do not.
  - "Buy Sudzo" vs. "I recommend that you buy Sudzo for your laundry."
- They defined a *shingle* to be a stop word and the next two following words.

Why it Works

- By requiring each shingle to have a stop word, they biased the mapping from documents to shingles so it picked more shingles from the article than from the ads.
- Pages with the same article, but different ads, have higher Jaccard similarity than those with the same ads, different articles.