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Trajectory Matching Using SRTM Elevation Data

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Abstract

Locational services typically require a large collection of existing infrastructure which represent multiple potential points of failure. Their use can also commonly be detected and disrupted or simply blocked by geography. Therefore, it is advantageous to produce a system which leverages static data to reduce both communication and reliance on infrastructure to determine location. Such an approach is to match relative movement along a trajectory in three dimensions with available global elevation information.

Data

- Relative trajectory consisting of 3 axes
  - Sequential series of measurements
  - Easily acquired through various means
- Shuttle Radar Topography Mission provides near-global digital elevation data
  - Coverage from 56°S - 60°N
  - Up to 1 meter resolution
  - Publicly available

Approach

The SRTM tiles contain absolute locations and elevations and the path contains relative location and elevation. From this one can leverage a process similar to dead reckoning to perform a brute-force search described in Algorithm 1. It is presently implemented as a web application allowing for the searching of the area featured in Figure 1. A visualization can be seen in figure 2.

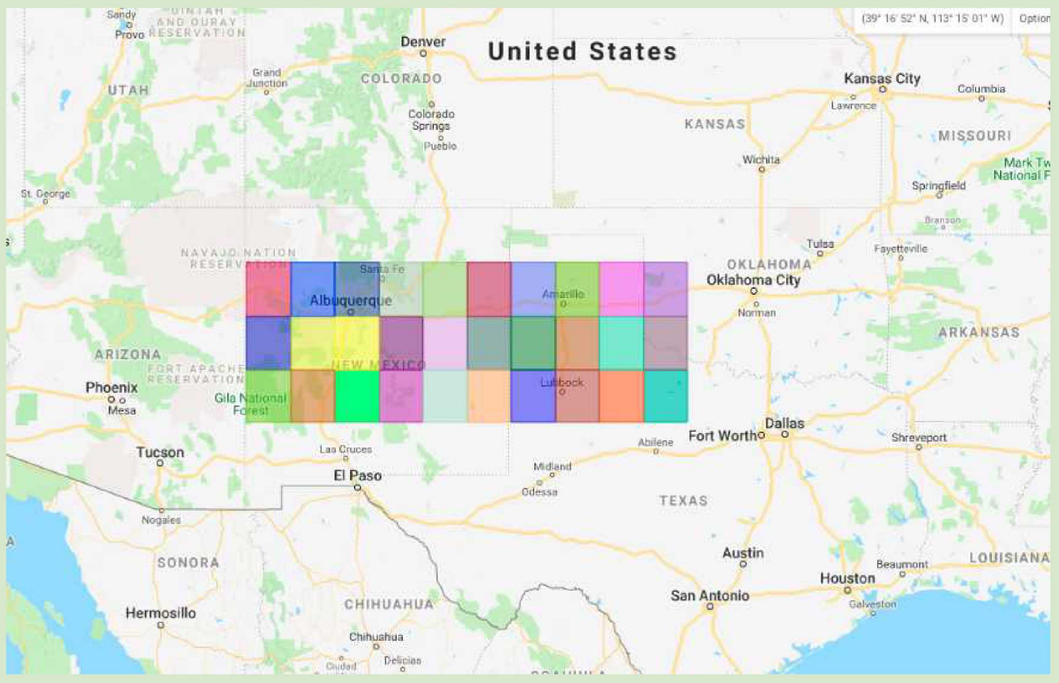

Figure 1. *Current coverage of the algorithm via USGS Earth Explorer*

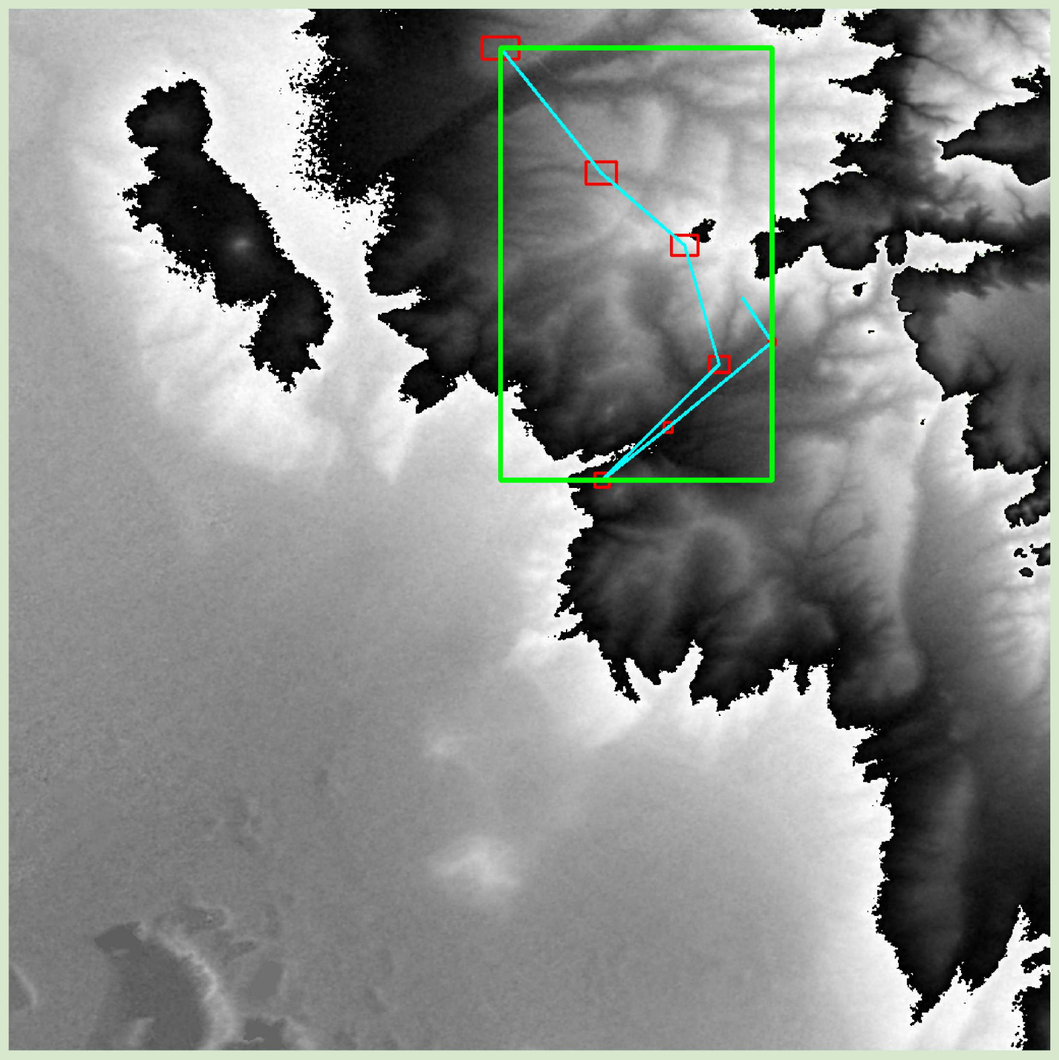

Figure 2. *Visualization of an SRTM tile and a match for synthetic data*

Challenges and Remediation

- *X* and *Y* axis of the path may not be north/south aligned
  - Easily addressed with matrix rotation of the path

$$R = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$$

- Error is present in the axes
  - Propagate error to search around each step point for the best elevation match
- Ranking of multiple matches

$$Conf = \frac{1}{n}\sum_{t=1}^{n}[1 - \sum_{a \in A} Scale_a * (True\_Err_{a_t} / Max\_Err_{a_t})],\ A = \{x, y, z\}$$

- Large search space

$$Convolutions = [(3601 * Range_{Lat}) - ([Max_x - Min_x] - 1)] * [(3601 * Range_{Long}) - ([Max_y - Min_y] - 1)]$$

  - No search modifies data used by any other, can be performed in parallel
- Possible movement of less than 1 meter (below SRTM resolution)
  - Can simply be ignored as it will not effect the total change between its previous and succeeding step

```
1   Find path bounding box
2   Find path start point in bounding box
3   For each convolution of the bounding box along the tile:
4       For each step change in the path:
5           Calculate new point from last point based of step change
6           Propagate error for each axis
7           If step elevation change != (path elevation change +/- error):
8               Go to 4
9       Add path to matches
```

Algorithm 1. Pseudocode implementation of the matching algorithm

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