IP Geolocation with Two-Tier Neural Network

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Outline

Background

System Design

Data Collection

Evaluation

Conclusion
What is IP Geolocation?

128.135.100.110

41.79N
87.60W

Ryerson Laboratory
1100 E. 58th St.
& West entrance
What can we do with IP Geolocation?

- Credit card Fraud
- CDN
- Online Ads
Previous work - IPGeo Database

Pros
- Easy to use

Cons
- Less accurate (City level)
- Not up to date (Periodic update)
Previous work - Measuring network delay

\[ \theta = \text{train}(\text{Latency}_{1,2}, \text{Pos}_{1,2}) \]

\[ \text{Pos}_3 = \text{predict}(\text{Latency}_3, \theta) \]
Design a simple model (mostly based on triangulation) and calculate the parameters. [GZCF06, KBJK+06, WSS07, DPCS12] Accuracy: $\sim$10km median error

Such a model requires a lot of assumptions, which are not necessarily true. (E.g., is there a linear relationship between latency and geographic distance?)
Previous work - Find nearby landmarks

Find the landmark that has the most similar observation results with the target. [WBF^{+}11]

Accuracy: $\sim$1km median error

Accuracy is greatly relied on the density of the landmarks. Hard to maintain a large group of landmarks.
Previous work - What do we learn

- Physically adjacent nodes have similar measurements
- Network topology is simpler in a local area than in a larger area
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Our method employs machine learning technique to solve the problem. Instead of “choose” a model, we collect latency data from landmarks with known locations and train a model, then use this model to predict the location of unknown targets.
Two-Tier Neural Network

Intuition:
Measurement from adjacent landmarks can yield a better estimation result.

Make a rough estimation with all landmarks, locate the region the target resides in. Then use only the landmarks in that region to do a more accurate prediction.
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We choose 14 anchors from Ripe Atlas Network as observers. These observers covers most area of US continental evenly. They are able to send ping/traceroute requests to arbitrary IP addresses.
A large enough landmark dataset is crucial to the accuracy of our method. Our dataset consists of landmarks from three data sources:

- Ripe Atlas Probes
- University Webservers
- City Government Webservers
Data Collection

University Dataset
- Get a U.S. university list from Wikipedia
- Use Google search API to obtain the geographic location and its website
- Use `host` command to obtain corresponding IP address

City Dataset
- Get a U.S. city and population list from government website
- Choose the top 50 cities of each state ordered by population in descending order
- Use Google search API to obtain the geographic location and its website
- Use `host` command to obtain corresponding IP address
We filter out invalid data using various methods

- Look for popular virtual host providers (Amazon, GoDaddy, Rackspace, etc.)
- Look for owners that own multiple IP addresses (through whois)
- Cross-validation using GeoIP database
# Data Collection - Result

<table>
<thead>
<tr>
<th>Category</th>
<th>Raw</th>
<th>Valid</th>
<th>Reachable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ripe Atlas Probes</td>
<td>637</td>
<td>637</td>
<td>429</td>
</tr>
<tr>
<td>University Websites</td>
<td>2170</td>
<td>1858</td>
<td>826</td>
</tr>
<tr>
<td>City Government Websites</td>
<td>2880</td>
<td>740</td>
<td>292</td>
</tr>
<tr>
<td>Total</td>
<td>5687</td>
<td>3235</td>
<td>1547</td>
</tr>
</tbody>
</table>

**Table**: Landmark Detail (Raw: All landmark candidates. Valid: Landmarks after filtering and cross-validation. Reachable: Landmarks that respond to ping)
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Evaluation - Error Distribution

We compare the performance of two popular neural network types: Multi-Layer Perceptron (MLP) and Radial-Basis Function (RBF)

Accuracy:

- Over 80% estimations have a error within 10km
- MLP has a overall better performance than RBF
Evaluation - Accuracy related to number of landmarks

- 3.7km in regions with > 100 landmarks
- 6km in regions with < 50 landmarks
- Error decreases when landmark density increases
Outline

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System Design

Data Collection

Evaluation

Conclusion
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Our Contribution:

- A novel method for IP Geolocation
- Achieved similar accuracy with state-of-the art with a fixed amount of landmarks
Future Work

- **Mobile client**
  In this research, our data source contains only wired network nodes. Mobile network, especially cellular network clients may have different properties that is not represented in our dataset.

  Contribution: High  Complexity: High

- **Region**
  Our method assumes two geographically adjacent IP addresses will be adjacent on network topology. While this has been justified by our research result on U.S. territory, we are interested in expanding the testing in regions such as Europe and Asia.

  Contribution: High  Complexity: Medium
Question?
Ziqian Dong, Rohan D.W. Perera, Rajarathnam Chandramouli, and K.P. Subbalakshmi.
Network measurement based modeling and optimization for IP geolocation.

Bamba Gueye, Artur Ziviani, Mark Crovella, and Serge Fdida.
Constraint-based Geolocation of Internet Hosts.

In *IMC '06*, pages 71–84, New York, NY, USA, 2006. ACM.
Yong Wang, Daniel Burgener, Marcel Flores, Aleksandar Kuzmanovic, and Cheng Huang.
Towards Street-level Client-independent IP Geolocation.

Bernard Wong, Ivan Stoyanov, and Emin Gün Sirer.