Heimdall
A Privacy-Respecting Implicit Preference Collection Framework

Amir Rahmati, Earlene Fernandes, Kevin Eykholt, Xinheng Chen, Atul Prakash
Allow "Yelp" to access your location while you use the app?
This app needs your location to search for nearby businesses.

Don't Allow  Allow

Get Started

Already have a Yelp account?
Log In
Example: This is probably my favorite steakhouse in town. If you’re going to splurge, this is the place to do it. The service is prompt but gruff, though I’d argue that’s part of the rustic steakhouse feel. Our waiter, Tom, was able to give us some great guidance and was especially helpful for pairing beers with our steaks. Everything you’ve heard is 100% true and then some! Obviously the steak is the main event, and every time I go it’s top-notch — juicy and perfectly cooked. Don’t skip dessert! The housemade cheesecake is out-of-this-world good, so save room on your main course.
1. Terry B's
- 47 Reviews
- 7504 Ann Arbor St, Dexter
- American (New), Bars
- Rating: $$$
- Distance: 1 mi

Dawn W. "Terry B's is great new American fare. An intimate, comfortably modern small restaurant in the heart of charm..."

2. Riverview Cafe Restaurant
- 93 Reviews
- 8124 Main St, Dexter
- Breakfast & Brunch, Diners
- Rating: $
- Distance: 0.9 mi

Megan K. "The service! The food! The owner! Loved our whole experience. The waitress was really nice, she even came b..."

3. Hotel Hickman Chuck Wagon
- 41 Reviews
- Rating: $
- Distance: 1.0 mi

L. A. "Opens Thursday to Sunday. They close earlier. Grab a slab with all the fixing to feed 2 to 3 people with all the fixin..."

4. Red Brick Kitchen & Bar
- 127 Reviews
- 8095 Main St, Dexter
- American (New)
- Rating: $$$
- Distance: 1.0 mi

Anne S. "We had a double date here Saturday night with friends, and I was quite impressed. I thought everything..."
<table>
<thead>
<tr>
<th>Price</th>
<th>Open Now</th>
<th>Good for Dinner</th>
<th>Good Food</th>
<th>Name</th>
<th>Distance</th>
<th>Reviews</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>$$$</td>
<td></td>
<td></td>
<td></td>
<td>Terry B's</td>
<td>1 mi</td>
<td>47</td>
<td>American</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Dawn W. &quot;Terry B's is great new American fare. An intimate, comfortably modern atmosphere set in the heart of charm...&quot;</td>
<td></td>
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</tr>
<tr>
<td>$</td>
<td></td>
<td></td>
<td></td>
<td>River View Cafe Restaurant</td>
<td>0.9 mi</td>
<td>93</td>
<td>Breakfast &amp; Bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Megan K. &quot;The service! The food! The owner! Loved our whole experience. The waitress was really nice, she even came b.&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$8</td>
<td></td>
<td></td>
<td></td>
<td>Hotel Buckman Truck Wagon</td>
<td>1.0 mi</td>
<td>41</td>
<td>BBQ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L.A. &quot;Opens Thursday to Sunday. They close earlier. Grab a slab with all the fixings to feed a large group...&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$$</td>
<td></td>
<td></td>
<td></td>
<td>Red Truck Kitchen &amp; Bar</td>
<td>1.0 mi</td>
<td>177</td>
<td>American</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Anne S. &quot;We had a double date here Saturday night with friends, and we were quite impressed. Everything was delicious...&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
State of the Art
State of the Art

• Rely on User Interaction and Feedback
  • Interaction Requirement
  • Data Sparsity
State of the Art

- Rely on User Interaction and Feedback
  - Interaction Requirement
  - Data Sparsity
- Coarse-grained Collection
  - Privacy Concerns
# Measurement Study

<table>
<thead>
<tr>
<th>Source</th>
<th>Type</th>
<th># of Samples</th>
<th>Definition of Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodreads</td>
<td>Books</td>
<td>500</td>
<td>Rating (1-5 stars)</td>
</tr>
<tr>
<td>Yelp</td>
<td>Restaurants</td>
<td>10,000</td>
<td>Rating (1-5 stars)</td>
</tr>
<tr>
<td>Google Play</td>
<td>Applications</td>
<td>10,000</td>
<td>Rating (1-5 stars)</td>
</tr>
<tr>
<td>IMDB</td>
<td>Movies</td>
<td>500</td>
<td>Rating (0.5-5 stars)</td>
</tr>
<tr>
<td>Youtube</td>
<td>Videos</td>
<td>500</td>
<td>Up/down vote</td>
</tr>
</tbody>
</table>
Data Sparcity

The graph illustrates the distribution of feedback responses across different platforms, showing the ratio of items with feedback responses against the number of responses. The platforms include Yelp, IMDB, Goodreads, Google Play, and Youtube. The x-axis represents the ratio of items, while the y-axis shows the number of feedback responses on a logarithmic scale.
Discrepancy Between Utilization and Feedback

![Graph showing the discrepancy between Google Play Ratings, Google Play Downloads, Youtube T-Up/T-Down, and Youtube Views. The x-axis represents the ratio of items, while the y-axis represents quantity on a logarithmic scale. The graph illustrates the difference in utilization and feedback metrics.]
Allow Privacy-Respecting Fine-Grained Data Collection
You are allowed to collect the location...
You are allowed to collect the location... **IF** the location is a restaurant.
Restaurant Collector
Restaurant Collector

Location Service → App
Restaurant Collector

Location Service → App → Cloud Server
Restaurant Collector

Location Service → App → Cloud Server
Restaurant Collector
Restaurant Collector

Location Service → App → Cloud Server
Immutable Blobs

<JSON Data, Path, Signature>
"Location"
{
   "lat": 40.7155809802915,
   "lng": -73.9599399197085,
   "time": "2012-04-23T18:25:43.511Z"
}

"googleapis:place"
{
   "results": [
      { "name": "Subway",
         "types": ["restaurant",
                  "...
               ]
      }
   ]
}
Immutable Blobs

"Location"
{
   "lat": 40.7155809802915,
   "lng": -73.9599399197085,
   "time": "2012-04-23T18:25:43.511Z"
}

googleapis:place:
results:types
Immutable Blobs

<JSON Data, Path, Signature>

"Location"
{
    "lat": 40.7155809802915,
    "lng": -73.9599399197085,
    "time": "2012-04-23T18:25:43.511Z"
}

"googleapis:place"
{
    "results": [
        {
            "name": "Subway",
            "types": ["restaurant"],
            "..."
        }
    ]
}

JSON Data
SHA256 HMAC

googleapis:place:
results:types
Restaurant Collector

Collector

Immutable Blob: <JSON Data, Path, Signature>
Restaurant Collector

Collector

Sandbox

Immutable Blob: <JSON Data, Path, Signature>
Restaurant Collector

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Restaurant Collector

Heimdall

Location Service

Secure API

Collector

Sandbox

Policy Checker

Immutable Blob: <JSON Data, Path, Signature>
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Restaurant Collector

Location Service -> Secure API -> Collector -> Sandbox -> Policy Checker -> Cloud Server

Immutable Blob: <JSON Data, Path, Signature>
Restaurant Collector

Location Service

Secure API

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Sandbox

Policy Checker

Cloud Server

Immutable Blob: <JSON Data, Path, Signature>
restaurant collector

location service

secure api

collector

sandbox

heimdall

policy checker

cloud server

immutable blob: <json data, path, signature>
Restaurant Collector

#Sources:
FINE_LOCATION
googleapis:place

#Collects:
@anonymized
if (googleapis:place:results:types=="restaurant"): submit (googleapis:place:results:name,"Link")
Restaurant Collector

#Sources:
FINE_LOCATION
gooleapis:place

#Collects:
@anonymized
if(googleapis:place:results:types=="restaurant"):
    submit(googleapis:place:results:name,"Link")

Supports relational constraints
Evaluation

• How is the performance of Heimdall?

• Can you develop useful collectors using Heimdall?

• Does Heimdall decrease user concerns?
MicroBenchmarks
Likert Scale

1. **Not Concerned** - Select this for actions which pose little to no risk to you or the people living with you.
2. **Mildly Concerned** - Select this for actions which pose a low risk to you or the people living with you, but are useful when used as intended.
3. **Concerned** - Select this for actions which pose a medium risk to you or the people living with you, but are useful when used as intended.
4. **Very Concerned** - Select this for actions which pose a high risk to you or the people living with you, but are useful when used as intended.
5. **Would Not Allow** - Select this for actions which pose a high risk to you or the people living with you and are better left disabled.
Results
Results

• Location
  • Reporting location all the time
  • Reporting location when using the app
  • Reporting name of restaurants
Results

- **Location**
  - Reporting location all the time
  - Reporting location when using the app
  - Reporting name of restaurants
Results

• Location
  • Reporting location all the time
  • Reporting location when using the app
  • Reporting name of restaurants

• Purchase History
  • Reporting purchases all the time
  • Reporting food purchases
Results

• Location
  • Reporting location all the time
  • Reporting location when using the app
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Results

• Location
  • Reporting location all the time
  • Reporting location when using the app
  • Reporting name of restaurants

• Purchase History
  • Reporting purchases all the time
  • Reporting food purchases

• Browser History
  • Reporting all your browsing history
  • Reporting restaurant websites you browsed
Heimdall: A Privacy-Respecting Implicit Preference Collection Framework

• We empirically show that recommendation systems suffer from sparsity of data.

• Heimdall allows users to control what type of data they are sharing with recommendation systems.
  • This allows recommendation systems to collect implicit signals while respecting user privacy.

• We implemented 3 data collectors using Heimdall and evaluated Heimdall performance and user response to it.