Positioning

CSCI 5715: Spatial Computing
October 28, 2014
Positioning is about a simple question:

“Where?”
Positioning is about a simple question:

“Where?”

Where is this property line?
Positioning is about a simple question:

“Where?”

Where is this property line?  Where should this missile go?
Positioning is about a simple question: "Where?"

Where is this property line?  
Where should this missile go?  
Where is this animal?
Positioning is about a simple question:

“Where?”

Where is this property line?  Where should this missile go?  Where is this animal?  Where is this smartphone user?
\[ \langle x, Z, z(x) \rangle \]

the “geo-atom”

(Goodchild et al. 2007)
Presence of cholera
Temperature
Population
Air Quality
Tweet content
Wikipedia article text
Presence of cholera
Temperature
Population
Air Quality
Tweet content
Wikipedia article text
Main subject of this module!

- Presence of cholera
- Temperature
- Population
- Air Quality
- Tweet content
- Wikipedia article text
User **position** is a particularly important type of x.
\( \mathbf{x} \) is a vector, not a single value!

\[
\langle \mathbf{x}, Z, z(\mathbf{x}) \rangle
\]

(44.97428, -93.232502, 264m, 10:33am)
Signal-based Positioning
Signal-based Positioning  

Content-based Positioning
Signal-based Positioning
Signal-based Positioning

Content-based Positioning

102.111.321.5

flickr
Signal-based positioning is how your smartphone knows where you are!
Signal-based positioning is responsible for....

...the little blue dot in mobile map applications
Signal-based positioning is responsible for correctly geotagging Instagram photos, tweets, and other social media VGI.
Signal-based positioning is responsible for...

... helping determine what’s nearby in location-based services like Yelp, Foursquare, and so on.
Signal-based positioning is responsible for helping determine what's nearby in location-based services like Yelp, Foursquare, and so on.
Signal-based positioning is responsible for helping scientists understand how species migrate.
Signal-based positioning is responsible for…

…allowing farmers to implement optimal strategies for their crops.
Key Types of Signal-based Positioning

in your smartphone and in general

1. Satellite-based Positioning
2. Wifi Positioning
3. Cellular Positioning
Global Navigation Satellite System (GNSS)
First GNSS

GPS

Global Positioning System
Scientists in America figure out how to track Sputnik using its radio transmissions. The U.S. wanted to be able to better target missiles (among other military applications). KAL 007 shot down after drifting into Soviet space.

GPS is a U.S. government technology born out of the Cold War.
GPS BFFs

GPS is a U.S. government technology born out of the Cold War
How does GPS work?
How does GPS work?

- 24 satellite (+ some extras)
How does GPS work?

- 24 satellite (+ some extras)
- each is on fixed, 12-hour orbit
How does GPS work?

- 24 satellite (+ some extras)
- each is on fixed, 12-hour orbit
- transmit radio signals at fixed intervals
How does GPS work?

• 24 satellite (+ some extras)
• each is on fixed, 12-hour orbit
• transmit radio signals at fixed intervals
• devices use trilateration
The more satellites, the better (3 = minimum)
GPS is failing you right now!
GPS limitations
GPS limitations

1. Does not work well indoors (that’s changing a bit)
GPS limitations

1. Does not work well indoors (that’s changing a bit)
2. Accuracy can be limited
GPS limitations

1. Does not work well indoors (that’s changing a bit)
2. Accuracy can be limited
3. Time-to-first-fix stinks
GPS limitations

1. Does not work well indoors (that’s changing a bit)
2. Accuracy can be limited
3. Time-to-first-fix stinks
4. Multipath issues (urban canyon effect)
GPS limitations

1. Does not work well indoors (that’s changing a bit)
2. Accuracy can be limited
3. Time-to-first-fix stinks
4. Multipath issues (urban canyon effect)
Hard for a smartphone to see satellites down there!
GPS limitations

1. Does not work well indoors (that’s changing a bit)
2. Accuracy can be limited
3. Time-to-first-fix stinks
4. Multipath issues (urban canyon effect)
5. Drain on power
GPS BFFs?
List of smartphones using GLONASS Navigation

From Wikipedia, the free encyclopedia

This article includes a list of references, but its sources remain unclear because it has insufficient inline citations. Please help to improve this article by introducing more precise citations. (October 2012)

This is a list of smartphones that support GLONASS, the Russian GNSS.

Contents [hide]

1 Acer
2 Alcatel
3 Apple
4 Asus
5 BlackBerry
6 HTC
7 Huawei
8 LG
9 Meizu
10 Motorola
11 Nokia
12 OnePlus

Galileo

Beidou-2 / COMPASS
GPS limitations

1. Does not work well indoors (that’s changing a bit)
2. Accuracy can be limited
3. Time-to-first-fix stinks
4. Multipath issues (urban canyon effect)
5. Drain on power
Go inside with Indoor Maps

Create a more convenient and enjoyable visitor experience at no cost, available on Google Maps across all devices.
Wifi positioning to the rescue!
Coit Tower  Candlestick Park  Golden Gate Bridge

San Francisco, CA
San Francisco, CA

Unique MAC Address

Unique MAC Address

Unique MAC Address

San Francisco, CA
Unique MAC Address  
Unique MAC Address  
Unique MAC Address  

\[ \downarrow \  \downarrow \  \downarrow \]  

Approx. Lat / Lon
How does wifi positioning work?
How does wifi positioning work?

Fingerprinting!
How does wifi positioning work?

PHASE 1
- calibration phase

PHASE 2:
- positioning phase

Fingerprinting!
Wifi Fingerprint

Collecting these is goal of Calibration stage

(MAC addresses, signal strengths, location of fingerprint collector)
Two-Thirds of a Wifi Fingerprint

(missing the location at which this reading was taken)
Calibration Phase
aka collecting fingerprints

War Driving
Google Street View cars: also used to collect Wi-Fi fingerprints.
Google told to delete Street View payload data or face UK prosecution

Information commissioner's office says it will launch contempt of court proceedings if data is not deleted within 35 days

Josh Halliday
theguardian.com, Friday 21 June 2013 07.45 EDT
Jump to comments (380)
WANTED: Wi-Fi fingerprint collector. Hrs = 24hrs/day, 7 days a week. Wage = $0/hr
WANTED: Wi-Fi fingerprint collector. Hrs = 24hrs/day, 7 days a week. Wage = $0/hr

Sounds good to me!

The New Street View Car Driver
“[Positioning calculations] are performed live on the iPhone using a crowd-sourced database of Wi-Fi hotspot and cell tower data that is generated by tens of millions of iPhones sending the geo-tagged locations of nearby Wi-Fi hotspots and cell towers in an anonymous and encrypted form to Apple.”

(Apple, Inc. 2011)
3G Apple iOS Devices Are Storing Users’ Location Data

By NICK BILTON  APRIL 20, 2011 3:04 PM  109 Comments
How does wifi positioning work?

**PHASE 1**
- calibration phase

**PHASE 2:**
- positioning phase

Fingerprinting!
Positioning Phase
aka using machine learning to determine position

These Wi-Fi networks are in range, so where am I?
Positioning Phase
aka using machine learning to determine position

Available Wi-Fi Networks and Signal Strengths
Positioning Phase  
aKA using machine learning to determine position

<table>
<thead>
<tr>
<th>Available Wi-Fi Networks and Signal Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>OverdrivePro1BD</td>
</tr>
<tr>
<td>2WIRE400</td>
</tr>
<tr>
<td>2WIRE114</td>
</tr>
<tr>
<td>2WIRE95</td>
</tr>
<tr>
<td>2WIRE944</td>
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<tr>
<td>2WIRE946</td>
</tr>
<tr>
<td>AREP</td>
</tr>
<tr>
<td>ATT096</td>
</tr>
<tr>
<td>Bea's network</td>
</tr>
<tr>
<td>belkin.433</td>
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<td>belkin.83c</td>
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<tr>
<td>belkin.932 guests</td>
</tr>
<tr>
<td>Caribou</td>
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<td>ChitownML</td>
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<tr>
<td>jms-620</td>
</tr>
<tr>
<td>Maffa</td>
</tr>
<tr>
<td>Millie</td>
</tr>
<tr>
<td>Moore</td>
</tr>
</tbody>
</table>

Lat/Lon = 41.93635, -87.64332
Wi-Fi Positioning Accuracy
Wi-Fi Positioning Accuracy

Worse than GPS, better than cellular
Wi-Fi Positioning Accuracy

Worse than GPS, better than cellular

Can be used *in combination with* GPS for improved accuracy
“Skyhook Location’s hybrid positioning improves upon Wi-Fi positioning accuracy up to 35% in difficult environments by leveraging signals from as few as two GPS satellites. In deep urban settings Skyhook Location uses weak GPS signals and WiFi to acquire a location 100% of the time (A-GPS works only 70% of the time). From a complete cold start, Skyhook Location delivers a full hybrid location in 4 seconds (compared to 30-60 seconds for A-GPS).”

(Skyhook Wireless 2014)
Predictors of Performance
Predictors of Performance

1. Number of access points
Predictors of Performance

1. Number of access points
2. Quality of fingerprint database (degrades over time, conditions)
Predictors of Performance

1. Number of access points
2. Quality of fingerprint database (degrades over time, conditions)
3. Quality of machine learning algorithm in positioning phase
No Wi-Fi hotspots in range out here…
Wi-Fi Positioning provides positioning for devices without GPS....
Key Types of Signal-based Positioning
in your smartphone and in general

1. Satellite-based Positioning
2. Wifi Positioning
3. Cellular Positioning
Cellular Positioning

1. Algorithms: Location of tower with strongest signal, Time Difference on Arrival, Angle of Arrival, Fingerprinting
2. Accuracy highly-dependent on number of towers
3. Least accurate of all three
74m accuracy (median)  
Wifi Positioning

599m accuracy (median)  
Cellular Positioning

(Zandbergen 2009)
Instructions

Travel around Keller Hall and its environs, testing the positional accuracy of your wifi and GNSS positioning on your smartphone.

Remember: to ensure wifi positioning, turn on airplane mode (and turn on wifi). To ensure GNSS, turn off wifi.

Checklist (for both methods)

Go to lots of spots (and wait), but at make sure to cover at least

* Places inside away from windows
* Places inside
* Places with obstructed view of sky
* Places with clear view of sky
* Go underground (optional)
Signal-based Positioning

Determining the location of a client’s device
(e.g. for a mobile map, location-based service, scientific application)

Content-based Positioning

Used when no signal-based position is available
(e.g. location inference in online communities)

Used when signal-based positioning is not useful for your needs
(e.g. need “home” not “current” location)
Only 1-3% of tweets are geotagged!
Geotags in tweets generally come from signal-based positioning in smartphones.

Figure 2. Mapping “Gross Community Happiness” in Greater London (best seen in color).

(Quercia et al. 2012)
edchi edchi
wonderful afternoon at the 20th anni. of HCI at StanfordU. Terry Winograd toasted by many, inc. my ex and current boss: S.Card and L.Page.
21 Feb
Let's go Ravens!
Only 1-3% of tweets are geotagged!
The use of implicit and explicit geographic information contributed or consumed by Internet users to generate a position for these users (with or without their knowledge or consent).

Content-based Positioning

102.111.321.5
We’ll cover the following content-based positioning-related topics:

1. **Geoparsing**: Extracting place names from natural language text

2. “**Home Locations**”: The dynamics of location fields in user profiles (and more)
We’ll cover the following content-based positioning-related topics:

1. **Geoparsing**: Extracting place names from natural language text

2. “**Home Locations**”: The dynamics of location fields in user profiles (and more)
Geographic Information Retrieval (GIR)

Search + Spatial Computing
Geoparsing and geocoding are useful for both...

...positioning for **users**

...positioning for **documents**
Headed to Washington to do some apple picking, jamming out to Chicago!
#seventiesmusic #itsraining
Gazetteers

geonames.org
Gazetteers

<place name, spatial footprint (x)>
<"Minneapolis, MN”, (44.9833, -93.2667)>

<place name, spatial footprint (x)>
<“McCarthy, AK”, (61.4328° N, -142.9108)>

<place name, spatial footprint (x)>
<“Riga, Latvia”, (56.9489, -24.1064)>
Headed to Washington to do some apple picking, jamming out to Chicago!
#seventiesmusic #itsraining
Headed to Washington to do some apple picking, jamming out to Chicago! #seventiesmusic #itsraining
**Ambiguity** is a fundamental problem in geographic information retrieval (and information retrieval and natural language processing more generally)
Geo/Geo Ambiguity

one place name (toponym) → more than one place

“Washington”
Geo/Geo Ambiguity

one place name (toponym) \(\rightarrow\) more than one place

“Paris”
Geo/Geo Ambiguity

one place name (toponym) → more than one place

“Albany”
Geo/Geo Ambiguity

one place name (toponym) $\rightarrow$ more than one place

“London”
Geo/Non-Geo Ambiguity

one term $\rightarrow$ a place name and $\geq 1$ other meaning
Headed to Washington to do some apple picking, jamming out to Chicago!

#seventiesmusic #itstraining
Geo/Non-Geo Ambiguity

one term $\rightarrow$ a place name and $\geq 1$ other meaning

“Chicago”
Geo/Non-Geo Ambiguity

one place name (toponym) → more than one place

“Washington”
Geoparsing!

Geo/Non-Geo Ambiguity

Geo/Geo Ambiguity
Headed to Washington to do some apple picking, jamming out to Chicago! #seventiesmusic #itsraining
Semantic Relatedness(A, B) =
A single numeric estimate of the number and strength of relationships between concepts A and B.

CONCEPT A
Dr. Shashi Shekhar

CONCEPT B
Spatial Computing

SR(A,B) = High
**SemanticRelatedness**(A, B) = 
A single numeric estimate of the number and strength of relationships between concepts A and B.

**CONCEPT A**
Dr. Shashi Shekhar

**CONCEPT B**
Garth Brooks

SR(A,B) = **Low**
Headed to **Washington** to do some apple picking, jamming out to Chicago!

#seventiesmusic #itsraining
Washington state is well-known for...

...Apples

...Rain
SR(“apple picking”) = High

SR(“#its raining”) = High
SR( , “apple picking” )

> 

SR( , “apple picking” )

SR( , “apple picking” )
Headed to Washington to do some apple picking, jamming out to Chicago!
#seventiesmusic #itssraining
Headed to Washington to do some apple picking, jamming out to Chicago!

#seventiesmusic #itsraining
Tools

DBPedia Spotlight

WikiBrain

Geoparsing coming soon!

Yahoo! BOSS PlaceSpotter API

Beric Technologies’ CLAVIN