PUG CHALLENGE EXCHANGE AMERICAS

Protecting Location Privacy:

It’s Not Who You Know, It’s Where You Go

Michael Solomon, Ph.D.

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Your speaker

- *Michael Solomon, Ph.D.*

  CISSP PMP CISA
- *Solomon Consulting Inc.*
  - *OpenEdge, Roundtable, Security architecture*
    - *Since 1988 (Progress Version 4)*
  - *CyberSecurity Simulation attack team leader*
    - *Penetration testing, attack detection and response*
- *Emory University*
  - *Assured Information Management and Sharing (AIMS)*
  - *Private location proximity detection research*
- *University of the Cumberlands*
  - *Associate Professor, Master of Science in Information Systems Security program*

Agenda

- Value – it’s all location, location, location
  - Where are my users?
  - Where have they been?
- Creeping vs Spatial determination
  - Location data analysis
  - Building trajectories
- Protecting user privacy
  - It is a choice

With mobile applications, the where matters.

Many devices sense location

- GPS
- Cellular ID
- Wi-fi proximity
- Inertial sensors
- Barometer
- Bluetooth beacons

Don’t forget about the subway!

Primary uses for location

- Gamification
- Social interaction
- Utilitarian


GAMIFICATION
BADGES
POINTS
APPLICATIONS
SITES
USERS
TECHNIQUES
ACTIVITIES
ENGAGEMENT
LOYALTY
COMPLETING
WEBSITES
ENCOURAGE
INCLUDING
ONLINE
SOCIAL
NUMBER
USED
ONE
SERVICES
ALSO
SITE
PEOPLE
REPUTATION
WEBSITE
GAME
GAINS
COMPANIES
FITNESS
PERFORM
EMPLOYEE
ENGAGE
LIKE
TRAINING
PROJECT
PARTNERSHIP
INCLUDE
NON-GAME
NETWORKS
SURVEYS
FINANCIAL
PLANNER
CAREERS
COMPANY
MEDIA
REDCRITTER
PLATFORMS
ACHIEVEMENT
INDICATE
EXPERTISE
FACEBOOK
PROCESSES
BUSINESS
COMPLETING
VIA
WEBSITES
DATA
SISTER
TOPIC
HELPING
USER
AVAILABLE
NETWORKING
MANAGEMENT
TECHNIQUE
ELEMENTS
RELATED
BASED
LEVELS
ENCOURAGING
ORGANIZATIONS
SHOPPING
USE
TV
ADOPT
LEVINE
MODERATE
ANSWERS
CHECK-INS
80%

Help

Google Transit BETA

Directions

Start address: **100 NW Couch St, Portland, OR 97209**
End address: **Hillsboro, OR**

100 nw couch st, portland to hillsboro, oregon by 8pm | Get directions

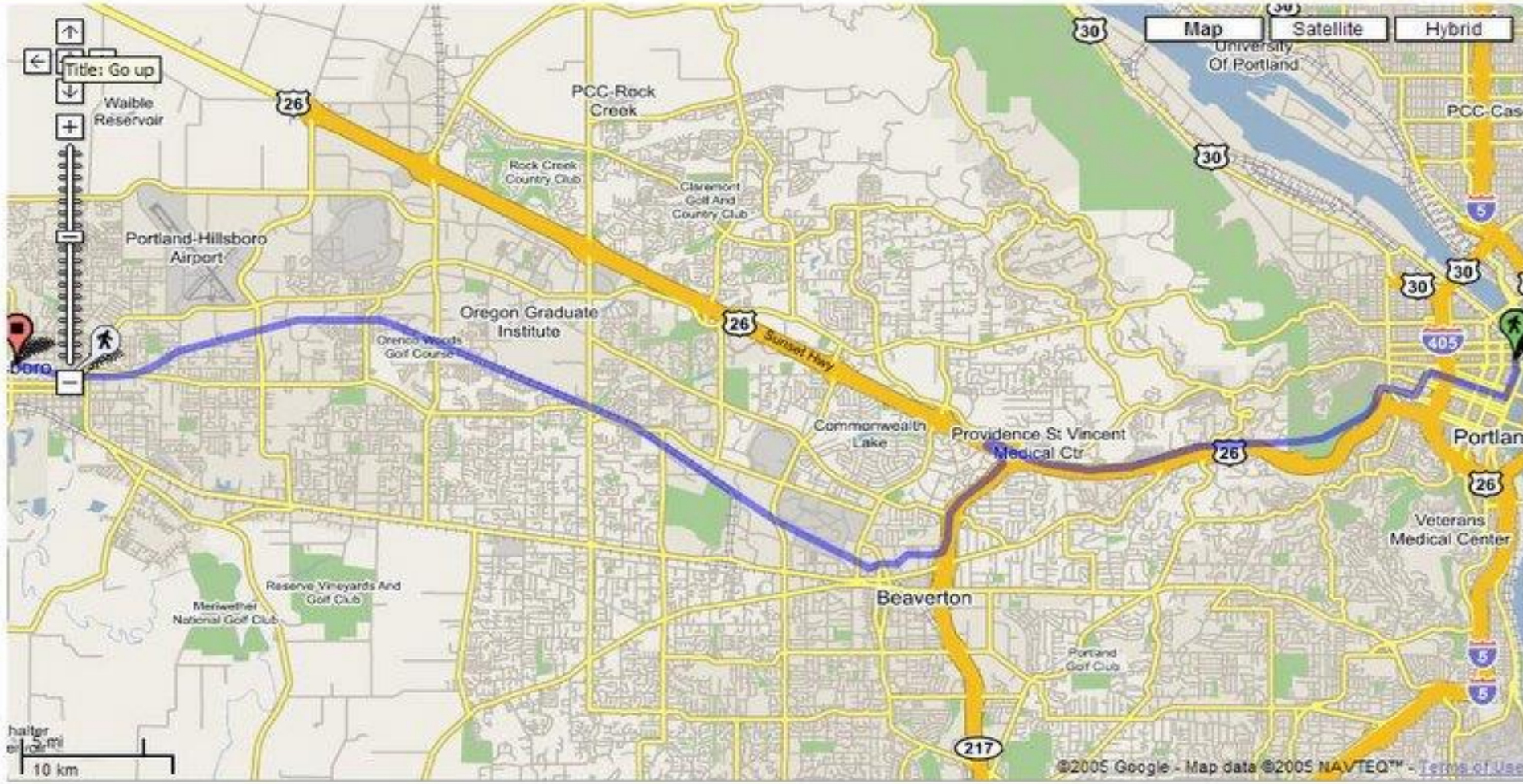
e.g., "pdx to 100 nw couch st, portland, oregon" or "pdx to portland, oregon at 7pm"

Transit Trip Planner

Email | Link to this page

Directions: Drive There - **Take Public Transit**

Start address:	100 NW Couch St Portland, OR 97209
End address:	Hillsboro, OR
When: [edit]	**Arrivals before 8:00pm:** 7:05pm ->7:57pm (51 mins) 6:49pm ->7:44pm (54 mins) 6:34pm ->7:30pm (55 mins) 6:21pm ->7:17pm (55 mins)
Duration:	51 mins in transit 13 mins walking to/from your route
Cost:	$1.80 (vs. $8.41 driving!) details



Begin by walking

1. Start at **100 NW Couch St**
2. Go to **Skidmore Fountain MAX Station** (takes about 1 min)

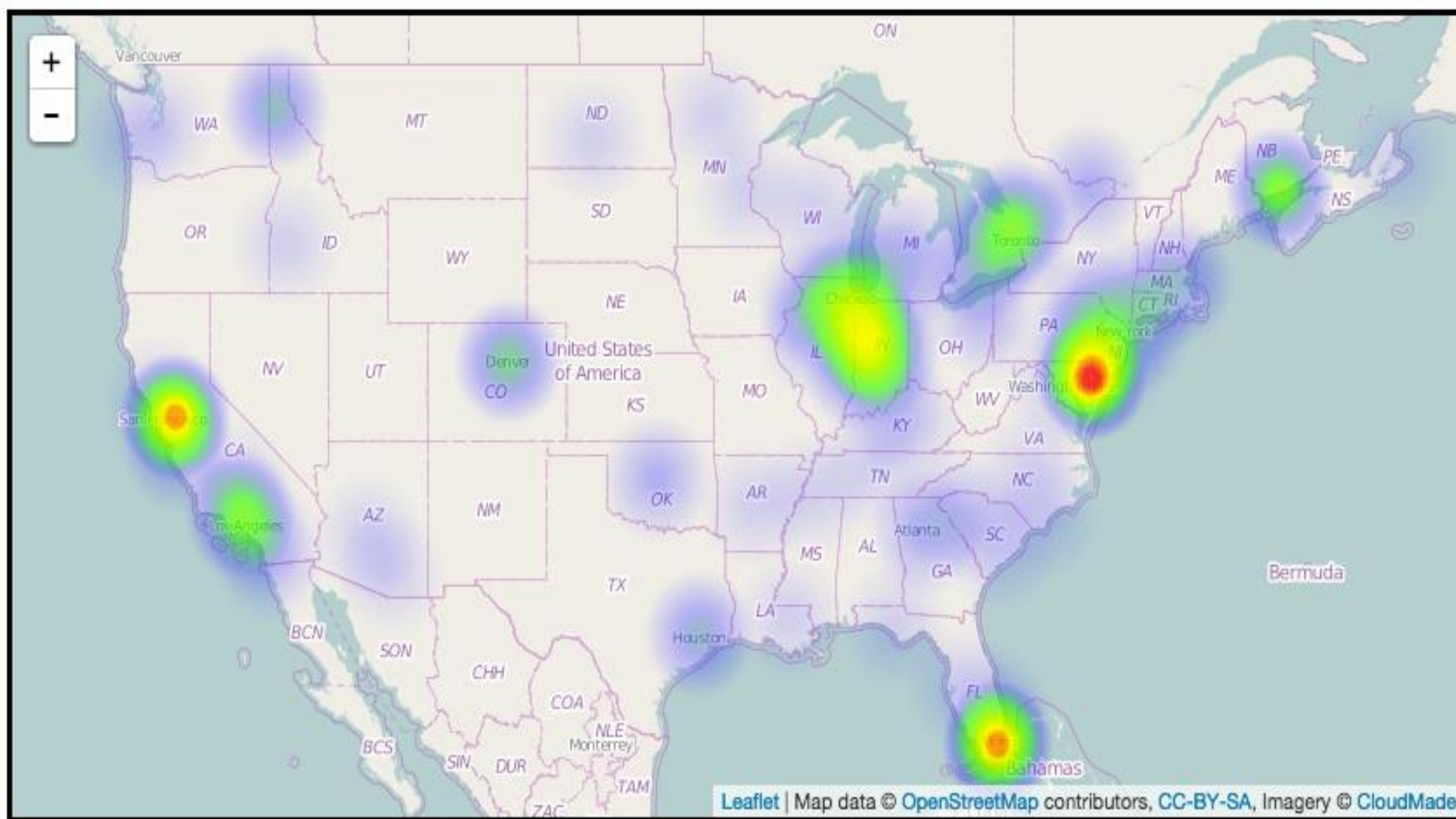
Take the MAX Blue Line (Direction: Hillsboro)

3. **7:05pm** leave from **Skidmore Fountain MAX Station**
4. **7:57pm** arrive at **Tuality Hospital/SE 8th Ave MAX Station**

End by walking

5. Go to **Hillsboro, OR** (takes about 12 mins)

These directions are for planning purposes only. You may find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Chicago
Denver
Houston
Atlanta
Bermuda
Bahamas
Leaflet | Map data © OpenStreetMap contributors, CC-BY-SA, Imagery © CloudMade

Where are my users?

- Finding a device's location is easy
  - Assuming the user allows it
- Many frameworks provide methods to return physical location
- HTML5 geolocation object
  - Returned by Navigator.geolocation
  - Handy methods
    - getCurrentPosition()
    - watchPosition()
    - clearWatch()
- But, what about Kendo UI?

Kendo UI - retrieve location coordinates

```
navigator.geolocation.getCurrentPosition(onSuccess, onError);


// onSuccess Callback
// This method accepts a Position object, which contains the current GPS coordinates
//
var onSuccess = function(position) {
    alert('Latitude: '          + position.coords.latitude          + '\n' +
          'Longitude: '         + position.coords.longitude         + '\n' +
          'Altitude: '          + position.coords.altitude          + '\n' +
          'Accuracy: '          + position.coords.accuracy          + '\n' +
          'Altitude Accuracy: ' + position.coords.altitudeAccuracy  + '\n' +
          'Heading: '           + position.coords.heading           + '\n' +
          'Speed: '             + position.coords.speed             + '\n' +
          'Timestamp: '         + position.timestamp                + '\n');
};
```

https://stackoverflow.com/questions/26117023/to-fetch-latitude-longitude-using-kendo-ui-in-telerik-appbuilder

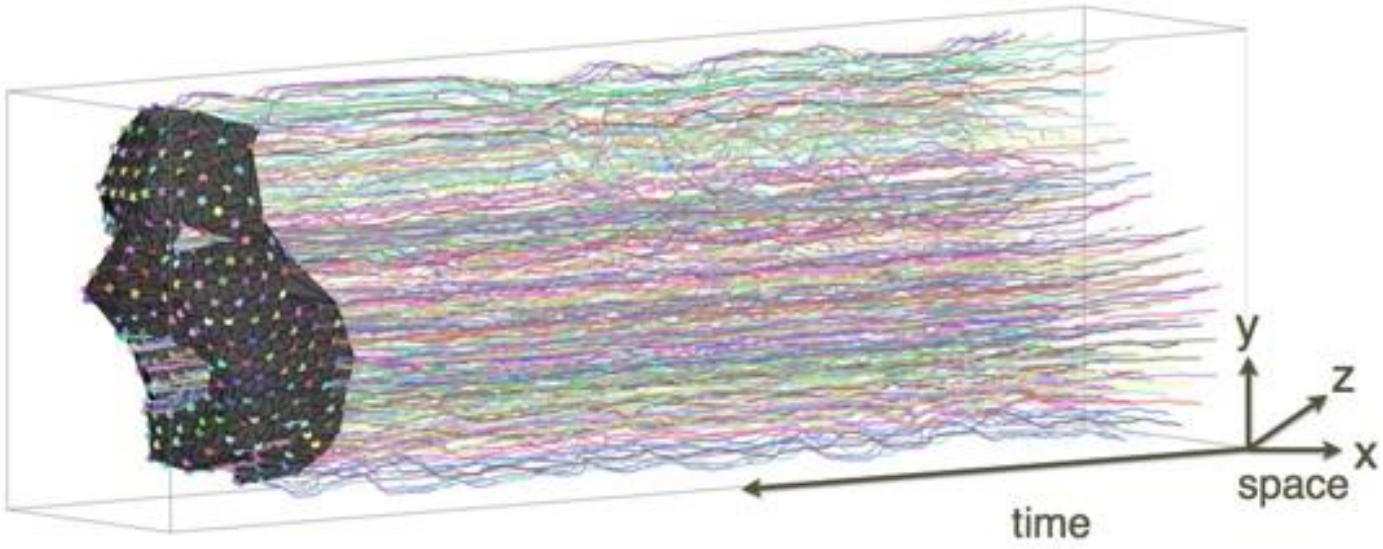
Location data can hold many **secrets**.

Storing spatiotemporal data

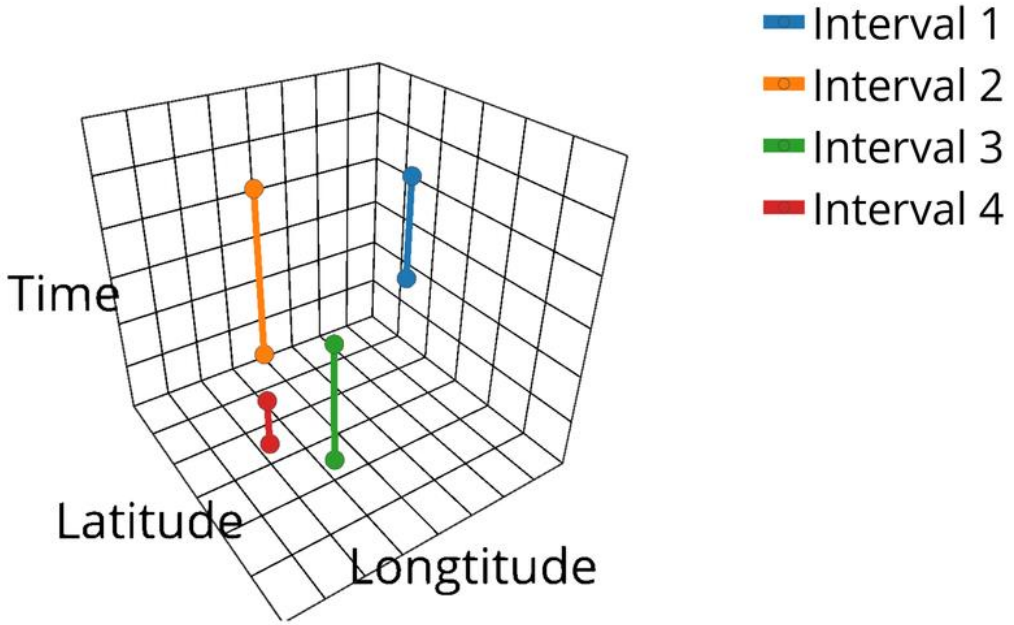
- Fairly easy
- Just more features

Visualizing can be difficult

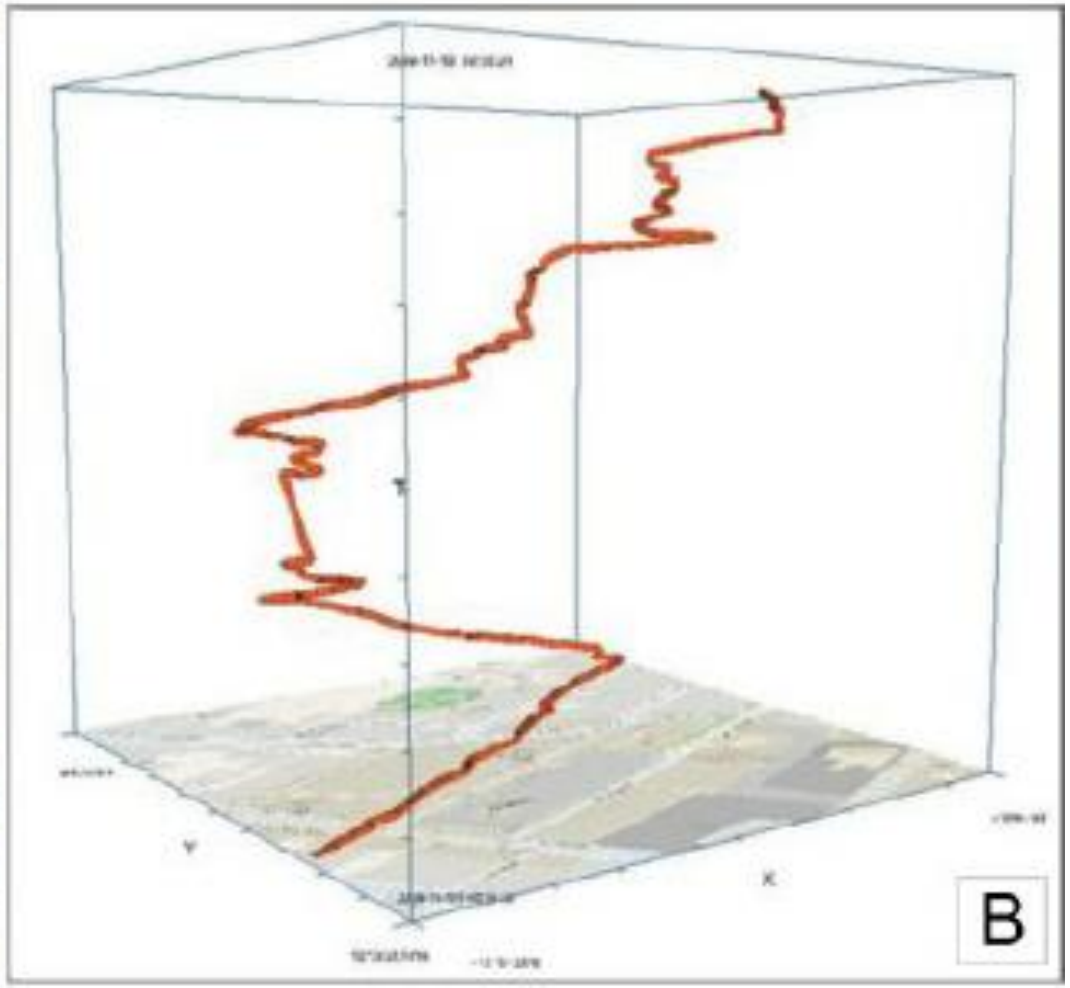
- Many creative techniques
- Important to prioritize features and dependencies

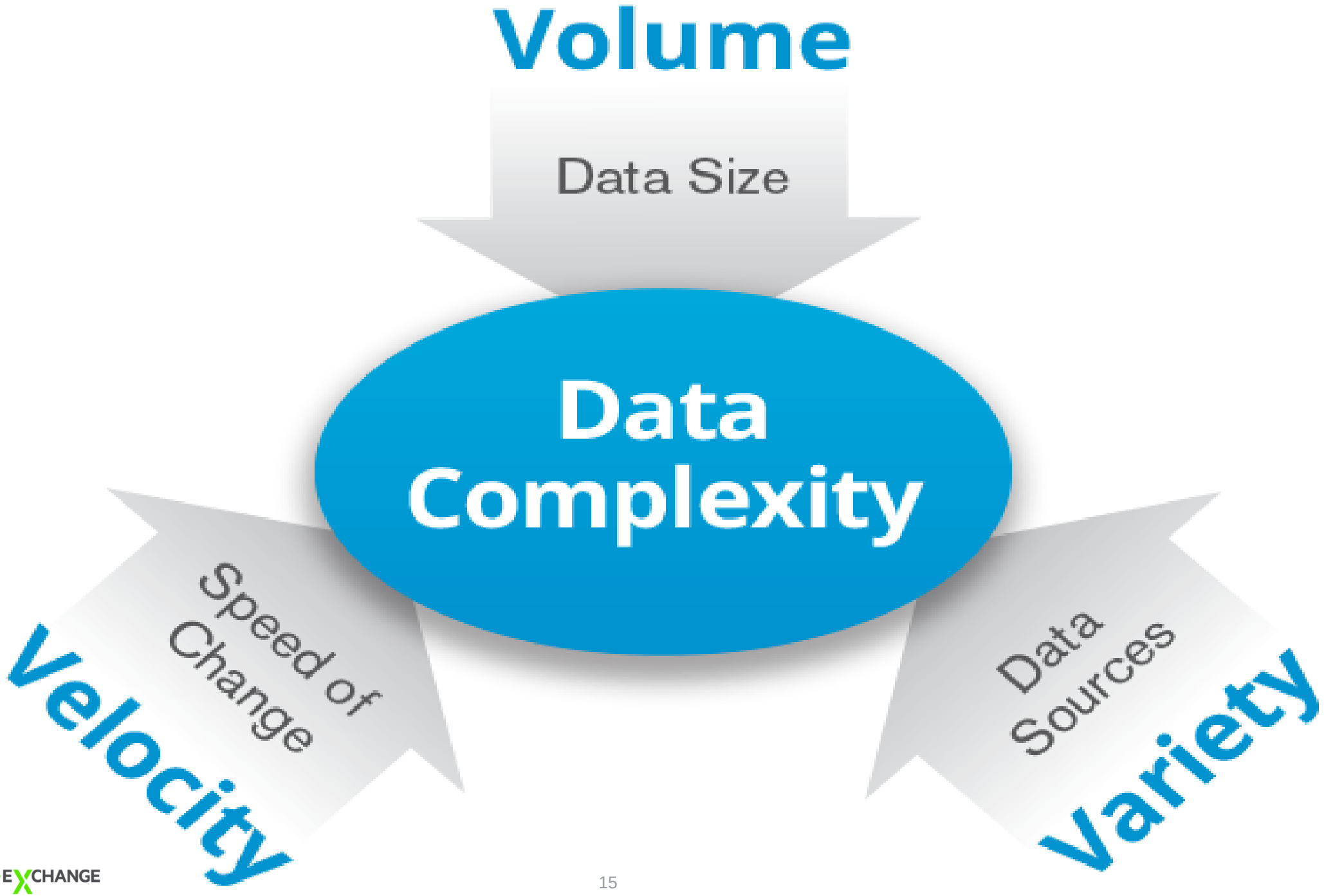


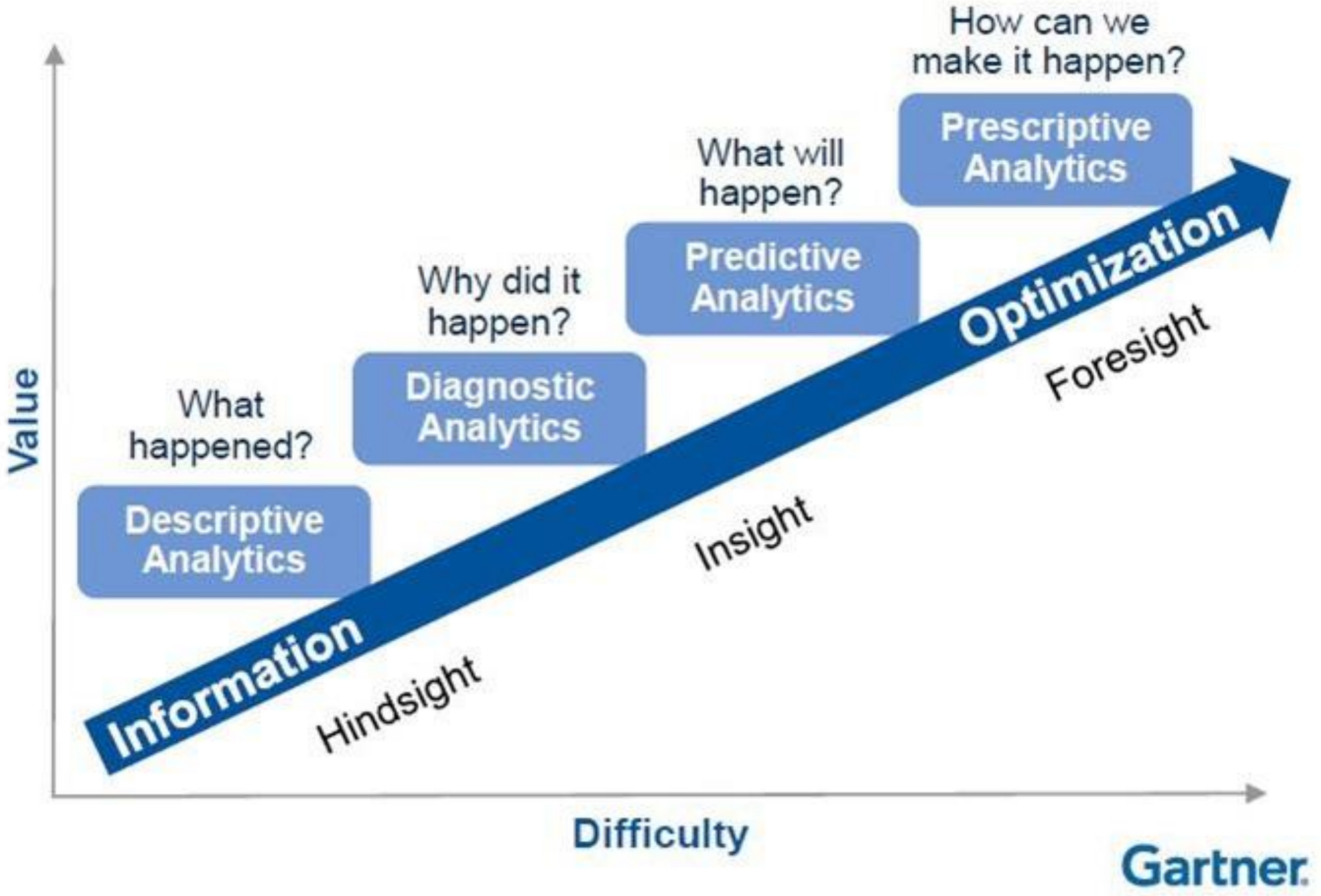
3D spatiotemporal domain



Trajectories - The real value of spatiotemporal data




Volume
Data Size
Data Complexity
Velocity
Speed of Change
Variety
Data Sources


How can we make it happen?
Prescriptive Analytics
What will happen?
Predictive Analytics
Why did it happen?
Diagnostic Analytics
What happened?
Descriptive Analytics
Optimization
Foresight
Insight
Hindsight
Information
Value
Difficulty
Gartner

Privacy. It matters.

What about privacy?

Confidentiality is about the data

- Access to data
- Intention is to keep data secret
- Allow access only to authorized users

Privacy is about the individual

- Access to the person (or organization)
- Appropriate use of information
  - More than just access to data
- Being free from public attention
- Ability to be left alone

Location data can identify individuals

- Current and past
- What about predictive analytics?

Problems with location privacy

Outright disclosure

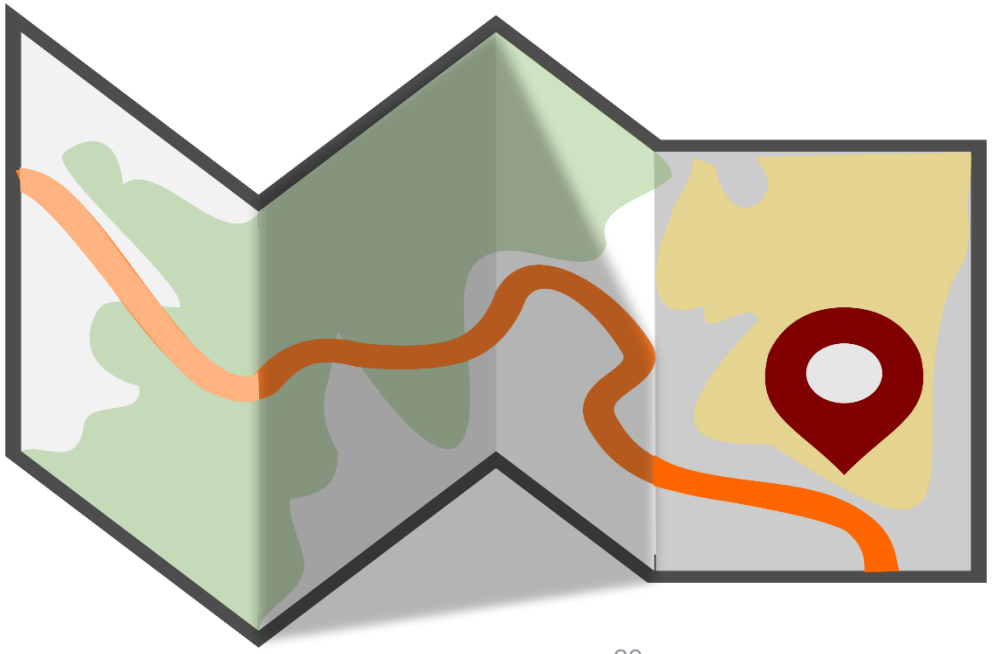
- Who knows where you are?
- Who knows where you've been?
- You have to divulge your location to consume services
  - Right?

Inference

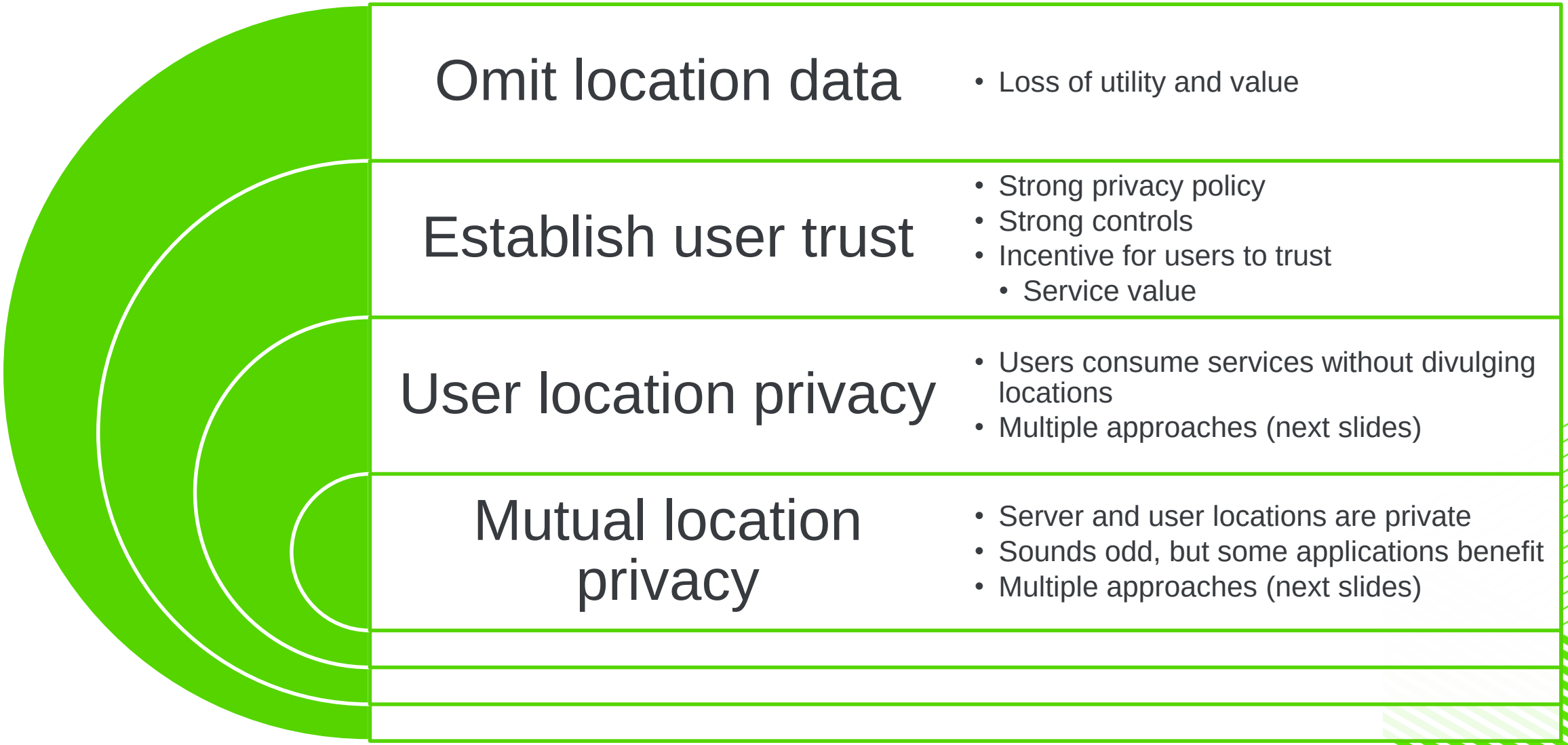
- Combining partial information to get an answer
  - Checkins
  - Pictures
  - Reviews
- Past and future

Trajectory analysis quiz

- Could be called “creeper quiz”
- What does the following trajectory imply?
  - Residence -> Elementary school -> Retail Dress shop-> Elementary school -> residence
- What about this trajectory?
  - Residence -> High school -> baseball field -> coffee shop -> residence

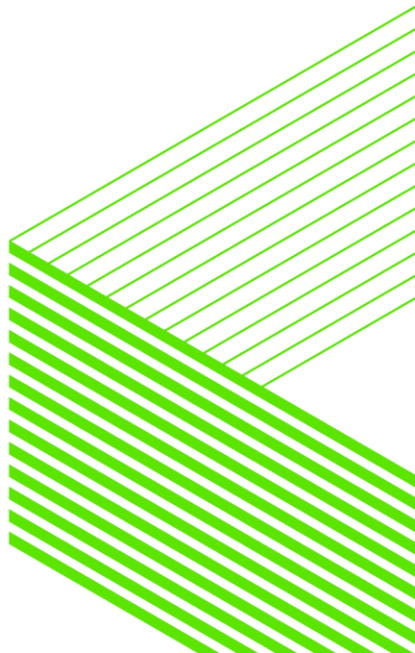


What can application providers do?



One class of location processing – proximity detection

- Simple – determining when a device is near some location
  - Area of Interest (AOI)
  - Defined by Data Provider (DP)
  - Can be of any size
- AOIs can be
  - Approach – interesting area
  - Avoid – dangerous area



Private Proximity Detection

Many solutions to keeping user locations private

- While still providing location-based services

Four leading strategies

- Multiple research efforts

Location perturbation and Transformation

- Loss of precision

Access control

- Limited granularity
- Requires trusted third party

Private Information Retrieval (PIR)

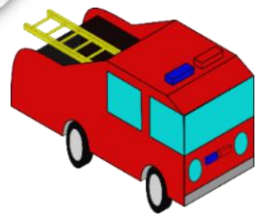
- Server location data is not private

Encryption

- Computational overhead

Mutually Private Proximity Detection (MPPD)

Am I near a dangerous area?

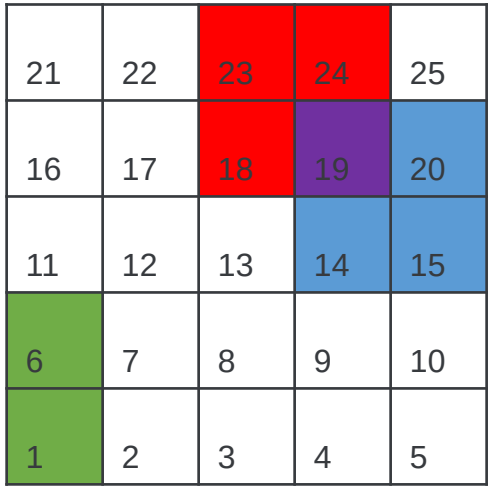


Where is the fire?

Are there any short lines nearby?

AOI definitions

AOIs “red”, “blue”, and “green”



AOIs available only to subscribed (paid) users.

Purple represents “red” and “blue” overlap.

Access policy: AOI “red”

“(subscriber=paid) AND (alertType=warn)”

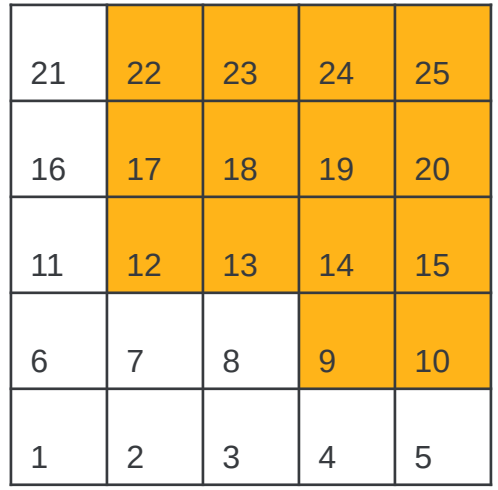
Access policy: AOI “blue”

“(subscriber=paid) AND (alertType=notify)”

Access policy: AOI “green”

“(subscriber=paid) AND (alertType=approach)”

AOI “yellow”



AOIs for free users are more generic (i.e. provide less specific information)

Access policy: AOI “yellow”

“(subscriber=free) AND (alertType=notify)”

MPPD promising approaches

Bloom Filter

- “Location privacy without mutual trust: The spatial bloom filter”
- Spatial Bloom filter / Paillier cryptosystem

Hilbert curve

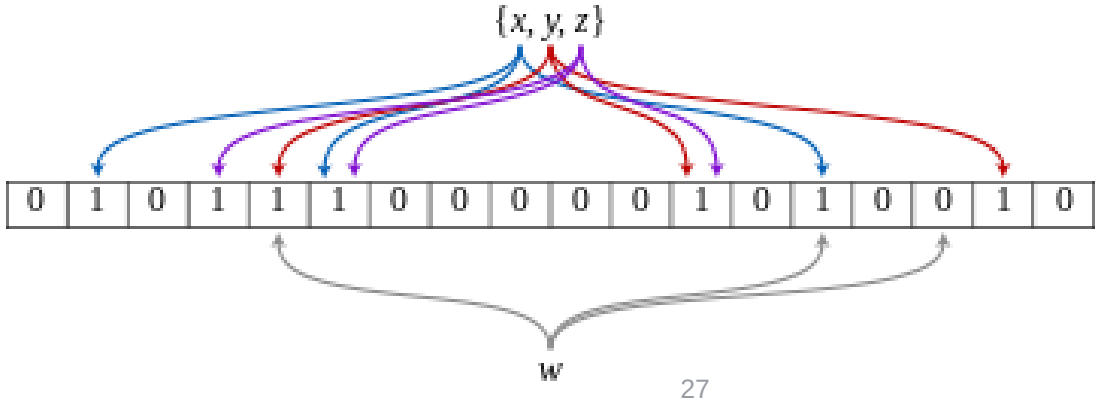
- “Hilbert curve-based cryptographic transformation scheme for spatial query processing on outsourced private data ”
- Hilbert Aggregation Index (HAI) / Range and kNN queries

Homomorphic encryption

- “Secure k-nearest neighbor query over encrypted data in outsourced environments”
- Paillier cryptosystem / Encrypted DB, query

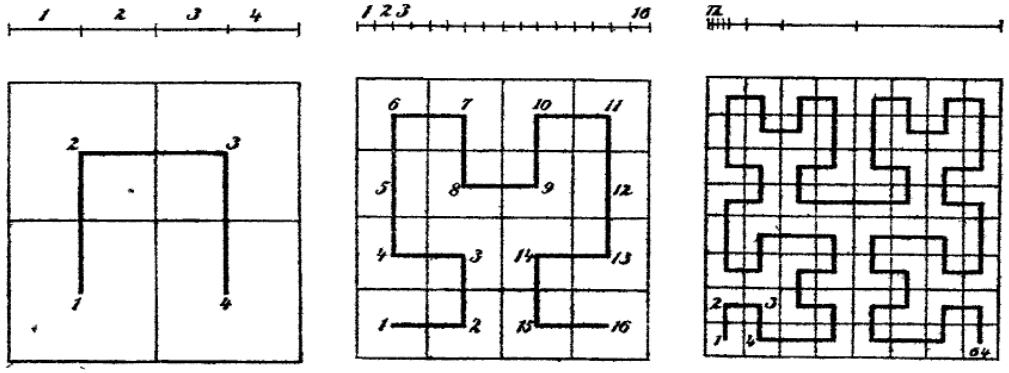
Spatial Bloom Filter (SBF)

- Bloom filter
  - Spatial bloom filter / Paillier cryptosystem
  - SBF constructed over multiple sets (AOIs)
- Overview
  - Data provider (DP) creates and encrypts SBF (AOIs)
  - User creates and encrypts SBF (location)
  - Service provider (SP) calculates SBF product
  - DO decrypts scrambled result and counts non-zeros
    - DO determines AOI proximity from result, informs user



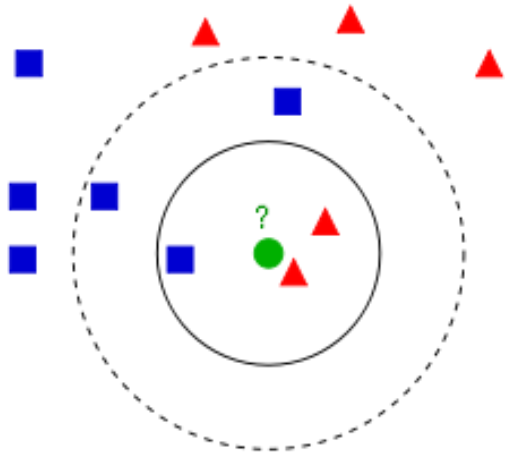
Hilbert Curve Transformation (MCT)

- Hilbert curve
  - Hilbert Aggregation Index (HAI) (range of cells)
  - Transformed Data Index (TDI) (AOI cells)
  - Range and kNN queries
- Overview
  - DP encodes AOIs in groups of F (fan-out)
  - DP creates index of start/stop cells, then encrypts entries (AES)
  - User (has AES key) requests and decrypts HAI, then requests overlapping TDI entries
  - User filters results to determine proximity

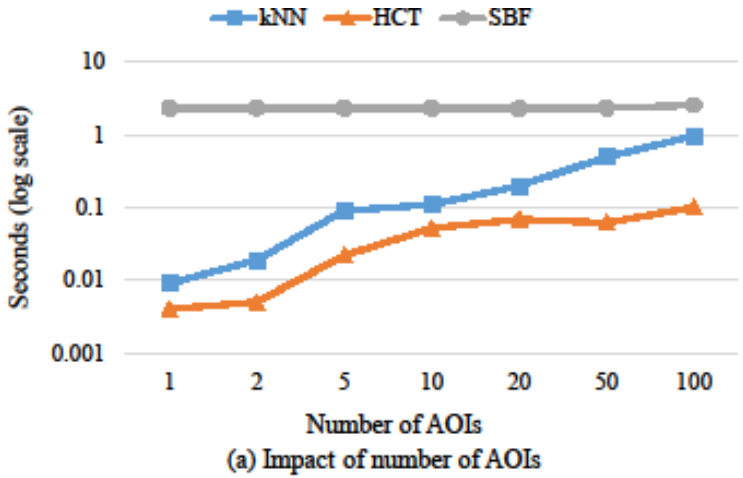


Secure k-Nearest Neighbor (SkNN)

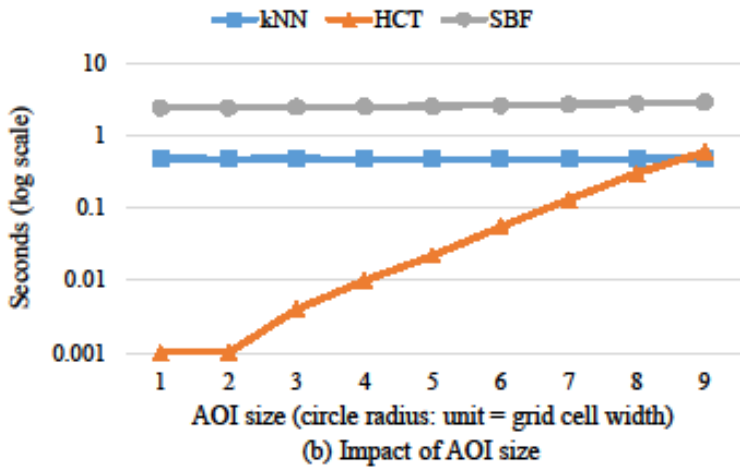
- Homomorphic Encryption
  - Paillier cryptosystem / Encrypted DB, query
- Original protocol not location specific
  - We extended SkNN distance calculation to consider distinct locations
    - Instead of distance between 2 attribute vectors
- DP encrypts AOIs, user encrypts location
- DP/SP use SSED to determine user/AOI proximity



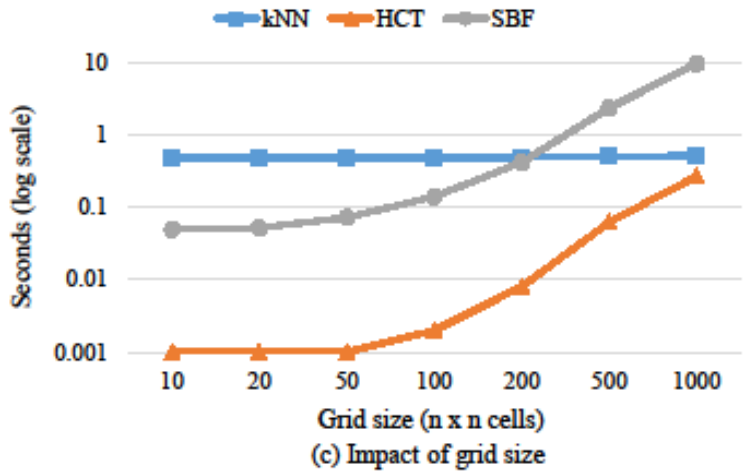
Performance results



(a) Impact of number of AOIs



(b) Impact of AOI size



(c) Impact of grid size

Factors affecting performance

Method	# AOIs	AOI Size	Grid size
SBF	No	No	Yes
SkNN	Yes	No	No
HCT	Yes	Yes	Yes

Privacy guarantees

Method	User	Data Provider	Query
SBF	k-anonymity based on filter size.	User only knows if loc overlaps AOI	DP only sees obfuscated results / cannot correlate to user
SkNN	DP only learns when user overlaps AOI	User only knows if loc overlaps AOI	DP and SP unable to correlate query to user
HCT	User location is never shared	k-anonymity based on fan-out (F) value	Limited, SP learns user/AOI proximity with 1/F accuracy

Location privacy. You can do it.


SolomonConsulting


Ready
Set
Secure