Walkway Discovery from Large Scale Crowdsensing

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1 National Science Experiment

- An island-wide outdoor science experiment carried by Singapore students.
- Organised by National Research Foundation and Ministry of Education in Singapore.
- Crowdsensing platform.
1 National Science Experiment

- Coverage of NSE project

- 450,000 students
- 122 schools in 2015
- 85 schools in 2016

- IMU
- WiFi
- Microphone
- Light sensor
- Infrared sensor
- Pressure sensor
- Humidity sensor
- Temperature sensor
1 National Science Experiment

- Coverage of NSE project

450,000 students
122 schools in 2015
85 schools in 2016

Atmospheric pressure
Relative humidity
Temperature
Sound pressure level
Light intensity
Inertial measurement
Locations
Step count
Travel mode
...

National Science Experiment (NSE) data

STEM education initiative involves students in scientific research

Sensor devices for data collection

Promotes hands-on learning and scientific inquiry
1 National Science Experiment

- Coverage of NSE project

- 450,000 students
- 122 schools in 2015
- 85 schools in 2016

Walkway Discovery

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Atmospheric pressure
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2 Motivation

- Walkways are important for pedestrians

Recommended route of Google Maps from NTU to BLK 941
2 Motivation

❖ Samples of uncharted walkways
3 Related Work

❖ Map completion: automatic map updating

◦ Frequently used uncharted route will be added to existing map.
3 Related Work

- Map completion: automatic map updating

Both of them focus on **motorways** using GPS data

Potential assumption: **structured** motorways

3 Related Work

❖ Map completion: automatic map updating

CrowdAtlas
MobiSys
2013

COBWEB
UbiComp
2015

Walkways
Unstructured

4 Problem Definition

❖ A road network is a directional graph $G(V,E)$

яд Previous work

*Given structured location data, discover road segments.*

A road segment is a directed edge in graph $G$, associated with a deterministic travelling direction and two terminal points.

яд Ours

*Given unstructured location data, discover walkable areas.*

A walkable area is an area bounded by nearby road segments or points of interest. Unconstrained movements of people are allowed within the area.
5 System Design

- System architecture

NSE Data → Location Data Classifier → Road Map

- Unmatched Locations
- Matched Locations

Walkable Area Estimation → Auto-Verification

Walkway Identification → Google Street View
5 System Design

- System architecture

- System Design
5 System Design

- Data classification

HDBSCAN
Map Matching
5 System Design

- Walkable area estimation

Unmatched locations
5 System Design

- Walkable area estimation

- Position: focal points determined by consecutive locations
- Shape: length sum = step_count x stride_length
5 System Design

- Walkable area estimation

Unmatched locations
5 System Design

- Walkable area estimation

Unmatched locations
5 System Design

- Walkable area estimation

Unmatched locations
5 System Design

- Walkable area estimation

Unmatched locations
5 System Design

- Representative walkway
  - Insufficient sampling data
  - Better compatible with current map

A representative walkway represents the connectivity a walkway area serves between two known road segments. If we specify the intersection points between the road segments and the walkable area, the representative walkway can be denoted as a polyline connecting the two intersection points and integrated into the road graph $G$ as an edge. There may be multiple representative walkways connecting different road segments adjacent to the same walkable area.
5 System Design

- Walkway identification

Probability density

\[ f(X) = \frac{1}{2\pi \sqrt{|\Sigma|}} exp\left(-\frac{1}{2} X^T \Sigma^{-1} X\right) \]

Probability: integral of \( f(X) \)
5 System Design

❖ Walkway identification

Score map

Weighted graph

Two-phase clustering

\[ \sum_{i=1}^{n} f(v_i) \]
6 Evaluation

❖ Walkway discovery

- 736 walkways discovered with data from about 13,000 students in 1 week
6 Evaluation

❖ Walkway discovery

❖ Region D contains most data more than 10G
Walkway discovery

The lengths of 90% of the walkways are shorter than 598m.
6 Evaluation

- Site-inspection

\[ accuracy = \frac{\text{N}_{\text{true}} \cap \text{N}_{\text{new}}}{\text{N}_{\text{new}}} \]

- 224 walkways are manually checked.
- The accuracy of 200–400 group is 89%.
6 Evaluation

❖ Example of new found walkways
6 Evaluation

❖ Utility study

- Initiate 100 trips in this study.

- Leveraging our new map can save travel distance.
One More Thing

- Google Street View
One More Thing

- Google Street View - easy to access
  - Help verify the ending points of new-found walkways

The image requirement is a HTTP URL formatted as below:

https://maps.googleapis.com/maps/api/streetview?parameters

- location
  - either a text string (such as Chagrin Falls, OH) or a lat/lng value (40.457375,-80.009353)

- size
  - specified as {width}x{height} - for example, size=600x400 (unit: pixel)

- heading
  - compass heading of camera. from 0 to 360 (both values indicating North, with 90 indicating East, and 180 South)

- FOV
  - horizontal field of view of the image.

- key
  - a key of Google Service monitoring API usage
One More Thing

❖ Google Street View - easy to access

An example

https://maps.googleapis.com/maps/api/streetview?
size=640x320&
location=1.3633164,103.8502798&
heading=30&
fov=120&
key=AIzaSyDCdDvb_rHXOhM-O4rG-fNfxrgR-YrU6GU
One More Thing

❖ Auto-Verification

Walkway

Google Street View

Features
One More Thing

❖ Auto-Verification

Walkway  Google Street View  Features
One More Thing

- Effect of Auto-Verification on accuracy

Two-phase clustering

- support of \(<\text{SC-1, SC-2}\) is 3
- support of \(<\text{SC-1, SC-3}\) is 1

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Conclusion

❖ This is the first paper targeting at walkway discovery.

❖ Our work is a great application of the crowdsensing NSE project.

❖ Our proposed method is general enough to be fed with all kinds of geolocation data.
Thank you very much.

Q & A

Thank you very much.

Source code: https://github.com/caochuntu/IPSN2018_guizu