Sidewalk Extraction Using Aerial and Street View Images

Xinyue Ye, Ph.D., Associate Professor
Department of Landscape Architecture and Urban Planning
& Department of Geography
Texas A&M University, Email: xinyue.ye@tamu.edu
Editor-in-Chief, Computational Urban Science

Acknowledgement

- Ning, H., **Ye, X***., Chen, Z., Liu, T., & Cao, T. (2021) Sidewalk Extraction Using Aerial and Street View Images. Environment and Planning B. (in press)

- **Ye, X**. and Lin, H. (eds.) (2020) Spatial Synthesis: Computational Social Science and Humanities, Springer.

- Jamonnak, S., Zhao, Y., AL-Dohuki, S., Curtis, A., **Ye, X**., Kamw, F., & Yang J. (2020) GeoVisuals: a visual analytics approach to leverage the potential of spatial videos and associated geonarratives. International Journal of Geographical Information Science. doi: 10.1080/13658816.2020.1737700

- **Ye, X**. and Liu, X. (eds.) (2019) Cities as Social and Spatial Networks, Springer.

Outline

- Introduction
- Related Work
- Methodology
- Results
- Discussion

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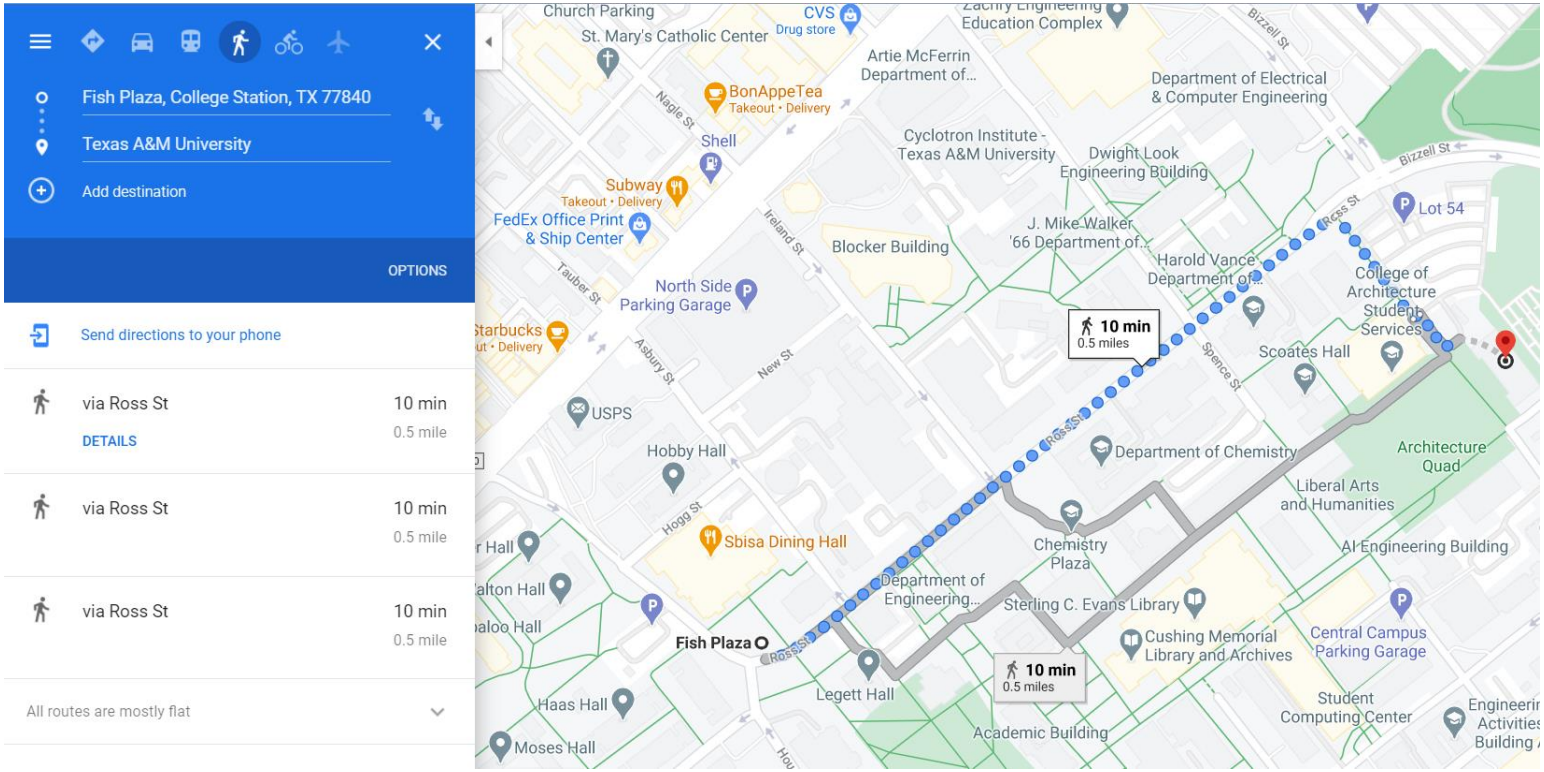
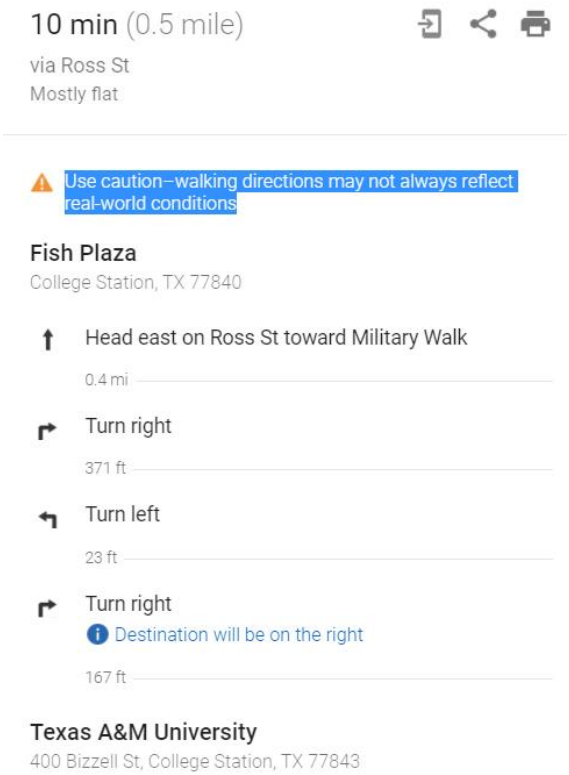
Walking


Fish Plaza, College Station, TX 77840
Texas A&M University
Add destination
OPTIONS
Send directions to your phone
via Ross St
10 min
0.5 mile
DETAILS
via Ross St
10 min
0.5 mile
via Ross St
10 min
0.5 mile
All routes are mostly flat
Church Parking
St. Mary's Catholic Center
CVS
Drug store
Artie McFerrin Department of...
BonAppeTea
Takeout · Delivery
Shell
Subway
Takeout · Delivery
FedEx Office Print & Ship Center
Blocker Building
North Side Parking Garage
USPS
Hobby Hall
Sbisa Dining Hall
Fish Plaza
Legett Hall
Haas Hall
Moses Hall
Academic Building
Cyclotron Institute - Texas A&M University
Dwight Look Engineering Building
Department of Electrical & Computer Engineering
J. Mike Walker '66 Department of...
Harold Vance Department of...
Lot 54
College of Architecture Student Services
Scoates Hall
Department of Chemistry
Architecture Quad
Liberal Arts and Humanities
Chemistry Plaza
AI Engineering Building
Department of Engineering...
Sterling C. Evans Library
Cushing Memorial Library and Archives
Central Campus Parking Garage
Student Computing Center
10 min
0.5 miles
10 min
0.5 miles
Nagle St
Ireland St
Tauber St
Asbury St
New St
Hogg St
Ross St
Spence St
Bizzell St

Which information is missed?



Big Image Data

http://shadeparadenashville.blogspot.com/2013/12/sidewalk-project-3-walking-from.html

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Semantic segmentation based on deep learning

- FCN (Long et al., 2015)
- SegNet (Badrinarayanan et al., 2017)
- U-Net (Ronneberger et al., 2015)
- PSP-Net (Zhao et al., 2016)
- LaU model (He et al., 2019)
- OCR model (Yuan et al., 2019)

Road extraction from aerial image

- ResUnet on the Massachusetts roads dataset (Mnih and Hinton, 2010)
- SegNet to segment roads in the Massachusetts dataset and the Thailand Earth Observation System (THEOS) dataset (Panboonyuen et al. 2017)

Sidewalk extraction from street view image

- Senlet and Elgammal (2012): a pixel-wise and a path-wise method to predict and connect the occluded sidewalks covering a university campus.
- Smith et al. (2013): random forest to identify sidewalk after extracting local and global features.
- Mattyus et al. (2016): fully connected deep structured networks and Markov random field.
- Wang et al. (2019):convert street view image into top-view representation.

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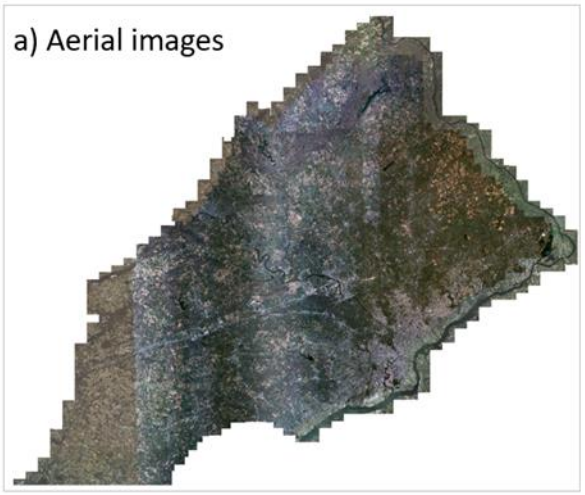
sidewalk datasets

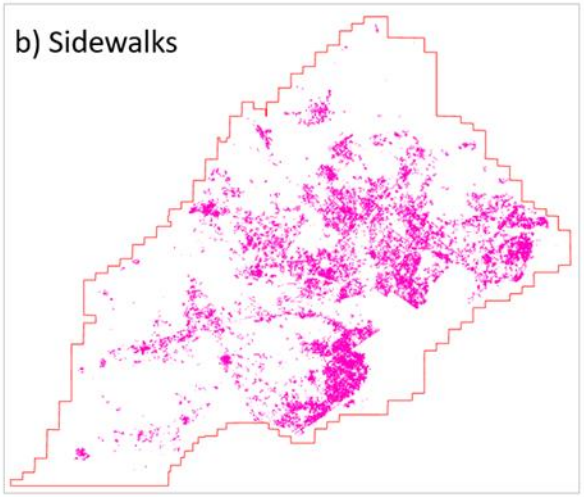
- field survey
- deriving from existing land cover data
- extracting from images

workflow


1. Collect aerial images
2. Extract sidewalks and occluded/missing parts.
3. Obtain street view images of the occluded sidewalk.
4. Extract sidewalks from street view images.
5. Reproject the location of sidewalk from street view images to match the sidewalk from aerial images.
6. Clean and merge the extraction of sidewalk from the satellite and street view image.

Study area (Delaware Valley Regional in Pennsylvania State)

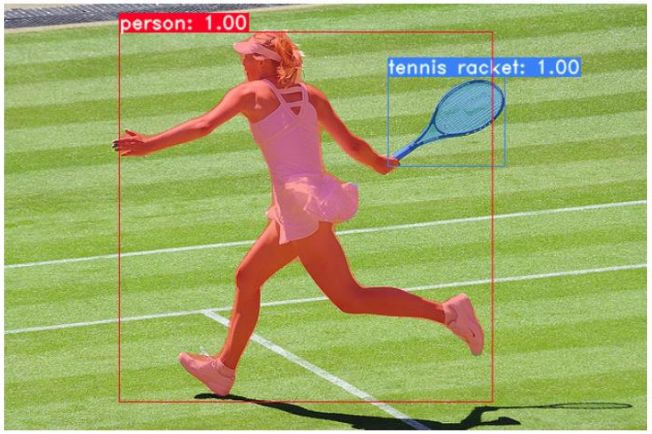




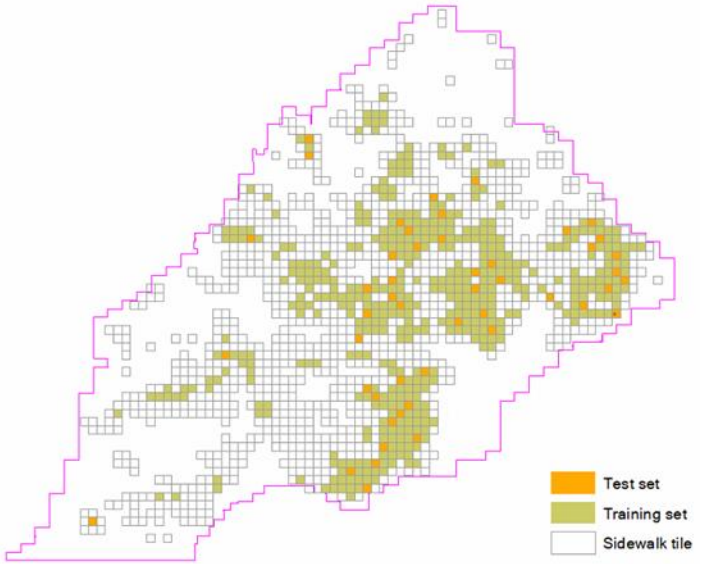
Training set and test set

[CV2019/PaperSummary] YOLACT :Real-time Instance Segmentation

abhigoku10 Follow
Dec 26, 2019 · 15 min read

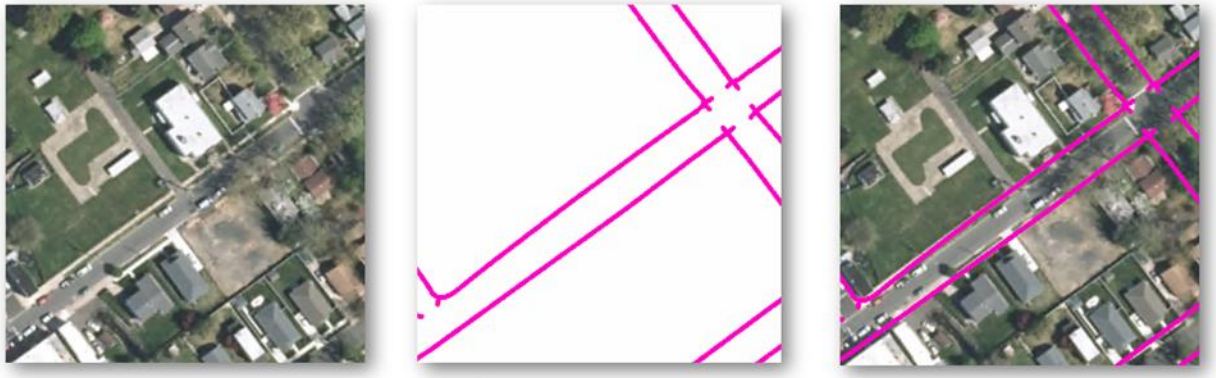


Yolact : Bounding Box with Instance Segmentation



https://medium.com/@abhigoku10/cv2019-papersummary-yolact-real-time-instance-segmentation-e62fa721957f

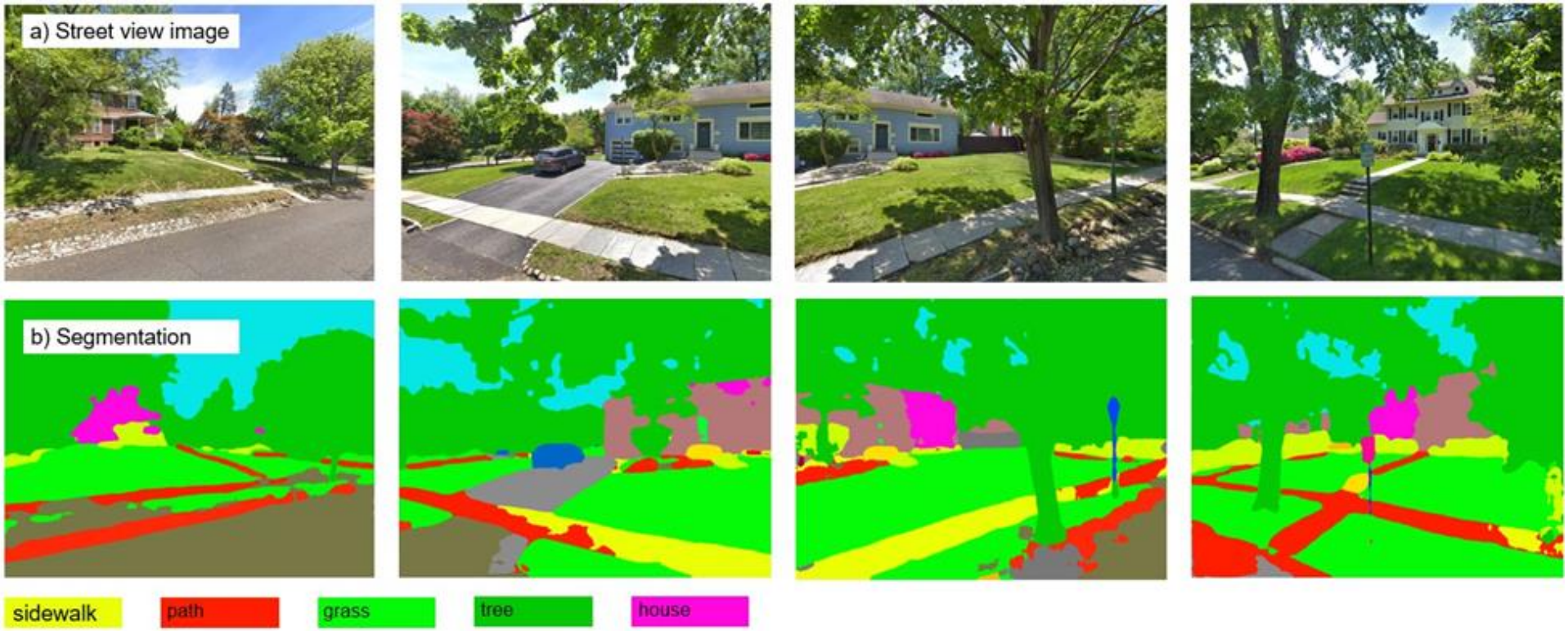
A sample of the sidewalk training set. The DVRPC sidewalks dataset uses a short line to represent the conjunction point with crosswalks, which is preserved in the training dataset.



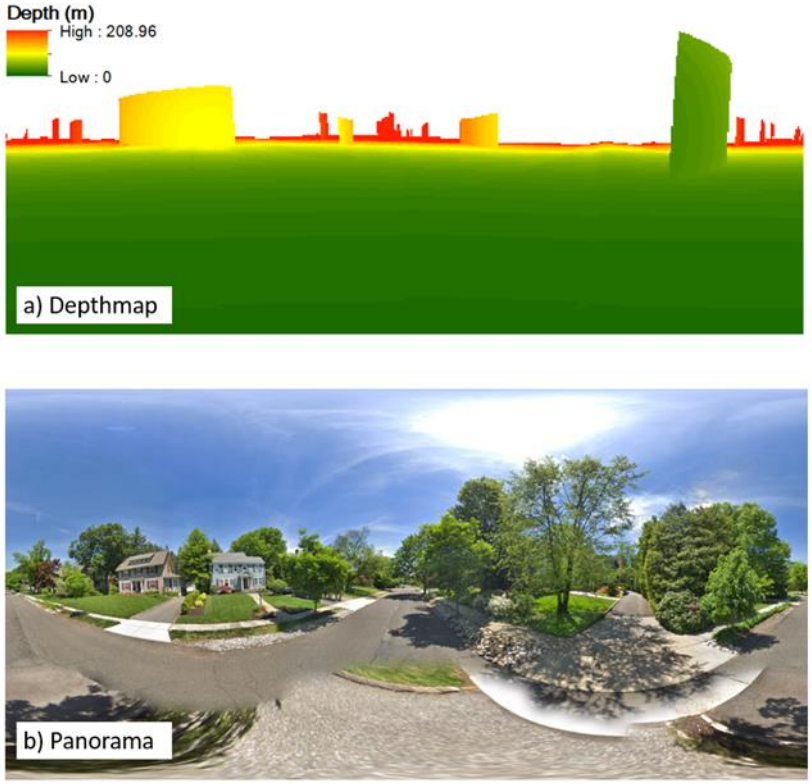
a) Image b) Label c) Label over on image

Missing sidewalks in aerial images between dangles

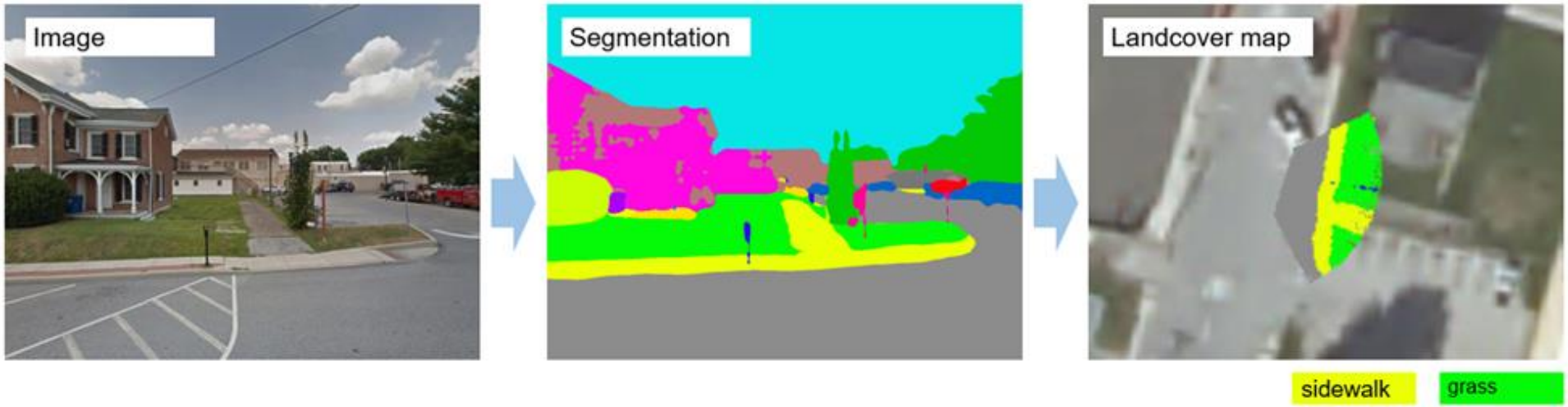
Segmentation of street view images by pre-train PSPNet



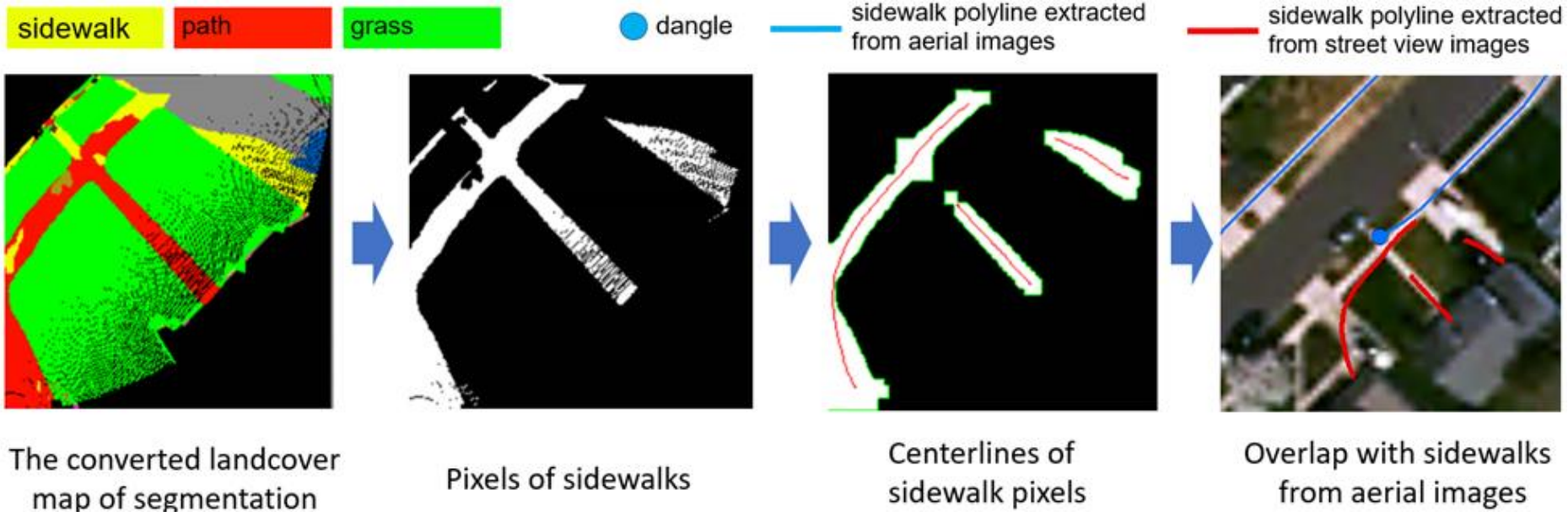
A panorama and its depthmap in Equirectangular projection from Google Street View



Reproject the segmentation to landcover map



Extracting sidewalk centerlines from street view images. The centerlines were extracted merely from landcover map for visual representation



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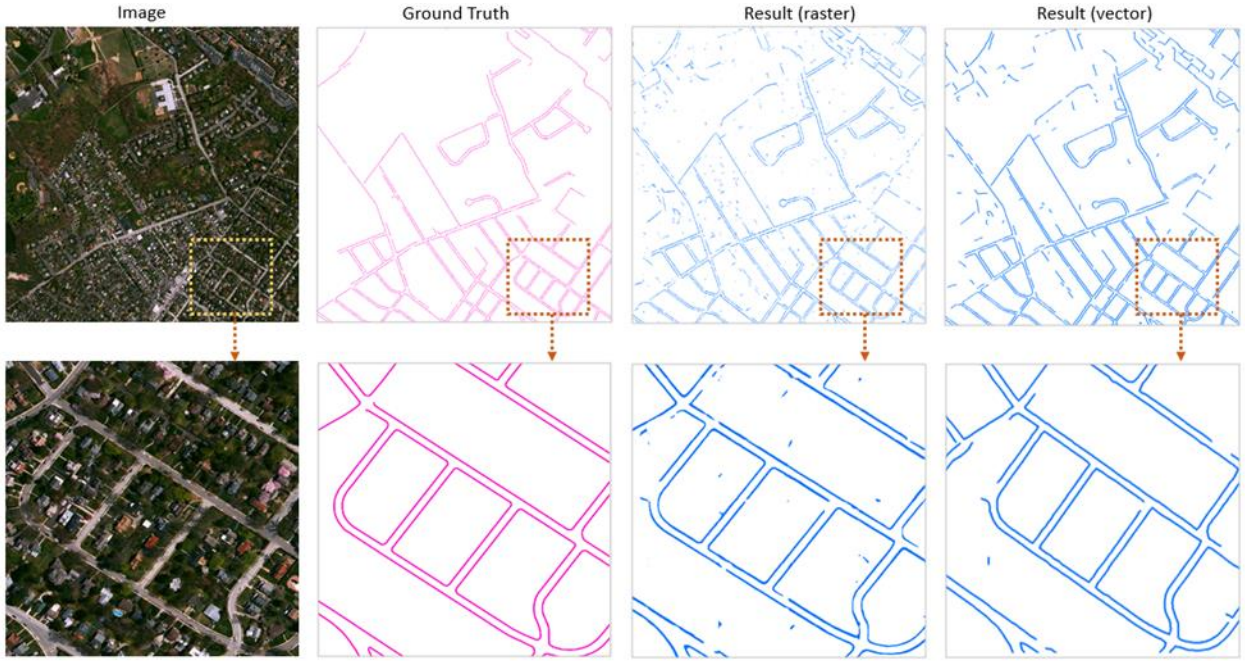
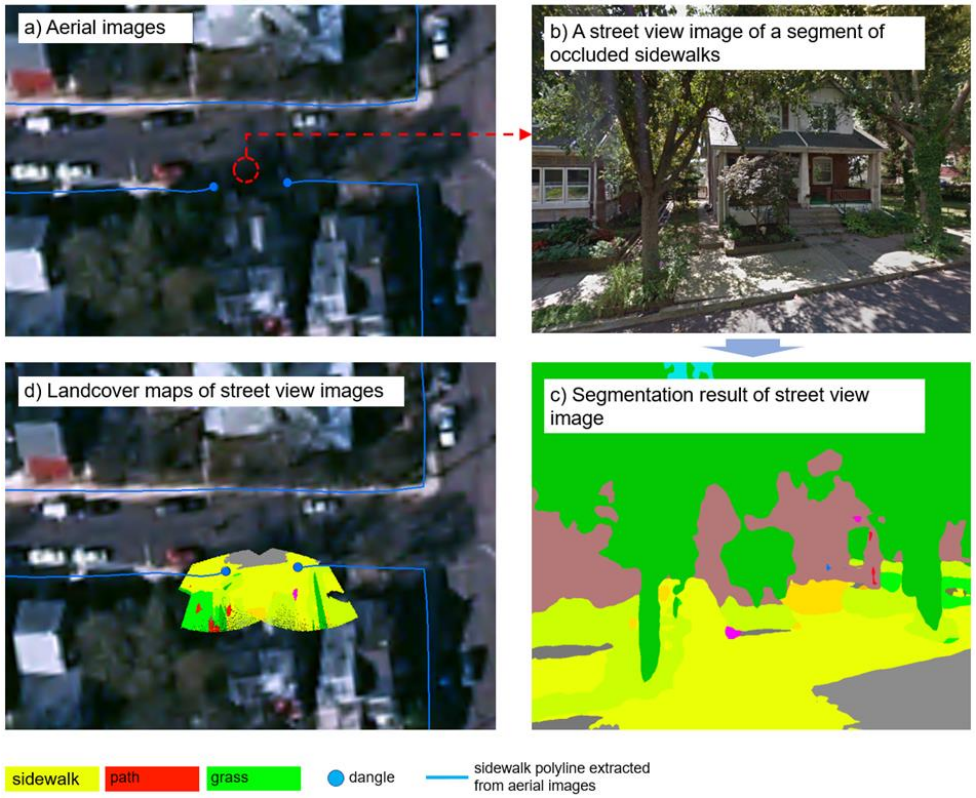
Sidewalk detection results of YOLACT



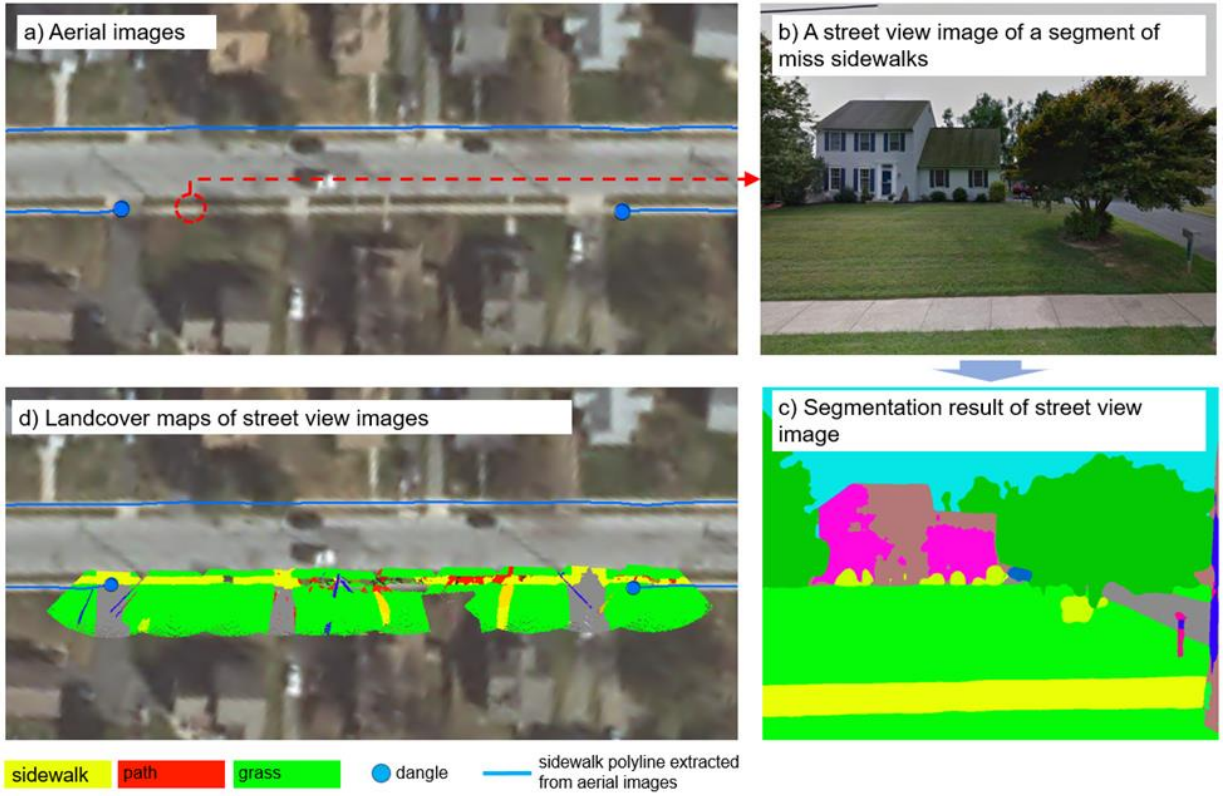
Precision and recall of segmentation results

Method	Precision	Recall
Pixel-wise	0.5508	0.7488
Line-wise	0.8221	0.9380
Line-wise (cleaned-up by road centerlines)	**0.8987**	**0.9301**

An occluded segment of sidewalks was restored using street view images



A missing sidewalk segment of 85 meters was restored using street view images



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https://www.scientificamerican.com/article/out-of-the-way-human-delivery-robots-want-a-share-of-your-sidewalk

ENGINEERING

Out of the Way, Human! Delivery Robots Want a Share of Your Sidewalk

As automated delivery ramps up, cities must decide how to make the best use of public spaces

State Rep. Shelley Kloba puts proposed delivery robot regulations in a Starship Technologies delivery robot to carry to the House Transportation Committee chair.

TOM BANSE / NW NEWS NETWORK

https://www.nwnewsnetwork.org/post/washington-lawmakers-ponder-rules-sidewalk-driving-delivery-robots

By Jeremy Hsu on February 19, 2019 أعرض هذا باللغة العربية

Delivery robots from Starship Technologies roll over sidewalks in Milton Keynes, England, in 2018. Credit: Starship Technologies

Reality?

https://www.latimes.com/local/lanow/la-me-ln-fix-broken-sidewalks-20140818-story.html

LOCAL NEWS

LA's 'broken' streets, sidewalks may not be ready for 2028 Olympics, city leaders say

By **ELIZABETH CHOU** | hchou@scng.com | Daily News

PUBLISHED: February 7, 2018 at 12:43 p.m. | UPDATED: February 7, 2018 at 5:21 p.m.

2028 Summer Olympics

Olympic games

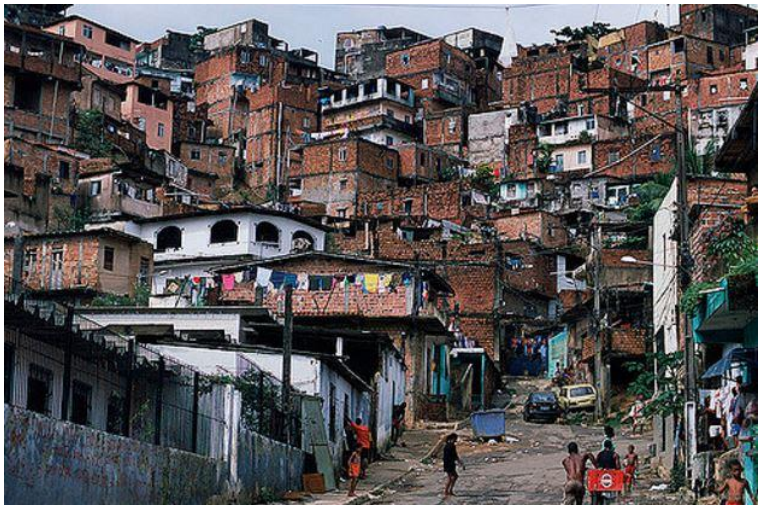
The 2028 Summer Olympics, officially known as the Games of the XXXIV Olympiad, and commonly stylized as LA28, is a forthcoming international multi-sport event that is scheduled to take place from July 21 to August 6, 2028, in Los Angeles, California, United States.

https://www.dailynews.com/2018/02/07/la-city-leaders-say-streets-sidewalks-are-broken-and-may-not-be-ready-in-time-for-olympics/

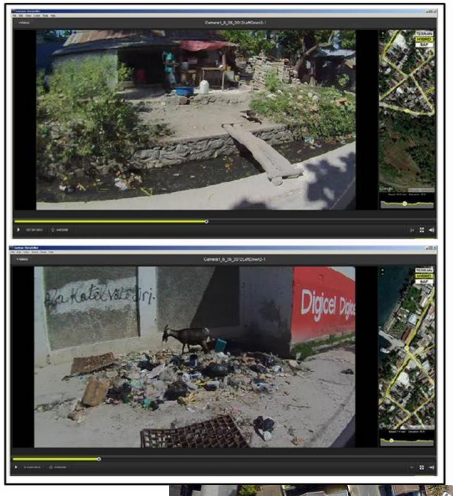
What makes cities vulnerable to COVID-19? Concentrated poverty, says econ professor - Edward Glaeser

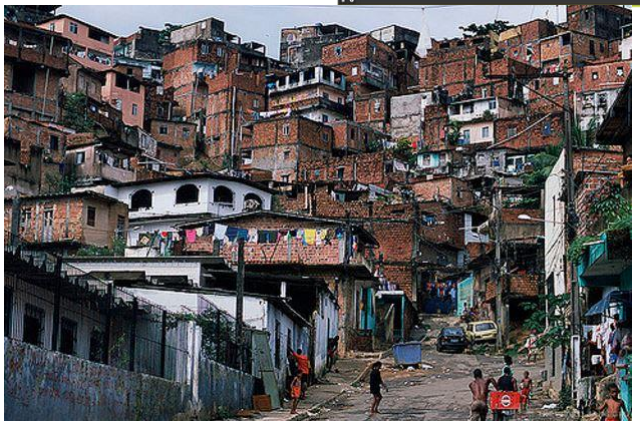
Excerpt

May 28, 2020, Audio, "Disease has thrived among dense populations since cities began. But COVID-19 is the worst example since 1918, and New York City is America's primary victim, with empty streets and skyscrapers. Can New York and other cities survive this pandemic?"
Listen on KCRW

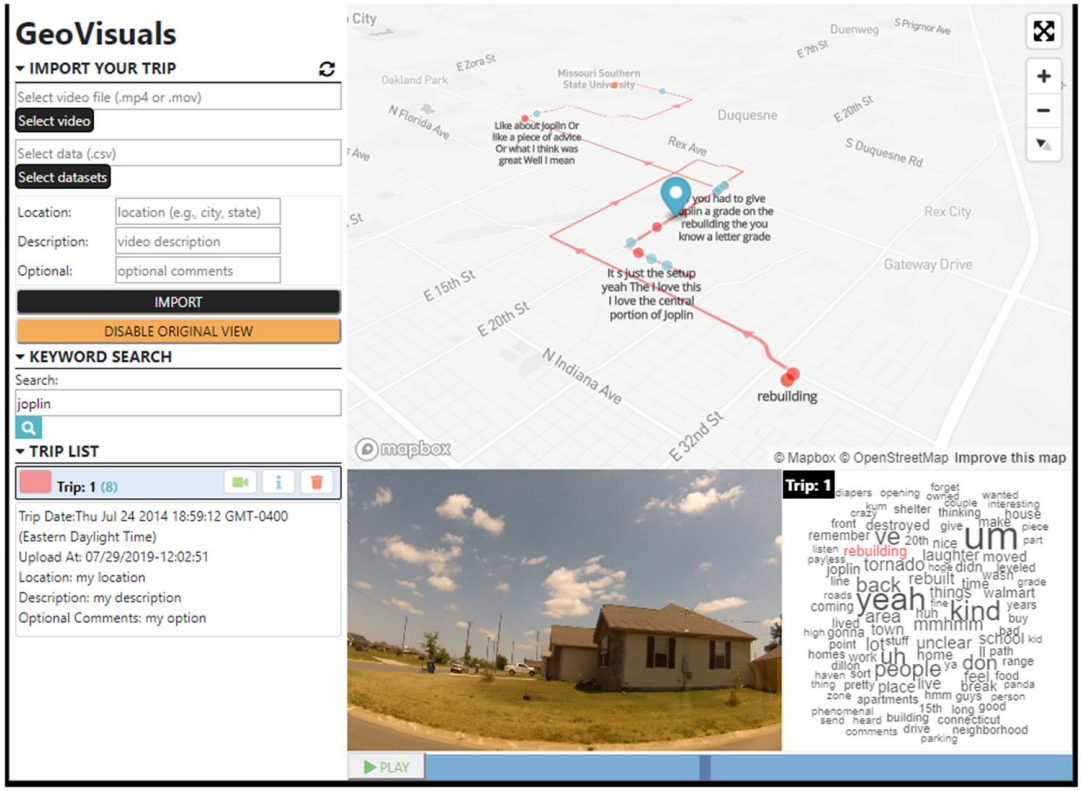


Data Challenging Communities





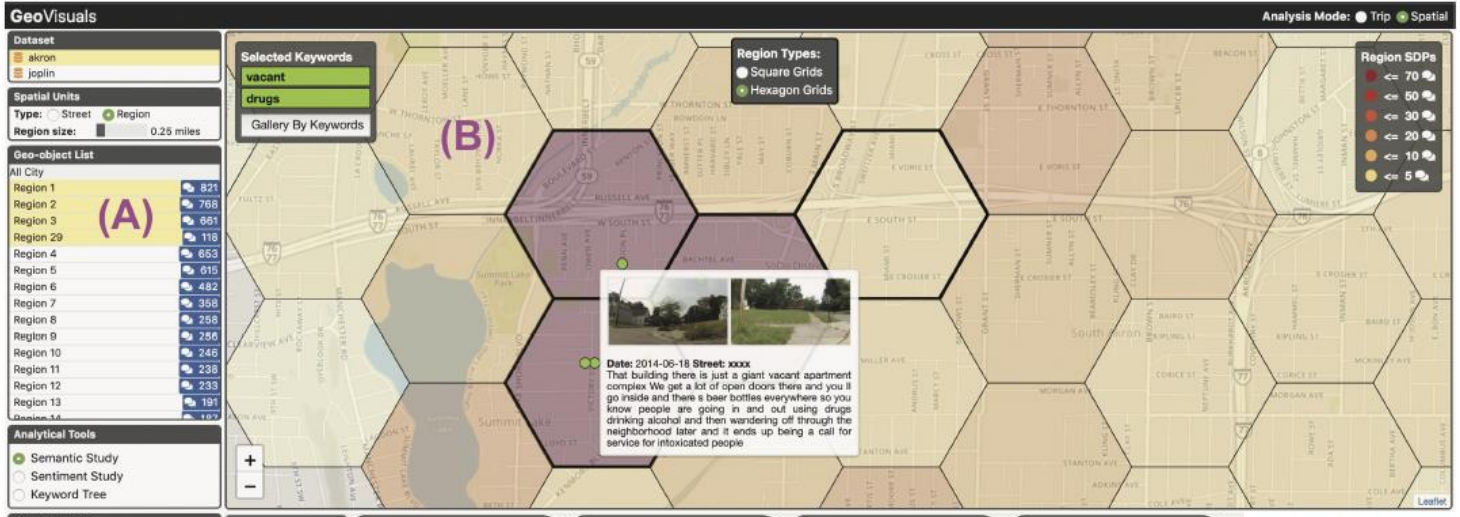
Urban Memory

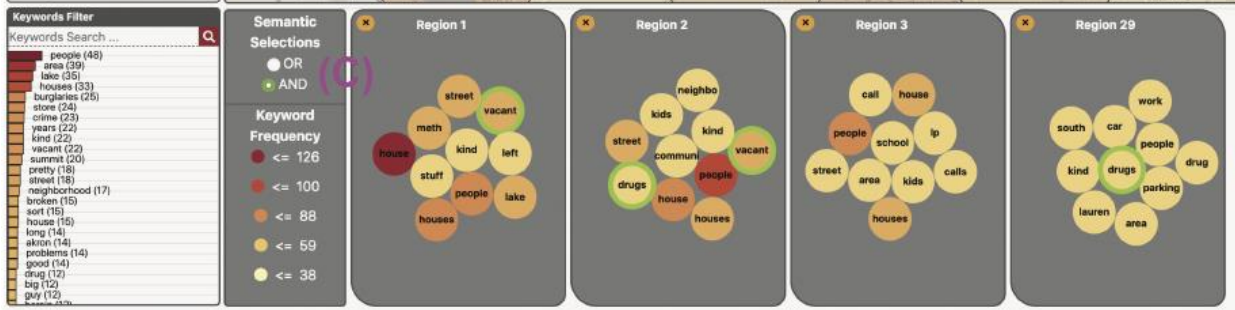


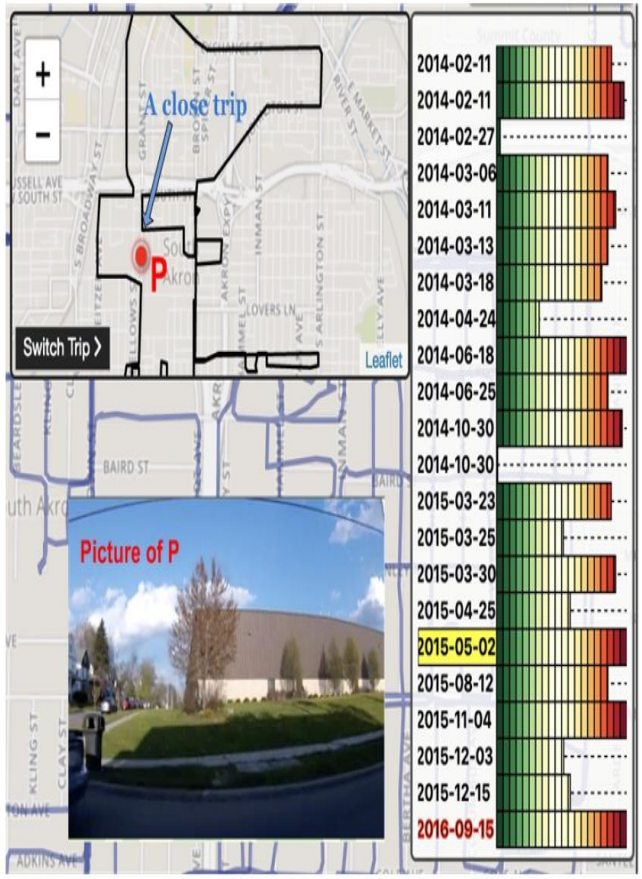
query, navigation, and comparison of video, photo, audio, and text over regions and locations

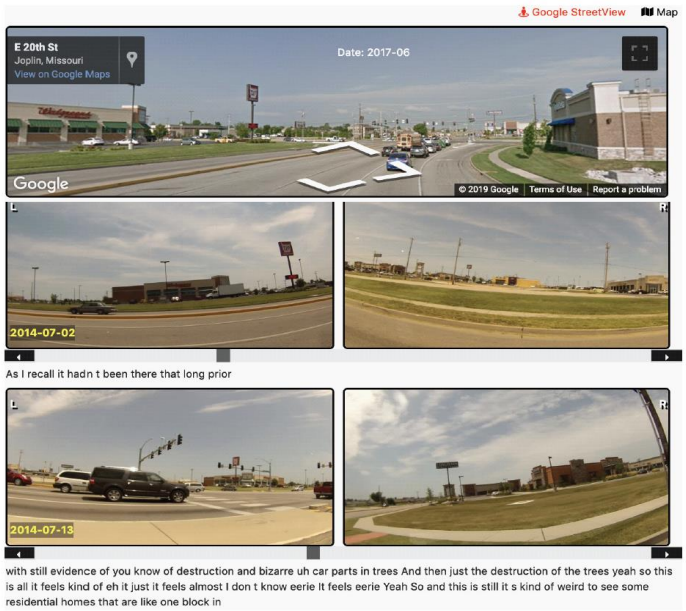
Urban Memory

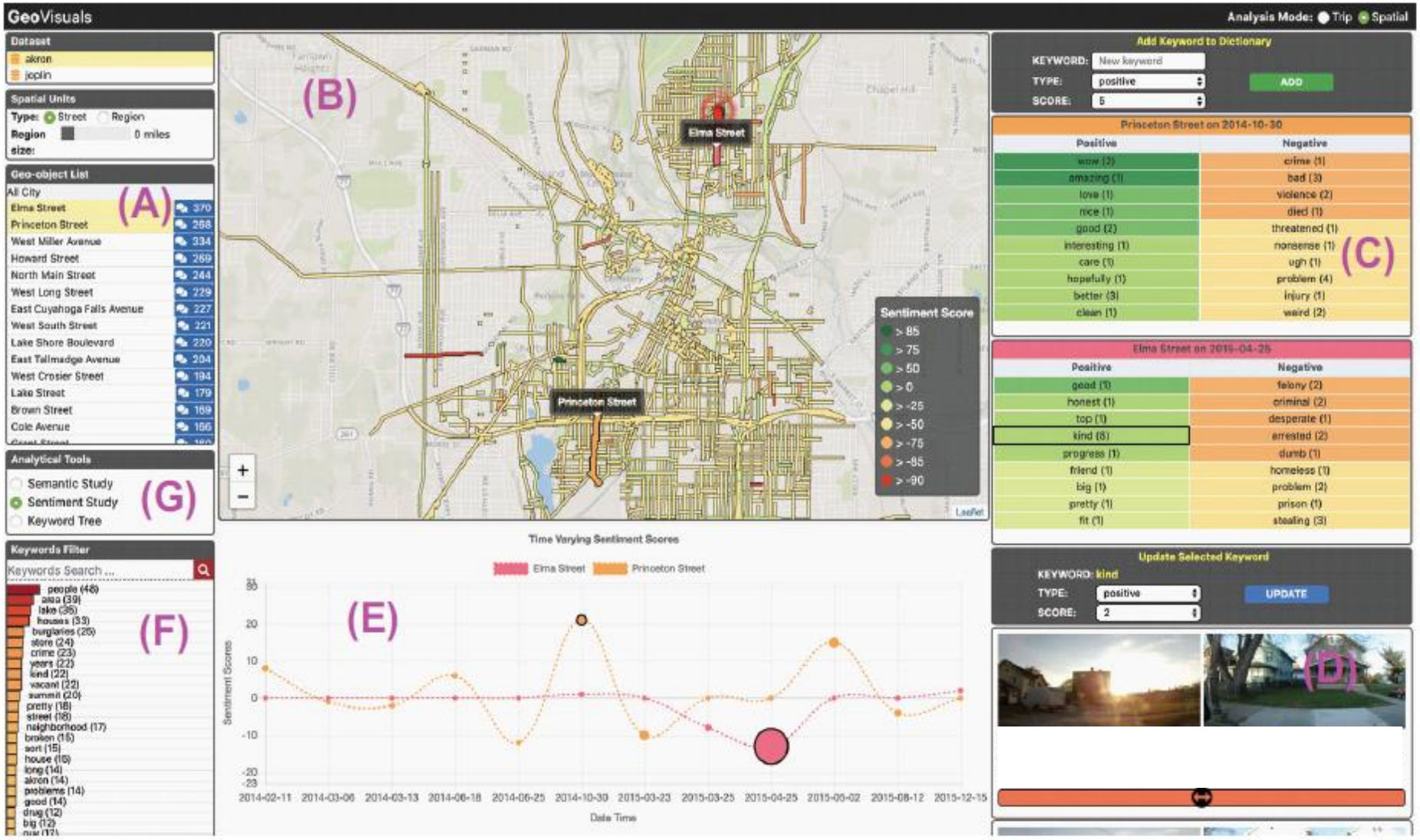
Procedure


GeoVisuals
Analysis Mode: Trip Spatial
Dataset
akron
joplin
Spatial Units
Type: Street Region
Region size: 0.25 miles
Geo-object List
All City
Region 1 821
Region 2 768
Region 3 661
Region 29 118
Region 4 653
Region 5 615
Region 6 482
Region 7 358
Region 8 258
Region 9 256
Region 10 246
Region 11 238
Region 12 233
Region 13 191
(A)
Analytical Tools
Semantic Study
Sentiment Study
Keyword Tree
Selected Keywords
vacant
drugs
Gallery By Keywords
(B)
Region Types:
Square Grids
Hexagon Grids
Region SDPs
<= 70
<= 50
<= 30
<= 20
<= 10
<= 5
Date: 2014-06-18 Street: xxxx
That building there is just a giant vacant apartment complex We get a lot of open doors there and you ll go inside and there s beer bottles everywhere so you know people are going in and out using drugs drinking alcohol and then wandering off through the neighborhood later and it ends up being a call for service for intoxicated peopie
Leaflet


Keywords Filter
Keywords Search ...
people (48)
area (39)
lake (35)
houses (33)
burglaries (25)
store (24)
crime (23)
years (22)
kind (22)
vacant (22)
summit (20)
pretty (18)
street (18)
neighborhood (17)
broken (15)
sort (15)
house (15)
long (14)
akron (14)
problems (14)
good (14)
drug (12)
big (12)
guy (12)
Semantic Selections
OR
AND
(C)
Keyword Frequency
<= 126
<= 100
<= 88
<= 59
<= 38
Region 1
street
vacant
meth
house
kind
left
stuff
people
lake
houses
Region 2
neighbo
kids
street
kind
communi
vacant
drugs
people
house
houses
Region 3
call
house
people
school
ip
street
area
kids
calls
houses
Region 29
work
south
car
people
drug
kind
drugs
parking
lauren
area


A close trip
P
Switch Trip
Leaflet
BAIRD ST
Picture of P
2014-02-11
2014-02-11
2014-02-27
2014-03-06
2014-03-11
2014-03-13
2014-03-18
2014-04-24
2014-06-18
2014-06-25
2014-10-30
2014-10-30
2015-03-23
2015-03-25
2015-03-30
2015-04-25
2015-05-02
2015-08-12
2015-11-04
2015-12-03
2015-12-15
2016-09-15


Google StreetView
Map
E 20th St
Joplin, Missouri
View on Google Maps
Date: 2017-06
Google
© 2019 Google
Terms of Use
Report a problem
2014-07-02
As I recall it hadn t been there that long prior
2014-07-13
with still evidence of you know of destruction and bizarre uh car parts in trees And then just the destruction of the trees yeah so this is all it feels kind of eh it just it feels almost I don t know eerie It feels eerie Yeah So and this is still it s kind of weird to see some residential homes that are like one block in

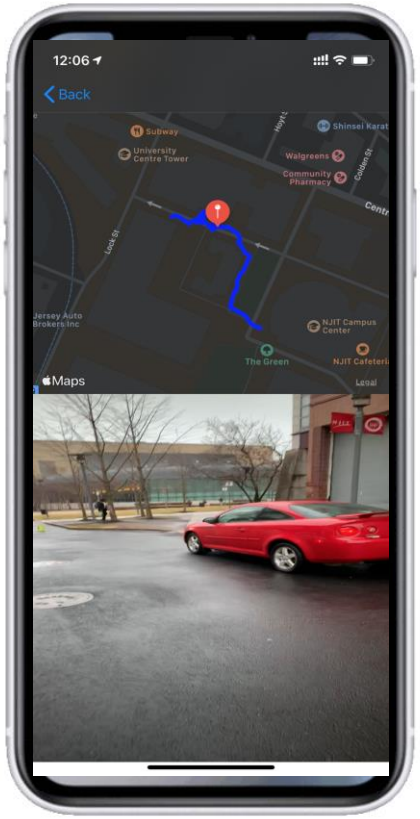

GeoVisuals
Analysis Mode: Trip Spatial
Dataset
akron
joplin
Spatial Units
Type: Street Region
Region size: 0 miles
Geo-object List
All City
Elma Street 370
Princeton Street 288
West Miller Avenue 334
Howard Street 269
North Main Street 244
West Long Street 229
East Cuyahoga Falls Avenue 227
West South Street 221
Lake Shore Boulevard 220
East Tallmadge Avenue 204
West Crosier Street 194
Lake Street 179
Brown Street 169
Cole Avenue 166
(A)
(B)
Elma Street
Princeton Street
Sentiment Score
> 85
> 75
> 50
> 0
> -25
> -50
> -75
> -85
> -90
Add Keyword to Dictionary
KEYWORD: New keyword
TYPE: positive
SCORE: 5
ADD
Princeton Street on 2014-10-30
Positive
wow (2)
amazing (1)
love (1)
nice (1)
good (2)
interesting (1)
care (1)
hopefully (1)
better (3)
clean (1)
Negative
crime (1)
bad (3)
violence (2)
died (1)
threatened (1)
nonsense (1)
ugh (1)
problem (4)
injury (1)
weird (2)
(C)
Elma Street on 2015-04-25
Positive
good (1)
honest (1)
top (1)
kind (8)
progress (1)
friend (1)
big (1)
pretty (1)
fit (1)
Negative
felony (2)
criminal (2)
desperate (1)
arrested (2)
dumb (1)
homeless (1)
problem (2)
prison (1)
stealing (3)
Analytical Tools
Semantic Study
Sentiment Study
Keywords Tree
(G)
Keywords Filter
Keywords Search ...
people (48)
area (39)
lake (36)
houses (33)
burglaries (26)
store (24)
crime (23)
years (22)
kind (22)
vacant (22)
summit (20)
pretty (18)
street (18)
neighborhood (17)
broken (15)
sort (15)
house (15)
long (14)
akron (14)
problems (14)
good (14)
drug (12)
big (12)
(F)
Time Varying Sentiment Scores
Elma Street
Princeton Street
(E)
Sentiment Scores
Date Time
2014-02-11
2014-03-06
2014-03-13
2014-06-18
2014-06-25
2014-10-30
2015-03-23
2015-03-25
2015-04-25
2015-05-02
2015-08-12
2015-12-15
Update Selected Keyword
KEYWORD: kind
TYPE: positive
SCORE: 2
UPDATE
(D)

Procedure

Apps

GeoVideo

- Location-based video capturer
- Without Internet connection
- Official website
  - http://vis.cs.kent.edu/GeoVisuals/mobile.html
- Appstore
  - https://apps.apple.com/us/app/geovideo/id1492419929
- Google Play
  - https://play.google.com/store/apps/details?id=com.nlapps.geovideo&hl=en



Behavior-driven agent-based models of spatial systems

Xinyue Ye & Yuri Mansury

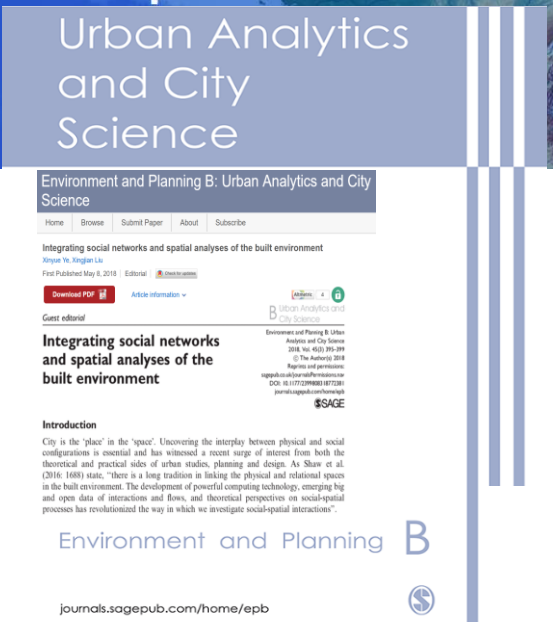
The Annals of Regional Science **57**, 271–274(2016) | Cite this article

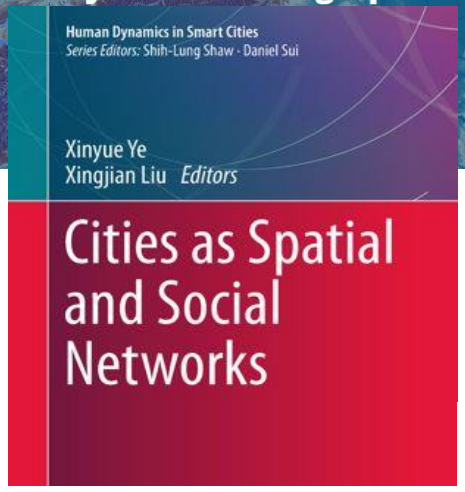
Human in Cities

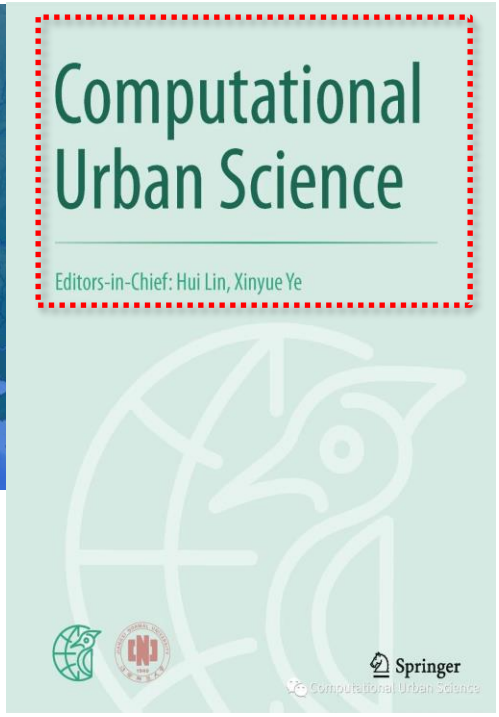
SHARI

Spatial Social Networks in GIScience

A New Special Issue from International Journal of Geographical Information Science







CONGRATULATIONS TO

Xinyue Ye

whose paper has been recognized as a top 20 most read paper in

Tijdschrift voor Economische en Sociale Geografie

Call for Papers: Special Issue on Big Data and Urban Planning

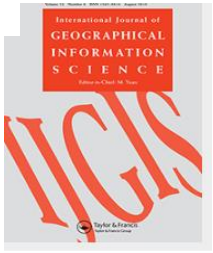
Guest Editors: Anthony G.O. Yeh, Qingquan Li, Michael Batty, Xinyue Ye, Sarah Williams.

Editorial

Editorial: human dynamics in the mobile and big data era

Shih-Lung Shaw, Ming-Hsiang Tsou & Xinyue Ye

Pages 1687-1693 | Received 05 Mar 2016, Accepted 06 Mar 2016, Published online: 24 May 2016

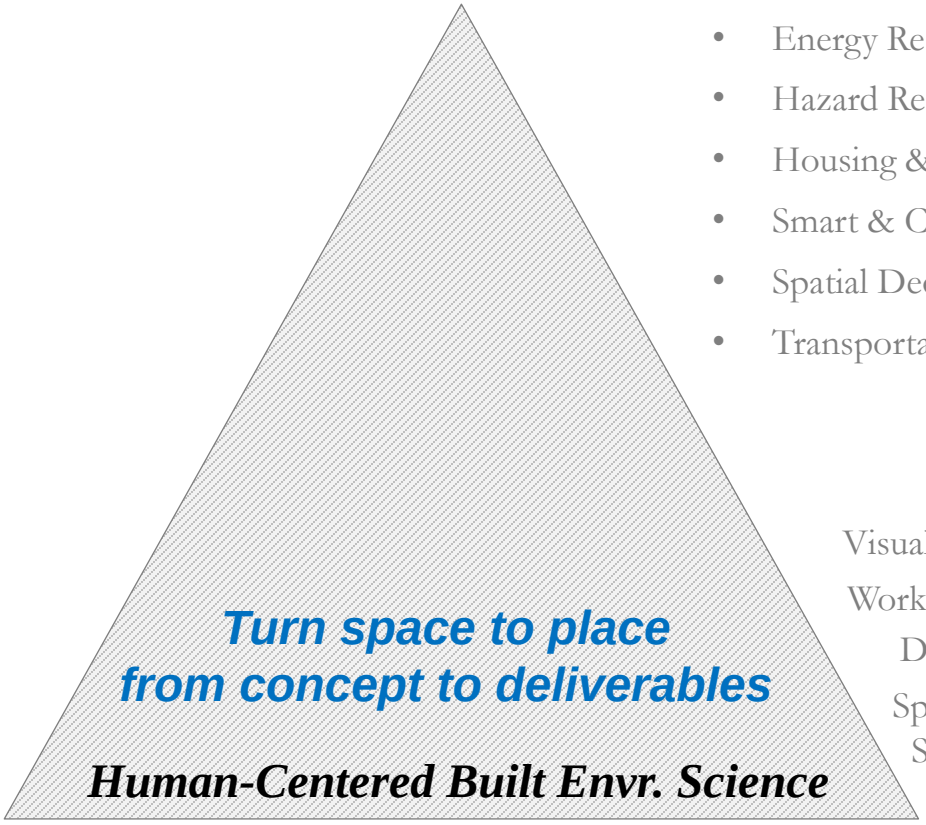


The new data landscape for regional and urban analysis

Xinyue Ye · Canfei He

Collaborative Research Plan

Transformative Outcome



- Energy Research
- Hazard Reduction & Recovery
- Housing & Land Use
- Smart & Connected Cities/Health
- Spatial Decision Support System
- Transportation & Travel Behavior

Human Dynamics

Conceptual

Urban Systems and Communities in the 21st Century

Visual Analytics
Urban Computing
Workflow Automation
Text as Data
Data Fusion
Image and Video Analytics
Space-time Analysis
Real-time System
Spatial Econometrics

Methodological

Emerging AI, ICT, and location-aware technologies