Transforming Smart Cities with Spatial Computing

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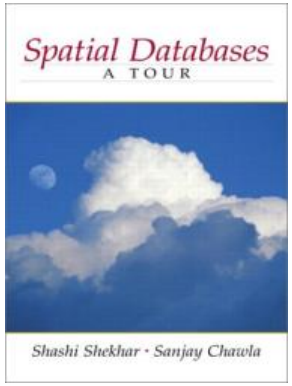
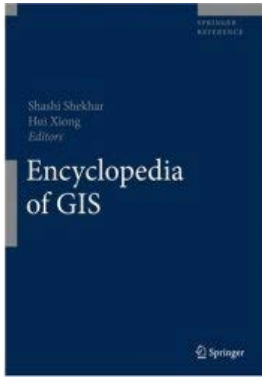
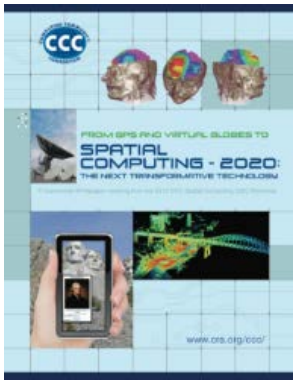






Details: Transforming Smart Cities with Spatial Computing,
Proc. IEEE International Smart Cities Conference, 2018 (w/ Y. Xie et al.).

Acknowledgements

- P.I., Connecting the Smart-City Paradigm with a Sustainable Urban Infrastructure Systems Frame- work to Advance Equity in Communities, NSF(Award 1737633), $2.5 M, 9/1/2017 - 8/31/2020.

- Co-P.I., Planning Grant: Engineering Research Center for Intelligent Infrastructure for Safe, Efficient and Resilient Mobility, NSF,(Award 1840432), 97K, 9/18-8/19, (PI: Anil Misra, University of Kansas).

- Co-P.I., Cloud-Connected Delivery Vehicles: Boosting Fuel Economy Using Physics-Aware Spatio- temporal Data Analysis and Real-Time Powertrain Control, USDOE ARPA-E, $1.78M (1.4M fed.), 2/17 - 2//20. (PI: W. Northrop)

- P.I., Identifying and Analyzing Patterns of Evasion (HM0210-13-1-0005), USDOD-NGA, $0.6M, 6/13- 12/18.

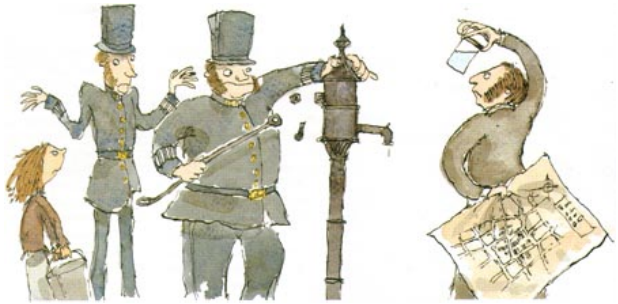
- Co-P.I., Increasing Low-Input Turfgrass Adoption Through Breeding, Innovation, and Public Education, USDA/NIFA/SCRI (contract 2017-51181-27222), $5.4 M, 9/17 - 8/21. (with E. Watkins).

OUTLINE

- Motivation
  - Spatial Methods and Industrial Cities
  - Spatial Computing in Modern Cities
- Knowledge Co-production (KC)
- KC Story 1: Evacuation Planning
- KC Story 2: A S&CC Project
- Conclusions

History of Transforming Cities with Spatial Computing

1854: What causes Cholera?

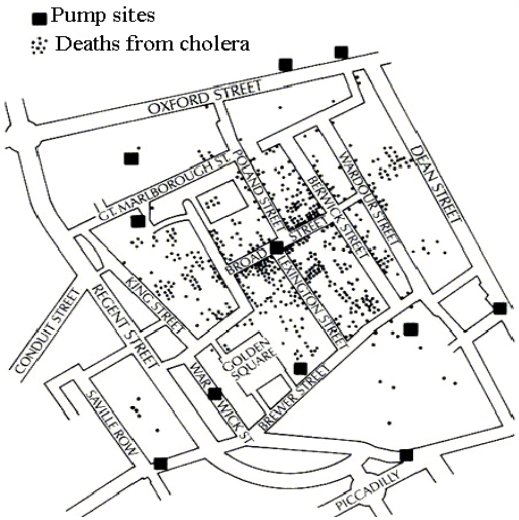


Collect & Curate Data → Discover Patterns, Generate Hypothesis → Test Hypothesis (Experiments) → Develop Theory

? water pump

Remove pump handle

Germ Theory



Impact on cities:
Health & well-being, parks, sewer system to protect drinking water, …

Q? What are Choleras of today?
Q? How may Spatial Computing Help?

Spatial Computing Examples

ArcGIS ESRI

SaTScan™
Software for the spatial, temporal, and space-time scan statistics

Google Earth Engine

OGC™
Open Geospatial Consortium, Inc.

MONSANTO

ORACLE
SPATIAL

THE CLIMATE CORPORATION

IBM Smarter Planet

OpenStreetMap

Ushahidi

Spatial Computing is a Critical Infrastructure Today!

- 2 billion GPS receivers in use, will hit 7 billion by 2022.
- Besides location, it reference time for critical infrastructure
  - Telecommunications industry
  - Banks
  - Airlines...

- GPS is the single point of failure for the entire modern economy.

- 50,000 incidents of deliberate (GPS) jamming last two years
  - Against Ubers, Waymo's self-driving cars, delivery drones from Amazon

Bloomberg Businessweek

July 25, 2018, 4:00 AM CDT

The World Economy Runs on GPS. It Needs a Backup Plan

Source: *https://www.bloomberg.com/news/features/2018-07-25/the-world-economy-runs-on-gps-it-needs-a-backup-plan*

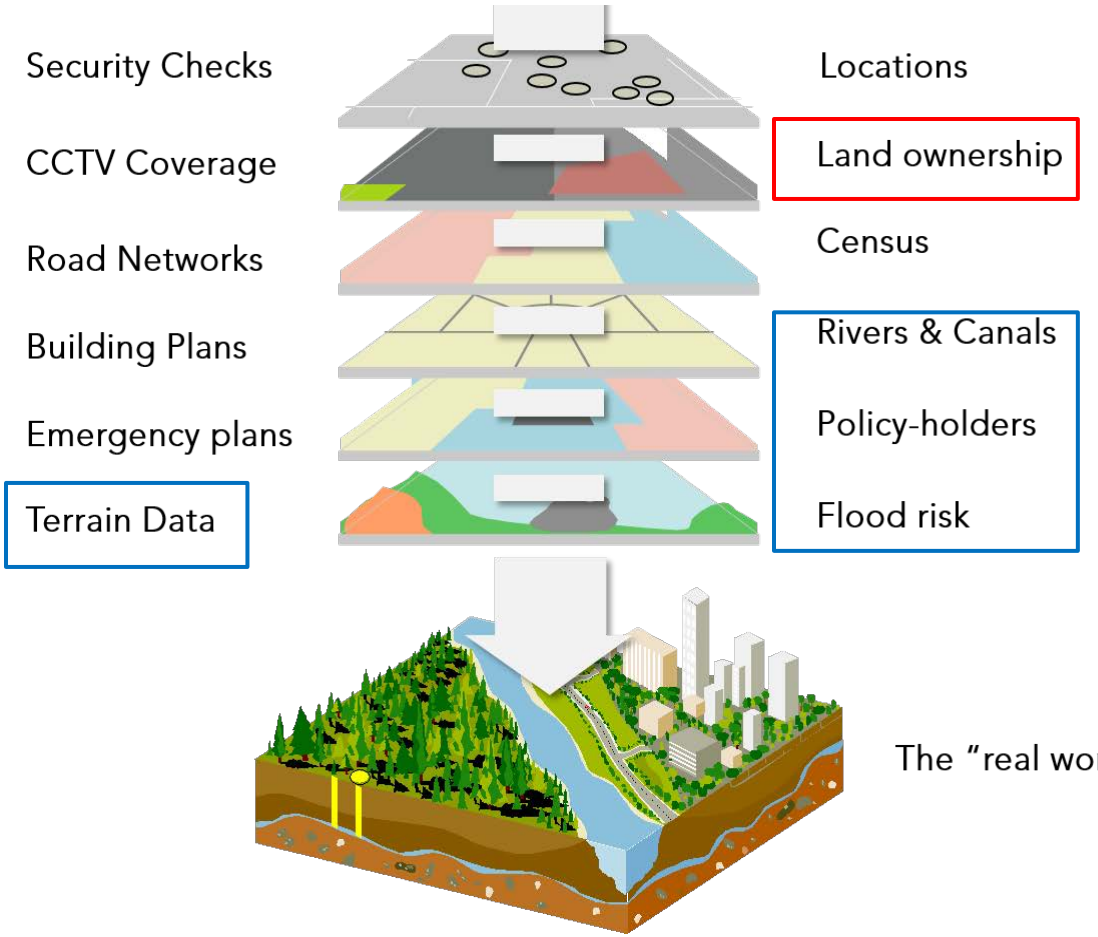
Spatial Computing in Modern Cities

Rank	2015	2016	2017
1	**(69%) Geospatial / Mapping**	(93%) Public Meeting records	**(53%) GeoSpatial / Mapping**
2	(67%) Virtualization	(92%) Wireless Infrastructure	(48%) Cybersecurity
3	(60%) Performance Benchmarks	(91%) Redundant/ Offsite Data Storage	(34%) Predictive Policing
4	(58%) Transaction Processing	(90%) Endpoint Security	(32%) eDiscovery
5	(57%) Project Management	(85%) Broadband Infrastructure	(20%) Predictive Analytics

Source: Digital Cities Survey, Center for Digital Government, GovTech.com, 11/9/2017.

Spatial Computing in Modern Cities

- Operational
  - E-911, CMAS/PLAN, …
  - Situation awareness
  - Public Safety, e.g., Floods
- Tactical
  - Property tax
  - Site selection
  - Asset tracking
- Strategic
  - Long-term planning
  - Land-use



Source: https://www.cbronline.com/wp-content/uploads/2017/03/what-is-GIS.png

Outline

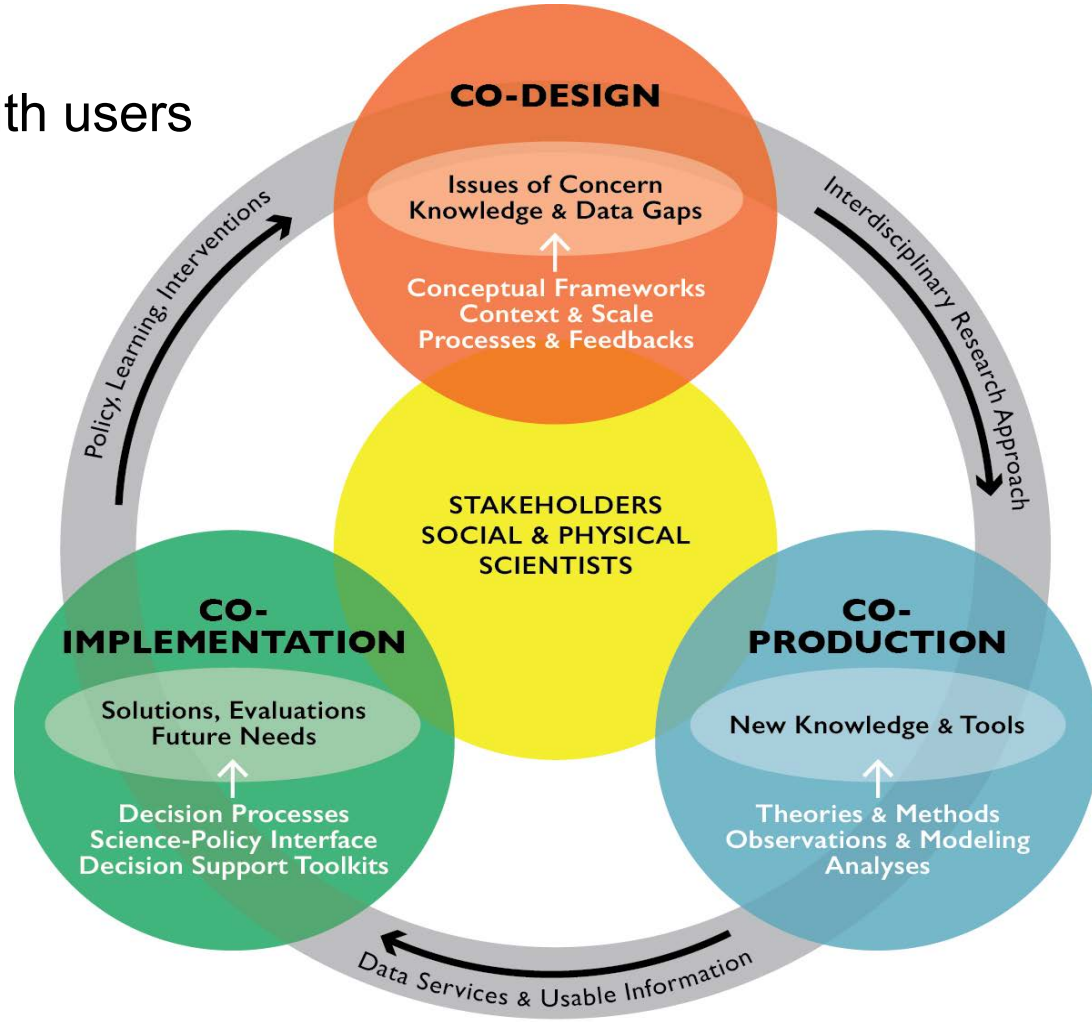
- Motivation
- Next: Knowledge Co-production (KC)
- KC Story 1: Evacuation Planning
- KC Story 2: A S&CC Project
- Conclusions

Source: The Sheffield Mental Health Guide, sheffieldflourish.co.uk, 5 Apr 2017.

Advancing Science Discovery to Application

- Knowledge **co-production** with users
  - Co-Visioning
  - Co-define Problems
  - Co-select Science Questions
  - Co-Evaluate Discoveries

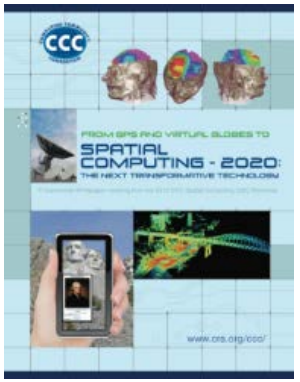
  - Ex. NCAR



Source: NCAR/UCAR 2016 Annual Report

Knowledge Co-Production

- **Co-production Initiatives**
  - CRA/CCC Visioning Workshops
  - (Midwest) Big Data Hubs & Spokes
  - NSF Sustainability Research Networks
  - NSF Smart & Connected Community



- **Co-Production Examples** in my work
  - 2005: Evacuation Planning: MN local governments
  - Current: NSF SCC Project: counties, cities in MN, FL

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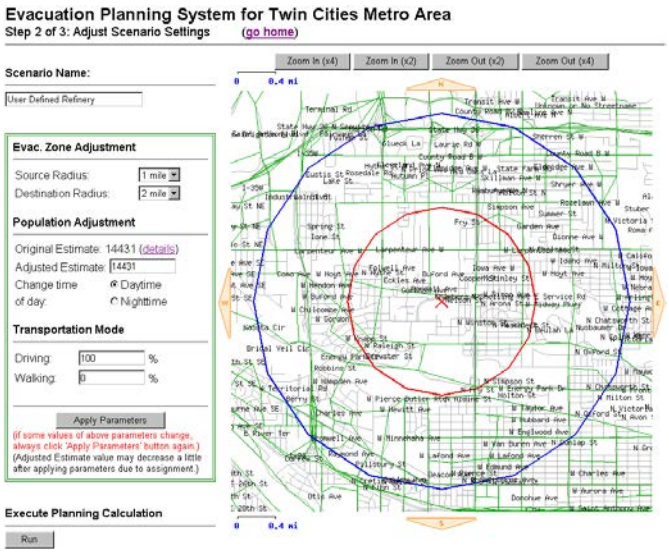
Knowledge Co-Production: Evacuation Planning (2005)

FoxTV newsclip (5-minutes), Disaster Area Evacuation Analytics Project
https://www.youtube.com/watch?v=PR9k72W8XK8

KC Story 1: Evacuation Planning (2005)

- **Team**: US DHS, MN Dept. of Transportation, URS Corp.
  - Emergency Mangers, Police, Fire Fighters, Natl. Guard
- Co-Visioning via monthly meetings
  - Challenges: evacuees & traffic maps
  - Police: focus on what can be done!
- Problem Co-Definition
  - 1-mile scenarios: 5 sites, work-day or night-time
- Co-Discovery
  - For 1st mile, walking faster than driving
- Co-Evaluation
  - Walk selected routes : avoid wooden bridge near E
  - Lock parking garages during evacuation ?

Scenario	Population	Vehicle	Walking
A	143,360	4:45	1:32
B	83,143	2:45	1:04
C	27,406	4:27	1:41
D	50,995	3:41	1:20
E	3,611	1:21	0:36



Details: FoxTV newsclip, Shashi Shekhar Disaster Area Evacuation Analytics, https://www.youtube.com/watch?v=PR9k72W8XK8

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KC Story 2: A NSF S&CC Project

- **Academic History**
  - Humphrey center
  - Center for Urban & Regional Affairs
  - Hennepin University Partnership
  - Center for Transportation Studies

- **Local Government History**
  - 2010-2020: Regional 10-year planning cycle (Metropolitan Council)
  - 2013-14: Thrive MSP 2040
  - 2015: USDOT Smart Cities Challenge proposal by Minneapolis

REGIONAL 10-YEAR PLANNING CYCLE

METROPOLITAN COUNCIL

2013 - 2014
Regional Development Guide
2040 Thrive MSP

2014 - 2015
Regional System and Policy Plans:
Regional Parks
Water Resources
Transportation
Housing

Fall 2015
System Statements

Fall 2015
LOCAL PLANNING HANDBOOK

December 31, 2018
Comprehensive Plan Updates

Local Plan Implementation and Plan Amendments

United States Census 2010

Source: https://metrocouncil.org/About-Us/why-we-matter/Equity.aspx

Draft Outcomes

- Stewardship
- Prosperity
- Equity
- Livability
- Sustainability

2040 Thrive MSP
ONE VISION, ONE METROPOLITAN REGION

METROPOLITAN COUNCIL

KC Story 2: S&CC – Co-visioning

- Co-visioning Meetings (Academics + Local Governments)
  - 2014: Smart City Workshop
  - 2015-16: NSF SRN Sustainable & Health Cities – Equity

- Co-Visioning
  - Infrastructure planning for driver-less, post-carbon future, climate change
  - Advance Environment, Health, Wellbeing & Equity via infrastructure refinement

- Co-select Questions
  - Understand spatial equity in infrastructure & outcomes
    - wellbeing. health, environment
  - How does equity first approach differ from average-outcome based approaches ?

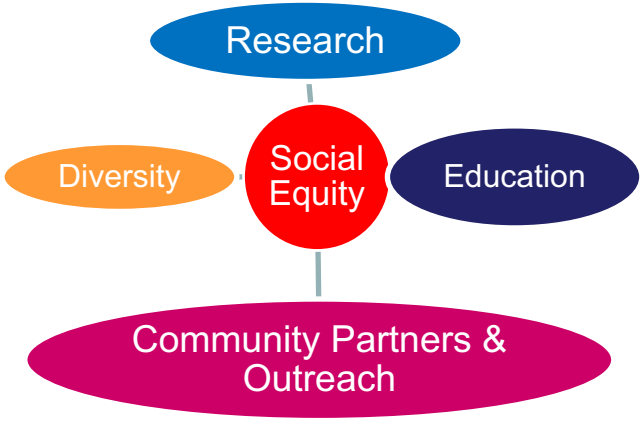
- Problem Co-Definition: How to measure spatial equity? Well-being?

KC Story 2: S&CC – Co-select Question

- Team: U of Minnesota, Purdue U, FL State U, U of WA
  - Schools, Counties (e.g., Hennepin), Cities (e.g., Minneapolis, St. Paul, Tallahassee);
  - MetroLab Network, National League of Cities, ICLEI-USA, Intl. City/County

- Co-Discovery:

- Co-Evaluation



Project Aims & Approach

- **Objectives**
  - Understand spatial equity (e) in the context of 7 basic infrastructure provisioning and related wellbeing (*W*), health (*H*), environment (*E*) and equity (e) outcomes in cities
  - Advance all four outcomes using smart spatial infrastructure planning in cities.

- **Approach in collaboration of Community Partners**
  - Comprehensive fine intra-urban scale data (SEIU-EHW parameters in Figure 1)
  - Spatial Data Science to understand relationships (Figure 2).
  - Model & visualize multi-infrastructure spatial smart city futures
  - **Knowledge co-production** theories, science and practice

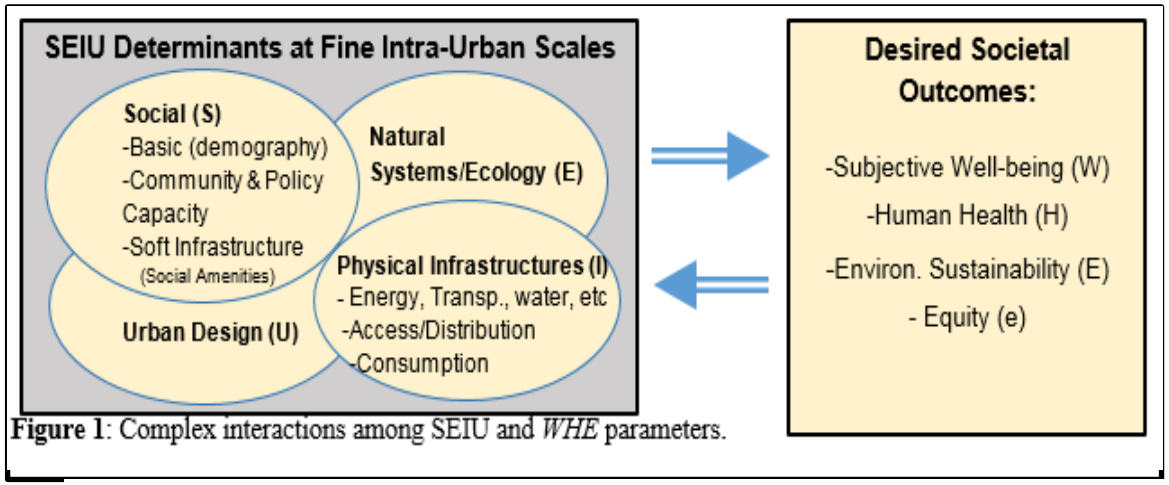


Figure 1. Complex Interactions among SEIU and EHW parameters

Figure 2. Spatial Patterns

Four Themes

Theme 1: Develop comprehensive data sets on SEIS-EHW at intra-urban scales:

- **Cyber infrastructure** for diverse and disparate data sets
- **Novel citizen science, sensor and survey techniques** to characterize
  - air pollution
  - near-realtime flooding
  - subjective well-being (W)

Theme 2: Advance spatial data analysis to understand SEIU-*WHEe* relationships

- Advanced **spatial computing algorithms**
- Data and Discipline-inspired Hypotheses
- Equity (e) as spatial dispersion & correlation of *WHE*-SEIU

Theme 3: Model and visualize spatial smart city futures for Equity-First Plan

- **Multiple & connected spatial infrastructure futures** scenario modeling
- Scenario **Visualization**
- **Value of information** and policy-learning

Theme 4: Education and Workforce Development: Citizen science with middle & high-school students; Interdisciplinary Graduate Certificate; Professional education; Visualization for Policy Leadership;

Data-Intensive Science of S&CC in 21st Century

SEIU EHW

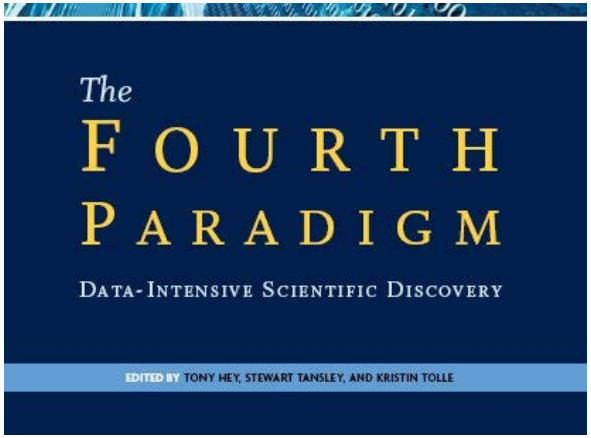
Hotspots of infrastructure deprivation, consumption, pollution, investment, disease & well-being. Correlates?

Equity first policies

Role of policies & urban forms

Collect, & Curate Big Data → Spatial Patterns, Hypothesis Generation → Test Hypothesis (Policy Intervention) → S&CC Theory

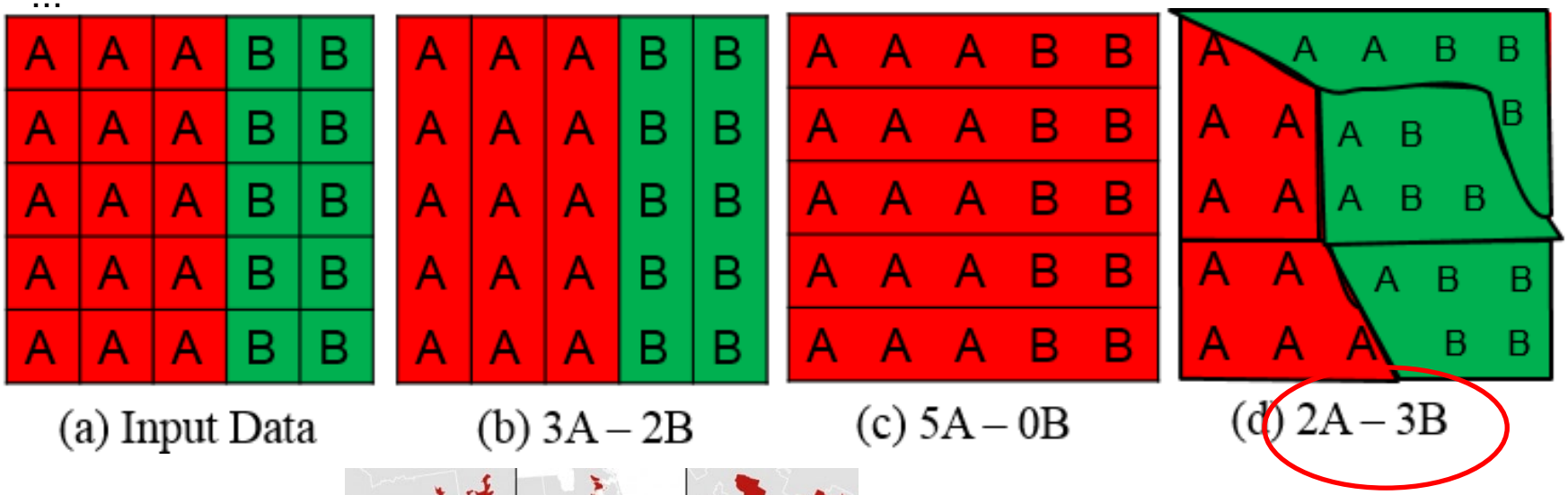
Volume, Variety

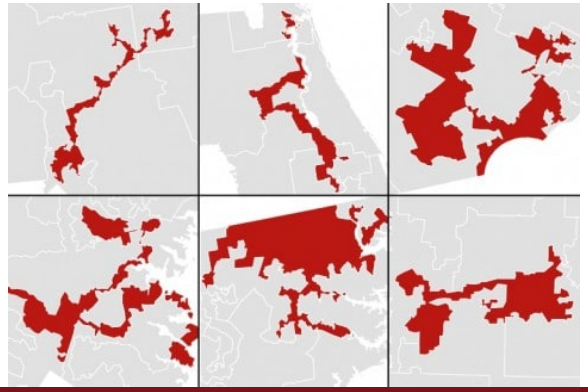


Data-driven and Discipline-inspired hypothesis generation

Spatial Data Science: Gerrymandering Challenge

- Challenge: Spatial partitioning affects election results
- Modifiable Areal Unit Problem (MAUP)
- ...

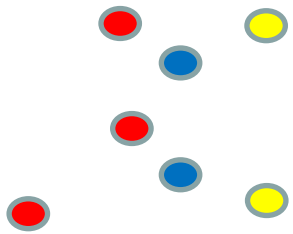




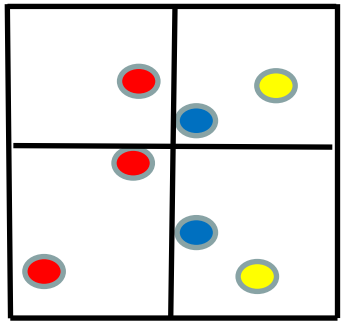
US Electoral District with Irregular shapes
Source: Washington Post

Task 2B: Discover co-location and teleconnection patterns

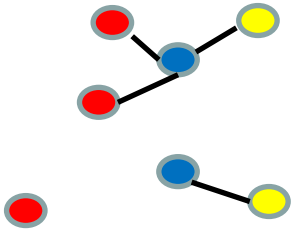
- Challenge: Traditional statistical methods miss spatial interactions
- Prelim. Results: Co-location and teleconnection reveal spatial interaction
  - between variables for point data types
- Proposed: address data with multiple levels of aggregation, e.g., areal summary



(a) a map of 3 features



(b) Spatial Partitions



(c) Neighbor graph

	Pearson's Correlation	Ripley's cross-K	Participation Index (colocation)
-	-0.90	0.33	0.5
-	1	0.5	1

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CONCLUSIONS & NEXT STEPS

- Cities is societally important and facing challenges
  - Majority live in cities
  - Challenges: climate change, aging infrastructure, …
  - Opportunities: renewable energy, self-driving vehicles, …
- Spatial Computing has already transformed Cities
  - Sanitation, green spaces, E-911, public safety, …
- Many Transformative opportunities lie ahead
  - Ex. Spatial equity

- However, these will not material without
  - **Knowledge Co-production**: local governments, academics, businesses, …
  - **Basic Research**, e.g., spatial data science to overcome gerrymandering challenge