S&CC-IRG Track 1: Connecting the Smart-City Paradigm with a Sustainable Urban Infrastructure Systems Framework to Advance Equity in Communities

NSF Award #1737633

**Team Composition**

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- R. Feiock, Florida State University
- J. Marshall, University of Washington
- V. Merwade, Purdue University
- J. Brown, D. Dalbotten, R. Johns, J. Cao, F. Douma, L. Kne, University of Minnesota

**Community Partners**

- B. Hjelle & K. Mayell, Minneapolis (public Works)
- M. Olson, Tallahassee (Utilities)
- Carl Michaud, Hennepin county (Public Works)
- Matt Larson, St. Paul
- C. Ellingson & B. Stretch, Minneapolis Public Schools
- A. Fyfie, ICLEI-USA
- T. Macgalliard, Intl. City/County Management Association
- B. Levine, MetroLab Network

Website: [http://www.spatial.cs.umn.edu/Project/smart-city/index.html](http://www.spatial.cs.umn.edu/Project/smart-city/index.html)
Two Overarching Questions

• **Address two inter-connected overarching research questions (RQs)**
  - **RQ1:** How can we better understand spatial equity (including inequality and fairness) in the context of 7 basic infrastructure provisioning and related wellbeing (W), health (H), environment (E) outcomes in cities (WHE)? (Note: Equity, e, is explored as the spatial distribution of the WHE outcomes and their correlates with SEIU parameters)
  - **RQ2:** Given the opportunity of transformative smart infrastructures on-horizon (e.g. smart electricity grid, autonomous vehicles) and their interactions with land use, buildings, solar PV deployment, urban farming and green infrastructure to manage climate risks, can smart spatial infrastructure planning in cities, initiated today, encompassing all 7 physical infrastructure sectors, advance all four WHEe outcomes? In particular, how does an equity first approach differ from conventional approaches that focus on “average” outcomes?

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

- Kick-off meetings with community partners: Minneapolis, Hennepin County, and Tallahassee (Theme 1 & 4).
- Developed a well-being survey that will be administered in Minneapolis (Theme 1).
- Developed framework for SEIU-WHEe database, added public & community partner data (Theme 1).
  - Collected 80% of the data needed for the surface-groundwater flood prediction model (Theme 1 & 4).
  - Obtained tree inventor for the City of St. Paul and the University of Minnesota.
  - Acquired parcel level housing characteristic, sales information, natural gas consumption, water consumption, spatial/land use, and voting characteristics data for Tallahassee/Leon County (Theme 1).
- Assembled a network of partners to implement the Citizen Science curriculum modules (Theme 4).
- Advertised Citizen Science summer teacher workshop (Minneapolis Public Schools; Theme 4)

Source: MPR News, Roanoke Times
What is Next?

- Complete the SEIU-WHEe database
  - Work with community Partners to finish populating the database
- Near-real time flood modelling
  - Parameterize the model, Acquire streamflow and rainfall data, Calibrate model using observed data
- Spatial green infrastructure analysis
  - Process high spatial resolution LiDAR and high temporal resolution satellite imagery
  - Incorporate ash tree features
- Gerrymandering risks (Effect of spatial partitioning) on statistical measures of inequality
  - Evaluate statistical measures, metrics with real data and assess point data and aggregate data.
  - Identify real world relevant use-cases for real-time spatial patterns and mine identified spatial patterns.
- Equity-first planning
  - Develop instruments for baseline measures of policy planning stakeholders
  - Organize a Tallahassee stakeholder meeting with workshop on measuring livability at FSU in October
- Citizen science curriculum development
  - Complete curriculum development, Further website development for Citizen Science component
  - Strengthen connections with schools, Minneapolis Public Schools teachers
  - Finalize logistics for Citizen Science summer teacher workshop
Mapping Ash Trees for Green Infrastructure Equity

- Theme 2: Advance spatial data analysis (Task 2A: Algorithms for spatial patterns)
- Activities: Met twice with Hennepin County, MN. Received:
  - Use cases: Map Ash trees to aid replacement planning
  - Data: tree inventory, remote sensing imagery and LiDAR
    - Data issues: (1) Tree location & canopy size inaccuracy
    - (2) Temporal misalignment with remote sensing data
  - New data: Tree inventory (road side) from Saint Paul, MN & University of MN campus
  - Current work: Individual tree detection

Source: MPR News, Roanoke Times
Current Approach to Mapping Trees

- Preliminary approaches
  - Individual tree detection: Gaussian-kernel approximation
  - Refinement: Deep learning based filtering
  - (remove non-tree detections, e.g., buildings, roads, etc.)

- Next steps
  - Data preparation
    - High spatial resolution LiDAR (under post-processing)
    - High temporal resolution satellite imagery (e.g., Digital Globe)
  - Ash tree feature construction
  - Ground Truth Training Samples: Identify Ash tree locations

- Expected Publications
  - IEEE Intl. Conf. on Data Mining (6/2018), IEEE Transactions on Knowledge and Data Eng. (2019)
Are inequality measures prone to Gerrymandering?

- **Theme 2**: Advance spatial data analysis
  - **Task 2A**: Algorithms for spatial patterns.

- **Challenges**:
  - Examining statistical measures, inequality metrics.
  - Check for gerrymandering vulnerability
  - a.k.a Modifiable Areal Unit Problem (MAUP)

- **Preliminary Results**:
  - Test stability of inequality measures (Figure 1).
  - Gini-Index, Entropy measures can be gerrymandered.

- **Next Tasks**:
  - Test with larger real-world data sets
  - Ex.: Tallahassee, FL

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Gerrymandering, a Tradition as Old as the Republic, Faces a Reckoning

Supreme Court to hear arguments on whether contorted voting maps drawn by both parties to cement power have finally gone too far

THE WALL STREET JOURNAL.

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Image: How to steal an election: a visual guide

By Christopher Ingraham  March 1, 2015

**Gerrymandering**

**Election Results**

- **Input**
  - 50 Precincts
  - 60% Yellow
  - 40% Green

- **Output depends on spatial partitioning:**
  - 5 Districts, each with 10 precincts

- **Gerrymandering**

- **Input**
  - 50 Precincts
  - 60% Yellow
  - 40% Green

- **Output**
  - 5 Green
  - 3 Yellow

**Fig. 1: Gerrymandering Elections & inequality measures**

Note 1: Calculation assumes that green has higher value.

Note 2: Gini index range is [0 – 0.5] and entropy function has a range of [0 – 1].

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Input 50 Precincts 60% Yellow 40% Green

Output depends on spatial partitioning: 5 Districts, each with 10 precincts

| Gini-Index | 0.47 | 0.47 | 0 |
| Entropy    | 0.97 | 0.97 | 0 |