TEXAS A&M INSTITUE OF DATA SCIENCE
Urban Artificial Intelligence Lab

TEXAS A&M UNIVERSITY
Center for Geospatial Sciences, Applications and Technology

Integrating Human Dynamics into AI-Driven Urban Science for Symbiotic Futures

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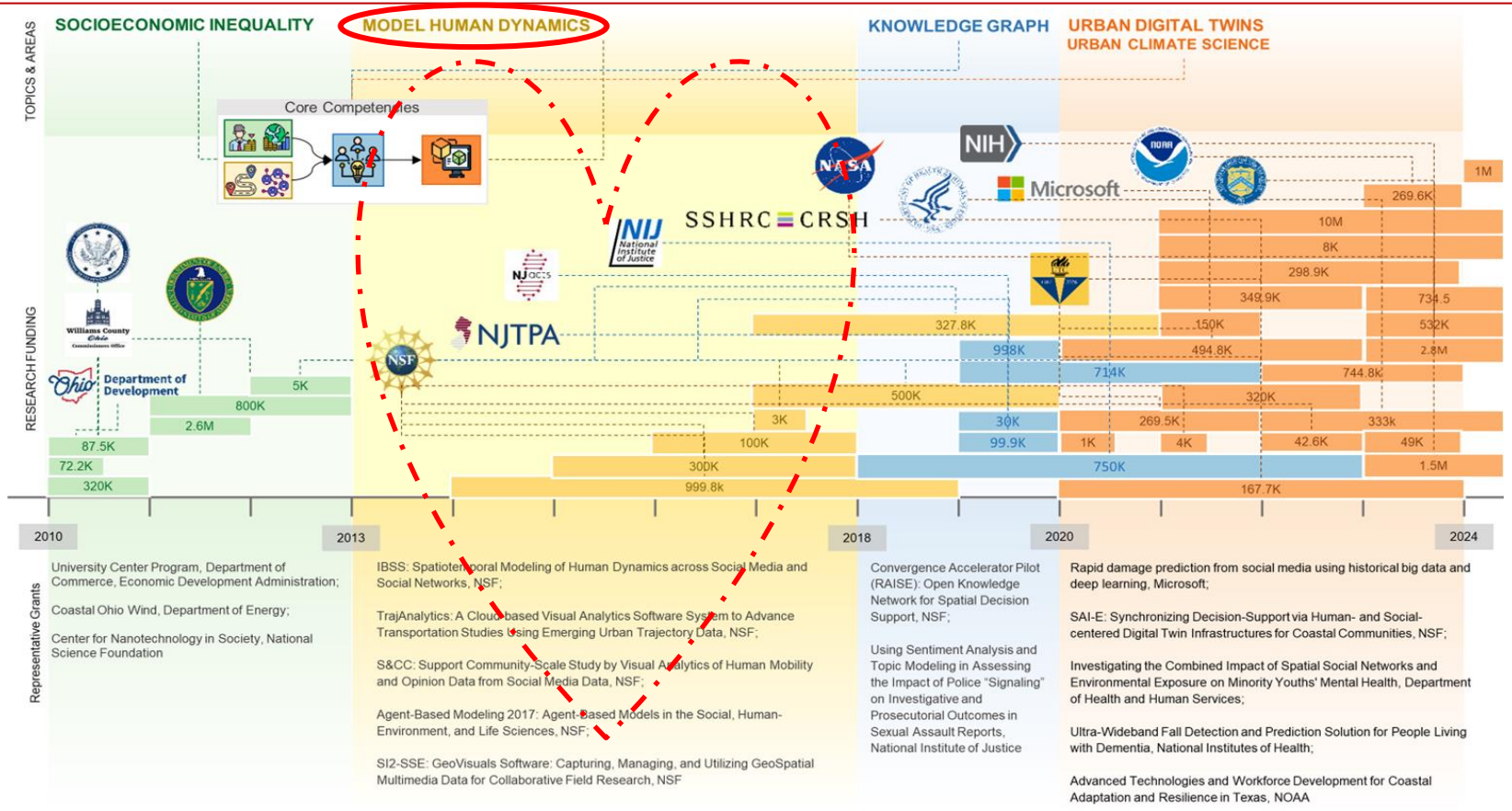
Texas A&M University, College Station

Outline

1. Introduction
2. AI’s Contributions to Urban Science
3. How Urban Science Can Shape AI Development
4. The New Urban Science: A Symbiotic Future between AI and Urban Science
5. Conclusion


SOCIOECONOMIC INEQUALITY
MODEL HUMAN DYNAMICS
KNOWLEDGE GRAPH
URBAN DIGITAL TWINS
URBAN CLIMATE SCIENCE
TOPICS & AREAS
Core Competencies
RESEARCH FUNDING
NIH
Microsoft
SSHRC CRSH
NIJ National Institute of Justice
NJTPA
Williams County Ohio Commissioners Office
Ohio Department of Development
1M
269.6K
10M
8K
298.9K
349.9K
734.5
327.8K
150K
532K
998K
494.8K
2.8M
714K
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800K
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87.5K
100K
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1K
4K
42.6K
49K
72.2K
300K
750K
1.5M
320K
999.8k
167.7K
2010
2013
2018
2020
2024
Representative Grants
University Center Program, Department of Commerce, Economic Development Administration;
Coastal Ohio Wind, Department of Energy;
Center for Nanotechnology in Society, National Science Foundation
IBSS: Spatiotemporal Modeling of Human Dynamics across Social Media and Social Networks, NSF;
TrajAnalytics: A Cloud-based Visual Analytics Software System to Advance Transportation Studies Using Emerging Urban Trajectory Data, NSF;
S&CC: Support Community-Scale Study by Visual Analytics of Human Mobility and Opinion Data from Social Media Data, NSF;
Agent-Based Modeling 2017: Agent-Based Models in the Social, Human-Environment, and Life Sciences, NSF;
SI2-SSE: GeoVisuals Software: Capturing, Managing, and Utilizing GeoSpatial Multimedia Data for Collaborative Field Research, NSF
Convergence Accelerator Pilot (RAISE): Open Knowledge Network for Spatial Decision Support, NSF;
Using Sentiment Analysis and Topic Modeling in Assessing the Impact of Police "Signaling" on Investigative and Prosecutorial Outcomes in Sexual Assault Reports, National Institute of Justice
Rapid damage prediction from social media using historical big data and deep learning, Microsoft;
SAI-E: Synchronizing Decision-Support via Human- and Social-centered Digital Twin Infrastructures for Coastal Communities, NSF;
Investigating the Combined Impact of Spatial Social Networks and Environmental Exposure on Minority Youths' Mental Health, Department of Health and Human Services;
Ultra-Wideband Fall Detection and Prediction Solution for People Living with Dementia, National Institutes of Health;
Advanced Technologies and Workforce Development for Coastal Adaptation and Resilience in Texas, NOAA

Acknowledgment

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Symbiosis of AI and Urban Science

Urban Digital Twins

Generative AI

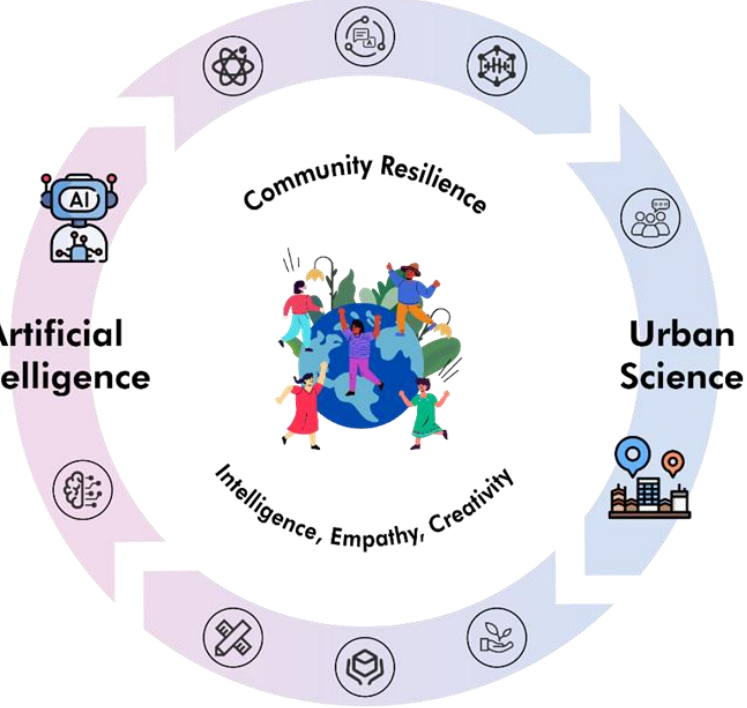
Large Language Models

AI for Urban Science

Predictive Modeling for Urban Infrastructure

Handling Multimodal Urban Data

Artificial Intelligence



Urban Science

Embedding Human Dynamics

Improving Complex Systems Analysis

Promoting Responsible AI Development

Urban Science for AI

AI and Urban Design

Ethical AI Development

Responsible AI for Desired Urban Outcomes

1. Introduction

The Rise of AI and Challenges in Urban Science

Background

- The 2024 Nobel Prizes in Physics and Chemistry highlight AI's **transformative role in natural sciences**.
- In natural sciences, AI fosters a **two-way collaboration** between development and discovery.
- Integrating AI into **urban science**, which bridges social and natural sciences, remains challenging.

Core Question

- **Why does AI matter for urban science?** What are the goals of urban science, and how can AI advance them effectively?
- Steinitz's **GeoDesign** framework is built upon six interconnected models—Representation, Process, Evaluation, Change, Impact, and Decision.

Transition

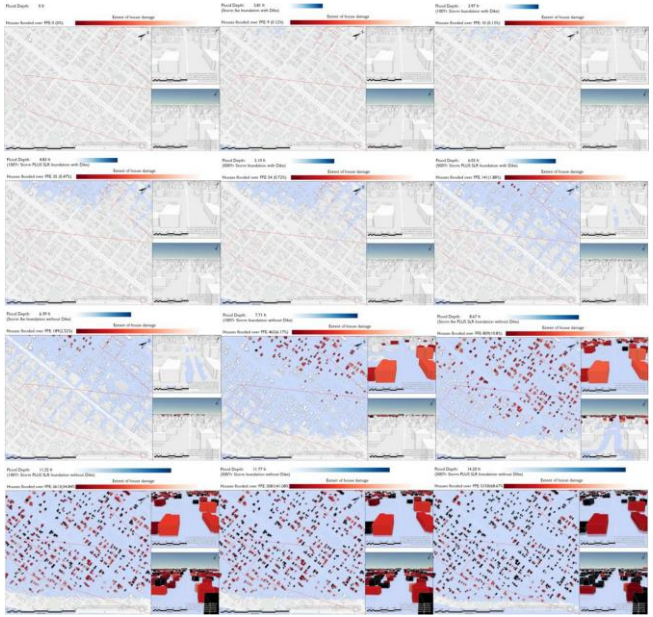
- Exploring the emergence of "**New Urban Science**," a data-driven interdisciplinary field enabled by advanced computational technologies and the co-design/co-learning spirits.

2. AI's Contributions to Urban Science

Predictive Modeling for Urban Infrastructure

- Targeted Damage Assessment: We incorporate a target detection approach, pinpointing the positions of building entrances. This allows for a more precise and practical assessment of flood impact on individual structures.

- Door Flooding as a Damage Indicator: Using door flooding as a damage indicator, we simulate potential harm to residences under varied storm conditions. This provides a more relatable and understandable measure of flood impact for urban residents and planners.

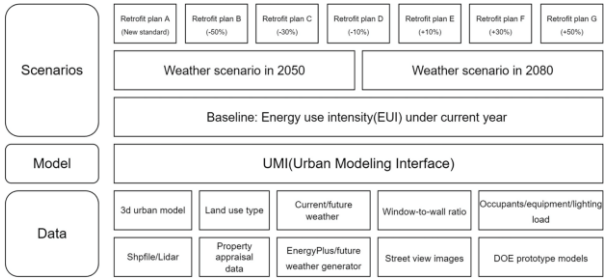


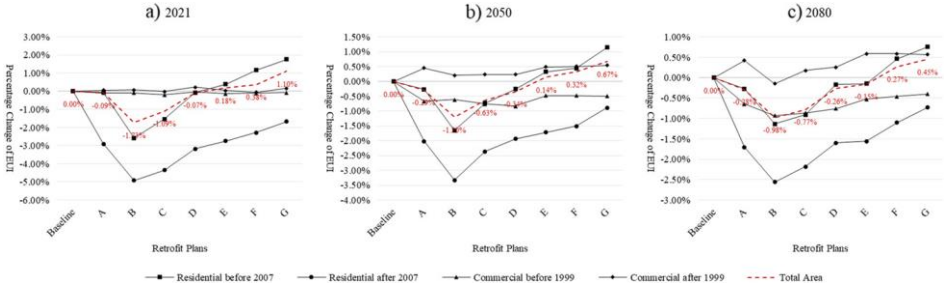
Ye, X., Li, S., Gao, G., Retchless, D., Cai, Z., Newman, G., ... & Duffield, N. (2024). 3D visualization of hurricane storm surge impact on urban infrastructure. Urban Informatics, 3(1), 1-14.

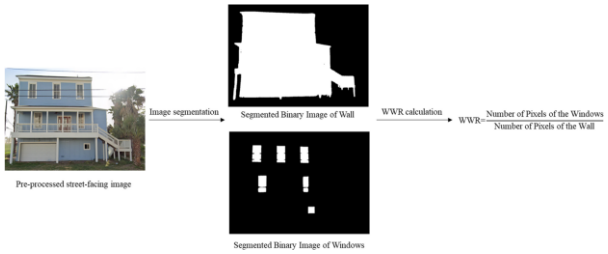
2. AI's Contributions to Urban Science

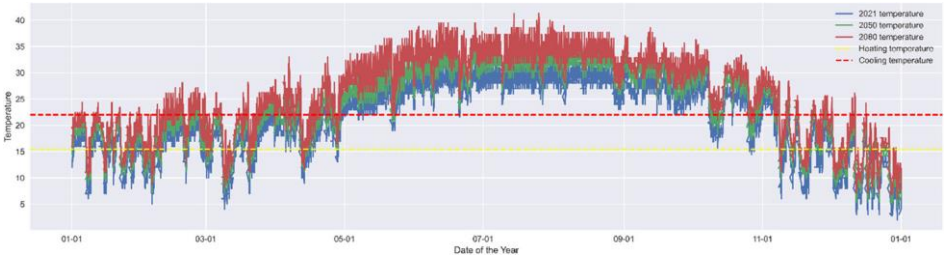
Handling Multimodal Urban Data

- Urban research is advancing beyond traditional methods by integrating diverse spatial and visual datasets into comprehensive urban models.
- Combining multiple data sources like building footprints, LiDAR, property records, and street view images helps overcome individual dataset constraints.
- Computer vision and image segmentation techniques enable automated extraction of architectural parameters from visual data.
- Enhances urban simulation accuracy and provides a scalable framework for transforming fragmented urban information into actionable insights.







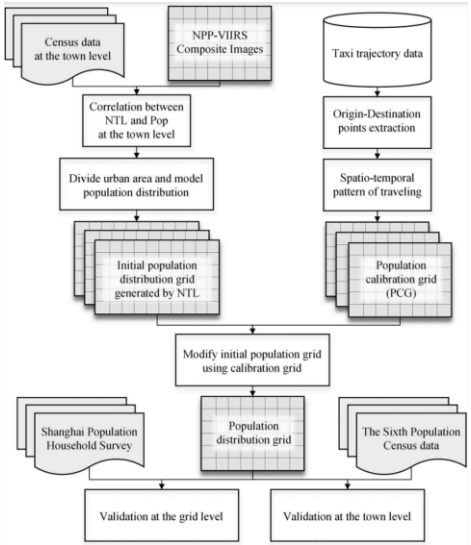


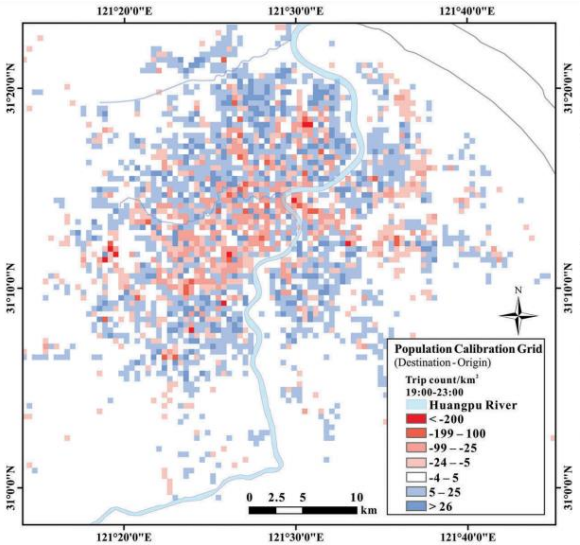
Zhu, C., Ye, X., Du, J., Hu, Z., Shen, Y., Retchless, D., 2024. Simulating urban energy use under climate change scenarios and retrofit plans in coastal Texas. Urban Info 3, 13. https://doi.org/10.1007/s44212-024-00046-8

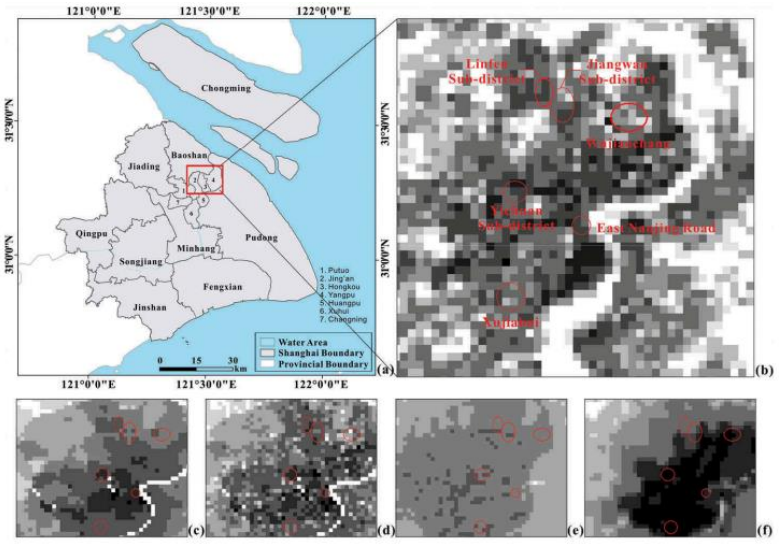
3. How Urban Science Can Shape AI Development

Embedding Human Dynamics

- Integrated nighttime light imagery and taxi GPS data for enhanced population distribution mapping.
- Combined 'static' remote sensing with 'dynamic' social sensing to improve population estimation.
- Calibrated initial population estimates using taxi movement patterns to reduce data limitations.
- Demonstrated multimodal data fusion's potential in urban analytical techniques.





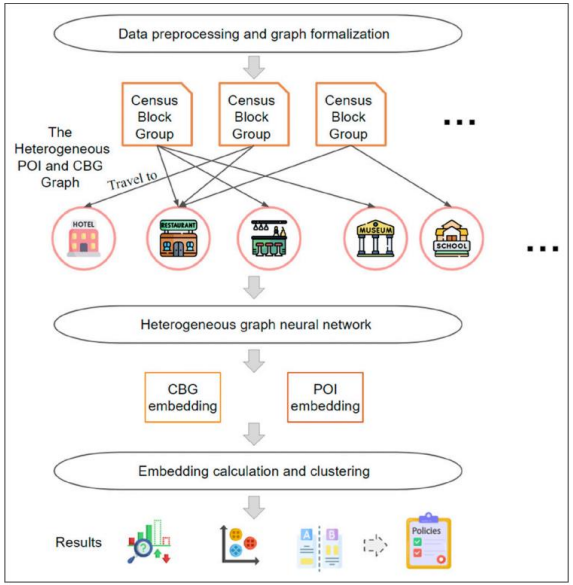


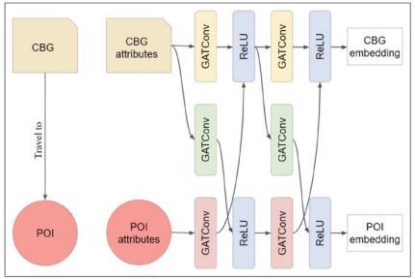
Yu, B., Lian, T., Huang, Y., Yao, S., Ye, X., Chen, Z., ... & Wu, J. (2019). Integration of nighttime light remote sensing images and taxi GPS tracking data for population surface enhancement. International Journal of Geographical Information Science, 33(4), 687-706.

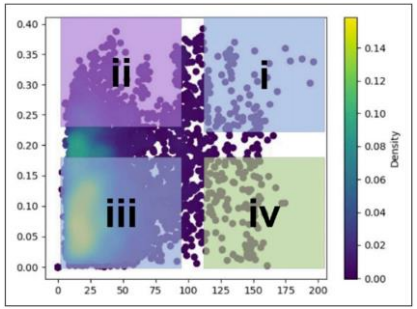
3. How Urban Science Can Shape AI Development

Improving Complex Systems Analysis

- Combines diverse datasets (mobility patterns, demographics, POI data) into a unified graph structure to enable comprehensive system analysis.
- Implements heterogeneous graph neural networks to capture both local interactions and global patterns across different scales.
- Identifies temporal changes in resilience through advanced clustering techniques and comparative analysis of visitation patterns.
- Develops a flexible modeling approach that can adapt to different scenarios while maintaining interpretability of results.







Du, J., Ye, X., Huang, X., Qiang, Y., & Zhu, C. (2024). Unveiling multifaceted resilience: A heterogeneous graph neural network approach for analyzing locale recovery patterns. Environment and Planning B: Urban Analytics and City Science, 23998083241288689.

3. How Urban Science Can Shape AI Development

Promoting Responsible AI Development

- Emphasizes transparent and open-source documentation of AI training processes and algorithms to mitigate built-in biases in urban planning decisions.
- Advocates for knowledge co-production through active collaboration between AI systems and diverse stakeholders.
- Highlights the need for AI to augment in planning processes, with a focus on facilitating communication between stakeholders.
- Incorporates ethical considerations and accountability measures in AI systems to prevent the perpetuation of existing socioeconomic inequities in planning.

ACSP
Connecting educators, researchers and students

Free access | Editorial | First published online February 10, 2023

Toward Urban Artificial Intelligence for Developing Justice-Oriented Smart Cities

Xinyue Ye, Galen Newman, [...], and Dawn Jourdan +2 View all authors and affiliations

Volume 43, Issue 1 | https://doi.org/10.1177/0739456X231154002

Articles

Artificial intelligence enabled participatory planning: a review

Jiaxin Du, Xinyue Ye, Piotr Jankowski, Thomas W. Sanchez & Gengchen Mai

Pages 183-210 | Received 19 Jan 2023, Accepted 18 Sep 2023, Published online: 04 Oct 2023

Cite this article https://doi.org/10.1080/12265934.2023.2262427 Check for updates

Ye, X., Newman, G., Lee, C., Van Zandt, S., & Jourdan, D. (2023). Toward Urban artificial intelligence for developing justice-oriented smart cities. Journal of Planning Education and Research, 43(1), 6-7.

Du, J., Ye, X., Jankowski, P., Sanchez, T. W., & Mai, G. (2024). Artificial intelligence enabled participatory planning: a review. International Journal of Urban Sciences, 28(2), 183-210.

About the
Digital Twins Study

NATIONAL ACADEMIES Sciences Engineering Medicine

Proceedings of a Workshop—in Brief

Opportunities and Challenges for Digital Twins in Atmospheric and Climate Sciences

Proceedings of a Workshop—in Brief

Committee

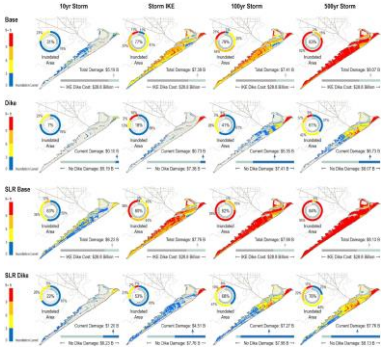
See all bios

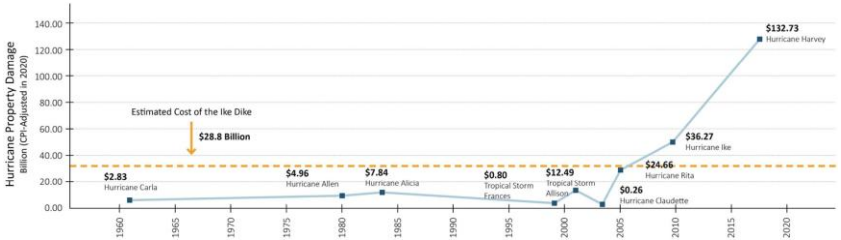
CHAIR Karen E. Willcox	MEMBER Derek Bingham	MEMBER Julianne Chung	MEMBER Caroline Chung
MEMBER Carolina Cruz-Neira	MEMBER Conrad J. Grant	MEMBER James L. Kinter, III	MEMBER Ruby Leung
MEMBER Parviz Moin	MEMBER Lucila Ohno-Machado	MEMBER Colin J. Parris	MEMBER Irene Qualters
MEMBER Ines Thiele	MEMBER Conrad Tucker	MEMBER Rebecca Willett	MEMBER Xinyue Ye

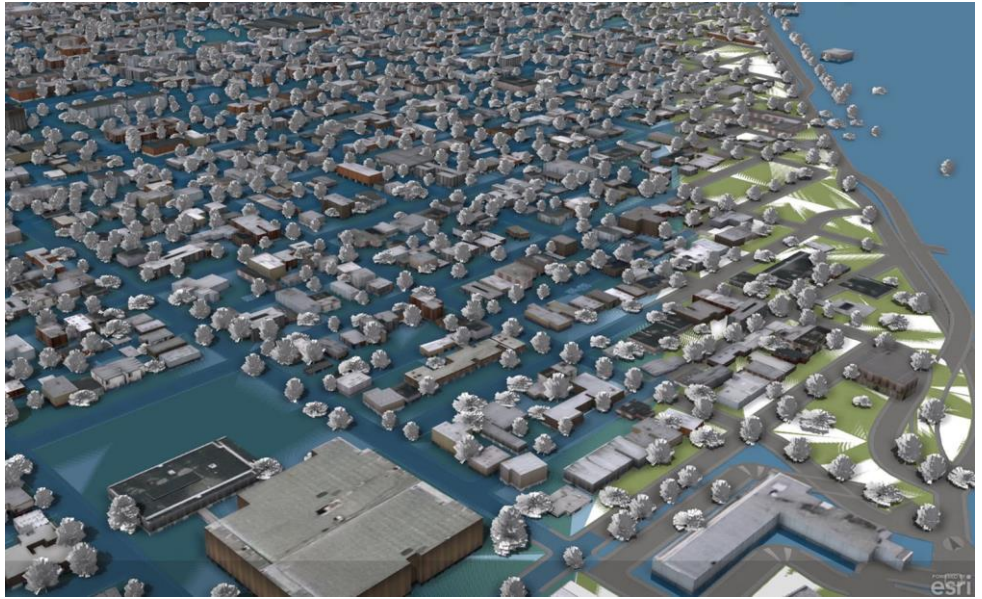
4. The New Urban Science: A Symbiotic Relationship between AI and Urban Science

AI for Urban Science—Urban Digital Twins

- Focus: Coastal barrier, Hurricane flood, 3D urban modeling
- Methods: CityEngine, Computer-Generated Architecture (CGA)
- Key Insights: Assesses the effectiveness of coastal barriers in reducing flood damage. The findings help emergency personnel understand the potential protection levels and plan evacuations and resource allocations based on various storm scenarios.





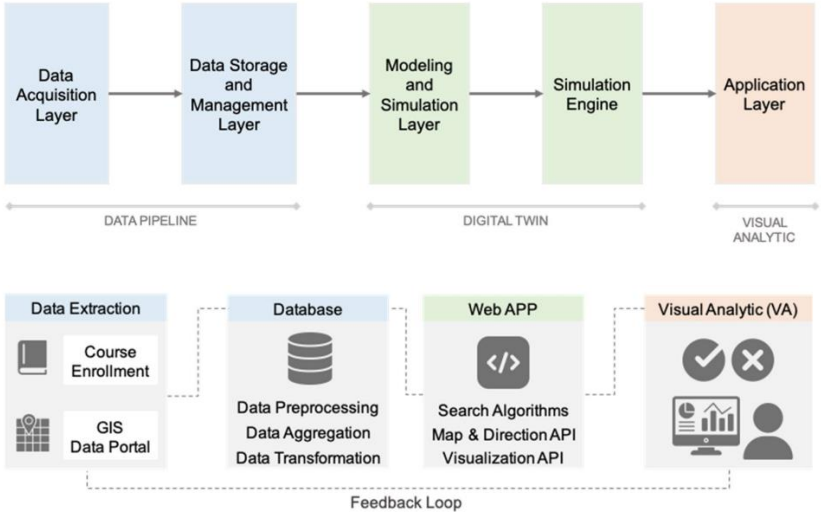


Cai, Z., Newman, G., Lee, J., Ye, X., Retchless, D., Zou, L., Ham, Y., 2023. Simulating the spatial impacts of a coastal barrier in Galveston Island, Texas: a three-dimensional urban modeling approach. Geomatics, Natural Hazards and Risk 14, 2192332. https://doi.org/10.1080/19475705.2023.2192332

4. The New Urban Science: A Symbiotic Relationship between AI and Urban Science

AI for Urban Science—Campus Digital Twins

- DTs enhance efficiency and decision-making in built environment applications.
- Key challenges include cost, complexity, interoperability, and data integration.
- The study presents a new visual analytics system demonstrated through university campus management.
- The system converts enrollment data into a spatial-temporal format for interactive analysis.
- Case studies prove the system's effectiveness and adaptability for practical DT implementation.

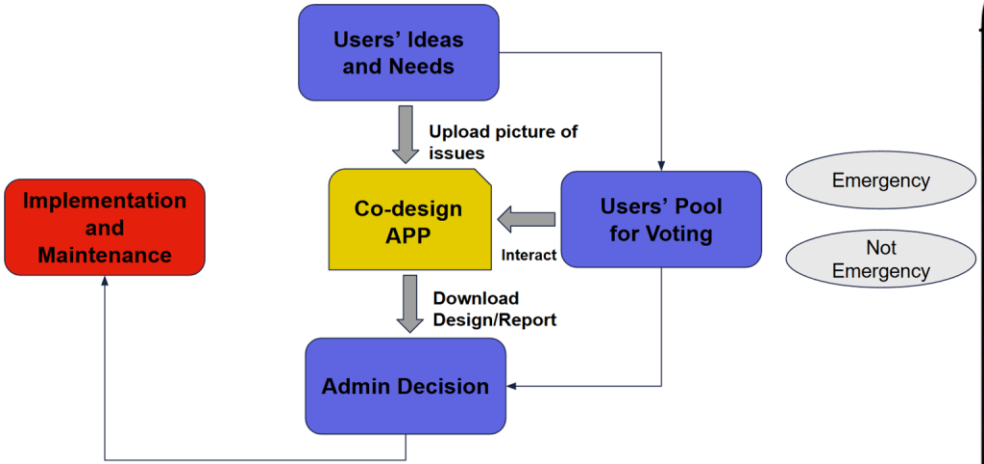


Ye, X., Jamonnak, S., Van Zandt, S., Newman, G., & Suermann, P. (2024). Developing campus digital twin using interactive visual analytics approach. Frontiers of Urban and Rural Planning, 2(1), 9.

4. The New Urban Science: A Symbiotic Relationship between AI and Urban Science

AI for Urban Science (Design)—Campus Digital Twins

- DTs enhance efficiency and decision-making in urban planning applications.
- Challenges to public participation in urban design include design expertise and how to collect public ideas of design.



Framework of Co-design DT System

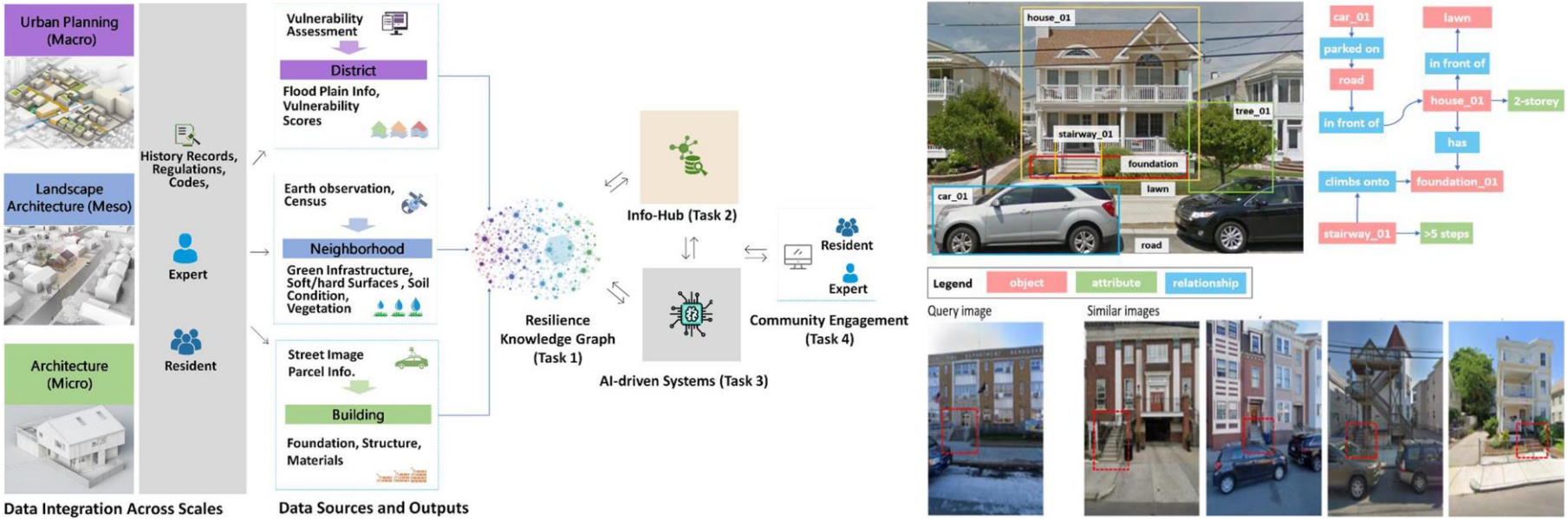
- The proposed Smart Phone APP provide an effective way to collect the public's' design demands and ideas. These ideas facilitate the urban planning experts better understanding how to design a infrastructure that matches the needs of the general public.

Ongoing project

4. The New Urban Science: A Symbiotic Relationship between AI and Urban Science

Urban Science for AI—Generative AI and Large Language Models

- Focus: Urban flood resilience, AI-driven platform, Design and planning
- Methods: Knowledge graph, Image segmentation (Residual Attention Network), Natural language processing
- Key Insights: Proposes an AI-driven platform for flood resilience planning. This tool enhances public awareness, improves collaboration, and supports emergency personnel in creating effective response strategies and coordinating evacuations during flood events.

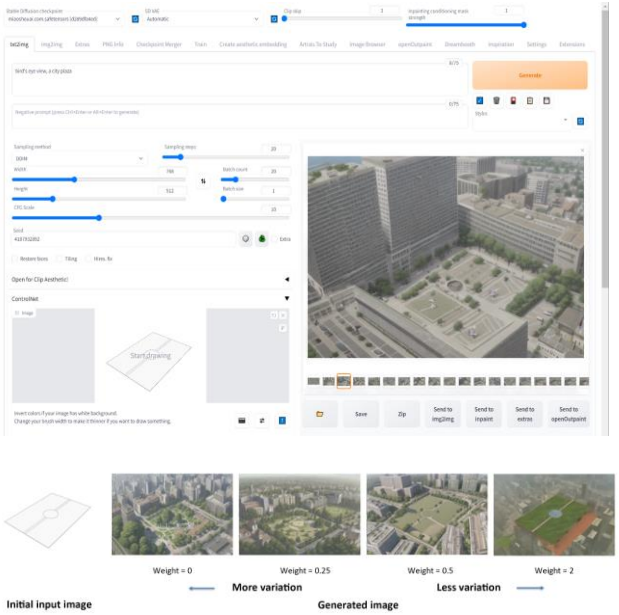


Ye, X., Wang, S., Lu, Z., Song, Y., Yu, S., 2021. Towards an AI-driven framework for multi-scale urban flood resilience planning and design. Comput.Urban Sci. 1, 11. https://doi.org/10.1007/s43762-021-00011-0

4. The New Urban Science: A Symbiotic Relationship between AI and Urban Science

Urban Science for AI—AI and Urban Design

- This study explores the integration of text-to-image generative AI, particularly Stable Diffusion, in conjunction with ControlNet and LoRA models in conceptual landscape design.
- We demonstrate a workflow that efficiently generates detailed and visually coherent landscape designs, including natural parks, city plazas, and courtyard gardens.



- Our results indicate that fine-tuned models produce superior designs compared to non-fine-tuned models, maintaining spatial consistency, control over scale, and relevant landscape elements.

Generated images via generative AI

Ye, X., Huang, T., Song, Y., Li, X., Newman, G., Lin, Z., Wu, D., 2025. Generating Conceptual Landscape Design via Text-to-image Generative AI Model. Environment and Planning B: Urban Analytics and City Science (Accepted)

4. The New Urban Science: A Symbiotic Relationship between AI and Urban Science

Urban Science for AI— Ethical AI Development

- Bias in AI: AI models often inherent biases from data, leading to unequal outcomes. In urban science, spatial biases—caused by uneven data distribution—can exacerbate resource allocation disparities, especially in underrepresented regions.
- Fairness in Urban Science: Fair AI ensures equitable benefits for all communities by addressing biases in data and decision-making, critical for urban policies impacting diverse populations.

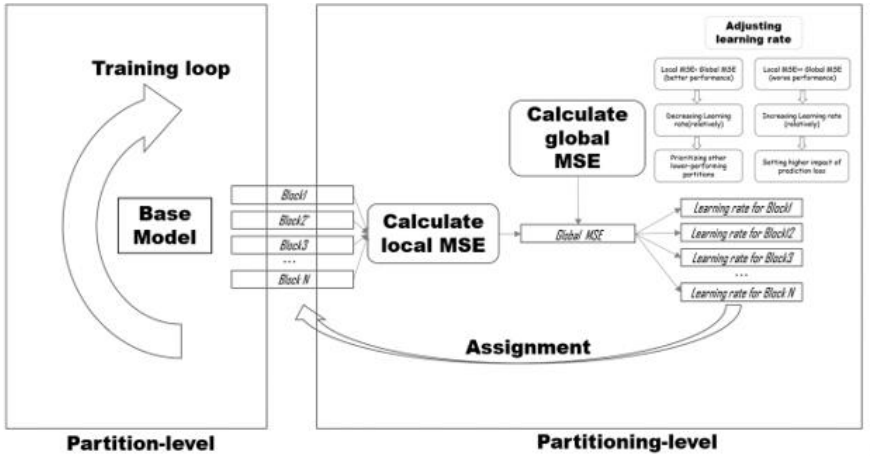


Figure 3 Architecture schematic of bi-level learning framework

- Addressing Bias: Our work introduces a bi-level learning framework applied to disaster management. Using Twitter and FEMA data, this framework prioritizes underperforming regions by dynamically adjusting learning rates, reducing spatial bias, and improving fairness in damage predictions. This approach highlights how AI can ensure equitable disaster responses.

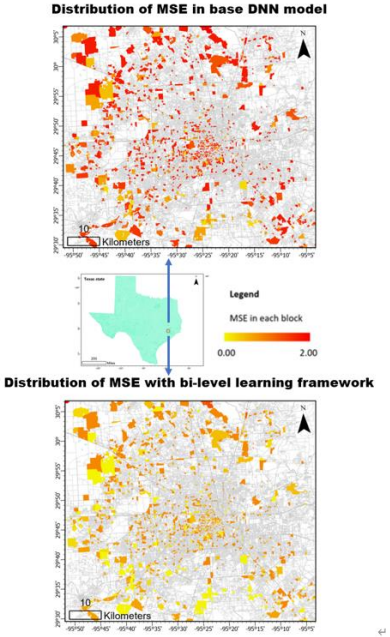
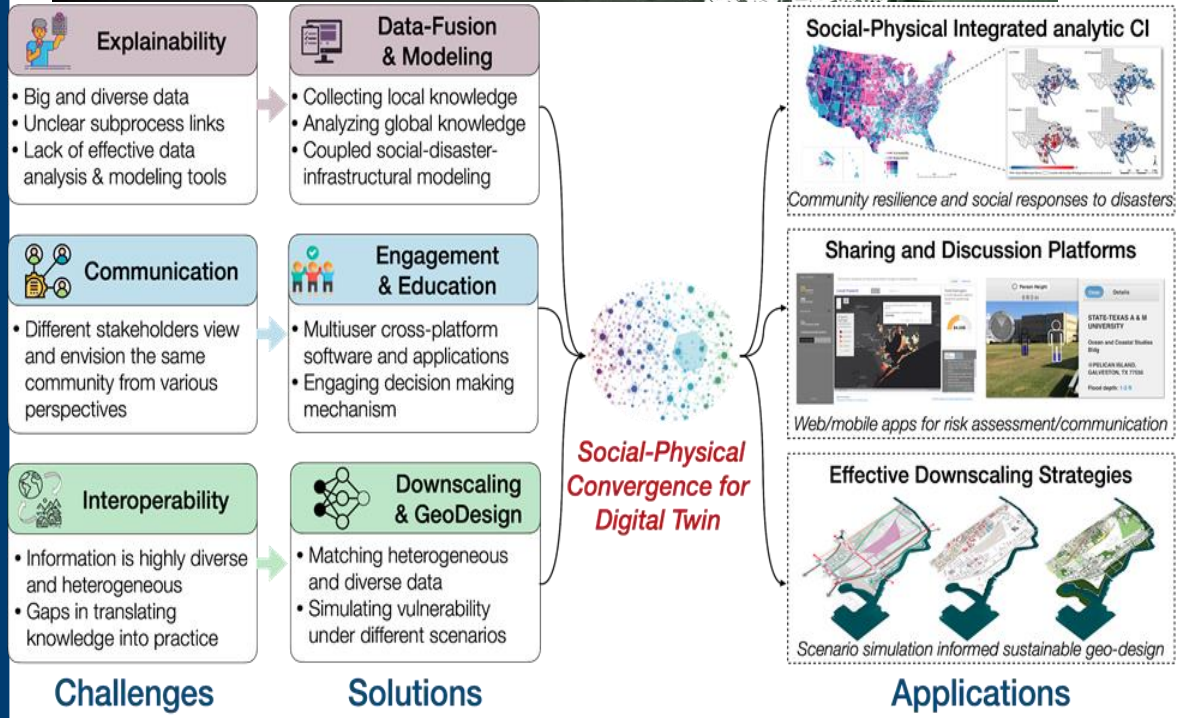


Figure 8. Visualization of model performance in map.

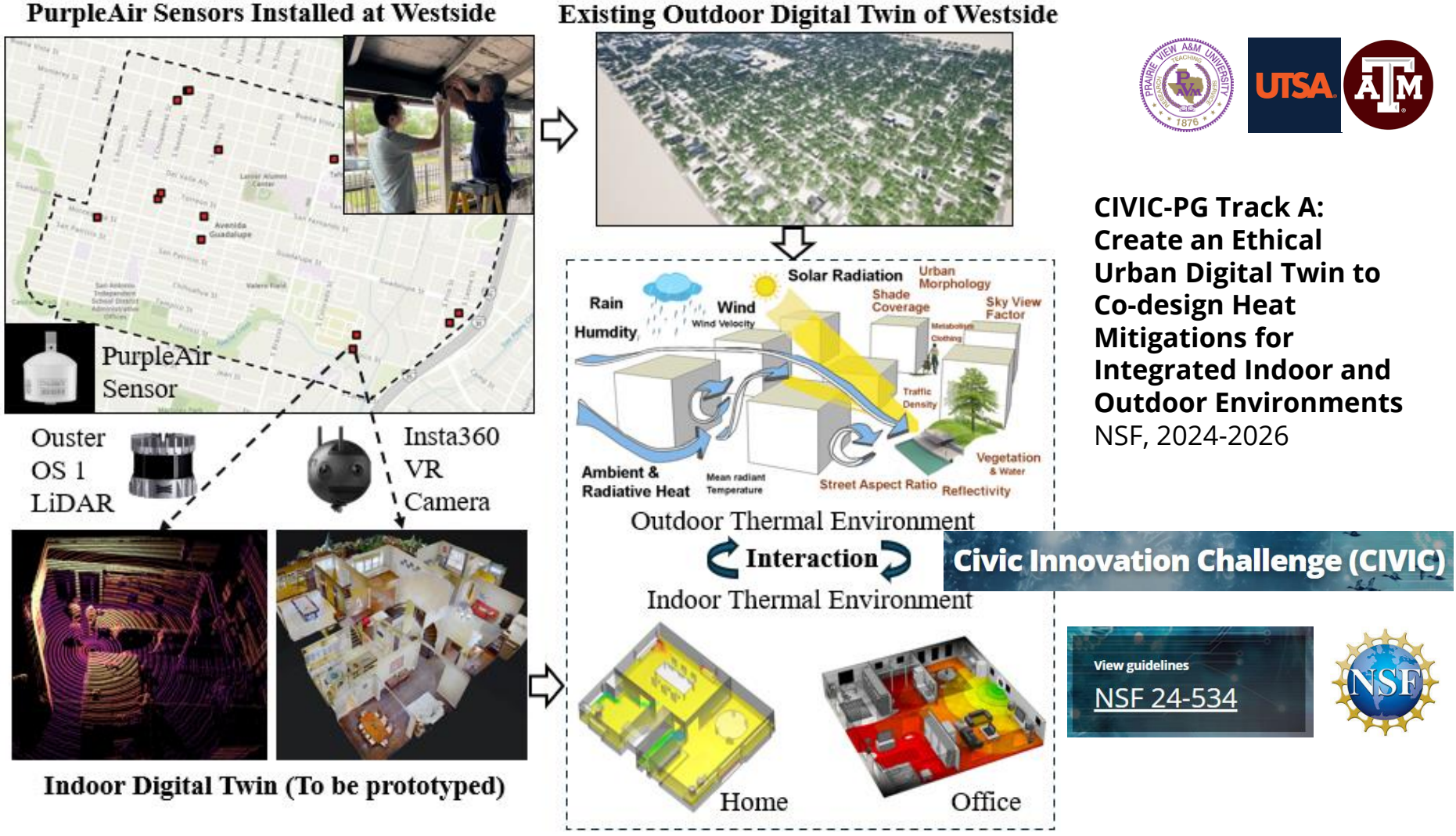
Bai, W., Ye, X., et al. (2025). Reducing AI Model Biases with a Bi-level Learning Framework: A Case Study of Leveraging Twitter Data for Damage Estimation, Annals of the American Association of Geographers (Under review)*

Urban Digital Twins



SAI-E: Synchronizing Decision-Support via Human- and Social-centered Digital Twin Infrastructures for Coastal Communities
NSF, 2021-2024

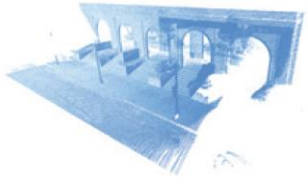
- Developed the Urban Digital Twin (UDT) framework for urban resilience and climate action.
- UDT integrates real-time analytics, human-centered design, and AI/ML for actionable insights.
- Empowered underserved communities through participatory planning and equitable solutions.

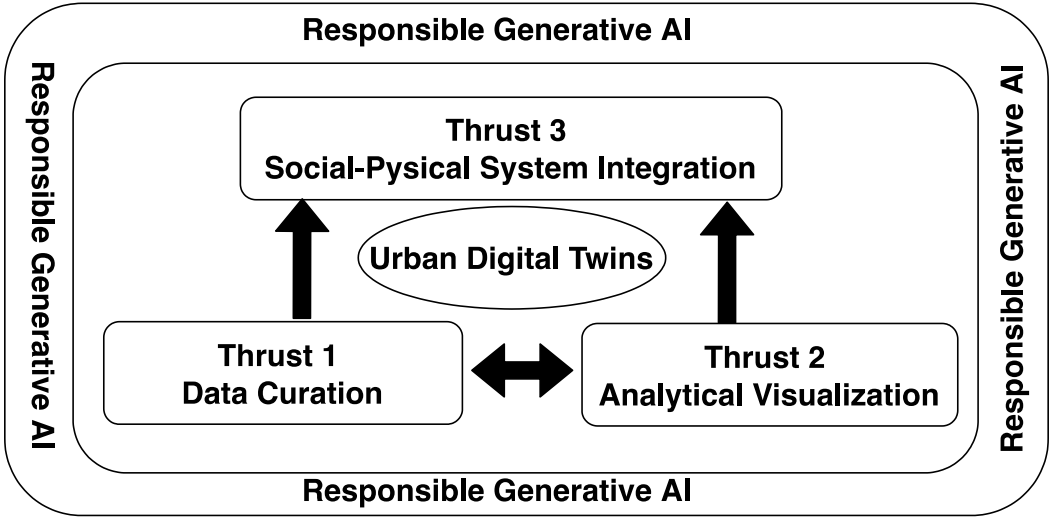


CIVIC-PG Track A: Create an Ethical Urban Digital Twin to Co-design Heat Mitigations for Integrated Indoor and Outdoor Environments
NSF, 2024-2026

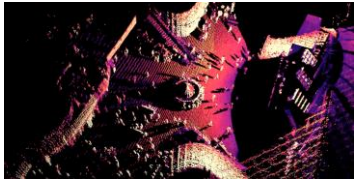
Civic Innovation Challenge (CIVIC)

View guidelines
NSF 24-534





Excellence in Research: Constructing Urban Digital Twins via Responsible Foundation AI for Community Resilience, NSF, 2024-2027



- Thrust 1 (Data Curation): Collecting and representing data in an unbiased format;
- Thrust 2 (Analytical Visualization): Building explainable foundation models for 3D Modeling;
- Thrust 3 (Social-Physical System Integration): Enhancing UDTs (Urban Digital Twins) with social system information.

Michael Batty **Budhendra Bhaduri** **Michael Goodchild**

- The first textbook on cloud-based social data analytics with the assistance of Generative AI.
- Introduces educational cloud resources from leading technology companies like AWS, GitHub, and MongoDB.
- Presents a fully AI-powered data analytics pipeline from Python coding to data collection with APIs, cloud-based data storage, natural language queries, and interactive visualization.
- Analyzes census and social media data with the latest large language models (LLMs).
- Provides hands-on exercises with real-world datasets on timely issues.

5. Conclusion

Be Strategic and Be on the Table

Overcoming Data Barriers

- **Challenges**: Privacy, cost, proprietary ownership.
- **Solutions**: Collaborative platforms and synthetic data sharing.

Co-Learning and Ethical Integration

- Establish networks for **cross-disciplinary expertise**.
- Emphasize **transparency**, **trust**, and **reproducibility** in AI applications.

Symbiotic Future

- **Build partnerships** between AI researchers and urban scientists.
- Leverage AI to create more **resilient, equitable, and sustainable** cities.

Be Strategic and Be on the Table

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Faculty Fellow of Strategic Initiatives and Partnerships, Office of Vice President of Research
Depts of Landscape Architecture and Urban Planning, Computer Science and Engineering,
Engineering Medicine, Geography, Public Policy, Multidisciplinary Engineering, Visual Computing & Interactive Media
Texas A&M University, College Station