RESEARCH PROPOSAL

DEVELOPING NOVEL DATA MANAGEMENT STRATEGIES TO ENHANCE URBAN HEAT ISLAND EFFECT MITIGATION

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Introduction

In the era of rapid urbanization and escalating global warming, the Urban Heat Island (UHI) effect, where urban regions experience significantly higher temperatures than their rural surroundings, has become a topic of increasing concern. These heightened temperatures result from factors such as urban surface modifications, increased human activities, and reduced vegetation. As urbanization intensifies, the UHI effect is anticipated to worsen, prompting a dire need for effective preventive measures.

In order to understand UHI's effects, it is imperative to keep track of its historical records. The industrial evolution begins to observe the UHI phenomenon far from the early centuries, which has steadily increased for more than hundreds of years due to urban planning and population growth. The resources were wasted and gradually depleted. In addition to affecting the immediate urban environment, the UHI effect contributes to global warming. Heat exacerbates energy consumption due to increased cooling demand, contributes to air quality degradation, and can negatively impact public health, including heat-related illnesses(Ngie et al., 2014).

The complexity and urgency of this issue are further compounded by the mounting challenges of climate change. Unprecedented heatwaves, rising average temperatures, and erratic weather patterns are increasingly the new normal, amplifying the UHI effect and its associated risks. Consequently, there is a pressing need to devise advanced, data-driven strategies to combat the UHI effect more effectively. This proposal aims to leverage the power of big data and computing to develop a novel data management strategy, designed to optimize measures against the UHI effect and contribute to more sustainable and resilient urban development.

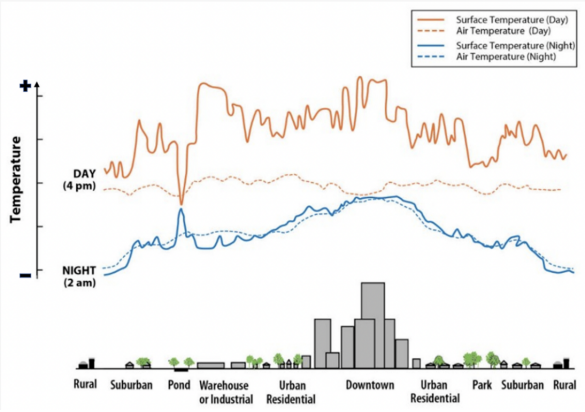


Figure 1. The temperature profile in different areas, with the formation of the UHI

Background

As global temperatures continue to rise, cities worldwide are grappling with the UHI effect's escalating impacts. Higher urban temperatures lead to increased energy consumption, elevated emissions of air pollutants and greenhouse gases, and impaired human health and water quality. While research and efforts are underway to mitigate these effects, many existing strategies are often reactionary, short-term, and fail to take into account the intricacies of urban climatic systems. Some confounding factors were political economy and negotiation roadblocks which severely affected the world boost the development of methods of controlling climate changes(Esty and Moffa, 2012).

Understanding and addressing the UHI effect is a multifaceted problem requiring data from diverse sources, including meteorological, geographical, socio-economic, and infrastructural data. However, the sheer volume, variety, and velocity of these data pose significant challenges for traditional data management and analytical approaches. These challenges often result in inefficiencies and missed opportunities in devising and implementing UHI preventive measures. The old methods of data collection, such as online surveys and face-to-face interviews, are inefficient and biased to a certain degree, so finding a new method is an emergent thing.(Singh and Burgess, 2007)

In response, urban informatics – the science of using information technology to make sense of urban data – has emerged as a promising solution. By leveraging advances in computer science, particularly in big data, urban informatics provides new opportunities to manage, analyze, and visualize urban data effectively. The development and application of data management strategies tailored for UHI effect analysis, however, remain underexplored. The fundamentals of urban informatics are still being developed as there are a huge number of related challenges that need to be considered before they are applied in the real world, such as privacy, ethical concerns, specialized skills required, and reliability.(Thakuriah et al., 2017)

Thus it is an essential step for modern cities and countries to do trials of applying urban informatics(an alternative name can be city smart heart) to tackle with problems caused by UHI. Recent years have seen an increase in the ability to support high-speed information collection by analyzing and managing data constantly. The UHI effect can be combated in a number of ways, ranging from urban planning solutions such as green spaces and the implementation of cool roofs to technological solutions like advanced HVAC systems. However, these strategies often fall short due to a lack of comprehensive data analysis and integration even though recent UHI variation studies has been enriched, decision of using

various kinds of scales is another problem(Kim and Brown, 2021). Furthermore, political economy and negotiation roadblocks often hinder the implementation of these strategies. For instance, the high upfront costs of implementing green infrastructure or the lack of political will to enforce stringent environmental regulations often impede progress.

Research Objectives and Questions

The primary objective of this research is to design and validate a novel data management strategy tailored to the specific requirements of UHI effect analysis. Leveraging my academic background in computer science and experience in big data, the proposed research seeks to bridge the gap between data science and urban climate studies. This will involve a comprehensive assessment of current data management strategies, identification of their limitations, and the development of an enhanced, scalable, and flexible strategy.

The research will primarily focus on four objectives:

- Objective 1: Conduct a comprehensive review and critical analysis of current data management strategies used in UHI effect analysis. It requires an understanding of the types of data used (meteorological, geographical, socioeconomic, infrastructure), the methods of data collection and analysis, and the tools and technologies used. A key objective is to determine where current strategies are strong and weak, so that improvements can be made.

- Objective 2: Develop a novel, scalable, and flexible data management strategy specifically tailored for UHI effect analysis using big data techniques and tools. To manage the volume, variety, and velocity of UHI-related data, advanced big data technologies, such as distributed storage and processing frameworks, NoSQL databases, and data streaming, must be explored and analyzed.

- Objective 3: To validate the efficacy of the developed data management strategy through rigorous testing in a simulated urban environment. This includes assessing the strategy's ability to facilitate efficient data ingestion, processing, and analysis, and its scalability and flexibility in handling increasing data volumes and changing data types and structures.

- Objective 4: To develop a framework for the real-world implementation of the data management strategy. This involves identifying potential barriers and facilitators to implementation, conducting stakeholder analyses, and establishing best practices for

integrating the strategy into existing urban planning and climate change mitigation workflows. In addition, we will state the following research questions:

- Question 1: What are the specific types of data used in existing UHI effect analysis, and how are these data collected, managed, and analyzed? What are the strengths and weaknesses of current data management strategies, and where do opportunities for improvement lie?
- Question 2: Which big data techniques and tools can be effectively leveraged to manage the volume, variety, and velocity of UHI-related data? How can these technologies be integrated to develop a novel, scalable, and flexible data management strategy for UHI effect analysis?
- Question 3: How effective is the developed data management strategy in facilitating efficient data ingestion, processing, and analysis in a simulated urban environment? How does the strategy perform in terms of processing speed, scalability, and flexibility?
- Question 4: What are the potential barriers and facilitators to implementing the developed data management strategy in real-world urban planning and climate change mitigation workflows? How can the strategy be effectively integrated into these workflows, and what are the best practices for doing so?

Throughout the whole research, the main goal is to analyze existing urban informatics and compose a new method to deal with UHI that boosts the development of urban informatics.

Methodology

- Literature Review: The literature review will involve a systematic search of academic databases for relevant research articles, reports, and other scholarly works. The search will focus on studies that have used data management strategies in UHI effect analysis. The review will not only summarize the findings of these studies but also critically evaluate their methodologies, providing a comprehensive understanding of the current state of the field. This process will help identify gaps in the existing literature and inform the direction of the proposed research.
- Analysis of Existing Practices: This part of the research will involve a detailed examination of existing data management practices in UHI effect studies. The

analysis will focus on understanding the types of data used (meteorological, geographical, socio-economic, infrastructural), the methods of data collection and analysis, and the tools and technologies employed. The strengths and weaknesses of these practices will be identified, providing a clear picture of the current state of practice and areas for improvement.

- Exploration of Big Data Techniques and Tools: This part of the research will involve a thorough investigation of big data technologies and their potential application in managing UHI-related data. This will include an exploration of distributed storage and processing frameworks, NoSQL databases, and data streaming technologies. Each technology will be evaluated based on its suitability for handling the volume, variety, and velocity of UHI-related data.
- Development of Novel Data Management Strategy: Based on the insights gained from the analysis of existing practices and the exploration of big data techniques, a novel data management strategy will be designed. This strategy will aim to efficiently handle the volume, variety, and velocity of UHI-related data. The strategy will be designed to be scalable to accommodate increasing data volumes and flexible to adapt to changing data types and structures. The development process will involve iterative testing and refinement to ensure the strategy meets the specific requirements of UHI effect analysis.
- Validation of Developed Strategy: The developed data management strategy will be validated through rigorous testing in a simulated urban environment. This environment will incorporate various data sources and types commonly used in UHI effect studies. The strategy's efficacy will be evaluated based on its ability to facilitate efficient data ingestion, processing, and analysis. Various metrics, such as processing speed, scalability, and flexibility, will be used to quantify its performance.
- Implementation Framework: Finally, a framework for the real-world implementation of the data management strategy will be developed. This will involve an analysis of potential barriers and facilitators to implementation, a stakeholder analysis, and the identification of best practices for integrating the strategy into existing urban planning and climate change mitigation workflows. The framework will provide a roadmap for practitioners and policymakers to implement the strategy in real-world settings.
- Some metrics that may be used in further researches:

Comfort Temperature

$T_c = 0.54T_o + 12.9$, T_o

is the mean outdoor temperature in the past few months and the unit is °C. Which this formula presents the comfort temperature for the human beings, and that significantly benefits urban informatic system to better analyze(Lee et al., 2017).

Measurements of rainfall anomaly

Urban mean rainfall anomaly(URA_{mean})=$\frac{Urbanmeanrainfall-Upwindmeanrainfall}{Upwindmeanrainfall} X100$

Downwind mean rainfall anomaly(DRA_{mean})=$\frac{Downwindmeanrainfall-Upwindmeanrainfall}{Upwindmeanrainfall} X100$

Urban maximum rainfall anomaly(URA_{max})=$\frac{Urbanmaxrainfall-Upwindmaxrainfall}{Upwindmaxrainfall} X100$

Downwind maximum rainfall anomaly(DRA_{max})=$\frac{Downwindmaxrainfall-Upwindmaxrainfall}{Upwindmaxrainfall} X100$

These four metrics will be used to measure the average rainfall within any regions. Although those formulas are simple to be understood, they can indirectly observe the effects of UHI in urban societies. The main purpose can also be investigating the close relationships between UHI and rainfall records as UHI may cause natural disasters such as storms or acid rains that severely affect the whole society. They will be analyzed the general pattern urban rainfall anomalies associated with storms for cities. More importantly, its data will be recorded in the urban informatic system(Ganeshan et al., 2013).

Results and Impact

This research is expected to significantly advance the field of urban informatics and contribute to the fight against UHI effect. By developing a novel data management strategy tailored for UHI effect analysis, it will enable more efficient and effective use of available urban data. Consequently, this can lead to the development and implementation of more targeted, efficient, and effective UHI mitigation measures.

Furthermore, the findings from this research could also inform policy and decision-making in urban planning and climate change mitigation. By providing a robust and flexible data management tool, urban planners, policymakers, and environmental managers will be better equipped to tackle the UHI effect and other climate change-related urban challenges. Ultimately, this research can contribute to creating more sustainable, resilient, and livable cities for the future.

Conclusion

In the face of rapid urbanization and escalating climate change, the UHI effect has emerged as a significant urban environmental issue. Tackling this problem requires not only a deep understanding of urban climatic processes but also effective data management strategies to leverage the wealth of available urban data. This proposed research represents a pioneering effort to develop a novel data management strategy for UHI effect analysis, with the potential to significantly enhance our capabilities to mitigate the UHI effect and promote sustainable urban development.

Work Plan

- **First year**

  1. Reading through and accomplishing a well-understanding literature review over many articles, conferences, report and research online with topics that related with communication overhead reduction and optimization of machine learning model.
  2. Construct an initial approach with the function of reducing communication overhead and optimize accuracy of machine learning model in federal learning. This also includes advantages of current existing federal learning techniques and limitations of each model changes will be revealed.

- **Second year**

  1. Design and conduct several experiments based on the approach introduced in the first year, and evaluating the results of experiments by various methods like ablation study, comparing with current federal learning results in terms of accuracy and communication overhead.
  2. Writing reports and analyzing the results from experiments. In this case, drawing and recording results is a must, and each experiment must have be shown for its performance.
  3. Begin to write research and conclude two years study of federal learning

- **Third year**

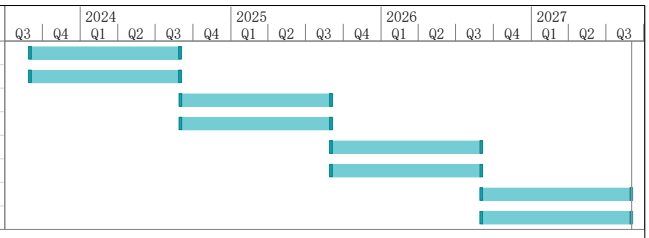
1. Finalize the writing of research and complete the conclusion of the research.
2. Submit current writing to journals.
3. Receive feedback and review them to change more.
4. Finding opportunities to attend conference to show the findings.

– **Forth year**

1. Defend the thesis in front of the doctoral committee.
2. Submit the writing to publication

Timeline

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Do literature reviev	261 days	'23 Sep 1	'24 Aug 30	
2		Construct an initial	261 days	'23 Sep 1	'24 Aug 30	
3		Design and conduc	262 days	'24 Sep 1	'25 Sep 1	
4		Writing reports anc	262 days	'24 Sep 1	'25 Sep 1	
5		Finalize the writing	261 days	'25 Sep 2	'26 Sep 1	
6		Submit current writ	261 days	'25 Sep 2	'26 Sep 1	
7		Defend the thesis i	261 days	'26 Sep 2	'27 Sep 1	
8		Submit the writing	261 days	'26 Sep 2	'27 Sep 1	



Project: Project2
Date: '23 Apr 6

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress

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