SLIIT UNI
THE KNOWLEDGE UNIVERSITY

IT4010 – Research Project - 2025

Topic Assessment Form

Project ID : R25-002

1. Topic (12 words max)

AI-Driven Detection and Mitigation of Urban Heat Island Effects Using Image Analysis and IoT

2. Research group the project belongs to

SST - Software Systems & Technologies

3. Specialization of the project belongs to

Software Engineering (SE)

4. If a continuation of a previous project:

Project ID	
Year	

5. Brief description of the research problem including references (200 – 500 words max) – references not included in word count.

Urbanization significantly contributes to Urban Heat Island (UHI) effects, where metropolitan areas experience higher temperatures compared to surrounding rural areas. This phenomenon is primarily due to the proliferation of heat-retaining materials like concrete, asphalt, and glass, combined with reduced vegetation and green spaces. UHIs exacerbate energy consumption, increase air conditioning usage, and intensify greenhouse gas emissions, leading to environmental and public health challenges.

Traditional methods for monitoring and mitigating UHIs rely on manual surveys and static thermal imaging, which lack precision, scalability, and the ability to provide actionable real-time insights. Furthermore, these methods fail to integrate spatial and material data effectively, limiting the ability to target specific urban areas for intervention.

Advancements in Artificial Intelligence (AI) and the Internet of Things (IoT) offer promising solutions to address these challenges. AI-powered image analysis can semantically segment urban landscapes into key materials (e.g., glass, concrete, metal) and calculate their surface areas, enabling precise identification of heat-retaining zones. Similarly, IoT devices can capture real-time temperature data for these areas, providing an accurate thermal profile of urban environments. The integration of these technologies ensures a comprehensive understanding of UHI effects and their contributing factors.

Despite existing research on UHI detection and mitigation, few approaches combine AI-based image analysis with IoT-driven temperature mapping. This project aims to bridge this gap by developing a scalable system that not only identifies and quantifies heat-prone areas but also proposes actionable solutions such as material replacements or structural modifications. This innovative integration of AI and IoT technologies addresses the limitations of traditional approaches and contributes to sustainable urban planning and environmental conservation.

References:

- Ghorbany, S., et al. *Towards a Sustainable Urban Future: A Comprehensive Review of Urban Heat Island Research Technologies and Machine Learning Approaches*. Sustainability, 2024.
- Deilami, K., et al. *Urban Heat Island Mitigation Technologies in Asian and Australian Cities*. MDPI, 2023.
- Springer, M. *Human-AI Collaboration in Mitigating Urban Heat Islands*. Springer, 2021.
- Polydoros, M., et al. *Land Surface Temperature Dynamics for Sustainable UHI Mitigation*. MDPI, 2020.

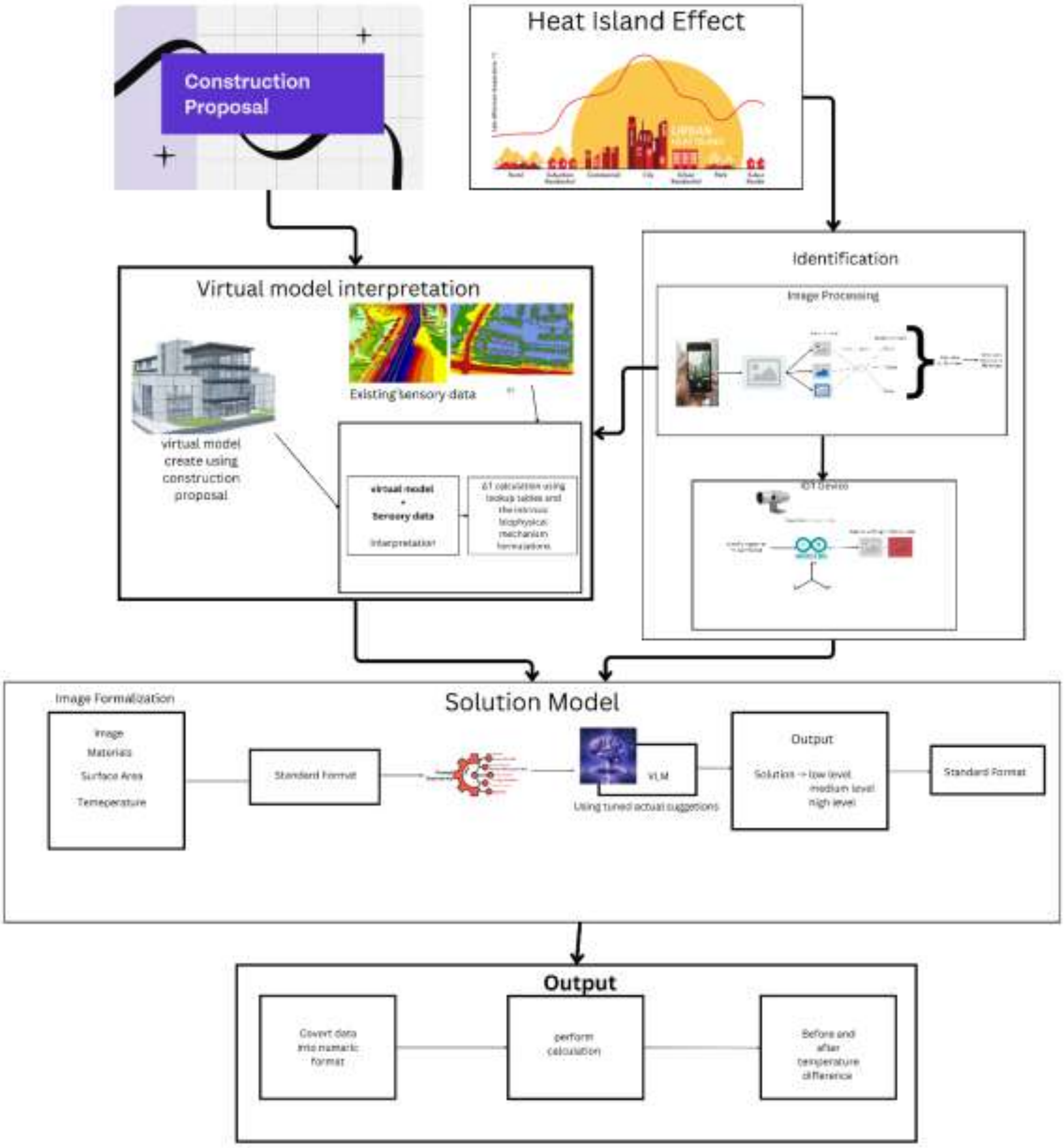
6. Brief description of the nature of the solution including a conceptual diagram (250 words max)

The proposed solution integrates AI-powered image analysis with IoT-based real-time temperature monitoring to detect and mitigate Urban Heat Island (UHI) effects. The approach consists of four core components:

1. **Image Analysis:**
   High-resolution urban images are processed using semantic segmentation to divide the environment into distinct elements such as buildings, pavements, and rooftops. The materials of these elements (e.g., glass, concrete, metal) are identified, and their surface areas are calculated. This information enables precise quantification of heat-retaining zones.
2. **IoT-Driven Temperature Mapping:**
   A 360-degree rotating IoT device collects temperature data for specific segments identified in the images. The temperature readings are mapped to corresponding image sections, creating a thermal profile of the urban landscape.
3. **Data Standardization and AI Integration:**
   The segmented image data, material types, surface areas, and temperature readings are converted into a standardized JSON format. This format is fed into a Vision-Language Model (VLM) or Large Language Model (LLM) to analyze the data and propose targeted mitigation strategies. These strategies could include material replacements, structural modifications, or energy-efficient designs.

4. Virtual Modeling and Simulation for UHI Mitigation

When a construction proposal is submitted, including the planned structure and materials (e.g., building, road), the system creates a virtual model of the proposed structure. This model is integrated into the existing urban environment to analyze its thermal impact (using lookup table and intrinsic biophysical mechanism formulations).



7. Brief description of specialized domain expertise, knowledge, and data requirements (300 words max)

The successful execution of this research project requires expertise in the following domains:

1. **Artificial Intelligence (AI) and Computer Vision:**
    a. Proficiency in semantic segmentation and material identification is essential to process urban images.
    b. Expertise in deep learning frameworks (e.g., TensorFlow, PyTorch) is needed for training and deploying image segmentation models.
2. **Internet of Things (IoT):**
    a. Knowledge of IoT systems, including sensors, 360-degree rotation mechanisms, and microcontrollers (e.g., Arduino, Raspberry Pi), is required.
    b. Skills in integrating hardware and software for real-time data collection and transmission are critical.
3. **Data Integration and Management:**
    a. Experience in handling large-scale image and sensor data is essential.
    b. Familiarity with standardized data formats (e.g., JSON) and libraries (e.g., NumPy, Pandas) to organize, process, and store data efficiently.
4. **Environmental Modeling and Simulation:**
    a. Proficiency in 3D modeling tools (e.g., AutoCAD, or Unity) to create accurate virtual representations of data get by the construction proposal.
    b. Expertise in environmental simulation frameworks to integrate virtual models with real-world parameters like temperature, humidity.
    c. Knowledge of thermal properties in material science to accurately predict temperature variations.
    d. Experience with GIS (Geographic Information Systems) tools to align virtual models with actual geographic data for realistic environmental placement.

Data Requirements

1. **Image Data:** High-resolution images of urban environments to enable accurate segmentation and material identification.
2. **Temperature Data:** Real-time temperature readings collected via IoT sensors to map thermal variations across segments.
3. **Material Database:** A reference database for urban materials and their thermal properties to validate the segmentation and material predictions.
4. **Urban Infrastructure Data:** Information about existing urban structures (buildings, roads, pavements).

This interdisciplinary approach ensures the project's ability to deliver precise and actionable insights for urban heat island mitigation. Access to these specialized domains and data sources will be critical for achieving the research.

8. Objectives and Novelty

Main Objective To develop an AI and IoT-driven system for detecting and mitigating Urban Heat Island (UHI) effects by analyzing urban images, identifying materials, calculating surface areas, and integrating real-time temperature data to propose targeted and sustainable urban interventions.			
Member Name	Sub Objective	Tasks	Novelty
Ayeshmantha S K S	To capture real-time temperature data for specific image segments using an automated IoT device.	1. **Designing an Automated IoT Device:** Create a 360-degree rotating IoT device equipped with temperature sensors to collect precise thermal data for urban surfaces. 2. **Mapping Temperature to Image Segments:** Automate the alignment of IoT-collected temperature data with the segmented image components, ensuring accurate representation of thermal properties.	The IoT-driven temperature mapping system offers an automated, real-time approach to collecting thermal data for urban surfaces. The use of a 360-degree rotating IoT device aligned with segmented image components provides a granular thermal profile that traditional static thermal imaging lacks. This method allows for precise identification of heat-prone areas and supports

		3. **Generating a Thermal Map:** Combine segmented data with temperature readings to produce a detailed thermal profile of urban environments, identifying hotspots and potential areas for intervention.	dynamic monitoring, significantly improving accuracy and scalability.
Kumara B D A N	To segment urban images into semantic components and identify material types with calculated surface areas.	1. **Developing a Semantic Segmentation Model:** Implement and train a machine learning model to divide urban images into distinct components such as buildings, pavements, and rooftops, ensuring accurate identification of each segment. 2. **Material Identification:** Apply algorithms to determine the material type (e.g., concrete, glass, metal) for each segmented component, enabling precise	This component introduces an innovative integration of semantic segmentation and material identification in urban imagery to precisely quantify heat-retaining zones. Unlike traditional methods that focus only on segmentation, this approach links material types (e.g., glass, concrete, metal) with their respective surface areas. This unique pipeline ensures a comprehensive analysis of urban environments, enabling

		categorization of urban structures. 3. **Surface Area Calculation:** Use image processing techniques to calculate the surface area of each segment based on its material type, providing critical data for subsequent thermal analysis.	targeted strategies for mitigating urban heat island effects.
Silva G M S S	To standardize the segmented image, material, and temperature data into a scalable format for Vision-Language Models (VLMs) or Large Language Models (LLMs).	1. **Developing a Standardized JSON Format:** Create a JSON schema to integrate data such as segment ID, material type, surface area, and temperature, enabling seamless compatibility with AI models. 2. **Fine-Tuning Prompts for VLM/LLM Integration:** Optimize input prompts to guide the AI models in analyzing data and generating actionable suggestions, such as	The integration of diverse data (segmentation, material, temperature) into a standardized JSON format for Vision-Language Models (VLMs) or Large Language Models (LLMs) is a novel approach. This scalable framework allows seamless communication between datasets and AI models, enabling detailed analysis and actionable insights. Additionally, fine-tuned prompts ensure the AI outputs are tailored for

		material replacements or structural modifications. 3. **Validating and Refining AI Outputs:** Test the outputs generated by the AI models, identify areas for improvement, and refine prompts or models to enhance accuracy and usability.	practical urban interventions, setting this apart from generic AI applications.
Madhuwantha G K O	To simulate the thermal impact of proposed construction projects by integrating virtual models with real-world environmental data and calculate temperature variations.	1. **Virtual Model Creation:** Develop a system to generate 3D virtual models based on construction proposals, including detailed attributes like material types and structural specifications. 2. **Environmental Integration:** Overlay the virtual models onto existing urban environments using GIS data to simulate real-world placement.	A approach to integrates detailed virtual models of proposed constructions with real-world environmental data. Unlike traditional methods that rely on static analyses, it enables real-time evaluation of potential thermal impacts within actual urban settings. By overlaying 3D models onto urban landscapes and considering factors like topography and existing infrastructure, it provides a comprehensive view of

		3. **Thermal Simulation:** Utilize a lookup table containing material properties (thermal conductivity, heat absorption, etc.) and real-time temperature data to calculate the thermal impact of the proposed construction. **4. Validation and Refinement:** Compare simulation results with existing benchmarks and refine the models or lookup tables to improve predictive accuracy.	the potential effects of new developments

9. Supervisor details

	Title	First Name	Last Name	Signature
Supervisor	Mr.	Vishan	Jayasinghearachchi	
Co-Supervisor	Ms.	Kaushalya	Rajapakse	
External Supervisor	Dr.	Rajitha	De Silva	
Summary of external supervisor’s (if any) experience and expertise				

This part is to be filled by the Topic Screening Staff members.

a) Does the chosen research topic possess a comprehensive scope suitable for a final-year project?

Yes		No	

b) Does the proposed topic exhibit novelty?

Yes		No	

c) Do you believe they have the capability to successfully execute the proposed project?

Yes		No	

d) Do the proposed sub-objectives reflect the students' areas of specialization?

Yes		No	

e) Supervisor's Evaluation and Recommendation for the Research topic:

Acceptable: Mark/Select as necessary

Topic Assessment Accepted	
Topic Assessment Accepted with minor changes*	
Topic Assessment to be Resubmitted with major changes*	
Topic Assessment Rejected. Topic must be changed	

* Detailed comments given below

Comments

Staff Member's Name	Signature

*__Important__:

1. According to the comments given by the evaluator, make the necessary modifications and get the approval by the **Evaluator**.
2. If the project topic is rejected, identify a new topic, and request the RP Team for a new topic assessment.