

Advancing Human-Centered Urban Planning: Incorporating Human Perception in Digital Twins for Sustainable City Development

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Urban Digital Twin, Computer Vision, Virtual Reality



BACKGROUND

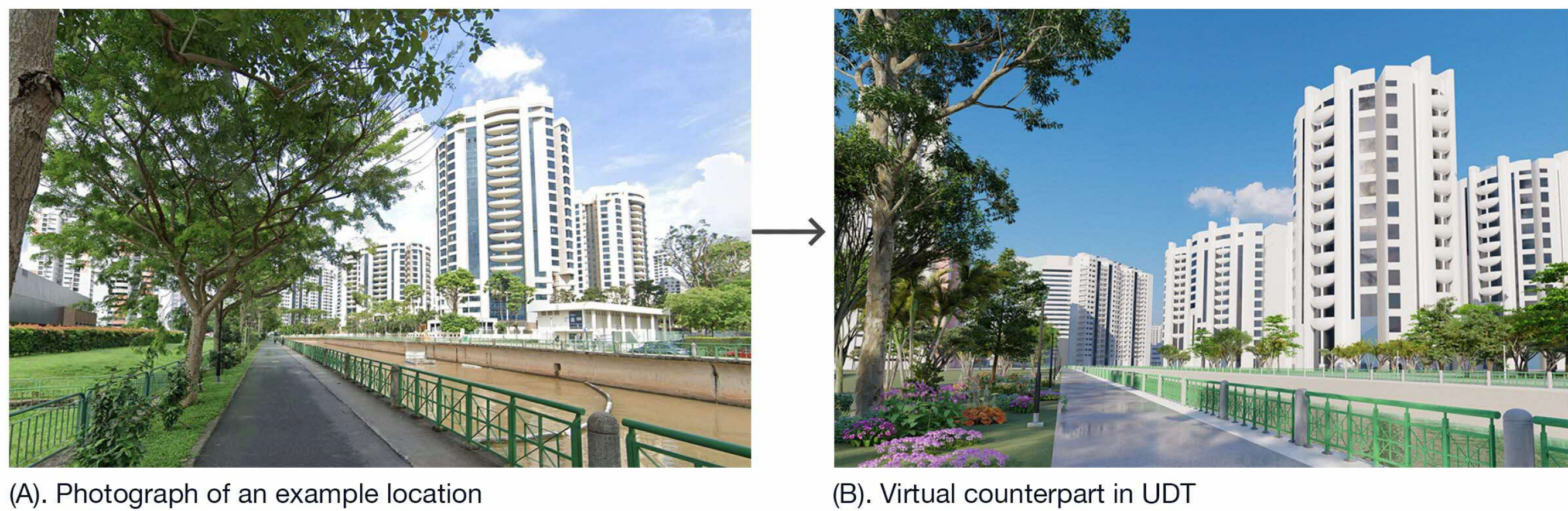
- Urban Digital Twins (UDTs) offer a promising avenue for advancing sustainable urban development by mirroring physical environments and complex urban dynamics.
- UDTs enable urban planners to predict and analyze the impacts of various urban scenarios, addressing a global priority for sustainable urban environments.

RESEARCH GAP

- The complex relationship between urban landscape characteristics and residents' subjective visual perceptions through the lens of UDTs remains underexplored.
- The potential of UDTs in public engagement for environmental perception remains unfulfilled, as existing research lacks the capability to analyze the visual features of urban landscapes and predict public perceptions based on photo-realistic renderings.

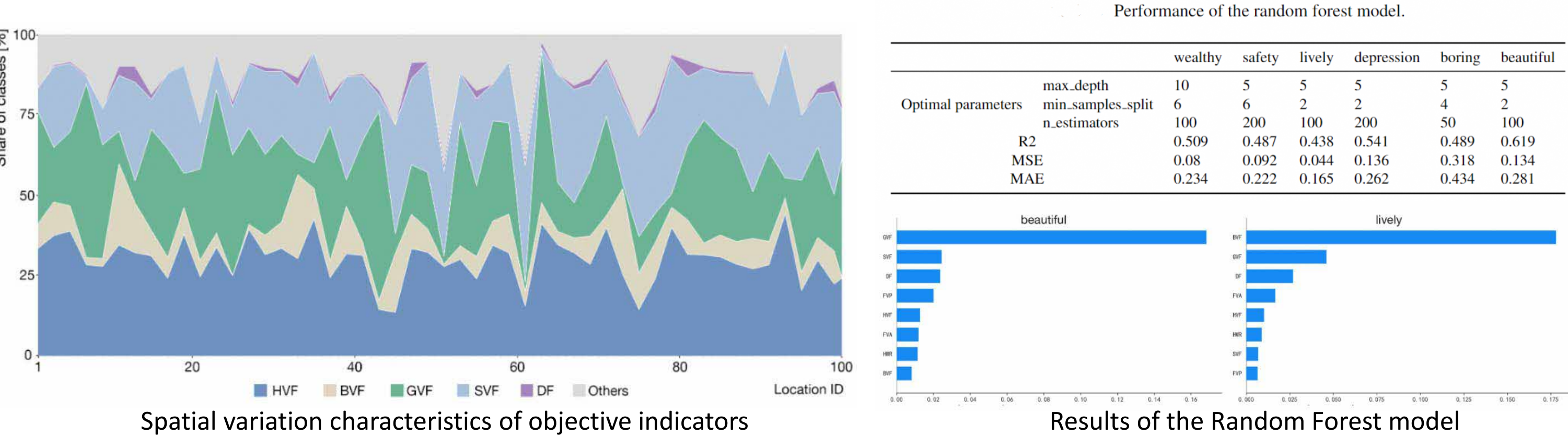
RESULTS

<The outcome of the urban digital twin>



We demonstrate that renders from the UDT platform give the same visual impression in surveys, confirming the value of photo-realistic renderings of scenarios that are yet to be built for participatory planning.

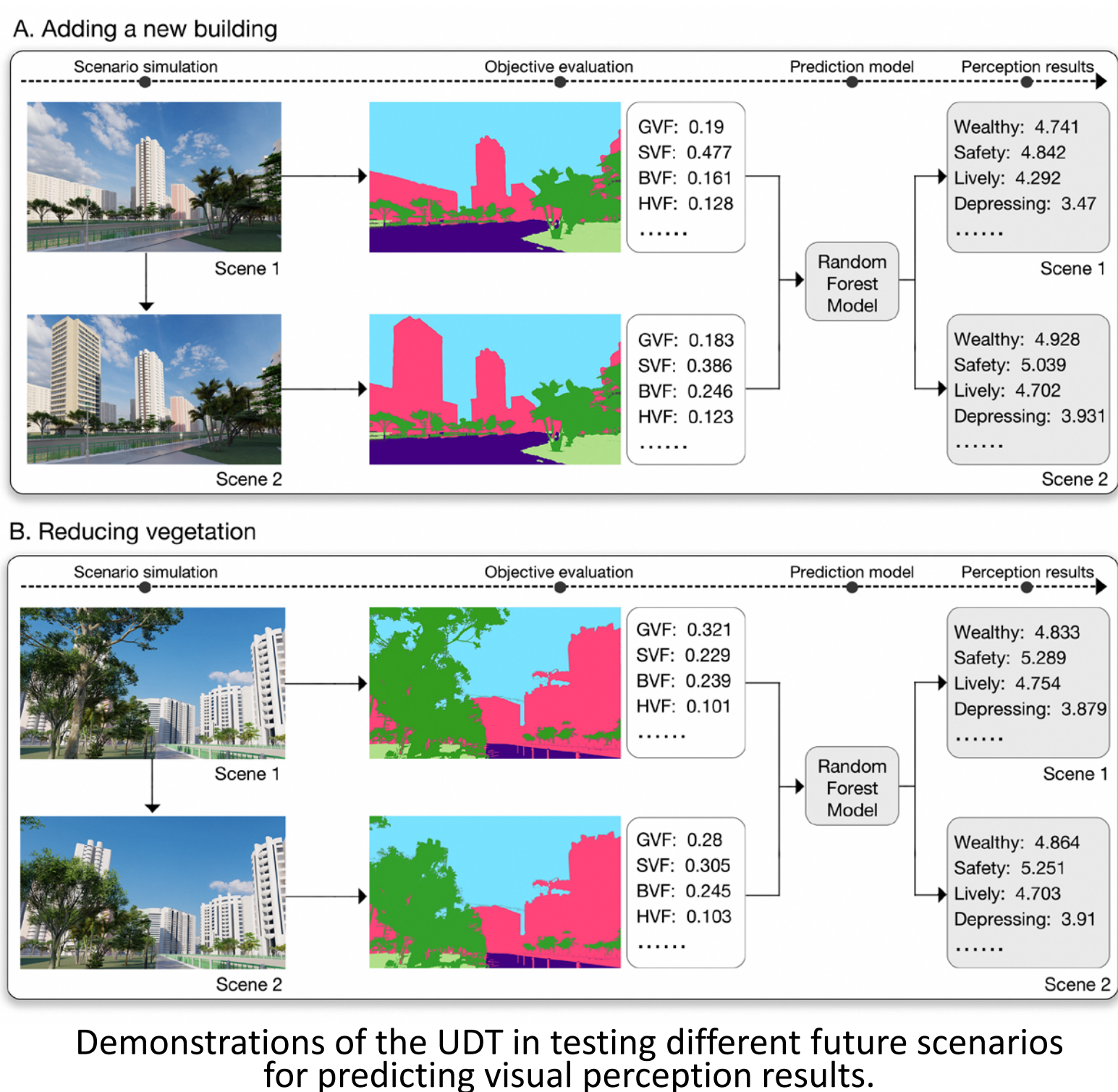
<Results of the perception study>



We illustrate the spatial variation characteristics of the objective and subjective indicators. Then, we show the performance of the Random Forest prediction model.

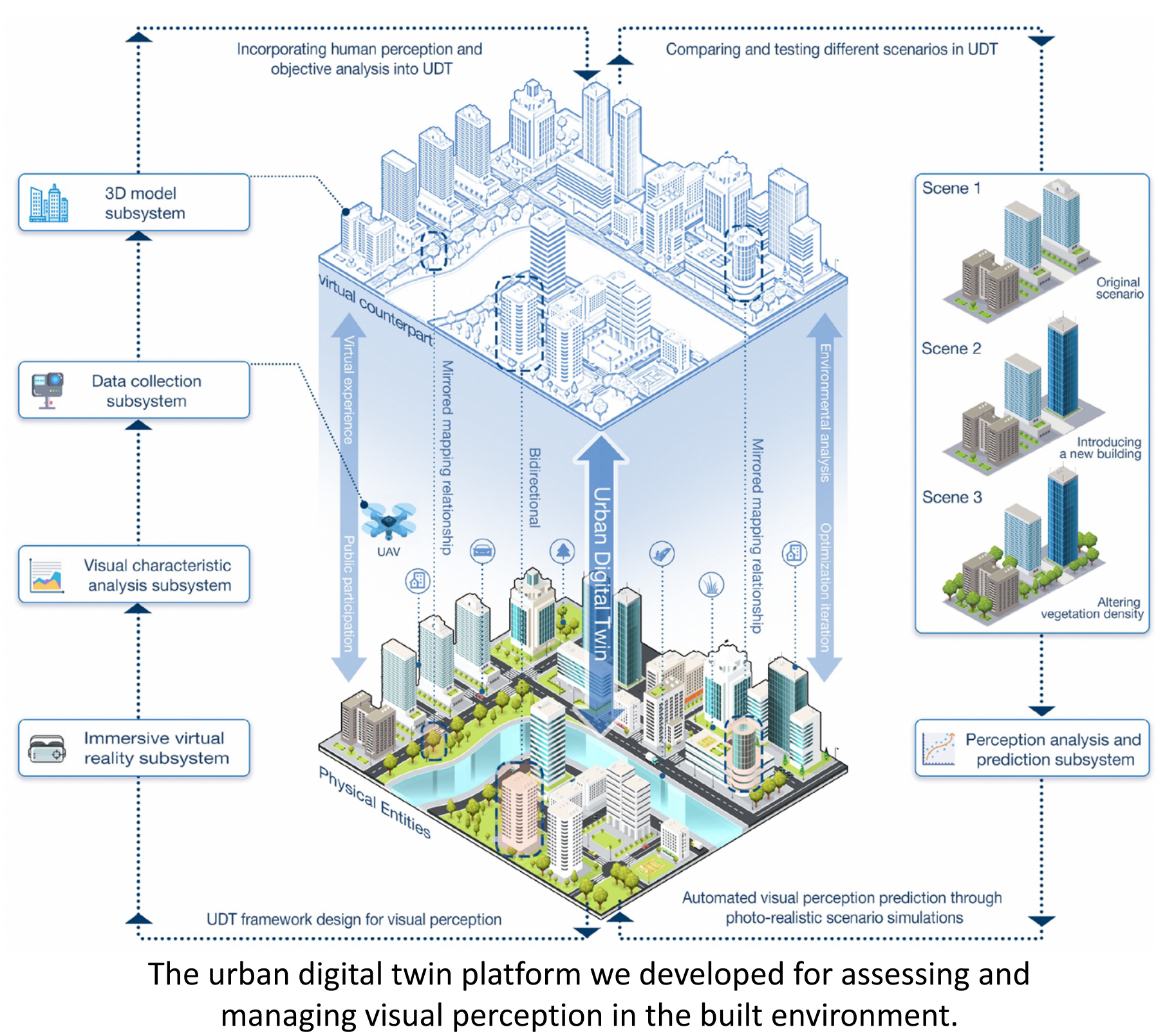
< Automated perception prediction through photo-realistic scenario simulations >

The primary application of the UDT is manifested in simulating various urban scenarios, such as modifying vegetation density or introducing new architectural elements to the skyline. Subsequently, we employed the Random Forest model to automatically predict subjective visual perceptions.

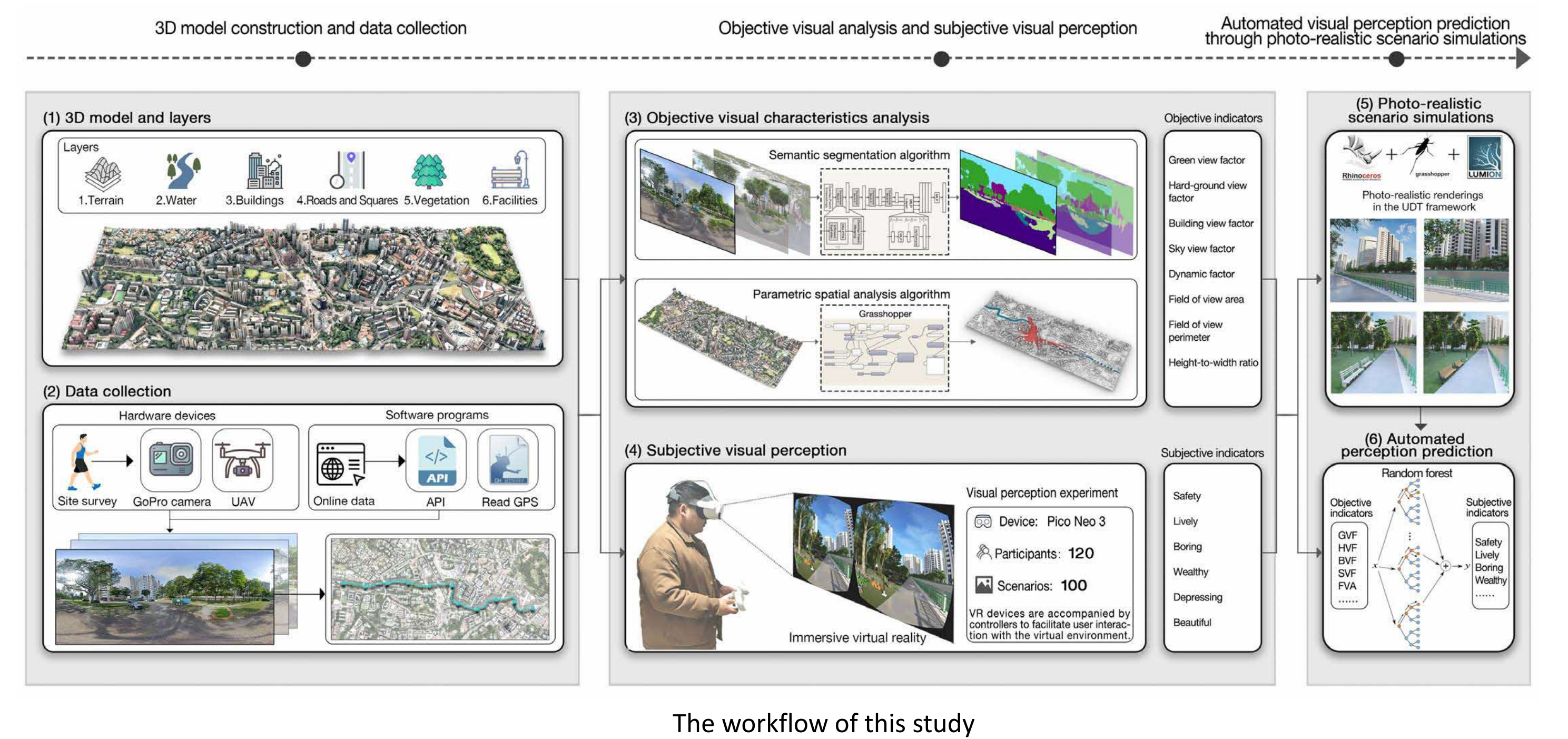


AIM

We aim to develop and implement a UDT platform designed for the dual purposes of objective feature evaluation and subjective visual perception, alongside the automated prediction of subjective perceptions in simulated scenarios.



METHODS



- We focus on a 3-kilometre-long linear urban greenway situated adjacent to the Singapore River as our study area.
- The UDT platform we developed for weaving human visual perceptions into the fabric of UDTs to analyze and evaluate the characteristics of urban landscapes.
- We utilize DeepLabV3 for imagery semantic segmentation and Grasshopper parametric spatial evaluation methods in the UDT platform for objective feature analysis and employ the random forest algorithm for automated perception prediction.
- The human-in-the-loop experiment was conducted to obtain the subjective visual perception outcomes by utilizing the immersive virtual reality subsystem of the UDT platform.

CONCLUSION

- This study contributes towards achieving a 'true' digital twin for urban planning, and it sets the foundation for automating the optimisation of urban scenarios and enhancing urban sustainability.
- We demonstrate that photo-realistic renderings based on the UDT can replace the traditionally used photos for this use case, confirming their value in participatory planning.
- We conduct a comprehensive comparison and spatial distribution analysis of the objective environmental features and subjective visual perception results of the urban greenway.
- The integration of public perceptions into UDTs is crucial for establishing a bidirectional connection between the 'digital platform---public perception---physical environment.' This integration encapsulates a specific manifestation of the sustainable urban development concept centred around the public.

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