



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 11, November 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.524

 9940 572 462

 6381 907 438

 ijirset@gmail.com

 www.ijirset.com

Creation of a Digital Twin Tool: A Smart Mobility Perspective in Smart Cities

Lalitha Bandeppa, Usha B.R, Devika S, Janavi K

Assistant Professor, Department of Computer Science Engineering, CIT, Gubbi, Tumkur, Karnataka, India

U.G. Student, Department of Computer Science Engineering, CIT, Gubbi, Tumkur, Karnataka, India

U.G. Student, Department of Computer Science Engineering, CIT, Gubbi, Tumkur, Karnataka, India

ABSTRACT: An enhanced Digital Twin (DT) structure is presented in this research in order to handle the intricate requirements of urban mobility in smart cities. By utilising automated 3D model production, immersive virtual reality (VR) simulations, and real-time data fusion from IoT sensors, the framework gives stakeholders and city planners the ability to control and optimise urban mobility with previously unheard-of precision. Traffic optimisation, environmental monitoring, and route planning applications can benefit from the DT framework's ability to produce high-fidelity, real-time digital copies of metropolitan infrastructure and vehicles through integration with machine learning and deep learning-based 3D reconstruction. In addition to supporting predictive analysis and modelling of important urban situations, like traffic congestion and environmental repercussions under various conditions, this system improves decision-making for city management. Case studies show that the typical car has significantly improved.

KEYWORDS: Digital twins, smart cities, urban mobility, IoT, 3D reconstruction, virtual reality, simulation.

I. INTRODUCTION

In order to overcome the shortcomings of current systems, this paper presents an advanced Digital Twin framework that focusses on urban mobility within smart cities. The proposed system allows stakeholders to interact with and manage digital twins of vehicles and infrastructure by combining immersive virtual reality (VR) simulations, deep learning-based 3D reconstruction, and real-time data ingestion from IoT sensors. The DT system automates the creation of 3D models from single-view images and point clouds, allowing it to scale efficiently across a city-wide context. Through VR, city planners may see and simulate situations such as route optimizations, congestion reduction, and environmental impact assessments, making educated decisions based on predictive and prescriptive analytics. [1][2]

This work makes three contributions: first, we provide a scalable DT architecture that automates the creation and real-time updating of digital representations of infrastructure and automobiles. Second, a thorough simulation module for route design, congestion analysis, and traffic flow optimisation is included in the framework. Third, we analyse the framework's performance through case studies proving its ability to reduce congestion, increase route efficiency, and minimise emissions in urban areas. [1][2] [3]

The ultimate goal of this research is to help cities create more livable, sustainable, and efficient urban environments by developing digital twin applications for smart city mobility management. [1][2][3]

II. RELATED WORKS

Methodology

1. Data Ingestion and Integration

- IoT Sensor Data Collection: A variety of IoT sensors, including as GPS, cameras, environmental sensors, and accelerometers installed in infrastructure and automobiles, provide data continuously. These data sources include up-to-date information on environmental factors like air quality, traffic density, weather, and vehicle position.
- Data Fusion and Preprocessing: To ensure accuracy and consistency across all inputs, data from various sources is

synchronised and fused using methods such as Bayesian fusion and Kalman filters. Data is cleaned, normalised, and formatted during this preprocessing step to make it compatible with the DT system.

- **Real-Time Data Management:** To minimise latency and facilitate real-time simulation and decision-making, the framework uses an edge computing architecture to process data locally before transferring it to the cloud.

2. 3D Reconstruction Automated

- **Deep Learning-Based 3D Model Generation:** The system uses deep learning models, such as occupancy networks and ResNet-based networks, that have been trained to produce 3D models from 2D single-view images or point clouds, as well as vehicle tracking methods like Mask R-CNN and Centroid Tracking, to produce 3D digital replicas of vehicles and infrastructure.[3]

- **Dynamic Model Updating:** As new data is absorbed, models are updated dynamically to provide accurate, real-time depictions of the urban environment.

3. Integration of Virtual Reality (VR) for Communication

- **Immersive VR Environment:** A 3D interactive representation of the urban environment is made available to stakeholders and city planners via the VR interface. Users can navigate and simulate different transportation scenarios by interacting in real-time with digital twins of infrastructure and cars.

Techniques for Human-Computer Interaction (HCI): A smooth user experience is produced via the VR environment's intuitive controls, which include gesture recognition, gaze-based navigation, and spatial audio cues.

- **Real-Time Simulation Scenarios:** In a virtual environment, users may visualise results and evaluate different urban planning techniques by simulating scenarios such as traffic congestion, accident impacts, and route optimisation.

Datasets Used

1. Dataset for 3D models:

- **Shape Net:** To create digital reproductions of cars and other urban assets, deep learning models are trained using this extensive dataset, which offers high-quality 3D models.

- **Object Categories:** To generate precise vehicle models and enable realistic simulations within the DT framework, the framework makes use of categories including cars, buses, and trucks.

2. IoT and Real-Time Data:

- **Traffic and Vehicle Data:** GPS, cameras, and accelerometers embedded in both private and public transportation systems gather real-time vehicle data, which includes information on the locations, speeds, directions, and densities of vehicles.

- **Traffic Signals and Road Networks:** To model traffic flow, congestion patterns, and vehicle routing, real-time traffic light data and road network information are combined. The DT framework's route planning and optimisation modules depend on this data.

3. External Urban Mobility Datasets:

- **KITTI Dataset:** This dataset offers 3D point clouds, high-resolution stereo pictures, and other data types gathered from urban driving situations. It is mostly utilised for training in autonomous driving research. By providing realistic traffic and road scenarios for training and evaluating the generalisability of the model, KITTI data complements the DT framework.

- **City-Provided Mobility Data:** Additional layers are added to the urban mobility simulation by utilising, when available, city-provided open mobility information, such as those on traffic patterns, public transportation timetables, and incident reports.

Performance Evaluation Metrics

1. **3D Model Accuracy and Quality:** Performance measurements that assess the quality of 3D reconstructions, such Chamfer Distance and Intersection over Union (IoU), make sure that the DT system appropriately depicts urban assets.

2. **Responsiveness and Latency of the Simulation:** The framework quantifies the VR simulation's responsiveness, guaranteeing minimal latency and real-time interactions to aid in decision-making.

3. **VR User Usability Testing:** To improve the VR experience, user interactions are monitored and examined to gauge user satisfaction and ease of use in the virtual world.

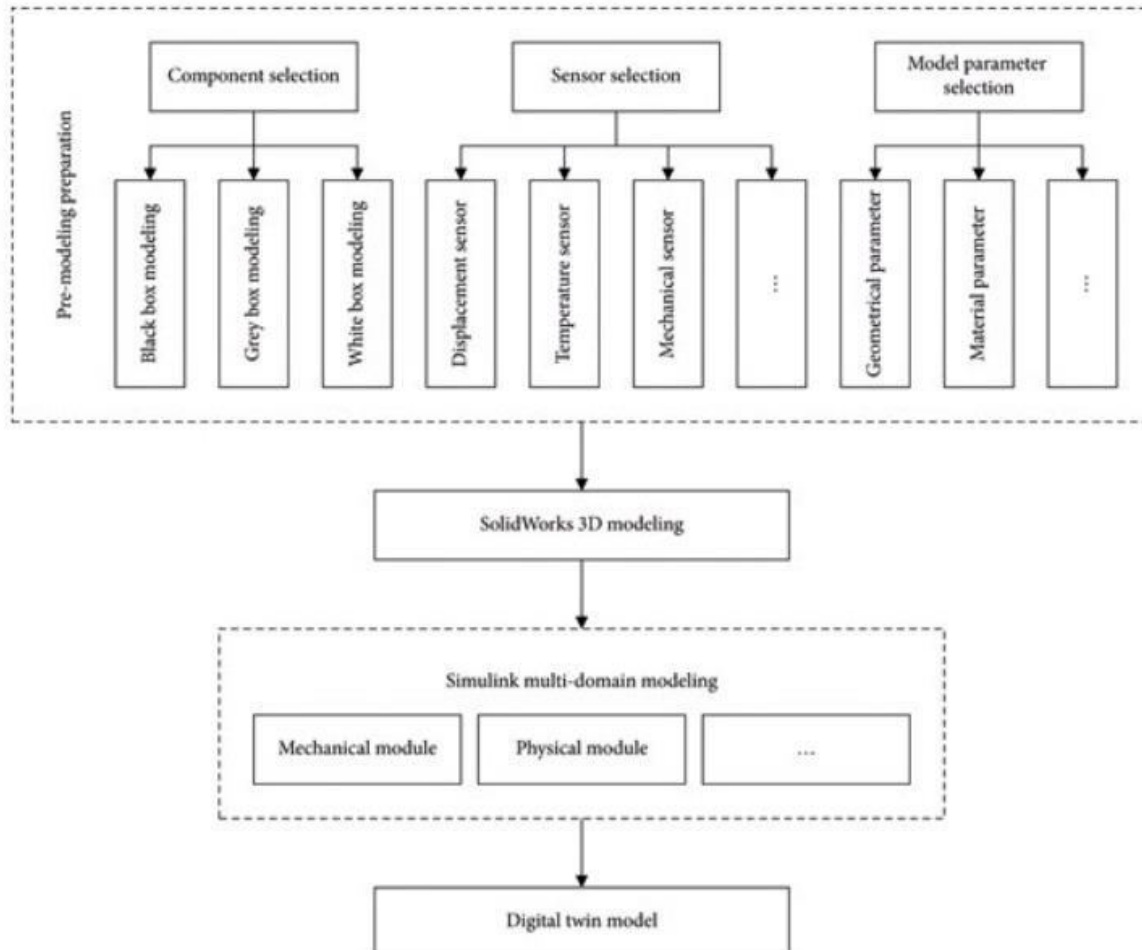


Fig 1: Proposed Model

III. CASE STUDY APPLICATION

1. Traffic Management Simulation: To demonstrate the system's capabilities, a busy metropolitan region is simulated. The case study's main objectives are to estimate traffic patterns using real-time data, assess route efficiencies, and optimise traffic signal timing.

2. Building 3D Models of Environments and Vehicles

- 3D Reconstruction: The DT framework creates digital copies of cars and incorporates them into a virtual city setting using single-view photos and pre-trained models (such as occupancy networks).
- Integration into VR: By visualising these 3D models in a virtual reality setting, stakeholders may view how cars are positioned on the road network and engage with the simulation in real time.

3. Optimisation of Traffic Flow in Real Time

- Traffic Simulation: Using agent-based modelling, the DT system replicates traffic flows in real time. Realistic urban traffic circumstances are replicated by the way vehicles interact with one another based on proximity, speed, and traffic light states.
- Route Optimisation: Taking into account real-time traffic data, vehicle density, and journey times, the framework uses algorithms like Dijkstra's and A* search to identify the most efficient routes.

- **Traffic Signal Management:** Real-time data from IoT sensors and congestion levels are used to dynamically modify traffic signals. In order to minimise vehicle pauses and cut down on wait times at intersections, the system optimises traffic signal timing.

4. Evaluation of the Environmental Impact

- **Integration of Environmental Data:** Real-time information on weather, temperature, and air quality is provided via IoT sensors. The environmental effects of traffic flow and car emissions are modelled using this data.
- **Impact Simulation:** The DT framework computes important metrics including emissions, average vehicle speed, and congestion rate by simulating traffic situations in a range of environmental circumstances, including clear, wet, and snowy weather.
- **Scenario Analysis:** By comparing environmental results under various weather and road conditions, the simulation evaluates how optimised traffic flow affects emissions.

IV. CONCLUSION

The Digital Twin Authoring Tool (DTAT) is a revolutionary development in digital twin (DT) technology, especially in the field of urban smart mobility, according to the study's conclusion. DTAT greatly improves the planning, management, and optimisation of smart city transport systems by fusing real-time simulation, immersive virtual reality, and autonomous 3D reconstruction. Our method emphasises how crucial it is to create precise 3D models of real-world items, like cars, in order to enable meaningful interaction in virtual spaces. We show the entire process, from gathering data in various formats to producing useful DTs for urban stakeholders.

DTAT addresses generalisability issues by enabling the reconstruction of 3D models for unseen vehicle types through the use of an occupancy network for 3D reconstruction of 2D images. By incorporating these models into a virtual reality platform, stakeholders are empowered to make well-informed decisions on urban mobility. Furthermore, we demonstrate the tool's use in a smart mobility environment by simulating traffic behaviour and optimising routes with brute-force techniques to control congestion and enhance traffic flow. Future studies will concentrate on expanding the tool's functionality, especially in automating the production of 3D models for different item types. Increasing the variety of 3D reconstruction methods and creating effective algorithms for model retrieval and reconstruction will be essential to enhancing DTAT's performance. In order to illustrate the tool's potential in actual smart city management scenarios, we also foresee the creation of a real-time, web-based application. Our goal with these upcoming developments is to make DTAT an indispensable instrument in the continuous development of intelligent, sustainable urban settings.

REFERENCES

- [1] M. S. Irfan, S. Dasgupta, and M. Rahman, "Toward transportation digital twin systems for traffic safety and mobility: A review," *IEEE Internet Things J.*, vol. 11, no. 14, pp. 24581–24603, Jul. 2024.
- [2] G. Bhatti, H. Mohan, and R. Raja Singh, "Towards the future of smart electric vehicles: Digital twin technology," *Renew. Sustain. Energy Rev.*, vol. 141, May 2021, Art. no. 110801.
- [3] B. Lei, P. Janssen, J. Stoter, and F. Biljecki, "Challenges of urban digital twins: A systematic review and a delphi expert survey," *Autom. Construction*, vol. 147, Mar. 2023, Art. no. 104716, doi: 10.1016/j.autcon.2022.104716.
- [4] Z. Allam and D. S. Jones, "Future (post-COVID) digital, smart and sustainable cities in the wake of 6G: Digital twins, immersive realities and new urban economies," *Land Use Policy*, vol. 101, Feb. 2021, Art. no. 105201, doi: 10.1016/j.landusepol.2020.105201.
- [5] S. H. Khajavi, N. H. Motlagh, A. Jaribion, L. C. Werner, and J. Holmström, "Digital twin: Vision, benefits, boundaries, and creation for buildings," *IEEE Access*, vol. 7, pp. 147406–147419, 2019.
- [6] V C. Boje, A. Guerriero, S. Kubicki, and Y. Rezgui, "Towards a semantic construction digital twin: Directions for future research," *Autom. Construct.*, vol. 114, Jun. 2020, Art. no. 103179.
- [7] S. Kaewunruen, J. Sresakoolchai, W. Ma, and O. Phil-Ebosie, "Digital twin aided vulnerability assessment and risk-based maintenance planning of bridge infrastructures exposed to extreme conditions," *Sustainability*, vol. 13, no. 4, p. 2051, Feb. 2021.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details