CS4632 Literature Review, Rev. 1

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1 Abstract

Traffic simulation models are essential for understanding traffic dynamics on college campuses, where class schedules create predictable pedestrian and vehicular surges. Traditional models often fail to capture these periodic fluctuations, leading to inaccurate traffic flow predictions. This paper reviews existing methodologies in traffic simulation and occupancy estimation, highlighting the integration of class schedules and building occupancy data into simulation models. By using structured college class schedules, better accuracy in traffic predictions can be achieved. This review identifies gaps in current research, particularly the need for campus-specific adaptations to refine traffic prediction and modeling techniques.

1.1 Keywords

Traffic simulation, Simulation of Urban Mobility, building occupancy-driven traffic modeling, structured schedule traffic patterns, college campus traffic patterns, college campus mobility, class schedule-based traffic patterns

2 Introduction

Traffic simulation models play an important in managing transportation on college campuses, where the start and end of classes create distinct surge patterns. Unlike urban settings, campus traffic has highly structured fluctuations due class schedules. However, traditional models often fail to incorporate these predictable fluctuations, leading to less optimal and less efficiency routing and congestion predictions. This literature review explores the integration of college campus building occupancy estimates, derived from class schedules, into traffic simulation models. By incorporating these estimates, simulations can better predict traffic patterns, better traffic management policies, and improve campus accessibility.

3 Review of Literature

Existing literature on traffic simulation and occupancy estimation highlights various methodologies, findings, and gaps that show that integrating building occupancy data into traffic models enhance traffic modeling accuracy.

3.1 "BuildSenSys: Reusing Building Sensing Data for Traffic Prediction with Cross-domain Learning"

This study introduces an approach for predicting urban traffic volume using building sensing data[5]. The increase of smart buildings equipped with IoT sensors generates a multitude of data, including occupancy levels. The authors propose BuildSenSys, a system that uses building data to predict traffic patterns rather than relying only on road-based monitoring systems that are costly and require regular maintenance.

The study identifies two important challenges: 1) establishing correlations between building data and traffic volume, which change over time, and 2) ensuring accurate traffic predictions using these relationships. The results confirm a strong correlation between building occupancy and traffic patterns. This study is relevant to the modeling of traffic on college campuses as it demonstrates that structured, predictable occupancy levels, such as those derived from class schedules, can enhance traffic forecasting without the need for an electronic monitoring system.

3.2 "Microscopic Traffic Simulation using SUMO"

This study discusses the role of microscopic traffic simulation in transportation research, with a focus on the open-source Simulation of Urban Mobility (SUMO) tool[7]. Microscopic models, which simulate individual pedestrian and vehicular behavior, allow for highly detailed traffic analysis and route planning.

SUMO provides a framework for generating, validating, and evaluating traffic scenarios. Key features include network data integration, traffic demand modeling, and pedestrian modeling. The study also outlines validation techniques to improve the accuracy of SUMO simulations. The relevance of SUMO to campus environments lies in its adaptability to highly structured traffic patterns, such as those dictated by college class schedules.

3.3 "Refining SUMO Simulation Strategies for Realistic Traffic Patterns: Insights from Field Experience"

This study explores the application of SUMO for modeling urban traffic and refining simulations to improve accuracy[9]. Using real-world data from a shopping center in France, the authors use an iterative process to adjust model parameters until simulated traffic behaviors align with observed conditions.

The findings of the study include improved traffic density estimates, and congestion pattern identification. The study highlights the importance of data-driven refinements in simulation models. Applied to a campus environment, this approach could increase the accuracy of SUMO-based simulations by incorporating structured traffic surges linked to class schedules.

3.4 "Urban Traffic Prediction through the Second Use of Inexpensive Big Data from Buildings"

This article presents an approach to urban traffic prediction by using building occupancy data[12]. The study, conducted in Hong Kong, examines data from the International Commerce Center (ICC) to forecast traffic conditions in the surrounding area.

The researchers develop the Occupancy-Traffic Model (OccTra), which establishes a relationship between building occupancy levels and traffic flow. The results indicate that this method improves accuracy, particularly during non-peak hours, outperforming conventional traffic prediction models. The findings suggest that structured occupancy estimates, such as those based on class schedules, can serve as reliable indicators for traffic forecasting in college campus environments.

3.5 "Mobile Assistive Technology Mapping and Integration"

This study explores the development of a campus accessibility map aimed at improving the navigation experience for individuals with mobility needs at Kean University[6]. The project implements an interactive Android-based navigation application with an accessible campus map design, allowing users to identify convenient accessible pathways.

The research follows a two-phase methodology. In the design phase, a review of existing accessibility maps was conducted, followed by usability studies to ensure the application meets user needs. In the development phase, an accessibility layer was implemented on Google Maps to display accessibility data for campus buildings and pathways. The findings indicate that this approach provides critical accessibility information while improving user experiences in human-computer interaction. The study highlights the importance of integrating assistive technology in campus navigation solutions to enhance accessibility and independence for individuals with disabilities.

3.6 "Mapping for Wheelchair Users: Route Navigation in Urban Spaces"

Navigation in urban areas presents significant challenges for individuals with mobility impairments due to the structural constraints of the urban landscape. Traditional pedestrian maps do not account for the varied barriers faced by wheelchair users, such as slope, surface type, and the availability of dropped curbs. This study quantifies these differences and develops a Geographical Information Systems (GIS) network model for creating accessibility maps tailored for wheelchair users[1].

The methodology involves measuring navigation barriers using Digital Elevation Models, calculating rolling resistance, and conducting field surveys with handheld GIS devices. A spatial database has been developed to store pedestrian route networks and accessibility barriers. The study implements a GIS-based application that provides a user-friendly interface for route planning, ensuring that selected paths account for impedances that affect wheelchair accessibility.

User testing with wheelchair users confirms that the generated routes closely align with real-world navigation patterns. The system offers personalized maps to assist new users in navigating unfamiliar environments, improve accessibility for existing users, and provide urban planners with valuable insights into designing more inclusive spaces. This study highlights the importance of GIS-based accessibility modeling in improving mobility for wheelchair users and advancing urban accessibility planning.

3.7 "Data Navigator: An Accessibility-Centered Data Navigation Toolkit"

The accessibility of data visualizations for people with disabilities remains a critical challenge in contemporary user interface design. Many existing visualization tools lack navigable structures, exclude essential input modalities, and rely heavily on visual-only rendering techniques, limiting accessibility for users of assistive technologies.

To address these limitations, this study introduces *Data Navigator*, a system built on a dynamic graph structure that allows developers to construct navigable lists, trees, graphs, flows, and spatial relationships. Data Navigator enhances accessibility by supporting multiple input modalities, including screen readers, keyboard navigation, speech input, gesture detection, and assistive devices[3].

Three case studies demonstrate Data Navigator's effectiveness: (1) providing accessible navigation structures on top of raster images, (2) integrating with existing toolkits at scale, and (3) facilitating the rapid development of new prototypes. The results indicate that Data Navigator significantly improves accessibility in data visualization, making it easier to design and implement inclusive interactive data representations.

3.8 "Reasoning about Accessibility for Disabled Using Building Graph Models Based on BIM/IFC"

Building Information Modelling (BIM) is widely used in the Architecture, Building, and Construction (ABC) industries to manage building data throughout its lifecycle. While BIM ensures compliance with legal accessibility requirements, it often neglects the quality of accessible routes in terms of distance, effort, and convenience for disabled individuals.

This study presents a graph-based method for identifying optimal accessible routes within buildings[8]. Using Industry Foundation Classes (IFC) data, a spatial model is constructed where nodes represent building spaces and edges encode movement costs, such as door width, ramp availability, and stair configurations. A modified shortest-path algorithm determines the most accessible routes based on these constraints.

The proposed system enables individuals with disabilities to select the least effort-intensive routes using mobile devices. Additionally, a visualization tool for designers highlights accessibility challenges in building layouts, promoting a shift from basic compliance to optimizing user experience. The study demonstrates the potential of BIM-integrated accessibility modeling to enhance inclusive design and real-time navigation solutions.

3.9 "AIoT-based smart traffic management system"

Presented within this study is an innovative AI-based approach to smart traffic management[4]. Using CCTV footage, the authors were able to gather important traffic information which they utilized to minimize congestion and travel time. While urban navigation is rarely so severe an impediment as bumper-to-bumper traffic, for differently-abled individuals, different challenges could be imposed by the presence of such great volumes of pedestrian traffic.

In pursuing smoother, easier navigation aid for differently-abled individuals, real-time traffic data provided by CCTV footage might help direct certain users appropriately. This study also helps to illustrate different software to simulate traffic, using PyGame as their simulation software.

3.10 "Deep Heuristic Learning for Real-Time Urban Pathfinding"

This study presents a novel approach to urban pathfinding, leveraging two methods to account for contextual data such as weather or traffic[2]. Using deep learning models, the study presents a methodology that utilizes both historical and live data to predict optimal path segments. The methods presented show remarkable efficiency increases, touting a 34% improvement to travel times using an enhanced A* algorithm.

This research is relevant to our project as it expands on methods in which we may use contextual data to enhance our pathfinding algorithm. The authors' comprehensive benchmarks of various deep learning models provides valuable insights into the comparative performance of various approaches. These findings help contextualize our usage of traffic data within pathfinding approaches, displaying a different way to determine pathing.

3.11 "Estimating Building Occupancy: A Machine Learning System for Day, Night, and Episodic Events"

This study explores a machine learning framework designed to estimate building occupancy dynamically across different time periods, including daily use, nighttime occupancy, and episodic events such as stadium gatherings or religious services [10]. The authors utilize Bayesian learning techniques to integrate a wide range of open-source data, including census records, survey results, and volunteered geographic information (VGI).

Key challenges identified in the study include:

1. Variability in Building Use – Occupancy estimation must account for diverse land uses, from residential housing to commercial buildings and public event spaces.
2. Uncertainty in Data Sources – Open-source datasets, while expansive, often contain inconsistencies that must be accounted for in the model.
3. Scaling to Global Estimates – Different geographic regions exhibit unique occupancy patterns that require localized adaptation of the estimation models.

The study highlights the importance of probabilistic occupancy modeling, particularly in settings where real-time occupancy tracking is infeasible. Its findings suggest that structured methodologies, such as those based on historical building occupancy trends, could improve the accuracy of traffic simulation models on college campuses.

3.12 "A State-of-the-Art Review on Methodologies of Occupancy Estimating in Buildings"

This literature review provides an in-depth analysis of occupancy estimation methods, evaluating their effectiveness in various contexts including energy efficiency, security, and traffic planning [11]. The review categorizes occupancy measurement approaches into vision-based, sensor-based, and hybrid techniques, discussing their trade-offs in terms of cost, accuracy, and privacy concerns.

The study identifies key technological challenges in occupancy estimation:

1. High-Density Occupancy Counting – Many existing models struggle to accurately count people in crowded environments.

2. Environmental Interference – Factors such as lighting, furniture layout, and sensor obstructions reduce system accuracy.

3. Robustness Across Applications – The effectiveness of different techniques varies across environments, requiring tailored approaches for schools, office buildings, and public spaces.

A major conclusion of the study is that hybrid approaches—combining multiple sensors (e.g., infrared with Wi-Fi tracking)—offer the best trade-off between cost and accuracy. These findings are relevant to traffic modeling on college campuses, as they suggest that integrating multiple data sources could improve predictions of pedestrian and vehicular movement patterns.

4 Methodology

This study adopts a systematic literature review approach to identify and evaluate existing research on traffic simulations and occupancy estimation within college campuses. The review focuses on methodologies used in SUMO-based simulations and case studies integrating building data with traffic modeling. The review highlights the strengths of this approach, particularly in settings with structured predictable schedules, such as college campuses.

5 Results and Discussion

The reviewed literature highlights the following key findings:

1. **Increased Accuracy:** Studies show that integrating real-time class schedules into simulations could improve the accuracy of traffic predictions on college campuses, based on class schedule relationship to building occupancy.

2. **Applicability of SUMO for Campus Traffic Modeling:** SUMO has been widely used for urban traffic simulation, but requires refinements to account for high pedestrian activity and college class-based surge patterns.

3. **Graph-Based Accessibility Modeling Enhances Navigation:** GIS and BIM-based models demonstrate that encoding spatial constraints such as slopes, surface types, tactile surfaces, and obstacles significantly improves the accuracy of accessibility routing for individuals with mobility needs.

4. **Assistive Technology Improves Navigation Usability:** Systems like Data Navigator highlight the importance of multi-modal interactions through technology such as screen readers or speech input in making digital navigation tools more inclusive for users with disabilities.

5. **Integration of Building and Urban Data Enhances Routing:** Combining occupancy estimation, building topology, and urban navigation models results in more accurate route planning by accounting for real-world constraints such as stair accessibility, door width, and pedestrian movement trends.

The review also identified several challenges:

1. **Limited Campus-Specific Studies:** Most research focuses on urban traffic patterns, overlooking the structured and predictable nature of college campus traffic.

2. **Building Occupancy Data Accuracy:** Occupancy data collection methods may not be reliable and may produce inaccurate data, affecting the reliability and accuracy of the model.

3. **Model Integration Issues:** Many traffic simulation frameworks are not designed to incorporate class schedule-based occupancy surges, requiring modifications for effective adaptation.

4. **Initial Traffic Data Collection:** This project may require the collection of current traffic data to be used as a starting point for the modeling research.

5. **Dynamic Route Optimization:** Current accessibility models are often static, meaning they do not account for real-time changes in environmental conditions, such as temporary construction barriers or shifting pedestrian traffic patterns.

6. **Challenges in Real-Time Occupancy Estimation:** One limitation noted in the studies is the difficulty of capturing real-time occupancy fluctuations due to data sparsity or privacy restrictions. While machine learning frameworks can estimate trends, real-time adjustments remain a challenge for traffic modeling applications.

7. **Occupancy Estimation Enhances Traffic Simulations:** The reviewed articles reinforce the idea that integrating building occupancy data into traffic models improves predictive accuracy. Occupancy estimates, particularly those derived from machine learning techniques, can provide better insight into structured surges in campus traffic (e.g., between class periods).

6 Conclusion

This review underscores the importance of integrating class schedules and building occupancy estimates into traffic simulations to enhance traffic and route planning on college campuses. Research suggests that occupancy data enhances traffic models by reflecting pedestrian and vehicle movements. Most existing studies focus on commercial or urban settings rather than college campuses and few studies have investigated the direct coupling of building occupancy predictions with traffic simulation tools such as SUMO. This represents an opportunity for further research in this domain.

Future research should focus on integrating building occupancy data into traffic modeling to increase prediction accuracy. The effectiveness of different occupancy estimation techniques in traffic modeling remains under-explored, particularly in structured environments, like college campuses, where expected periodic fluctuations (such as class start and end times) create specific and distinct surges in traffic.

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Evidence of collaboration in Overleaf (share screen and sample of history log):