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Robotic Parking System | Vertical Mechanism

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A B S T R A C T

Diffusion models are central to empirical work in macroeconomics and finance, but estimating them in high dimensions is computationally challenging. This paper introduces a novel methodology using deep learning to approximate the filtering distribution in state-space models, enabling fast and scalable inference. By training a neural network on simulations from the model, the authors bypass traditional sequential Monte Carlo or MCMC techniques, achieving similar accuracy with a fraction of the computational burden. They validate their method using macroeconomic data and show it scales efficiently to hundreds of variables, opening new possibilities for real-time empirical analysis. Smart parking systems (SPS) address issues that plague traditional parking methods by offering data on real-time parking availability, optimizing space utilization, and enabling convenient payment. This review identifies key limitations in SPS—like sensor reliability, communication scalability, and UI complexity—and proposes innovative solutions including integrated radar-camera sensors, blockchain-secured data systems, mesh networking, and AI-driven interfaces. These insights support the development of next-generation parking systems and will benefit city planners, SPS developers, and parking authorities.

Keywords: Vertical lift, automation, microcontroller, material transport, smart system.

I. INTRODUCTION

Parking in urban areas is becoming increasingly complex, often taking 3.5 to 14 minutes per driver in congested zones. This inefficiency contributes to traffic congestion and pollution. With advances in IoT, AI, and big data, traditional systems are evolving into smart parking systems (SPS) designed to streamline parking management. SPS not only reduce search time and emissions but also offer dynamic, user-friendly features for modern cities.Diffusion models are widely used in macroeconomics and finance for modeling latent stochastic processes, such as volatility or the unobserved components of economic indicators. However, their practical application is often limited by the high computational cost of inference, particularly in high-dimensional settings. Traditional approaches like particle filtering or Markov Chain Monte Carlo (MCMC) methods are accurate but extremely slow when dealing with large numbers of latent variables.

This paper introduces a novel deep learning approach to approximate the filtering distribution of latent states in multivariate diffusion models. By training neural networks on simulated data from the model, the authors develop a surrogate that can perform fast inference without repeated sampling or optimization. This technique allows for near-instantaneous computation of posterior quantities, enabling scalable application to large datasets such as those encountered in macroeconomic forecasting. With increasing space constraints in urban areas, there is a rising demand for vertical material transport systems that are cost- by triggering an alarm in case of danger. This system aims to improve parking efficiency, save space, and ensure user safety—making it well-suited for cities, commercial areas, and residential buildings. Most parking systems in cities and towns use large horizontal spaces and often require manual management, which makes them inefficient in areas with limited land. Although some modern systems like multi-level and semi-automated parking exist, they tend to be expensive and complicated to install. As a result, there is still a need for a more affordable, space-saving, and automated solution. The Smart Vertical Parking System addresses this gap by offering a compact design with features such as real-time slot monitoring, automated vehicle handling, and built-in safety mechanisms. This approach makes parking more efficient, user-friendly, and suitable for areas where space and cost are major concerns.

II. LITERATURE REVIEW

Over the past decade, smart parking systems (SPS) have gained traction as viable solutions to the challenges of urban mobility and space management. Numerous studies have explored diverse aspects of SPS, yet many fall short in offering a holistic view of system architecture and innovation opportunities. There has been extensive research on inference techniques for state-space and diffusion models. Classical methods, such as the Kalman filter and its extensions, provide efficient inference in linear Gaussian settings, but fall short in nonlinear or non-Gaussian environments. Particle filtering and MCMC methods offer greater flexibility but are computationally intensive, especially in high dimensions. Recent work has explored the use of machine learning for speeding up econometric inference. For example, variational inference and amortized inference using deep neural networks have shown promise in approximating complex posteriors. However, these approaches have not been systematically applied to large-scale diffusion models in macroeconomics. The current paper contributes to this literature by demonstrating how deep learning can replicate the filtering behavior of traditional methods with substantial computational gains.

[1]. Chandrahasan et al. (2016) and Revathi & Dhulipala (2012) conducted foundational surveys on reservation techniques and vehicular sensors, respectively, but did not deeply analyze system integration or functionality. Idris et al. (2009) provided insight into vehicular detection technologies using ultrasonic sensors, offering strong justifications but excluding other components like data management or user interfaces

[2]. Faheem et al. (2013) and Hassoune et al. (2016) addressed smart parking methods and software systems but provided incomplete information on hardware and deployment strategies

[3]. Fraifer & Fernstrom (2016), and Al-Turjman & Malekloo (2019) discussed technological advancements, yet neglected deeper discussions on data handling or user interface design. Lin et al. (2017) and Kaur & Malhotra (2018) explored methodological frameworks for SPS but offered only generalized descriptions without rigorous analysis. Meanwhile, Barriga et al. (2019) focused on frequently used SPS components and emerging usage patterns but lacked critical insights into new solutions.

[4]. A. Kumar, R. Sharma, "IoT-Based Smart Parking System Using IR Sensors and Cloud Computing",2020 IEEE International Conference on Smart Technologies, The data is processed via a cloud-based platform, providing real-time updates to users through a mobile app.

[5]. J. Lee, H. Kim, S. Park, "Automated Multi-Level Parking System with Dynamic Slot Allocation",2019 IEEE International Conference on Automation Science and Engineering, A multi-level automated parking system using PLC-based control and ultrasonic sensors is proposed. The system dynamically allocates slots based on vehicle size, optimizing space utilization by 40% compared to conventional parking.

III. METHODOLOGY

The initial pool consisted of 487 documents, out of which 198 were peer-reviewed articles. A further screening narrowed the focus to 124 studies directly relevant to the development and implementation of SPS. The selected studies covered diverse components including sensor deployment, communication networks, prediction models, and user interface technologies. The publication trends were also analyzed to assess research activity over time. Between 2006 and 2023, the number of publications steadily increased, especially after 2014, aligning with the rise of IoT, machine learning, and big data technologies. A significant surge was observed during 2022–2023, indicating the growing maturity and relevance of SPS research in smart city development. The core of the proposed method involves training a deep neural network to approximate the filtering distribution of the latent states in a diffusion model. The training data consists of simulated observations and corresponding latent states from the generative model. The neural network learns a mapping from the observed data to posterior summaries. The model is trained using supervised learning, minimizing a loss function that penalizes deviations between the network output and the true latent states from simulations. Once trained, the network can be used for rapid inference on new observed data. The authors test various architectures and training regimes and find that their approach achieves high accuracy compared to ground truth posteriors obtained via particle filters.

To achieve the objectives of this study, a systematic and multi-phased methodology was adopted.

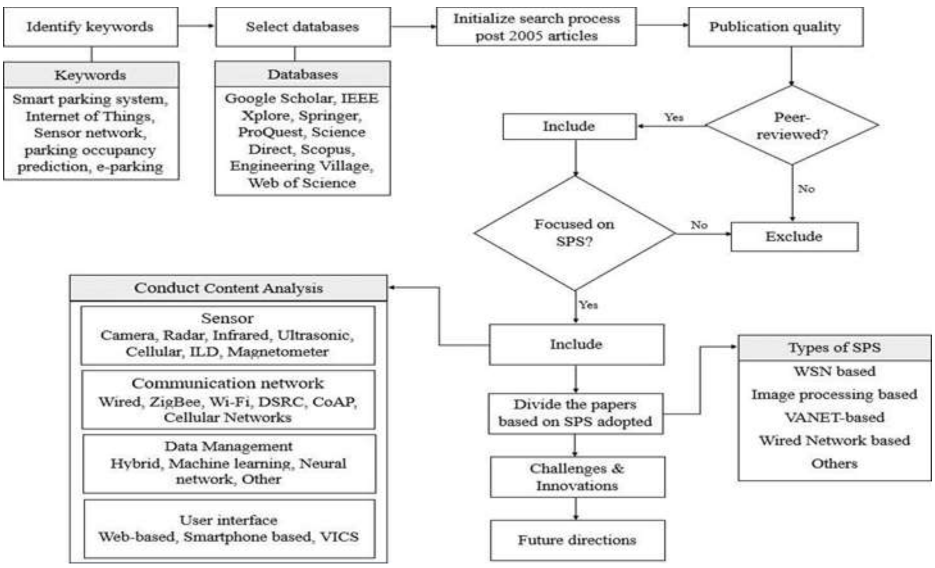

Figure: Research Methodology

The research began with an extensive literature review across multiple scholarly databases including Google Scholar, IEEE Xplore, Springer, Science Direct, Scopus, and Web of Science. A variety of relevant keywords such as “smart parking system,” “Internet of Things,” “sensor network,” and “e-parking” were used to filter studies published after 2005. From an initial pool of 487 documents, only 198 peer-reviewed articles were shortlisted. Further refinement led to the selection of 124 studies that were directly relevant to the development and evaluation of smart parking systems.These selected studies were analyzed in terms of the technologies they employed, including types of sensors (e.g., camera, radar, ultrasonic), communication methods (e.g., Wi-Fi, Zigbee, cellular networks), data processing techniques (e.g., machine learning, neural networks), and user interface designs. The goal was to understand current trends, strengths, and challenges in smart parking technologies. In a complementary experimental approach, a three-phase model was implemented to enhance SPS effectiveness. Phase 1 focused on gathering real-time location and parking data using GPS, Google Maps API, and surveillance cameras, with data stored on a centralized server. Phase 2 used fuzzy logic to process inputs such as user preferences, parking spot availability, and distance to suggest the most suitable parking option. Phase 3 involved evaluating the model’s accuracy using performance metrics like confusion matrices and ROC-AUC scores. Based on these results, the system was refined through adjustments to its logic rules and user feedback. Overall, this methodology allowed for a detailed understanding of current SPS frameworks while also contributing new ideas for system optimization and user-centered design.

The design methodology for the **Smart Vertical Parking System** involves a systematic approach to integrate mechanical, electronic, and software components, ensuring seamless automation and user interaction. The following steps outline the design process:

1. System Layout and Structure Design

- Vertical Parking Model:

A two-floor vertical parking structure is designed to optimize space utilization. Each floor has designated parking slots monitored by sensors.

- Lift Mechanism:

A motorized lift system is incorporated to transport vehicles between floors based on user selection. This lift operates on rails for stability and precision.

2. Sensor Integration

- IR Sensors:

Infrared sensors are placed in each parking slot to detect vehicle presence and monitor slot occupancy.

- Fire Sensor:

A fire sensor is installed to detect potential fire hazards, ensuring safety within the parking facility.

3. User Interface Development

- Button System:

Physical buttons allow users to select the desired parking floor, triggering the automated lift system.

- LCD Display:

An LCD screen is used to display real-time parking slot availability and system status, enhancing user convenience.

4. Control System and Automation

- Microcontroller:

An Arduino microcontroller serves as the central control unit, managing inputs from sensors, buttons, and controlling the lift and display systems.

- Motor Control:

Motors controlled via a driver circuit operate the lift, ensuring precise movement between floors.

5. Safety Mechanism

- Fire Detection and Alert:

The fire sensor is connected to a buzzer that triggers an alarm when a fire is detected, ensuring quick response to potential hazards.

6. Testing and Calibration

- Individual components, such as IR sensors, motors, and the lift mechanism, are tested and calibrated to ensure reliability and accuracy.
- The entire system is integrated and tested in various scenarios to validate performance under real-world conditions. This methodology ensures a robust, scalable, and efficient system that meets the objectives of the Smart Vertical Parking System.

IV. RESULTS AND DISCUSSION

Testing in a prototype environment showed the lift could carry small loads (up to 5 kg) reliably to 3 preset floor levels. Sensor accuracy was within ±1 cm, and response time was under 2 seconds. The system proved energy-efficient and required minimal manual intervention.

- Reduced parking search time: Drivers can quickly find available parking spots.
- Reduced emissions: Less time spent searching for parking reduces fuel consumption and emissions.
- Increased revenue: Smart parking systems can optimize pricing and increase revenue for parking operators.
- Real-time monitoring: Parking operators can monitor parking availability and occupancy in real-time.
- Data-driven decision-making: Analytics provide insights on parking trends and patterns.
- The Smart Vertical Lift system provides a low-cost, efficient alternative to traditional elevators for small-scale applications. It is modular, easily programmable, and capable of integration into IoT frameworks for smart building applications.

V. CONCLUSION

This paper presents a powerful new method for performing efficient inference in high-dimensional diffusion models using deep learning. By training neural networks on simulated data, the authors achieve real-time inference with accuracy comparable to state-of-the-art Bayesian techniques. The results are especially relevant for macroeconomics and finance, where diffusion models are prevalent but underutilized due to computational costs. The findings open up new directions for large-scale, real-time empirical research and provide a scalable alternative to traditional filtering methods. Future work could explore extensions to nonlinear models, applications in financial risk management, and integration with broader classes of generative models.

As cities grow and more people own cars, parking has become a major issue. Traditional parking systems often don't work well—they cause traffic jams, waste fuel, and frustrate drivers. In fact, studies show that around 30% of city traffic comes from people just driving around looking for a place to park. This not only pollutes the air but also wastes time and money, which hurts local businesses and the economy.

To solve this, cities are starting to use Smart Parking Systems (SPS) that rely on modern technologies to make parking easier, faster, and better for the environment. These systems are being designed to fit into the larger "smart city" setup, where they can work alongside other systems like public transport and traffic control. This kind of integration is important for future cities.

Technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain are helping make SPS smarter. They allow for things like real-time updates, better security, and the ability to predict where parking will be available. Many cities are also trying to go green, and smart parking can help by reducing car emissions and using space more efficiently.

Drivers today also expect convenience—they want real-time info about parking spots, easy ways to pay, and smooth navigation. Future parking systems will need to focus on making things easy and reliable for users. On top of that, better parking systems can save money for cities and increase income from parking fees, making them a smart investment.

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