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6CS014

COMPLEX SYSTEM

AI-driven Optimization for Sustainable Transportation Route Planning

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Abstract

In the case of cities, as more and more people become eco-conscious, AI based transport networks solve inefficiencies while ensuring ecological balance. AI and sustainable transportation are explored in this report, along with smart routing as the game changer. The aim is to demonstrate how AI-driven optimization can contribute to the advancement of sustainability in transport networks. The aim of the review is to reveal whether and how AI algorithms can provide fuel efficiency, reduction in air pollution as well as calculating estimated carbon footprint. There are seven research projects that contains useful information regarding usage of AI for transport.

Introduction

Sustainable transportation solutions has become critical at this point. The convergence of artificial intelligence (AI) and transportation holds enormous guarantee for handling the inefficiencies and environmental burdens that plague our current transportation framework. The combination of artificial intelligence (AI) with transport framework has risen as a reference point of development in our look of a greener, more effective future.

Sustainable Transportation Route Optimization utilizing AI captures this collaboration, changing how we move goods and individuals. Sustainable Transportation Route Optimization with AI speaks to a game-changing methodology, tackling the control of modern calculations and information analytics to progress how products and individuals move through our systems. AI algorithms can cut fuel utilization, unsafe outflows, and travel coordination's by consequently optimizing courses and by automatically optimizing routes. AI serves as a basic driver for making greener, more versatile communities. As we investigate deeper into this field, examining the delicate exchange between cutting-edge innovation and ecologically mindful travel strategies, the potential for reconsidering portability standards develops, recommending a future where transportation is both proficient and ecologically harmonious.

Aim

- To find the adequacy of artificial intelligence-driven course optimization in expanding maintainability in transportation systems.

Objectives

- **Optimization Efficiency:** Assess the proficiency of AI calculations in bringing down fuel utilization and outflows by optimizing transportation courses.
- **Environmental Impact Assessment:** Examine the coordinate natural benefits of AI-based course optimization, with a center on quantitative reductions in carbon impression and poison levels.
- **Economic viability:** Examine the cost-effectiveness of deploying AI-driven course optimization arrangements, taking under consideration operational costs, time productivity, and asset assignment.
- **Scalability and Applicability:** Evaluate the adaptability and versatility of AI advances in different transportation settings, taking into consideration distinctive modes of transportation and geographic scales.

Literature Review

Research 1:

AI-enhanced optimization approach for analyzing and predicting modal mix in road transportation

The paper approaches incorporate fluffy logic procedures, artificial neural networks **(ANN)** and least square support vector machines modeling among others. The transport sector is a fundamental means of creating cut-cross scenarios as well as for determining de-carbonization and carbon neutrinos approaches. Researchers developed multi-modal scenarios to illustrate different modalities. Specifically, their studies involve developing optimization software with pollutant cut alongside duration and budget. As a result, there were minimal levels of pollution and lower aerosol counts, with some studies claiming that PM2.5 and COVID-19 are related. The researchers talked about people using Multilinear Regression **(MLR)** and Multiple Polynomial Regression **(MPR)** to predict future emissions based on usual business **(BAU)**. These models help with transportation, the environment, and more. The **GRA** method is often applied in China to examine the connection between transportation, energy use, and CO2 emission data collected from different regions. **GRA** In a range of combined scenarios, like the fresh **Partial Least Square Model** that merges **Markov** and **Grey** concepts, grey theory often pops up in data analysis. Distinctive combinations for CO2 outflow estimation are displayed in this paper, which combines principal component analysis **(PCA)**, a long-short memory neural organize **(LSTM)** and **GRA** (Rauf & Umer, 2023). In any case, modern progressions in statistical methods like manufactured neural systems give great comes about since they can address nonlinear input-output connections. This work is pointed at the transportation division which is dependable for worldwide warming through CO2 outflows.

Research 2:

Machine Learning in the Context of Sustainable Transportation System

An outline of data science and machine learning thoughts related to transportation analytics and **STS** are found in (Antoniou, et al., 2018). The researchers utilize a random **forest** model within the context of machine learning applications in urban transport investigation to see into designs of conduct among residents whereas choosing between a cab and a bike-sharing framework. Their discoveries show that there's a regular component to the request for bike-sharing programs and a downward tendency within the utilization of taxis. They distinguished the factors that influence citizen’s choices around owning a car using a combination of neural systems and logit regression. These factors included the accessibility of a compelling open travel framework, age, sexual orientation, income and industry of work, taxi services, etc. The paper propose **a demand-based enhancement model** and an arrangement heuristic for effective parking cost. The model looks for to adjust the different shapes of urban travel, such as private vehicles and open buses. Neural systems, decision trees, and support vector machines were a few of these methods. These machine learning models, were able to outperform a regression show that was already made for estimating activity noise in a city within the United Arab Emirates. It is obvious that heuristics are basically used to realize efficient execution within the plan of autonomous vehicle routing plans and pricing, that **neural systems** and **decision trees** have been utilized over and over for forecast purposes, which different machine learning methods have been utilized to analyze citizen patterns and transportation models.

Research 3:

An Overview of Artificial Intelligence Applications in Transportation

Research previously concentrated on short-term stream forecast through the utilization of a fundamental feedforward neural organize. (Ledoux, 2021) Combined the common urban activity control framework with a neural arrange framework that had one covered up layer. The objective of applying AI to transportation is to address issues with rising travel request, CO2 outflows, open security, and natural disintegration. Roadside sensors give historical information that's utilized to develop intelligent predictive frameworks. After that AI calculations utilize this information as an input to create both brief and long term estimates in genuine time. Utilizing exclusively recreated information, the author appeared how highly probable it is to anticipate traffic flow for up to one minute. A **time-lag recurrent network (TLRN)** was integrated into an object-oriented **neural network** model. The calculation had a 90–94 accuracy rate in anticipating speed five minutes ahead of time. Moreover, the organize anticipated travel times up to 15 minutes with the same precision as speed expectations when speed and stream were utilized as inputs. The authors made a profound neural network that can estimate activity stream for up to 60 minutes within the future. The information on activity stream was assembled from California's motorways. The creators trained the **SAE** model, an unsupervised stack of auto-encoders, employing a greedy layer-wise algorithm. Since each output is transmitted back into organize as an input, it extracts significant traffic flow data. A **supervised logistic regression layer** is used for the final prediction.

Research 4:

Modelling route selection in urban transport systems

Using Jordan's neural network, the authors made an essential **recurrent neural network** for short-term determining. It has an extra setting layer, which sets it apart from traditional feedforward systems. This setting layer capacities as a memory box by putting away the earlier information. After that, the input at a time (t) and the put away information at (t-1) are feed-forward to the covered up layer. Since of this, arrange is frequently referred to as "Jordan's Successive Organize," which helps with subsequence forecast. Traffic volume from Ireland's street activity control was utilized as the information input. The activity stream in the future is the result. In arrange to reduce error, this organize is prepared as a feed-forward neural network employing a **backpropagation** method. In any case, the researchers illustrated that arrange performs more precisely when the covered up layer's neuron number pairs that of the input layer's neurons. Also, a 0.5 learning rate and less cycles result in a **92%–98%** accuracy extend for stream expectation (Wysocki & Czuk, 2018). As this show is respected as a to begin with arrange framework and yields uncertain forecasts when computing higher arrange flow, authors prescribed that, in arrange to streamline calculation computation, the organize be linearized frequently at each working point online. Furthermore, authors addresses about ATOS Logical Community making a **Pattern-Based Strategy** (PBS). The primary type of design recognition is supervised learning, which uses labelled data to supply precise comes about. Second, semi-supervised learning with little-supervised information combined with an endless number of unlabeled information for design acknowledgment examination; and unsupervised learning, where unlabeled information are utilized to find a design and discover the correct yield. Berlin given the speed and stream rate information, and comes about appeared **93% and 86%** estimate exactness, individually, for the two parameters.

Research 5:

Artificial Intelligence- Planning System for Logistics Vehicles

The paper study offer an optimal route recognition system for logistic vehicles based on AI, addresses the current other studies on route planning only focus on time and distance but route planning requires more than time and distance for consideration to identify an ideal route. The proposed paper method decides the most excellent routes for multi-stop travel utilizing data such as historical traffic congestion, climatic information, big information analysis, and an **MLP model**. The researchers utilized Dijkstra's calculation to recognize stray automobiles which is based on GPS and vehicle speed. Authors talks about traffic congestion forecast utilizing an **Artificial Neural Network (ANN)**. The framework is planned to predict traffic congestion by organizing delivery orders of cargo based on recipient needs and requests. The calculation uses Google Maps to calculate routes between stops A and B, and after that uses an **MLP** show to anticipate traffic blockage. The model uses big data examination to check road highlights such as speed limit, time of day, average values, and climate conditions. The input layer information is separated into four input values, and the hidden layer learns a linear pattern between input and output. The framework computes neurons in layer l-1 by outputting zi towards neurons within the l layer. The output layer is Yi, which stands for the prediction of traffic blockage situation. The framework calculates a road's blockage rate, which represents activity speed during blockage. The dispatch center analyzes each coordination's vehicle's tasks and locations every day, utilizing Google Maps to calculate different possible routes between points. The **MLP** show offers an expectation of activity speed and decides the ideal course for transportation travel. The study utilized 1500 street and 700 climate information for a **MLP** model, which accomplished **95 accuracy**, improved transportation efficiency, decreased idle driving, and progressed coordination's vehicle delivery effectiveness.

Research 6:

A Computing Platooning Algorithm for Eco-Friendly Transport Networks in Smart Cities

In this paper the author’s research on the platoon's ideal speed is induced through the ideal speed model from the density of vehicles at intersections. Reinforcement learning decreases computing complexity by teaching cars to connect at the most excellent speed. The **fluid flow model** is used for dynamic simulations in this paper. Researcher’s assumed traffic density as constant. The lane is two-way and two lane and the speed is also set to random in reasonable intervals of different vehicles. The vehicle will select the direction at the intersection randomly, and the same target vehicle will be set in arrangement. The collision location shows improves both generally and driving security by utilizing sensors to distinguish secure entrance destinations. Platooning vehicles can increase the road's capacity and effectiveness. When driving, there are four states: forward, left, right, and return. When the platoon starts moving, other cars will connect it. The area is separated into networks indefinitely to select the optimal inclusion way based on the reinforcement learning approach. The **OBB collision detection** method is used to identify security and the reinforcement **Q-learning** strategy to arrange the course of vehicle inclusion into the fleet. Finally, method's efficacy is validated utilizing recreation programs composed in **Python and MATLAB**. This paper uses a **fluid flow** show to recreate vehicle flow, particularly the platooning show, a continuous first-order response system that smooths thickness discontinuities and can predict negative stream heading and speed.

Research 7:

Using linear programming, optimise the route distance for order delivery

Making use of the **Mixed Integer Linear Programming (MILP) model** and Sustainable Transportation Route Optimization, this study deals with how to provide maximum delivery services for fast-food chains. In 1930s linear programming was introduced to optimize economic systems. But, because of its calculation complexity and the fact that it is not dedicated to single-variable optimization only, linear programming was rarely used. In this study, the practical problem of optimizing a restaurant chain's delivery and transportation activities within the city is presented as an example of applying extended linear programming techniques to solve it. The **MILP model** attempts to reduce transportation costs by adding manufacturing capacity in many branches. The implementation process consists of creating client requests, mapping branch positions and then simulating using **MATLAB**. The **MILP model** incorporates to ensure effective assignment of delivery. It takes important variables including product price, manufacturing capacity, transportation cost and storage space into consideration in establishing the model. To show its practical consequences, the paper cites actual statistics from a Manila fast-food franchise. The simulated mapping reveals the optimized supply routes. It shows that the model can effectively reconcile differing constraints and variables to cut costs. The work extends what is known about this field by employing a **MILP** model to optimize fast-food delivery systems. With the focus on real-world data, practical application and showing optimum routes represented a first in terms of using mathematical models for sustainable transportation route optimization within fast-food delivery services.

Analysis and Findings

Research 1: Utilizing artificial neural networks, support vector machines, and fuzzy logic, the research addresses complex road transport issues. Models, including Multiple Polynomial Regression and Multilinear Regression, provide a comprehensive strategy for projecting emission levels and streamlining the transport network, demonstrating AI's potential for robust solutions.

Research 2: delves into advanced machine learning methods: random forest models, neural networks, and decision trees for sustainable transportation. It highlights AI's superiority in assessing activity noise and predicting transit patterns over traditional regression models, offering insights into influencing people's movement choices.

Research 3: AI applications in this study, emphasize machine learning algorithms and historical data for building intelligent prediction frameworks. The study underscores AI's potential in real-time traffic management, providing a clear solution to urgent transportation problems.

Research 4: The study introduces a short-term forecasting model for urban transportation networks using Jordan's neural network. Various learning methods, including supervised and semi-supervised machine learning, optimize traffic flow through pattern recognition in urban settings.

Research 5: Focusing on route optimization, the research presents an ideal system for logistics vehicles considering factors beyond time and distance. Integrating Dijkstra’s algorithm, artificial neural networks, and big data analysis, the study offers an approach to enhance transportation effectiveness.

Research 6: Investigating AI for vehicle unit optimization in smart cities, the study utilizes 5G technology, reinforcement learning, and fluid flow models to boost street capacity and efficiency. These advancements provide a solid foundation for future progress in the transportation sector.

Research 7: The research pioneers the use of mixed integer linear programming to optimize fast food delivery systems. Employing real world data and actual implementation, the study cuts transportation costs and increases production potential, marking a significant step in the application of mathematical models for green route optimization.

Key Findings using Bar graph

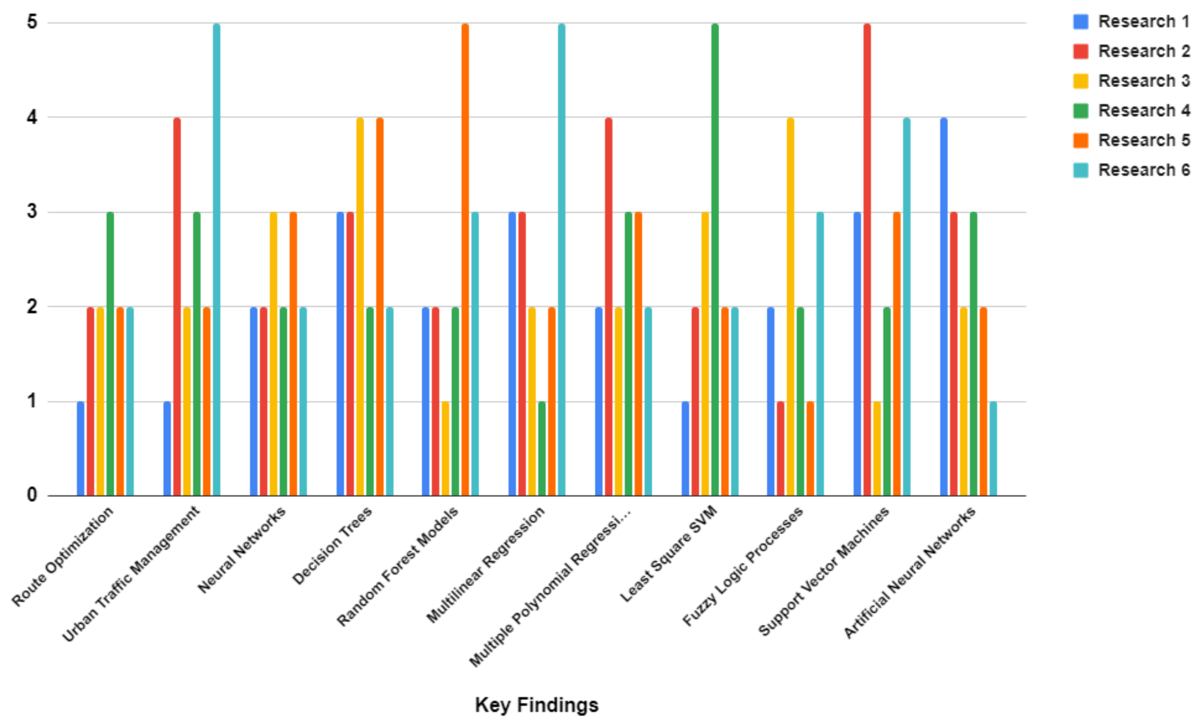

Figure 1: Findings

Conclusion

The review briefs various methods and strategies used in the research gives people some facts about how best to plan out transportation routes, without overlooking environmental concerns. The study of the body of literature associated with releasing these many papers shows how AI-based path optimizing can enhance sustainability through transportation systems. These findings are essential to understand research results, as well as the comparison and choice of different strategies, they provide a basis for mathematizing intelligent agents so that these can be used within the context of sustainable transportation. This comparative study explains the advantages of AI approaches over traditional and how they are capable of completely changing sustainable transportation activities.

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