THE FUTURE ROLE OF ARTIFICIAL INTELLIGENCE IN ROAD WEATHER INFORMATION SYSTEMS

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Summary

Artificial Intelligence (AI) has embarked on a progressive trajectory, steadily progressing towards the attainment of Artificial General Intelligence. The increasing adoption of Large Models and digital twins positions AI to significantly improve the delivery of public services within the domain of Winter Road Maintenance. This research discusses the inevitable future role of contemporary AI technologies in winter road maintenance, starting with an appraisal of the challenges faced by current AI applications in Road Weather Information Systems (RWIS). It anticipates a future characterized by smarter cities and transportation, highlighting the potential integration of these technologies with broader rapidly evolving advancements.

Introduction

Extreme winter weather, seriously affects transportation and can have a significant impact on the safety of vehicle travel [1]. Since the 1970’s, experts from Europe and the USA carried out research into the prediction and forecasting of ice and snow on road surfaces, achieving large advances in road surface condition prediction [2]. Technology has been a key driver with significant advances enabled by improvements in computer processing power, GIS and GPS technology, more sophisticated sensors, the Internet of Things and data from connected vehicles [3]. A common element of all these new technologies is increasing amounts of (big) data. Hence, Artificial Intelligence (AI) becomes a key tool that could yield significant further benefits with more direct applications in Winter Road Maintenance.

The development of AI

While AI diverges from human intelligence, it possesses the capacity to emulate human-like thinking and has the potential to surpass the cognitive capabilities of humans which has implications for daily decision making in winter road maintenance. It is clear that this prevailing trajectory is anticipated to markedly stimulate innovation in the domains of intelligent transportation infrastructure and advanced maintenance methodologies [3].

This leads to the question of how AI can be *comfortably* embedded into a Road Weather Information Systems (RWIS) to provide more nuanced decision support functionalities, or even autonomous generation, of precise pavement maintenance schedules over the winter season. The benefits of AI have the potential to extend across the entire maintenance decision support system and has the additional prospect of concurrently elevating thoroughfare security, reduce budgetary outflows from maintenance activities, and mitigate environmental risks associated with the road network.

Current Applications of AI

The driving force behind the current use of AI in winter road maintenance is the connected vehicle. The veracity, variety and volume of data available of this data source is already proving transformative for winter road maintenance in itself. For example, NIRA Dynamics have built large highway weather databases by collecting large amounts of data from on-board sensors(Fig.1), such as: wiper speed, air temperature, friction, etc which subsequently drives forecasts [4]. AI is the only realistic way of handling such big data in real time, providing new insights in road friction and other parameters. Combined with weather data from in-situ sensors, it can assist decision making be higher engineers and potentially the drivers themselves in making travel decisions. It provides the best example of how AI is starting to be used effectively in the sector.

An AI Generation Road Weather Information System

However, friction forecasts are clearly just the start. The next step is to understand how such approaches can become embedded in a bigger decision support system underpinned by automated decision making and digital twins: i.e. a smart transportation system, toward a broader link, faster response, more accurate prediction and more flexible decision-making.

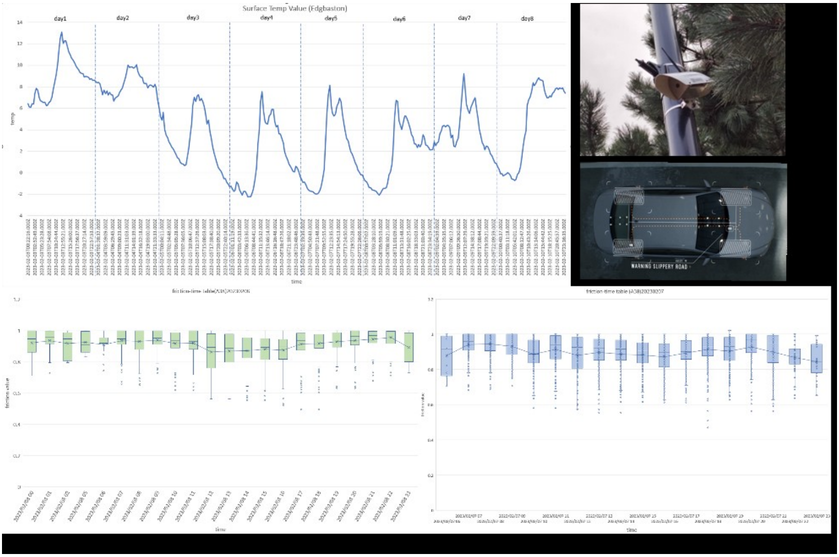

Fig. 1. Real-time data diagram, the first upper side diagram is road surface temperature value (03/02/2023~10/02/2023, eight-days) via infrared temperature sensor and the two blow is road friction data (day6 and day7) via vehicle sensor.

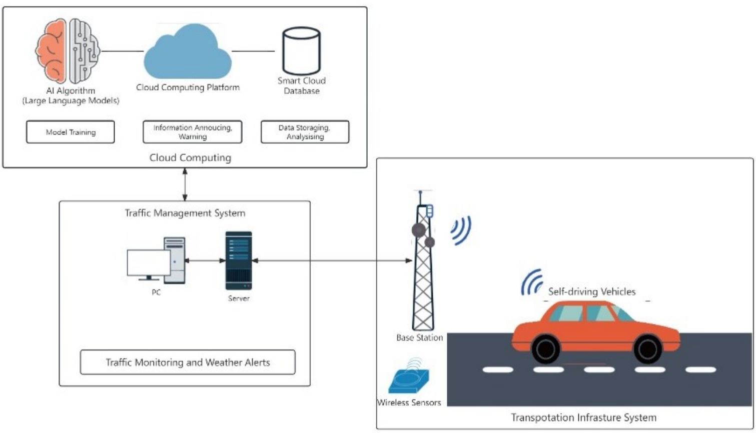

Fig. 2. Digital Twin Framework Diagram of Intelligent Transportation System

The integration of nuanced decision support functionalities represents a significant advancement in the realm of road maintenance planning, particularly during the winter season. For example, with the advent of large language models (LLMs) such as GPT-4, Claude v3 and Gemini, there exists an unprecedented opportunity to leverage natural language processing capabilities for enhancing decision-making processes in infrastructure management. These LLMs possess the capacity to analyse vast datasets encompassing historical observation data, maintenance records, weather patterns, transportation statistics, among other relevant parameters. By harnessing this wealth of data, LLMs may facilitate the a priori formulation of maintenance schedules by predicting optimal intervention times and strategies based on probabilistic machine learning and scenario analyses. Furthermore, through iterative learning and adaptation, it is highly possible for LLMs to autonomously generate precise maintenance schedules tailored to specific road segments, taking into account local variations and evolving conditions.

In addition to leveraging large language models (LLMs) for decision support, the integration of digital twin technology further revolutionizes road maintenance practices. Digital twins offer a virtual representation of physical assets, enabling real-time monitoring, analysis, and simulation of road conditions. By coupling data from wireless sensors network and connected vehicles data along with advanced simulation algorithms, digital twins can provide comprehensive insights into pavement condition trends(Fig.2). This will enable the creation of *dynamic* maintenance schedules that adapt to changing conditions, optimizing resource allocation and minimizing the risk and affects to travellers.

Conclusion

The application of AI in highway maintenance is a future trend that will bring immeasurable benefits to highway maintenance, unlocking automated and intelligent maintenance. In the future, data-driven AI LLMs and digital twins will gradually become an important decision-making support for the highway weather system, and we look forward to seeing a safer travel and a more convenient and smooth transportation road network.

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