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STATE OF THE ART IN APPLICATION OF AI METHODS FOR TRANSPORT AND LOGISTICS

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Abstract:

Research, development and application of intelligent methods and techniques represents one of the most dynamic factors influencing the quality and safety of processes in transport and logistics. Intelligent information, communication systems represent such complex systems that, using intelligent elements and systems, intelligent control methods and modern information, communication and control technologies using the Internet of Things (IoT), Industrial Internet of Things IIoT, virtual and mixed reality, can ensure and significantly improve the current functionality of transport and logistic systems and processes. This paper addresses the current issue of modeling and intelligent control of complex transportation systems and processes with the support of advanced integrated HW and SW technologies, artificial intelligence methods, adaptive and self-learning techniques capable effectively improve and optimise the conventional transport and logistic processes.

Keywords:

Artifical intelligence, fuzzy logic, transport system, logistics systems, neural networks, IoT - Internet of Things, mathematical model.

Introduction

Intelligent Transport Systems (ITS) are a group of technologies and methods that can nowadays significantly influence and optimise the control of complex transport systems and processes, public transport, as well as individual decisions regarding many aspects of goods transport and travel. Current ITS technologies include state-of-the-art wireless, electronic and automated technologies to improve safety, efficiency and passenger comfort. An Intelligent Transportation System (ITS) [5] is a complex integrated system composed of SW and HW subsystems aimed at transport to improve its safety, mobility and reliability. ITS encompasses a wide range of applications that process and share information in order to minimize, e.g., congestion, improve traffic management, minimize environmental impact, and enhance the benefits and advantages of transportation for both commercial users and the public [4]. ITS today uses advanced artificial intelligence methods in the field of information communication and control technologies such as Internet of Things (IoT) for interaction vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I), infrastructure-to-infrastructure (I2I) technologies implemented by wireless and wired communication, information and electronic technologies (Fig.1).

Intelligent Transportation System (ITS) is complex system which applies advanced technologies of electronics, informatics, communications, computers, artificial intelligence, control, sensing and detecting in all kinds of transportation system in order to improve safety, efficiency and service, traffic situation through transmitting real-time information.

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IoT technology is mainly used to process vehicle information and transmit it to other vehicles, other modes of transport users (Fig.2), (e.g. pedestrians or cyclists), local and remote infrastructure. ITS methodology is continuously evolving and has a significant impact on transportation in a wide range of applications such as electronic toll collection, ramps, traffic light cameras, traffic signal coordination, transit signal priority, and traveler information systems. The quality and implementation of ITS is expected to increase especially in applications, which will use artificial intelligence methods for monitoring (image processing - machine learning, convolutional neural networks, deep learning), toll management, ticket management, transit pricing, telematics and traffic monitoring (Fig.2).

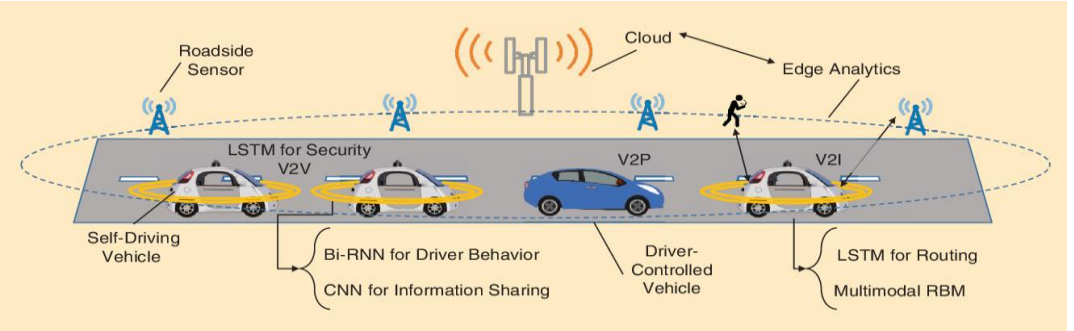


Fig.1. Intelligent Transport Systems with advanced technologies applications.

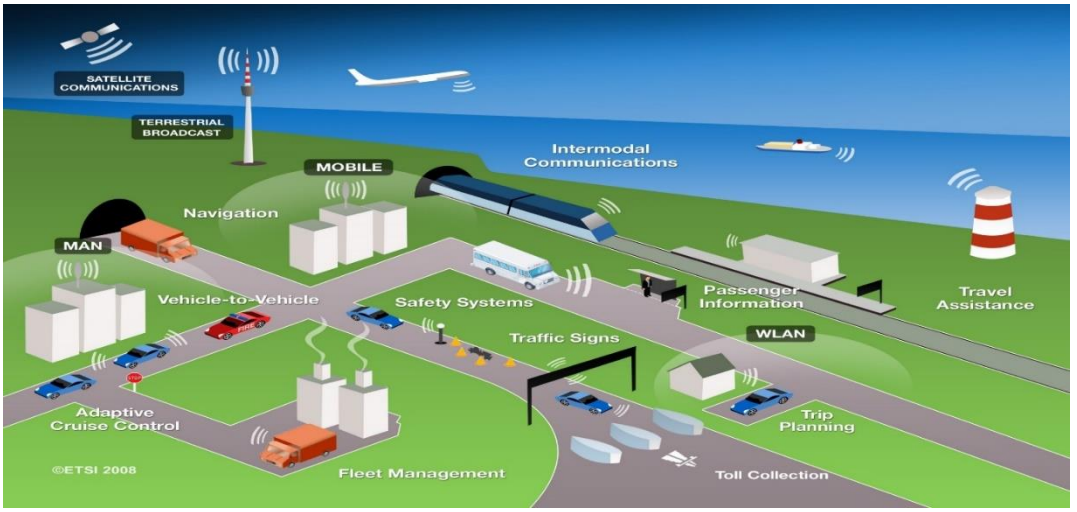


Fig.2. Application of Advanced Intelligent Information and Communication Technologies to the transport.

The key beneficiaries of ITS use are passengers, businesses and transport agencies. The effective deployment of ITS is affected by the slow growth of global infrastructure and the high cost of implementation. Other issues that make ITS attractive to users are ensuring the security of highly advanced technologies and resistance to hacking and data protection.

Intelligent Transportation System (ITS) is aimed at achieving transport efficiency by minimising traffic problems and optimising the transport of people and goods. It provides users with the necessary comprehensive traffic information, linked to other local information in real time. The deployment of ITS can reduce commuters' travel time and increase their safety and comfort. Further development of ITS cannot be done nowadays without the deployment of IoT, Big Data, Clouds and Artificial Intelligence methods. The development and use of the new complex methodology for transport an logistics systems is closely related to the development and integration of the so-called exponential technologies (Fig.3).

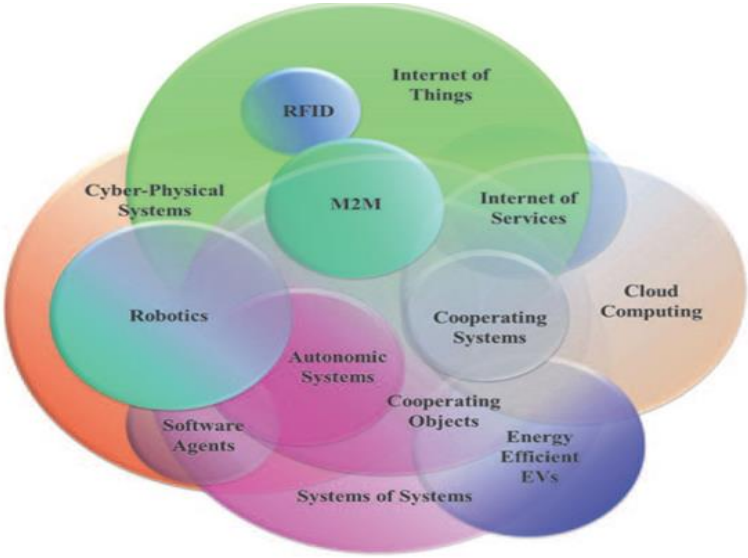


Fig.3. Convergence of Adavance Technologies for Transport and Logistics processes.

1 Artificial Intelligence in Transport and Logistics

Artificial Intelligence (AI) is a modern scientific field that deals with the research, development and application of methods and algorithms that enable intelligent behavior not only of humans but also of machines. It is a multidisciplinary science using the results of many other disciplines, especially computer science, mathematics, physics, automation, statistics, logic and neuroscience [2]. Research and applications of artificial intelligence (AI) methods have seen tremendous growth in the last decades in all areas of human activity. The use of AI methods in transportation [5] is largely based on pioneering research results from the 1960s and 1970s, in the areas of fuzzy logic, artificial neural networks, and genetic algorithms. In particular, biological systems, the behaviour of living organisms, the communication between them and, above all, the ability to learn, to react quickly and make optimal decisions in normal and critical situations have been the inspiration for the research, development and application of artificial intelligence methodologies [3].

One of the reasons for the use of artificial intelligence methods is their versatility and high ability to model, approximate and predict complex processes and processes in both technical and non-technical domains. The use of AI in transportation and logistics is significant. The use of conventional mathematical methods for modelling processes in transport is challenging and complex due to the non-linear descriptions and relationships of dynamic models.

Using mathematical models through AI methods and artificial neural networks, we can achieve much higher quality and accuracy of these "intelligent" models. The application of AI methods, which have the properties and capabilities of self-learning, adaptation and self-organization, allows us to efficiently design and apply AI models for the optimization of control and decision-making tasks in transportation and logistics (Fig.4). Artificial neural networks are nowadays mainly implemented through software modules or special hardware modules and special fast parallel computing systems and processors. These modules are the dominant representatives of the efficient use of AI algorithms and technical solutions related to direct deployment in practice.

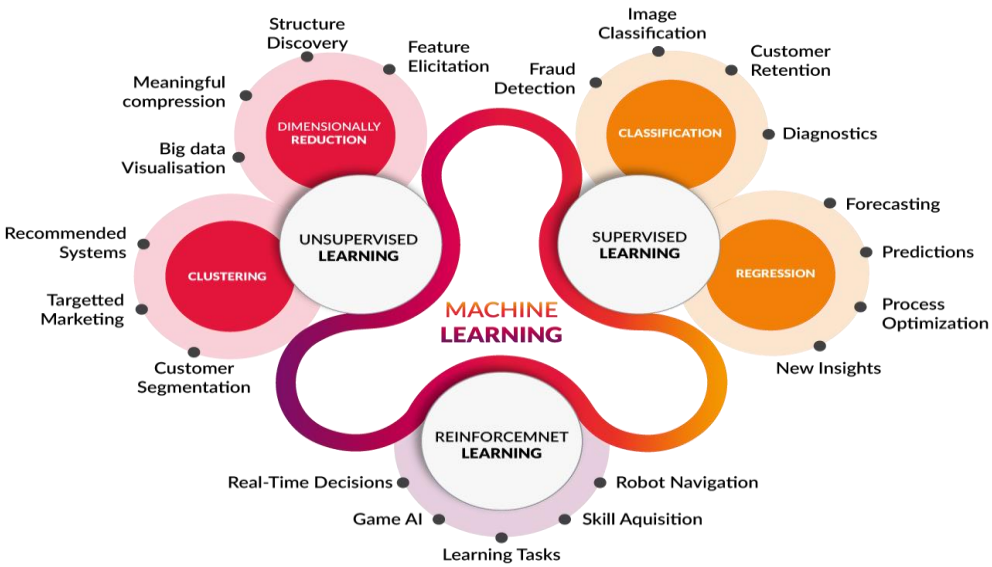


Fig.4. Development and applications of AI methods
based on machine learning methods and algorithms.

Artificial neural networks are the basis for modeling of complex processes, representing a mathematical computational model constructed by abstracting the properties of biological neural systems. There are several types and possibilities of representing the behaviour of processes using artificial neural network models (multilayer perceptron, RBF networks, ART networks, Hopfield network, Kohonen network, etc.). The basic part of an artificial neural network is a model of a neuron with inputs and outputs. One of the most important properties of neural networks is the ability to abstract the rules of behavior between input and output values presented in a suitable form and then apply the obtained rules to any input values. The abstraction process represents the learning process. During the learning process, the values of the connection weights in the network are updated. The learning (training) process represents the modification of synaptic weights and thresholds according to the selected learning algorithm. The essence of learning is to select features and experiences from the input signals and adjust the network parameters so that the deviation (in a given metric) between the desired (reference) and actual output in response to the training patterns is minimal. Once learning is complete, the values of the weights no longer change and the network produces outputs according to the above rule applied to the input values. The neural network itself is composed of multiple layers with different numbers of neurons that are interconnected. There may still be hidden layers between the input and output layers, which is why these structures are called multilayer neural networks (Fig.5).

Another important feature of artificial neural networks is the principle of self-organization, which is used precisely when we do not know the target solution to the problem. Even in such a case, the artificial neural network is able to recognize the same or close features based on the input patterns to cluster them and sort them through clusters (clusters).

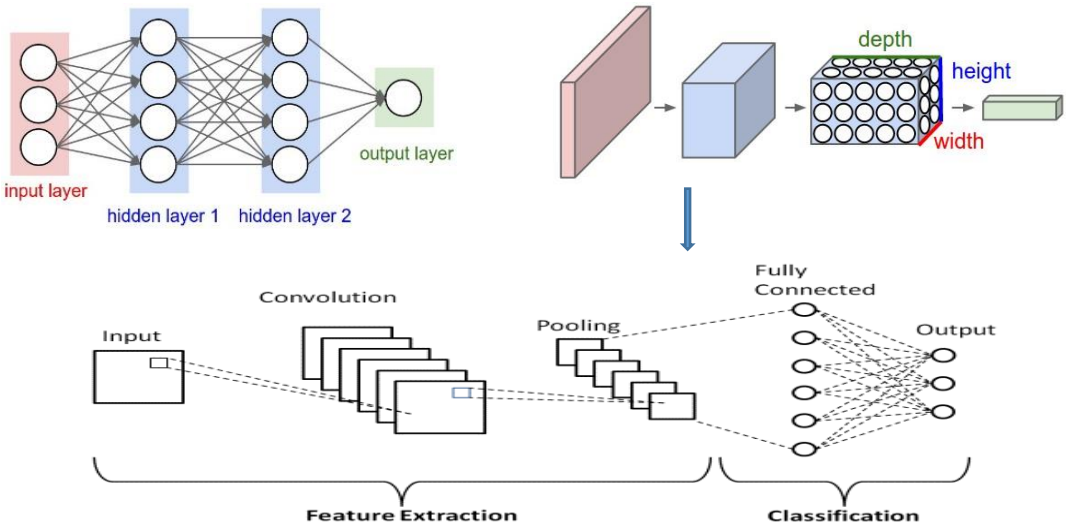


Fig.5. Conventional neural network (above left) and deep neural network structure.

Conventional machine-learning techniques were limited in their ability to process natural data in their raw form. discover the representation seeded for diagnosis, recognition and classification. Deep-learning methods are representation-learning methods with multiple levels of representation (Fig.5). Deep learning is making today many advances in solving complex problems modelling, control, visualization and prediction for large-scale tranports and logistics processes. The use of AI methods for a broad class of applications is shown in (Fig.6).

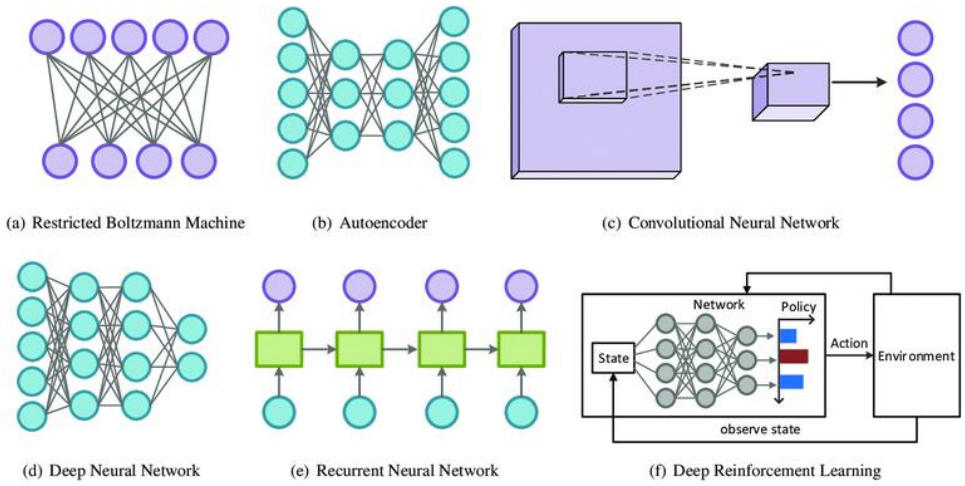


Fig.6. AI methods for a broad class of applications for transport and logistics processes.

The greatest today development of the application of artificial neural networks in transport and logistic is based on convolutional networks. They are particularly suitable and usable in the processing of image, audio and text information and directly applicable in transport. For image information processing, deep learning (DL) methods and algorithms used convolutional neural networks are the most powerful. Convolutional networks (Fig.7) are software networks that consist of layers of small computational units, called neurons, that hierarchically send each other the information to be processed. The system is conceptually similar to the biological system of neurons and synapses of the brain, hence its name. However, convolutional neurons are robust and are primarily used for tasks that involve processing image information. Other types of networks are, for example, recurrent (feedback)) neural networks, in which information does not pass from simpler to more advanced layers, and instead the information cycles dynamically between them. When convolutional neural networks are trained as part of a recognition process, they produce a representation whose complexity increases as part of a hierarchical process. Convolutional neural networks are a special kind of multilayer neural networks that are used for recognizing visual patterns directly from images using minimal preprocessing.

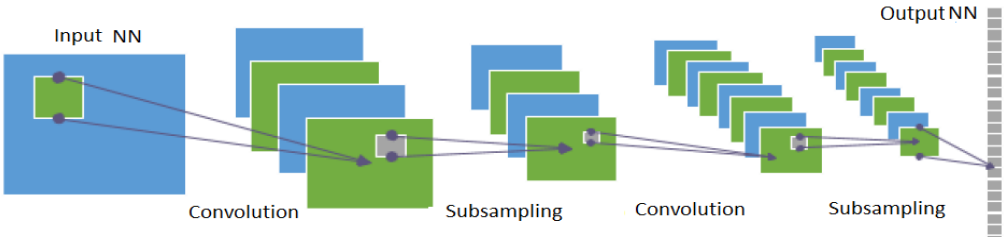


Fig.7. General convolution neural network architecture.

The first layer (Fig.7) is the so-called convolutional layer. The image is first fed to the input of the convolutional neural network, to which a filter is applied in order to extract the features. This filter is composed of neurons that share the same set of weight vectors between them, which reduces the number of network parameters and therefore the size of its capacity. Using these local receptive fields, the network can extract features such as edges or corners from images. Another advantage of convolutional neural networks is the sharing of weights, which speeds up the learning of the network by reducing the total number of network computations. This filter is referred to as a receptive field. This receptive field is successively applied to the entire input image, thus computing a single operation in different parts of the image. In most cases, several receptive fields are applied to a single input image, with the individual receptive fields differing in the values of the shared vector weights. The output of one receptive field that has been applied to the entire input image is called a flag map, and the number of flag maps corresponds to the number of receptive fields applied to the image.

2 Application of Artificial Intelligence in Transport and Logistics

The greatest development of the application of artificial neural networks is related to the research, development of the convolutional networks. They are particularly suitable and usable in the processing of image, audio and text information and directly applicable in transport. For image information processing, deep learning (DL) methods and algorithms based on convolutional neural networks are the most powerful. Convolutional networks are software networks that consist of layers of small computational units, called neurons, that hierarchically send each other the information to be processed. The system is conceptually similar to the biological system of neurons and synapses of the brain, hence its name.

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Deep learning based AI systems are part of modern methods of so-called machine learning and AI routing and exploitation [1]. Deep neural network (DNN) architectures got their name because of the novel 3D artificial neural network architecture consisting of several levels. Meanwhile, each layer has its own information processing elements. The deep network methodology is characterized by the fact that it does not follow the set of the task rules, but the regularities and rules determine themselves based on the input data received, thus it does not determine exactly the procedure that the neural network must follow to achieve the correct result. Instead, the network is trained on a number of examples against which it evaluates its success rate. In this way, the neural network changes its internal parameters and tries to achieve the best possible results. It retains and further exploits the elements and rules that work for learning, and gradually discards those elements that lead to deteriorating results. The network is thus constantly evolving, self-organising and adapting. In case a symptom is identified using a receptive field, the location in which the symptom was identified becomes less relevant. Hence, there is an additional layer after the convolutional layer, which is referred to as the subsampling layer. The goal of this layer is to reduce the input size [3]. In practice, a function is applied to all the symptom maps that are the output of the convolutional layer to reduce these maps. There are several types of functions that can be applied in the subsampling layer such as averaging, maximum selection or linear combination of neurons in a given symptom map. (Fig.7) shows the application of convolutional networks for situation representation, traffic prediction and object identification in the traffic process. The tracked objects are continuously identified and transmitted to the computing center (Cloud) for optimization and prediction. The convolutional network and its software implementation algorithm allows to embed, for example, images of intersections, based on which the system determines what the traffic roughly looks like and then applies this knowledge to recognize people and cars even in new images that it has never seen before. It is not the case that someone has programmed the likeness of a person or vehicle into the neural network. In short, the system is given the information that there is a car in this particular image, not in the next, and yes in the third, and so on. The neural network tries to recognise certain specific elements and then verifies its methods itself. One of the current applications of artificial intelligence methods is autonomous vehicles.

Modern autonomous vehicles would not work today without the application of intelligent methods and the extensive use of machine learning methods. Today, only a small portion of conventional solutions are still used in autonomous vehicles to control the direction/movement of the vehicle. Autonomous vehicles use machine vision algorithms such as convolutional neural networks to recognize the road and obstacles and train cars to identify the road and react to hazards, (cars in other lanes and pedestrians). With training on the surroundings and these hazards, the cars can then move safely.

3 Applications of Artificial Intelligence Methods in Transport

Currently, there are several areas where neural networks have moved to a "superhuman" level of cognition. One important application area where artificial intelligence and its methods and principles can be effectively used in transportation and logistics systems. Artificial intelligence methods and algorithms in transportation can be used for a wide range of applications (Fig.8).

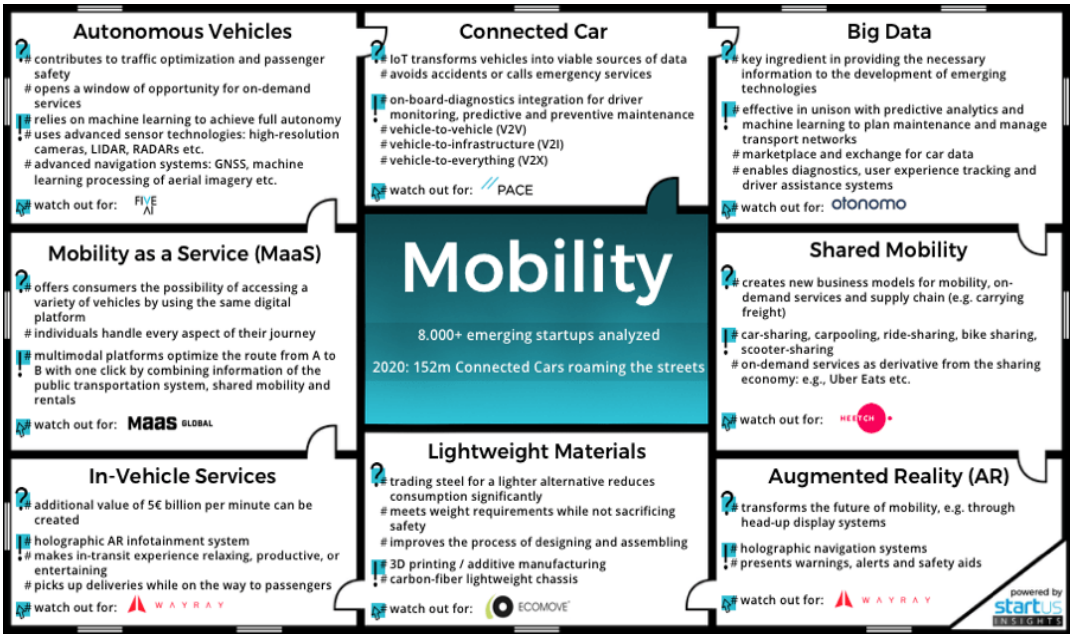


Fig.8. Applications of AI methods to the transport systems.

The advantages of artificial intelligence methods for process control in transport compared to conventional methods can be summarised as follows:

a. Conventional traffic control methods are largely based on mathematical models whose parameters and structures are difficult to identify based on known analytical and experimental methods.
b. Problems with mathematical traffic modelling arise especially when it is necessary to model system behaviour under conditions of uncertainty and contingency, which are often influenced by unexpected traffic phenomena and situations, human errors or accidents. In such cases, AI can help significantly.
c. AI, through its structures, uses sensed and observed data to correctly and optimally manage traffic processes and situations and even predict decisions based on learned and practiced situations.
d. Artificial neural networks and fuzzy-neuro systems are a versatile approximator for modeling complex traffic situations based on learning techniques allowing, together with efficient numerical algorithms based on genetic algorithms, to solve problems of unpredictability types. They are developed and implemented in different ways and their applications are conditioned by the use of powerful computing systems.

Recently, applications of AI are well known in the world, and in particular deep neural networks (DNN), which have demonstrated the ability to predict, e.g., traffic flow for traffic processes with large I/O datasets. While current existing DNN-based models provide much better results than conventional models, there is still the open question of fully exploiting the spatiotemporal characteristics of traffic flow to improve their performance. Significant achievements for HNS-based traffic flow prediction model are documented worldwide significantly affecting the improvement of prediction accuracy.

The HNS model fully exploits the weekly/daily periodicity and spatio-temporal characteristics of traffic flow. Inspired by recent work in the field of machine learning, a sensing and observation-based model was thus developed that automatically learns to determine the importance of past traffic flow.

A convolutional neural network was also used to extract spatial features and a recurrent neural network to catch up with the temporal features of the traffic flow. Through the visualization of traffic situations, it has been shown in practice how the HNS model accepts the traffic flow data and challenges conventional thinking about neural networks in the transportation domain, where neural networks are purely a "black box" model.

The scale of the data received in a traffic system and even the interaction of the different components of the system that generates the data have become a barrier to traditional data analytics solutions. Machine learning, on the other hand, is a form of artificial intelligence (AI) and a data-driven solution that can handle new system requirements. Machine learning learns latent patterns in historical data to model system behavior and to respond accordingly in order to automate analytical model building.

The use of AI methods has now gained significant use in the transportation industry and many applications have been shown to yield a higher return on investment compared to conventional approaches. The areas of application of these methods with effective implementation of AI methods are still open and require the training of new experts capable of configuring intelligent SW and HW modules. The main objectives of these solutions are to reduce congestion, improve safety and reduce human errors, mitigate adverse environmental impacts, optimize energy efficiency, and increase productivity and efficiency of surface transportation.

Potential areas of application of AI methods in transport include, but are not limited to:

- Monitoring, visualisation and performance management of the transport system.
- Management of autonomous vehicles and road traffic.
- Optimisation and operation of freight transport.
- Optimisation and management of road traffic.
- Predictive analysis and subsequent synthesis of intelligent public transport.
- Detection of critical situations and events from sensed image, audio and text information.
- Intelligent mobility services for transit planning, operations and reporting based on image and audiovisual data.
- Safety monitoring of vehicle movements.
- Passenger safety monitoring.
- Route safety monitoring and road damage analysis.
- Efficient journey planning and sharing of human-vehicle, vehicle-to-vehicle, vehicle-to-infrastructure communication.
- Traffic sign object recognition and detection.
- Passenger behaviour analysis.

4 Applications of Artificial Intelligence Methods in Logistics

Large logistics companies have long been using modern tools to organize and optimize transportation through intelligent neural networks complex architectures (Fig.9). As the volume of data grows, these companies are increasingly using and implementing AI (machine learning, deep learning and natural language audio and text processing) methods and algorithms. The use of AI brings efficiencies to the management and optimization of supply chains and logistics operations that already represent a significant competitive advantage.

The alignment of logistics with information technology is leading to the creation of 'cyber-physical systems'. Cyber-Physical Systems (CPS), which represent the intelligent interconnection of the real and virtual worlds.



Fig.9. Advanced intelligent architectures and AI methods for logistics.

Logistics is facing a fundamental change of approach with regard to the application of AI methods and algorithms, towards proactive, predictive, automated and individualised logistics operations in operational activities and customer contact. AI methods in logistics operations can be used for the application of image recognition methods (convolutional networks) in tracking the status of shipments and equipment, providing complete autonomous transportation, or predicting and minimizing fluctuations in total shipment quantities before they occur. The purpose of artificial intelligence methods and algorithms (Fig.9) in logistics applications is to enhance and develop human skills and also to eliminate routine work activities. Intelligent route planning systems represent a significant part of the use of AI in the transportation of goods and business transactions between customers.

Supply Chain applications for logistics can be built using machine learning algorithms with better predictive analytics tools. These prediction tools can accurately determine the average waiting time by just entering the location and day, it can also provide better predictions of appointment times and dynamic Estimated Time for Arrivals. Many Logistics & Supply Chain companies are utilizing **Chatbots** to carry out automated registration processes along with solving customer queries and feedback. AI-based chatbots can help in two essential ways:

- improve customer-based operations
- improve Supply Chain operations
- customers can interact with Chatbots for placing any sort of orders. The Chatbot will handle significant order details like pickup and delivery location, dates, and rates. It can even send receipts directly to the client’s email in an automated way.

Self-Driving Cars in transport and Logistics

- The idea of having self-driving car systems in logistics is going around for some time now. This technology is considered to be much more safer and reliable as it outperforms human driving capabilities. With the development of modern intelligent sensor systems and 3D Picture formulation visualization technology, self-driving cars are just 3-4 years ahead of us. Intelligent cars can recognize traffic signals and laws, avoid barriers, interpret road signs and many other things by applying advanced AI algorithms to sense and forecast changes in their surroundings.

Predictive analytics for logistics - with the implementation of Big Data, logistics companies are able to make accurate predictions and signicantly improve performance. AI-based nethods and algorithms can enhance predictive analytics and improve automation to achieve maximum efficiency.

Automated Robots for logistics - artificial intelligence in logistics can be effectively used for smart management of operations carried out in warehouses. Robots in process logistics (Fig.9) can be put in place, where they can identify, sort, move and track inventories, without the need for any human interference.



Fig.10. AI in logistics warehouses applications.

Logistics for 4.0/5.0 generation and advancing digitalization offer development opportunities through AI methods and algorithms in ever-growing and interconnected markets. Companies operating in the logistics industry and using AI, have a high probability of successfully advancing and creating modern logistics with autonomously managed multidimensional systems on a national and transnational scale. It shows that logistics companies with a proactive AI strategy in the transport and logistics sector have profit margins higher than conventional companies by more than 5%. On the other hand, competitors that do not use intelligent optimization methods see their margins decline. However, these key benefits have not led to widespread implementation of AI methods. It is estimated that about 21% of transportation and logistics firms have moved beyond the initial testing phase and have begun to deploy AI-based solutions. The introduction and acceptance of AI methodologies in supply chain and logistics requires large capital investments and organisational changes. Therefore, it can be expected that in the future, AI methods and algorithms will be implemented primarily by the "biggest players" in the logistics industry. And it is the speed of adaptation to new intelligent solutions that will determine a company's competitiveness in the future.

Conclusion

The use of artificial intelligence methods has now gained significant application in the transportation industry. In many applications, it has been shown to deliver higher quality and return on investment compared to conventional approaches. The areas of application of these AI methods with effective implementation of AI algorithms are still open and require the training of new experts capable of configuring and integration of intelligent SW and HW modules. The main objectives of deploying these intelligent solutions are to reduce congestion, improve safety and reduce human errors, mitigate adverse environmental impacts, optimize energy efficiency, and increase transport productivity and efficiency.

Acknowledgement

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