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Yevhen Biezhyn Student, Ph.D.; Assoc. Prof.; Assoc. Prof. Tetiana Sichko
Vasyl' Stus Donetsk National University, Ukraine

INTEGRATION OF ARTIFICIAL INTELLIGENCE INTO VISION SYSTEMS FOR SELF-DRIVING CARS: CHALLENGES OF DATA TRANSMISSION IN URBAN NETWORKS

The age of self-driven travel is impossible without the integration of artificial intelligence (AI) and vision systems as the "eyes" of autonomous vehicles. Yet, city environments, where the density of obstacles, object movement, and human interaction are highest, place new requirements on technological development. Data transmission in such environments becomes a complex problem that combines technical limitations, cyber risks, and ethical dilemmas.

The role of artificial intelligence in the interpretation of visual information

Modern vision systems for self-driving cars are based on deep neural networks that can analyse images from cameras, lidars, and other sensors in real time. For example, image segmentation algorithms are good at distinguishing between pedestrians, traffic lights, and road signs, while object detection in real time helps maintain safety on the roads. However, the accuracy of such systems is directly related to the data transmission rate between the car, infrastructure, and cloud services. [1]

Theoretical aspects of data transmission challenges

- Latency as a risk factor

In an urban environment where split-second decisions are made, delays in data transmission can be fatal. For example, if a vision system detects a pedestrian, but the information is delayed due to communication interference, the car will not be able to stop in time. Studies show that the maximum permissible latency for self-driving cars should not exceed 10 ms for safety-critical subsystems, which requires the development of technologies such as MEC (Multi-access Edge Computing) to process data directly at the point of receipt. [2]

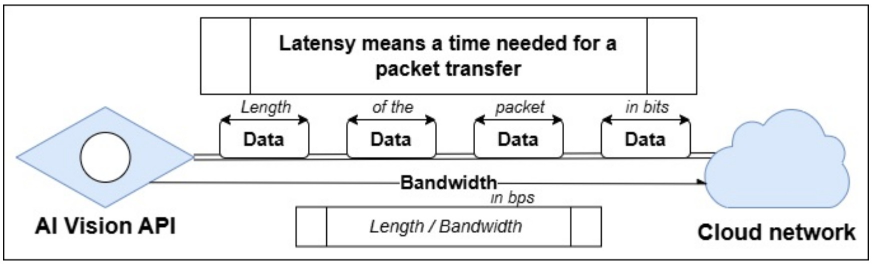

Figure 1: Dependence of data transfer rate on network bandwidth and size of transferred data

- Infrastructural differences

Even in sophisticated cities, the deployment of 5G networks is spotty. Blind spots where autonomous cars lose contact are created by low-coverage zones such as underpasses or high-density residential areas. This emphasises the need for hybrid networks that combine 5G, Wi-Fi 6, and satellite communications to ensure continuity. To overcome this problem, it is also worth integrating local computing nodes (edge computing), which allow data to be processed directly near the point of collection, reducing dependence on the central network. This approach increases the reliability of autonomous systems in complex urban environments. [3]

- Cyber threats and data integrity

Urban networks are targets for attacks because they connect many devices and users. For instance, hacking of camera data can result in the breakdown of artificial intelligence systems, which can result in accidents. To prevent such vulnerabilities, it is advisable to utilise blockchain technology for decentralised data storage, combined with quantum encryption for protection of communication channels. Moreover, implementation of multi-level authentication is also necessary to control access to systems and monitor potentially malicious activity in real time.

- The problem of data scaling in megacities

Urban networks are facing an exponential increase in the amount of data generated by self-driving cars. According to research, a single vehicle with a vision system can transmit up to 40 TB of information daily, which puts a critical strain on existing infrastructure. [4] This volume requires not only high bandwidth, but also intelligent traffic management, for example, by prioritising critical data (e.g., signals of a sudden obstacle).

Specificity of the urban environment: from theory to practice

Cities are characterised by high entropy due to chaotic pedestrian traffic, sudden changes in road conditions (e.g., road works), and heterogeneity of architectural forms. Such factors make it difficult to train AI algorithms, as standard datasets often do not reflect the real variety of scenarios. Studies have shown that car vision systems are less effective at detecting children or small objects (e.g., bicycles) if they are not represented in the training data. [5]

Conclusions

The integration of artificial intelligence into self-driving car vision systems is not only a technical challenge, but also a sociotechnical project that requires a revision of existing network architectures, legal regulations, and ethical principles. Overcoming the challenges of data transmission in urban networks is only possible if there is synergy between AI developers, telecom operators, and city planners. The key areas remain the development of 5G/6G, improvement of AI algorithms to suit urban scenarios, and creation of global security standards.

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