Smart cities: How AI in Traffic Management can reduce pollution and make citizen's life easier

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Abstract

This paper, starting from the notion of smart city, reviews the role of AI in smart cities and it places attention on the changes new technologies can bring to the field of traffic management. The new model proposed faces one of the challenges for the future to have autonomous vehicles interconnected and sharing a huge amount of data. Consequentially the model will change the life of the citizens by reducing pollution, car accidents, and making the whole driving experience more enjoyable. Many are the papers commented to underline the different points of view for the advantages and disadvantages. In conclusion the future that now is only in the imagination with new ideas, new data and new technologies will be our reality.

Introduction

In the last decade, several metropolitan areas around the world have started defining themselves as "smart cities". But what is exactly a smart city?

According to the European Union, a smart city is "a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business". These cities can control the traffic, waste, and maintenance, as well as predict the energy consumption, pollution risks, and the effects on the environment.

Smart cities cause lesser effects on climate change, smarter decisions, and improved quality of life, by exploiting the progress made in the fields of Internet of things (IoT), Machine Learning, Information and Communication Technologies (ICT), and Artificial Intelligence (AI).

Basic Notions

In the following sections the role of AI in smart cities is going to be analyzed.

Role of AI in smart cities

As highlighted before, to improve efficiency in smart cities, AI can play a crucial role, especially in the following fields:

- Environment: Smart cities can use artificial intelligence to monitor the local environment, global warming, as well as pollution levels. Moreover, AI can be used to detect CO_2 levels which can then lead to decisions around transportation.
- Waste management: Smart cities make use of a technology that allows cities to track recycling and identify what can be recycled in the area. This can be taken a step further by using AI-powered robots to sort rubbish, as well as clean areas such as lakes and rivers.
- Security: security cameras are already present in every city, but they don't prevent or stop crime because their footage can only be detected afterward. Security cameras that use artificial intelligence can analyze footage in real time and detect criminal behavior which can then be instantly reported and dealt with. These cameras can also detect people from their clothes, allowing the technology to find suspects quicker than ever.
- Traffic Management: AI technology is implemented within the transportation industry to reduce traffic and accidents. The aim is to predict and reduce traffic, which can then reduce the pollution created by traffic as well. AI can also be used throughout traffic camera systems to detect road crimes in real-time, making them easier to deal with. This specific field can make extensive use of AI for improvement in several ways, which will be dealt with in the following paragraphs.

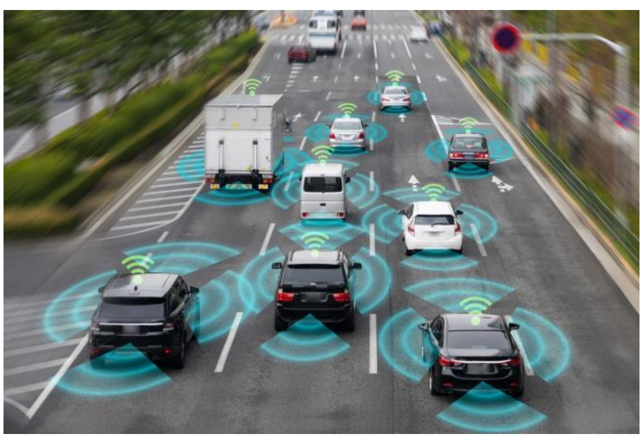
Traffic Management

Artificial Intelligence can be used in the field of traffic management to increase safety and efficiency, reduce traffic congestion, improve air and noise pollution and reduce costs.

Research shows that a significant change in urban mobility could be obtained through the automation of both private and public transport, which can improve energy efficiency along with traffic safety.

In terms of public transportation, the traditional means of transport could be replaced by autonomous electric shuttles. With the decreased use of privately owned cars and the increased deployment of these shuttles, high emission levels and congestion on the transportation infrastructure will be reduced. In addition, these shuttles can be used to provide specific services, such as trips from medical centers to retirement homes; service and supply trips for people with limited mobility; company shuttles for employee transportation.

Besides public transportation, a significant improvement would derive from the implementation of autonomous private vehicles: sensors and cameras on the car would make it possible to collect a much larger and more accurate amount of data than a human; this data can also be shared with other vehicles using clouds. All these elements combined result in a possible impressing improvement of traffic flow: the consequent decrease of congestion on the road could cut energy consumption by 90%, besides making commuters' lives easier in a variety of ways. This is the idea behind our model, which is presented in the following section.



Interconnected cars: Our Model

We now present a model for a smart city with connected and automated vehicles, also called CAVs. These vehicles share data and collect data from the infrastructure, for example from streetlights, using clouds.

In our model, each vehicle uses the data regarding where it is directed, where the other cars are directed, and when the streetlights on the way to the destination are going to be green to determine the ideal speed to maintain so that the car will never have to stop and will decrease the speed as least as possible. In this way, the journey to the destination will be more pleasing for the passengers and the amount of fuel consumed will be highly reduced.

Once the passengers have communicated their destination to the vehicle, the vehicle will calculate the shortest path to take. To calculate the ideal speed, the path will be divided into sub-paths, each from one crossroad or streetlight or roundabout to the next one. Indeed, these elements represent the spots where typically a car has to stop or slow down: our goal is to make cars arrive in these spots at different times so that the slow down won't be significant. For each subpath, the vehicle calculates the "ideal time", hence the time needed to get to its destination, considering the amount of traffic on the way, and by keeping a maximum speed of 50 km/h in the case where the subpath is inside the city.

If the destination of the subpath is a streetlight, the vehicle will collect data from the streetlight itself to know if after the calculated interval of time it will be green or red. If the answer is red, then the "ideal time" will be increased so that the vehicle will arrive with a green light.

However, whether the vehicle is directed to a streetlight, a roundabout, or any kind of crossroads, in that spot it may encounter other vehicles that will force a significant slowdown or even a stop. For this reason, it's important that the cars are interconnected and therefore at each moment the vehicle can know how many vehicles are directed to its destination and where these vehicles are located. In this case, the algorithm assigns a priority to the vehicles that are the closest to the destination and increases the time needed for the other vehicles to get there. If there are vehicles equally as close the priority is assigned randomly. After increasing the time of a vehicle, if its destination is a streetlight, then another check it won't be red will be made and the time will be adjusted accordingly.

Once the ideal time to get to the destination is finally calculated, the vehicle will then calculate the speed to maintain to get there in this amount of time. Of course, since the initial calculation was done taking into consideration a speed below limits (50 km/h) and the ideal time has only increased with the calculations, there's no risk that the final speed will cross limits.

A few clarifications need to be made; first: after calculating such speed the environment might change, for example, some passengers of other vehicles could decide to change the destination or make a stop, or some other vehicles that were not being used could be inserted into the picture. For this reason, in our model, the vehicle continuously checks the surrounding environment and updates accordingly. However, statistically the number of cars that claimed they were going to a certain destination and then changed their mind and the number of cars that are inserted into the picture at every moment are going to balance out, so the speed will not change significantly.

Another point to make is that along the way our vehicle will also encounter vehicles that are not directed towards the same destination, but that could cause a slowdown. For this reason, the amount of traffic along the way is considered when calculating the time needed to get to the destination the first time. Moreover, we're also considering a simplified version of the model in which for every street there are enough lanes to allow every car to maintain the speed desired. Indeed, as will be explained in one of the following sections, to allow autonomous driving there will be a change in the infrastructure and in the way cities look, and one of these changes will be regarding the number of lanes.

Theoretical Analysis of the model

The task environment previously described is:

- Fully observable: through the use of cloud shared data the complete state of the environment is known at each time.
- Strategic: the action to take, i.e. the speed to choose, is deterministic except for the actions of the other agents (the other vehicles).
- Sequential: a current decision may affect a future decision, i.e. the decision to slow down may affect a future choice of speed.
- Dynamic: the vehicle keeps observing the environment and the actions of other vehicles to update the speed.
- Multiagent: the actions of every vehicle are taken into account.
- Cooperative: the vehicles work together to cross paths at least as possible.

How autonomous driving will change the way cities look

We're still years away from fully autonomous cars hitting the mass market because we won't be able to go fully autonomous without the right infrastructure.
Here are changes to be made so that the new smart city infrastructure will be suitable for autonomous vehicles:

- Lane marking: Poor road markings are challenging even for the already existing connected vehicles. The road markings should not only be reflective but machine-readable.
- Roadside sensors: To be prepared for the driverless future roadside sensors should be included on sidewalks, curbs, and lanes. They will allow vehicles to keep track of their surroundings and foresee potentially dangerous situations.
- Machine-readable signs: They will include an embedded code that could be transmitted. They'll send messages detectable by computers.

It's expected that the driverless future will fundamentally change the look of cities' infrastructure. For instance, traffic lights might no longer be needed, as they were originally designed for humans. Instead, machines could determine driving priority themselves and be more efficient. Autonomous cars are also connected, and they could form fleets that travel in the same direction and share all the information on their surroundings. Smart roads that include the right signage, sensors, and lining will be extremely useful for vehicles, making passengers' experience safer than ever.

Furthermore, with the revolution of autonomous vehicles cities won't need any type of parking anymore. Garages will move outside of downtown areas, thanks to the predicted trend of shared mobility. Moreover, self-driving cars can use narrower driving lanes and maneuver better than existing cars, so parking spaces will be optimized to accommodate more cars. All the space that is currently used for parking could find new uses in smart cities.

Differences with related papers

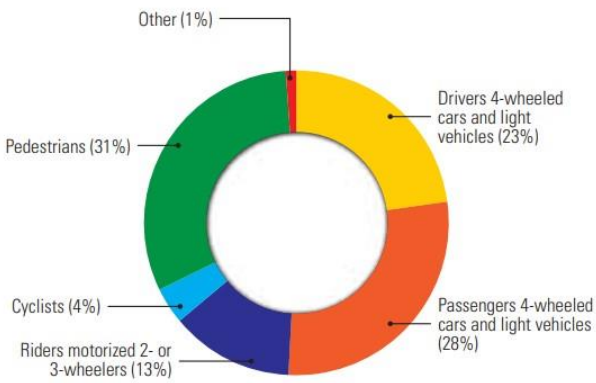
This paper mainly explores the advantages of smart cities and smart traffic management, whereas other papers represent smart cities as a combination of advantages and disadvantages, depending on the perspective. As shown in the article "AI Perspectives in Smart Cities and Communities to Enable Road Vehicle Automation and Smart Traffic Control", AI technologies provide accurate predictions and classifications, but there is an ambiguity regarding the correctness of their outputs. The question at this point is: humans can trust the system? Certainly, with the right data and model the agent will be efficient, but what happens if the data are not sufficient and there is some situation not covered in the model? How should the agent react?

The most relevant problem involves ethics and moral choice: these autonomous cars will not only have to be reliable in terms of safety, but they will also need to be able to solve the moral dilemmas that from time to time will show up. But how can a car be programmed morally?

Provided that the owner of the vehicle, no longer a fully active driver, will be subjected to the decision of the vehicle even against his will, it will be the car to coldly decide, based on the settings received, which good to sacrifice compared to another.

In this regard, a team of researchers from MIT (Massachusetts Institute of Technology) conducted an online investigation identifying and evaluating probable scenarios in which autonomous vehicles will be forced to make critical choices.

The results were completely differentiated according to the geographical area: Europe and North America showed the tendency to see the elderly as more expendable; Japan



and other eastern countries, on the other hand, do not: instead, they show a strong tendency to protect pedestrians regardless of age; finally, China, Taiwan, and Estonia considered the lives of the passengers in the car to be more precious.

On the other hand, traffic security is for sure one of the main goals of the future smart city, from the "Global status report" traffic accidents are the main causes of global deaths and injuries. The autonomous vehicle will reduce accidents using the future sensors system: the user will be monitored to detect distraction, stress level, emotional state, or health state avoiding the loss of control of the car.

Other researches underline that the environment created by a Smart City is an environment for human interaction, communication, and cultural development improvements in the quality of life, creating a condition for social sustainability. Smart cities structurally have the potential to impact or improve the mentioned qualities: information and communication technologies help people to connect, collaborate and share.

The 'Sharing Cities' concept should become the guiding purpose of the politics, planning, and policymaking for the future city as it prioritizes social justice and increases trust and collaboration.

The optimal model for city management and the creation of a smart city and smart sustainable city is based on the synergy between four stakeholder groups: administration, business, science, and citizens.

The overriding aim of this synergy should be to improve the quality of life for inhabitants in various dimensions of their individual and socio-occupational functioning. But at the same time, such technology should not limit an individual's ability and decline community life.

In recent years, the so-called Smart Cities have been fertile ground for social innovation, where innovation is precisely linked to technological development in a very evident way. If today's cities can be considered one great opportunity for social innovation, they can also represent a great challenge due to various factors, such as the increasing aging of the population, and the increasing pollution. Following this picture of action, technologies play a fundamental role in addressing certain challenges. It must be equally important to nurture and encourage the creation of innovative ecosystems and networks, through training policies correct, and to continuously adapt them to the context that surrounds them. In this framework, two interconnected aspects become fundamental: the first a framework that guarantees a correct diffusion of innovation and the second the so-called public-private partnerships.

In conclusion, a solution for the future can be a cohesion between humans and intelligent vehicles.

Conclusions

When we talk about a smart city, we think about a magic world, a magic world that in the future will be reality; in which smart technology will be the people's daily routine.

All the roads will be with many sensors, all the cars will be connected one each other, all the people will walk around the city with total security, and will breathe pure air, the economy will be improved, our life will change in a way that now we only imagine. Our paper highlights how AI is already being used for the achievement of this goal and how using it for the implementation of autonomous interconnected vehicles would make the transition from traditional to smart city even faster and easier.

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