

DIBRIS DIPARTIMENTO DI INFORMATICA, BIOINGEGNERIA, **ROBOTICA E INGEGNERIA DEI SISTEMI**

Future perspectives of freeway traffic control

Madrid October 28, IEEE ITSS Chapters Meeting





IEEE Intelligent Transportation Systems Society

Cecilia Pasquale





Outline

- The main aspects of freeway traffic control
- The era of autonomous vehicles
 - Traffic models with autonomous vehicles
 - Autonomous vehicles as control actuators
- Conclusions

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In recent years, research in this area has been expanded to include sustainable-related objectives

C. Pasquale, S. Sacone, S. Siri, A. Ferrara. Traffic control for freeway networks with sustainability-related objectives: Review and future challenges. Annual Reviews in Control, 48, 312-324, 2019

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- emissions reduction

- improvement of safety

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The most common techniques may be categorized into 3 groups:

Ramp metering control: aims to regulate the traffic volume entering the freeway by means of traffic lights installed at the on-ramps.

Mainstream control: aims to directly regulate the flows traveling on the roadways (speed limits, lane control, etc)

Route guidance: can be applied whenever the possibility of suggesting alternative routes for drivers to reach their destinations exists

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S. Siri, C. Pasquale, S. Sacone, A. Ferrara, "Freeway traffic control: A survey." Automatica, 130, 109655, 2021



Traditional freeway traffic control methods have been conceived considering that both actuators (i.e., traffic lights, variable message signs, etc.) and traffic measurement systems are placed at **fixed locations** in the freeway networks.





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From: A. Ferrara, S. Sacone, S. Siri, Freeway Traffic Modelling and Control, Advances in Industrial Control Series, Springer, 2018.







Traditional traffic control strategies are very effective, but suffer from the limitations of their static nature





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THE ERA OF AUTONOMOUS VEHICLES

Autonomous vehicles combined with advanced communication systems, such as Vehicle-to-Everything (V2X) they promise to result in a highly connected and efficient environment

We can imagine a near future in which control actions can be directly actuated on board connected and automated vehicles (CAVs)

Furthermore, CAVs are designed with the aim to **overcome** the **drawbacks** related to the human driving:

- safer

- more energy-efficient

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THE ERA OF AUTONOMOUS VEHICLES

turn out to be **beneficial** or **detrimental** for the traffic flow efficiency.

The lack of real data is the most critical issue

coexist is necessary

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- The presence of automated and connected vehicles in the traffic stream may

 - The definition of artificial environments in which to test the effect of different traffic scenarios in which traditional and autonomous vehicles





THE ERA OF AUTONOMOUS VEHICLES: TRAFFIC MODELS

Macroscopic traffic models with mixed-flow allow to quantifying the effects due to the presence of autonomous vehicles, and how the values of significant parameters, such as the desired time gap and penetration rate, affect the performance of the entire system



work in collaboration with: M. Papageorgiou and the DSSL of TU Crete

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METANET calibration with T = 1.1 [s], a = 100%: density (a), average speed (b), flow-density diagrams for a specific section (c).

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THE ERA OF AUTONOMOUS VEHICLES: TRAFFIC MODELS

This analysis has also been conducted in order to evaluate the impact of autonomous vehicles in a traffic flow



Mainstream density (a) and average speed (3b) for 100% manual vehicles

work in collaboration with: M. Papageorgiou Technical University of Crete and the DSSL of TU Crete

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THE ERA OF AUTONOMOUS VEHICLES: TRAFFIC MODELS





Average density for time gap of CAVs equal to 0.95 [s], in the cases with penetration rate of 20% (a), 50% (b), 80% (c) and 100% (d)

work in collaboration with: M. Papageorgiou Technical University of Crete and the DSSL of TU Crete

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Average density for time gap of CAVs equal to **1.4** [s], in the cases with penetration rate of 20% (a), 50% (b), 80% (c) and 100% (d)

The presence of CAVs in traffic opens to new scenarios in which vehicle-based traffic control schemes, can be developed.

CAVs, alone or combined in **small** platoons (i.e. moving bottleneck), are adopted as **mobile actuators** of control strategies through which it is possible to regulate the traffic flow by enforcing the other vehicles to move at a certain speed.

G. Piacentini, C. Pasquale, S. Sacone, S. Siri, A. Ferrara, Multiple moving bottlenecks for traffic control in freeway systems. In 18th IEEE. European Control Conference, 3662-3667, 2019.

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Mainstream control performed with CAVs is more flexible allowing the management of **non-recurring bottlenecks** (e.g., accidents or roadworks) and more effective since drivers are forced to follow the speed that is considered optimal to minimize congestion and its consequences.

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In this work a platoon-actuated mainstream traffic control is proposed to **decongest bottlenecks** due to recurrent and nonrecurrent events

The size of the area to be controlled is dynamically adjusted based on the predicted congestion at the bottleneck

The number of platoons to be controlled and the time at which the platoons begin to be controlled depend from the size of the controlled area.

M. Čičić, C. Pasquale, S. Siri, S. Sacone, K. H. Johansson, Platoon-actuated variable area mainstream traffic control for bottleneck decongestion. European Journal of Control, 100687, 2022

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Average density in the no control case

Average density with the platoon-actuated mainstream control



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CONCLUSIONS

There are still technological and ethical challenges to be faced before CAVs can become commonplace in the vehicle market

Several studies are underway to determine the effect of their introduction in the vehicle market, and the debate on the possible opportunities and disadvantages related to the efficiency of whole traffic flows is still open.

However, preliminary studies show that using autonomous vehicles as actuators of control strategies leads to **significant improvements** in traffic efficiency by allowing to overcome some of the limitations of traditional control methods

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Some references

[1] C. Pasquale, S. Sacone, S. Siri, A. Ferrara. Traffic control for freeway networks with sustainability-related objectives: Review and future challenges. Annual Reviews in Control, 48, 312-324, 2019

[2] S. Siri, C. Pasquale, S. Sacone, A. Ferrara, "Freeway traffic control: A survey." Automatica, 130, 109655, 2021

[3] A. Ferrara, S. Sacone, S. Siri, Freeway Traffic Modelling and Control, Advances in Industrial Control Series, Springer, 2018.

[4] G. Piacentini, C. Pasquale, S. Sacone, S. Siri, A. Ferrara, Multiple moving bottlenecks for traffic control in freeway systems. In 18th IEEE. European Control Conference, 3662-3667, 2019

[5] M. Cičić, C. Pasquale, S. Siri, S. Sacone, K. H. Johansson, Platoon-actuated variable area mainstream traffic control for bottleneck decongestion. European Journal of Control, 100687, 2022

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Thanks for the attention and... any questions?



