ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

SimuSafe Workshop

Use of simulators collected data for providing predictive road user models

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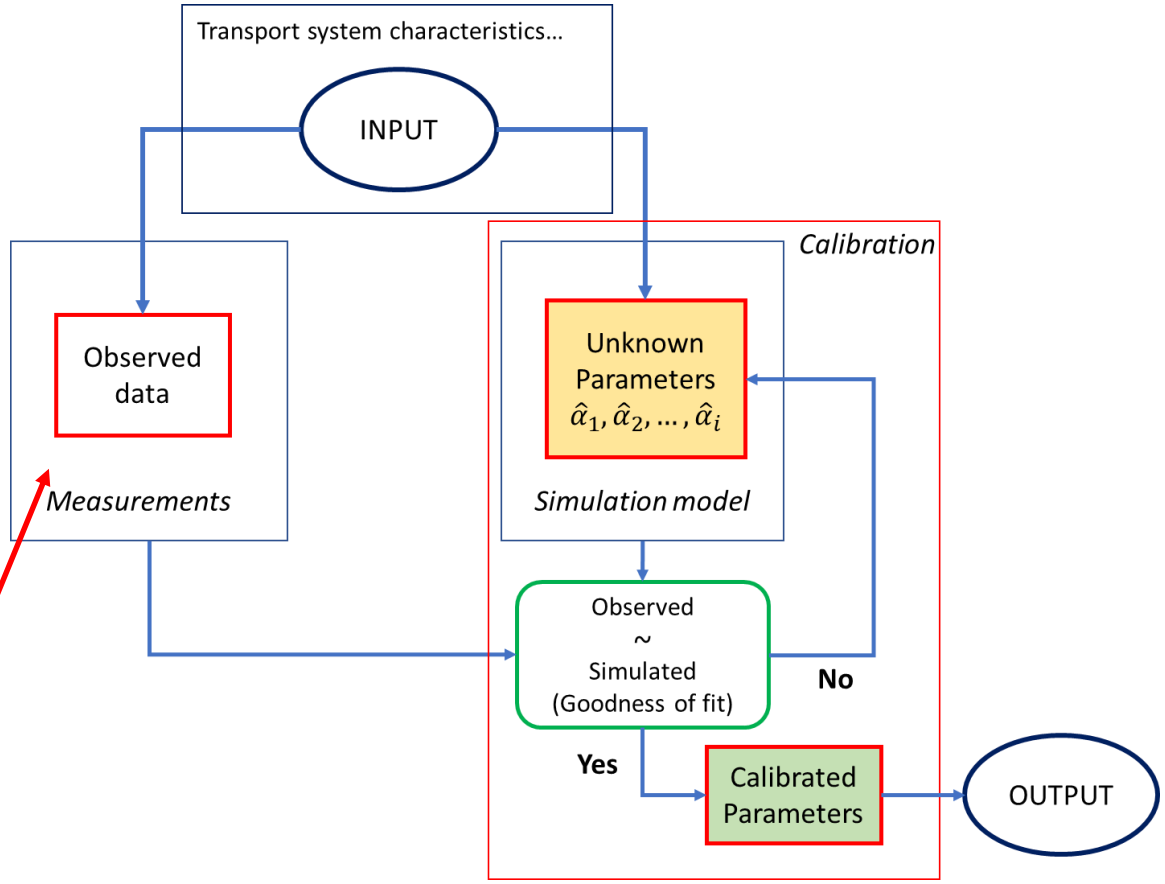
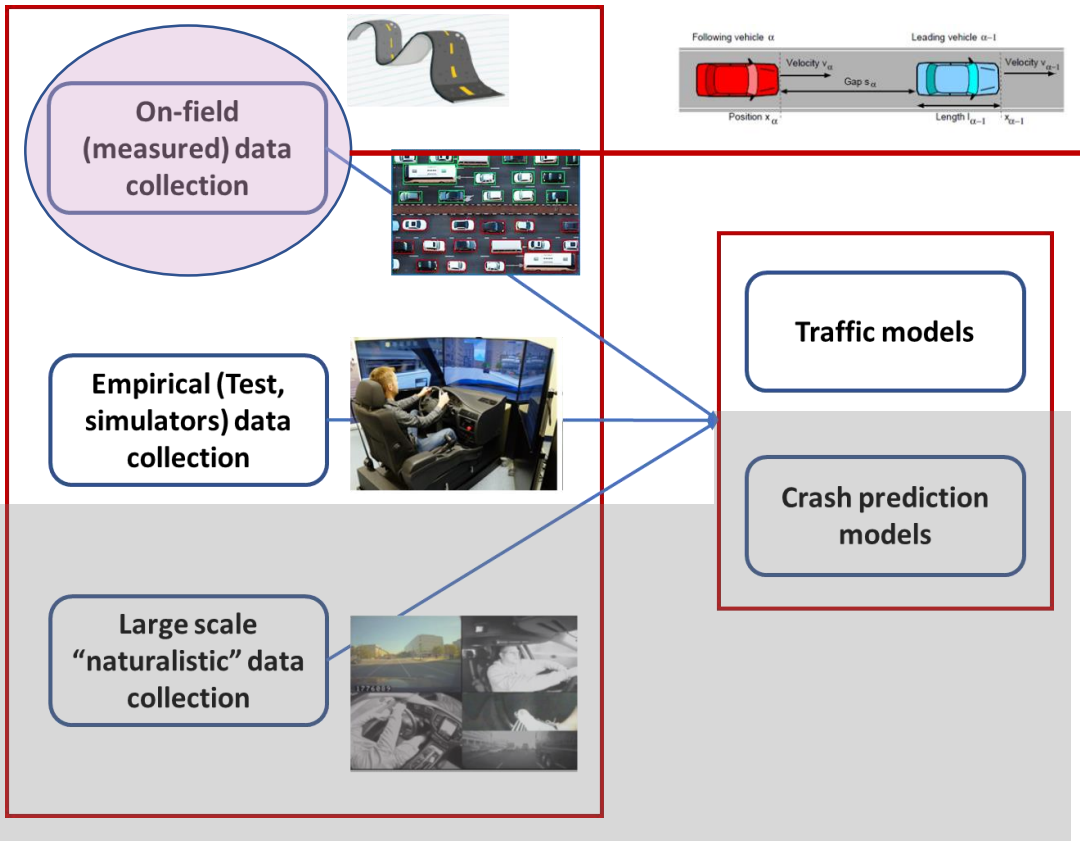
Traffic models and simulation

- Road crash prediction models aim to determine both the crash frequency occurrence and the severity of crashes, by taking into account factors such as driver behavior, vehicle characteristics, roadway geometry and road-environment conditions
- Over the past decades, several researchers have contributed to the development of traffic behavior modeling from different perspectives
- Traffic engineers try to model traffic flows and the characteristics of traffic streams starting from motion equations, vehicles interaction conditions and fluid dynamics analogies
- Traffic psychologists try to describe the human factors involved in traffic models and to evaluate their impact on traffic safety
- In this brief presentation we'll focus on the opportunities arising from the integration of data obtained from driving simulators in the framework of traffic simulation models

Calibration framework

- In the last decades, simulation optimization has received considerable attention, especially in traffic simulation.
- The framework of calibration procedure relies on several factors: the transportation systems characteristics; the considered traffic model and the phenomena to be simulated; the nature and quality of measured data; the measure of goodness of fit used to define the objective function, the algorithm, the constraints…
- Each of these aspects would be worthy of an in-depth description, but the element of interest here is: which data do we rely on for model calibration? Based on this data, do the models reproduce "true" traffic conditions, especially in this new era characterized by connected, autonomous and shared mobility?





Car Following (CF) models

GHR models and extensions: $a_n(t) = \lambda.\Delta V_n(t-\tau_n)$

Memory functions: $a_n(t) = \int_0^t M(t-s)\Delta V_n(s)ds$

Intelligent driver model (IDM):

$$a_n(t) = a_{\max}^{(n)}\left[1 - \left(\frac{V_n(t)}{\tilde{V}_n(t)}\right)^{\beta} - \left(\frac{\tilde{S}_n(t)}{S_n(t)}\right)^2\right]$$

Collision avoidance model (Gipps' model):

$$V_n(t+\tau_n) = \min\begin{cases} V_n(t) + 2.5\tilde{a}_n\tau_n(1 - V_n(t)/\tilde{V}_n)(0.025 + V_n(t)/\tilde{V}_n)^{1/2} \\ \tilde{b}_n\tau_n + \sqrt{\tilde{b}_n^2\tau_n^2 - \tilde{b}_n[2(\Delta X_n(t) - s_{n-1}) - V_n(t)\tau_n - \frac{V_{n-1}(t)^2}{\tilde{b}}]} \end{cases}$$

Optimal velocity models (OV):

$$a_n(t) = \alpha[V_n^*(\Delta X_n(t)) - V_n(t)]$$

$$V_n^*(X_n(t)) = V_0\left[\tanh\left(\frac{\Delta X_n(t) - L_{n-1}}{b} - C_1\right) + C_2\right]$$

Cellular automata (CA) models:

$$\tilde{V}_n(t+1) = \min[V_n(t) + a_{\max}, V_{\max}, S_{gap}(t)]$$
$$V_n(t+1) = \max[0, (\tilde{V}_n(t+1) - b_{\max}, \eta_{ran,0,1})]$$
$$x_n(t+1) = x_n(t) + V_n(t+1)$$

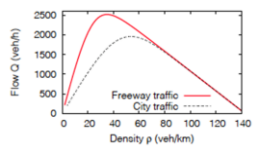
Macroscopic flow models

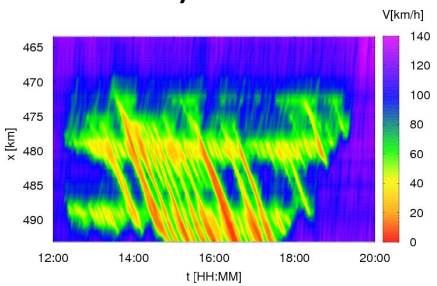
Steady-state conditions: q = kv

Continuum (first and second order) flow models:

$$\frac{\partial k(x,t)}{\partial t} + \frac{dQ(k(x,t))}{dk}\frac{\partial k(x,t)}{\partial x} = 0$$

Shockwave analysis:



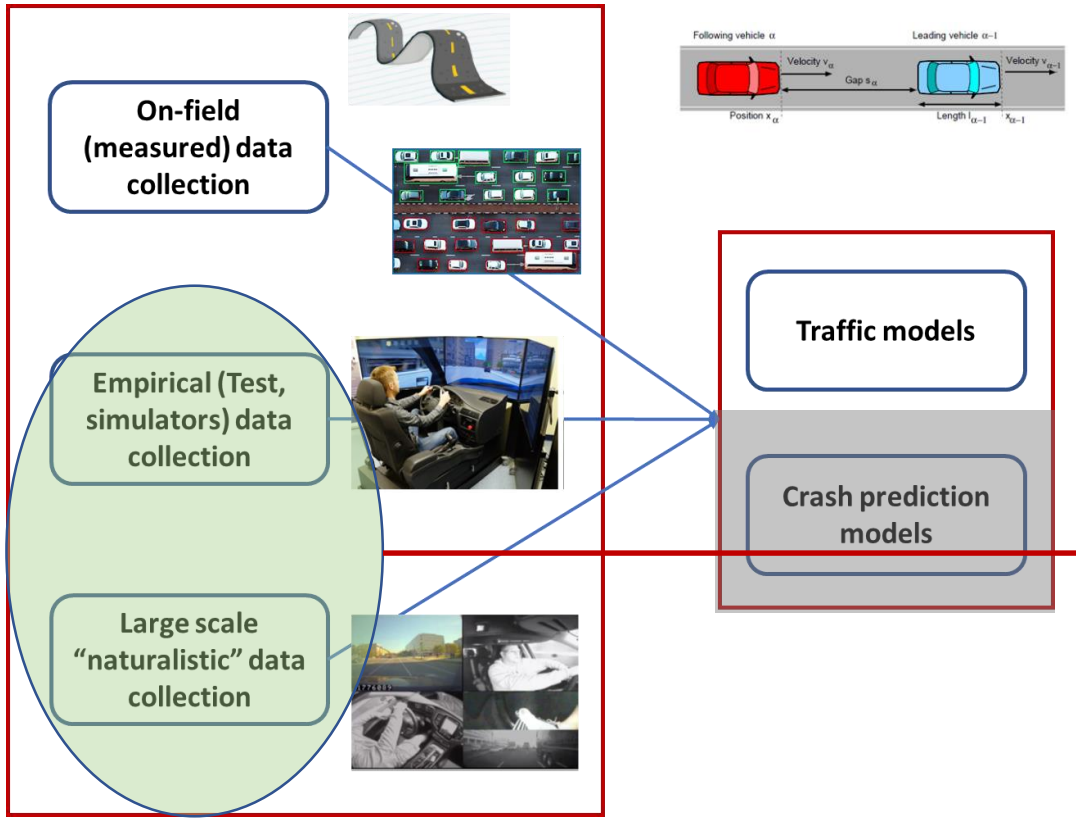


Traffic models traditionally focus on a wide set of variables:

a. Network characteristics (topology, geometry, traffic control and regulation policies…);
b. Socio-economic characteristics of users (e.g., age, gender, income, education, family structure).
c. Surrounding environment;
d. Traffic flow characteristics (i.e. presence and types of heavy vehicles);
e. Vehicle kinematics;
f. Driver inputs (reaction time, desired speed,…).

A major limitation of CF models is that they are designed to produce crash-free environments for the convenience of traffic simulations. However, crash-free environments are not desirable in case of safety analyses and for the measurement of the effectiveness of in-vehicle active safety technology.

Use of microscopic traffic simulation for road safety assessment.



Human-like car following models: The availability of high-fidelity data (both from naturalistic studies and driving simulator tests) and consequential data-driven approaches provide an opportunity to model drivers' car-following behavior directly from mass field data. Data-driven approaches are more flexible than traditional models, as they allow introducing additional parameters that affect driving behavior, and thus leading to advanced traffic models.

Autonomous driving technology is capable of providing safe driving by avoiding crashes caused by driver's errors.

We are looking at a long period of coexistence between autonomous vehicles and traditional vehicles: we need to ensure they interact safely. Human-like microscopic models can help achieving this result.

On-field (measured) data collection

Empirical (Test, simulators) data collection

Large scale "naturalistic" data collection

Traffic models

Crash prediction models

Traffic model

Safety model
Crash prediction models

SSAM (Surrogate Safety Assessment Model)
Integration of traffic simulation and traffic conflicts prediction

Driving trials simulations can provide

Physiological data

Driver Input data

Surrounding environment data

Information fusion, data processing, modelling…

Is the relationship between traffic engineering approaches and psychological studies concerning traffic models a recent challenge?

Driving simulators and traffic models: which was born first?

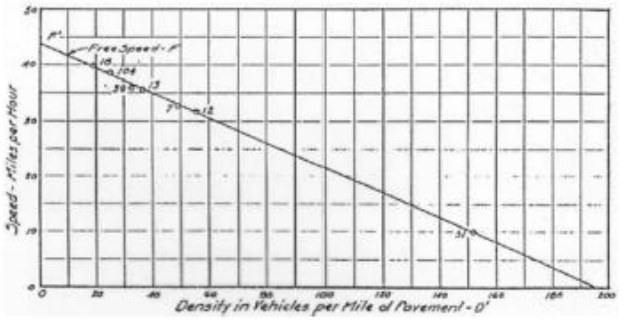
REACTION TIME IN AUTOMOBILE DRIVING

BRUCE D GREENSHIELDS
Denison University

AN automobile does not become a complete mechanism until the driver has placed himself behind the wheel It is the driver who sees the curve ahead and turns the wheel accordingly, who senses the roughness of the road and lessens the pressure of his foot on the accelerator, and who hears the policeman's whistle and brings the brakes into action The quickness with which the driver can react to any

A pioneering driving simulator (Ohio State Fair, August 1935)

Bruce Greenshields, the father of traffic models, wrote this article in 1935, just two years after the publication of his study postulating the first speed-density relationship, lying at the basis of modern traffic flow models…



To summarize…

- ✓ Conventional traffic simulation models perform adequately for the simulation of network traffic flows; however, they could be improved by psychological driving behavior aspects, particularly for **investigating crash-prone traffic conditions, developing safety assessment models and developing and evaluating advanced vehicle control and safety systems**

- ✓ Data collected during driving simulations can be used to understand widely-reported puzzling phenomena such as **capacity drop, stop-and-go oscillations, traffic hysteresis and the microscopic analysis of traffic dynamics**.

- ✓ Moreover, some recent issues such as **heterogeneity of traffic flow due to mixed human-driven and automated vehicles** on the same road, could be studied.

- ✓ Finally, data from driving simulators can be used **to support the integration of traffic simulation models and safety assessment techniques**, as Surrogate Safety Assessment Models.

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Thank you!

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