Around the world traffic congestion causes a drain on the economy due to time and fuel wasted and collisions associated with traffic congestion. In 2011 congestion in America alone caused a loss of \$121 billion due to 5.5 billion hours of extra travel time and 2.9 billion gallons of wasted fuel. Although congestion levels in America are much higher now than several decades ago, they have dropped below the peak in 2005, but will increase when the economy improves[8]. As personal vehicle ownership increases globally, traffic congestion continues to be a persistent problem. It is no surprise then that research in the physics of traffic is developed with the ultimate goal of mitigating road traffic. Traffic control strategies such as ramp metering and variable speed limits are in place today, but a good model of traffic dynamics is needed for proper coordination of control strategies.

The topic of traffic models is vast and here focus is set on freeway sections. In particular no ramps or intersection are taken. The 1950's saw the development of the Lighthill-Whitham-Richards (LWR) model [5, 7], which became the seminal model for traffic flow, still studied today. This model is a conservation law for vehicles, based on fluid dynamics. Let ρ the lineic vehicular density (veh/m) and q the traffic flux (veh/s), dynamics follow the equation $\frac{\partial \rho}{\partial t} + \frac{\partial q}{\partial x} = 0$. The simplicity of the model enables many developments. Simple yet powerful numerical discretization schemes such as Godunov ([4, 6]) or cell transmission models ([2, 3]). These are used in everyday's transportation research (e.g. Berkeley Advanced Traffic Simulation system).

Yet as a first-order model it has inherent shortcomings. Most of these have been pointed out in [1]. The LWR model fails to describe realistically what happens when a vehicle crosses a shock. Although the Rankine-Hugoniot condition can help guarantee macroscopic mass conservation, at the microscopic the speed of travelling particle would be discontinuous. It is also well known that this first order model fails to predict light traffic dynamics accurately. Considering all drivers as similar helps build an elegant model but does not account for plattons disolving because users' desired speeds vary from one person to another. Stop and go behavior otherwise named traffic oscillations or jamitons cannot appear in the model with expanding amplitudes although this phenomenon is observed in practice. This phenomenon has attracted more an more attention in transportation research. Empirical studies have focused on detecting and quantifying this effect ([9]). Car-following behaviors and lane-changing are often seen as the cause of these oscillations.

This prompted the development of second-order models, the prototype of which is the Payne-Whitham (PW) model \cite{payne1971models} \cite{whitham1974linear}. This and later second-order models consist of two equations, the first being the LWR equation and the second a momentum equation analogous to that describing fluid flow. Daganzo later published a study of the serious flaws of second-order traffic models, namely the emergence of gas-like behavior. While the second-order models up to that point were able to capture physics that the

LWR model could not, these "improved" models also lost the anisotropy of the LWR model, incorrectly predicting that vehicles are affected by vehicles from behind \cite{Dag_requiem}.

Soon after, Aw and Rascle, and independently Zhang, developed the ARZ model which avoided the inconsistencies of earlier higher-order models \cite{AR} \cite{Z}. Want a model that is suitable for all traffic regimes (need for control).

Talk about behavioral models and data driven approaches

The objective of this article is two-fold. First we aim at developping strategies that enforce the readability and easiness of use of the ARZ model. Solutions to these non-linear equations are practically hard to derive in an efficient manner. Linearizing the system about an equilibrium in therefore a sound strategy to open the way to usual control schemes with multiple inputs and outputs. In particular the techniques that have extensively developed by X. Litrico in [] can readily be applied to that framework. The other objective is assessing the fit quality of the model by practically comparing its output with actual data collected as part of the NGSIM project. In particular, the second order linearized model will be compared to its first order counterparts.

This article presents several new contributions

Oscillations without wavelets.

Objectives
Contribution
Organization

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