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Traffic flow within a two-dimensional continuum anisotropic network

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Abstract

Network flow computing based on macroscopic traffic flow models for large and dense networks involves a large number of parameters and variables, and significant computational efforts. We aim at reducing these and introduce a modelling framework at two-dimensional scale in order to model traffic flow of transportation systems of large surface networks. We present a network flow pattern corresponding to network flows modelling with a few network sensors of traffic count locations. We manage and evaluate traffics on wide and dense networks with a minimum of available measurements and data, through modelling of global behaviours based on local behaviours. We find that the traffic at this scale is governed by multidimensional hyperbolic conservations laws. Godunov-type method has been proposed to compute the network flow flux across computational domains.

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Keywords: dense network of large surface, continuum anisotropic network, two-dimensional traffic flow, multidimensional hyperbolic PDEs system, finite volume method.

1. Introduction and Motivation

We often observe phenomena of congestion and mobile jams in areas where users' travel traffic demand is very important with respect to the supply of existing networks, especially at peak hours. To ensure greater safety and reduce the risk of traffic incidents, a new trend has emerged in the field of transportation networks modelling for traffic management of large surface networks. That is the two-dimensional modelling of network flows. It aims at managing and evaluating traffic on wide and dense networks with a minimum of available measurements and traffic data, through modelling of global behaviour based on local behaviours. The technique allows aggregating the network links as a continuous medium, where road traffic flows as a fluid on a surface. This modelling approach intends to reduce the

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large number of parameters, the unknown variables and the significant computational efforts involved in macroscopic flow models for large and dense urban networks. The approach aims to be suitable for network modelling with scarse traffic data. It considers the area of the large network as a continuum anisotropic media where vehicles behave like a two-dimensional fluid with four preferred directions of propagation (Saumtally, 2013; Wong, 1998). Roads and vehicles are both aggregated, and the anisotropy of the network is due to the directions of propagation of vehicular flows in any position of the network. Few researches on this approach for network flows management and control have been performed, mainly in the statical case (Wong, 1998; Prez and Benitez, 2010; Saumtally, 2013) and recently based on the concept of network fundamental diagram (Keyvan-Ekbatani et al., 2012, 2015b,a).

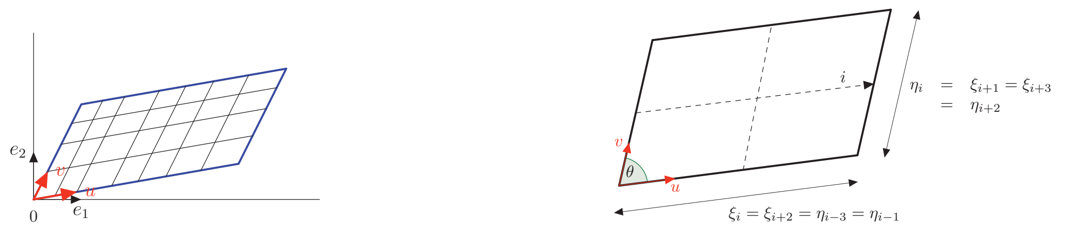
The outline of the paper is the following. First we recall the definition of the terms ”dense urban network” and ”continuum anisotropic network” and give examples of cities which road network may be considered as dense, continuum and anisotropic. With intersection model of (Costeseque and Lebacque, 2012) we express the relations between cars-flow through any point of an urban network, and the non-negativity of flows. And we describe at the same time, in details, existing movements at a point. We build thereafter a multidimensional hyperbolic conservation laws that describes the dynamic of vehicles in all the computational domains. A Godunov-like scheme is deduced, which allows easy numerical calculation of the two-dimensional model.

2. Two-dimensional Anisotropic continuum network

2.1. Anisotropy of network

Definition 2.1.
In traffic theory, a network is said anisotropic when there are many possible interactions within a cutoff location.

One derives from local interactions global interactions which may be predetermined in a network. In the paper we reduce the local interactions in four different preferred directions of propagation of vehicles-flow in any location. Let us denote by $\mathscr{U}$ the area of a urban road network. $\mathscr{U}$ is supposed be a bounded and open subspace of the Euclidean space $\mathbb{R}^2$, since any city has a frontier and then its urban road network is limited by its frontier too. Clearly $\mathscr{U} \subset \mathbb{R}^2$ and $meas(\mathscr{U}) < +\infty$, with *meas* the Lebesgue measure in two dimensions. At any point P of coordinates (x, y) of the network, we assume four preferred directions of movement of vehicles, depicted by the Figure 1(a).



(a) Considered directions - anisotropy

(b) A zoom on an elementary cell and the related local basis

Fig. 1: Anisotropy - Structure of the network - Local and global basis

We assumed that $\mathscr{U}$ is decomposed in zones or sub-areas $\mathscr{U}_m$, $m = 1, \ldots, M$ respecting the below criteria:

1. $\mathscr{U} = \bigcup_{p=1}^{P} \mathscr{U}_m$
2. $\mathscr{U}_m$ is a polygonal domain of $\mathbb{R}^2$, which frontier is of Lebesgue measure strictly positive.
3. Each zone $\mathscr{U}_m$ is subdivided in elementary cells or grids, providing an admissible mesh in the sense of (Eymard et al., 2000, Definition 5.1).
4. $\forall m, m' \in M, m \neq m' \Rightarrow \mathscr{U}_m \cap \mathscr{U}_{m'} \in \{\varnothing,\ \text{point, polygonal segment}\}$.