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A multi-layer social force approach to model interactions in shared spaces using collision prediction

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Abstract

In shared space environments the movements of road users is not regulated by traffic rules, but is the result of spontaneous interaction between traffic users, who negotiate the priority according to social rules such as eye contact or courtesy behavior. However, appropriate micro simulation tools, which can reproduce the operation of shared spaces, are currently lacking. In this paper, a multi-layer approach for representing the movement of road users and their interaction, based on the Social Force Model, is developed. In a free-flow layer a realistic path is calculated for each user towards his destination, while a conflict layer is used for detecting possible conflict situations and computing an appropriate reaction. The novelty of this work in the field of shared space modeling is in the implementation of group dynamics and a SFM based approach for cyclists. The presented approach is qualitatively tested in different traffic situations involving cyclists, pedestrians and pedestrian groups, and shows realistic behavior.

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Keywords: Shared space; microscopic simulation; social force model; mixed traffic; traffic conflict.

1. Introduction

The coexistence of different transport modes within the same traffic area has always raised problems. In particular, the difficulty is how to conciliate motorized traffic with bicycle and pedestrian traffic, compensating for the physical and operational disparity by designing solutions which could preserve efficiency and safeness.

According to a classical approach, this issue is addressed by separating different transport modes spatially or temporally. When all modes of transport are traveling towards the same direction, spatially separated traffic areas for each type of user are established. In the case of crossings, traffic flows are separated on a temporal level by control devices such as markers, signs and signal devices.

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Nomenclature

CA	Conflict avoidance
CAR	Motorist
CONF	Conflict status
CU	Competitive User (opponent to the EGO)
CYC	Cyclist
EGO	Regarded user
FF	Free-Flow
FFT	Free-Flow Trajectory
LR	Long-Range
LRCA	Long-Range Conflict Avoidance
NO_CONF	No-Conflict status
PED	Pedestrian
SFM	Social Force Model
SR	Short-Range
TTC	Time-To-Collision

Opposingly, new road design approaches have been developed, which aim to let all transport modes share the same space and minimize road signs and regulations. The purpose is to force traffic to regulate itself as much as possible, encouraging user interaction and the use of the space for social activities, by giving the street a social function instead of simply a traffic function. According to this philosophy, the concept of living streets, namely residential streets, where motorists share the road with cyclists and pedestrians on a level surface has been developed.

The regulation of these streets, whose designation depends on local regulations, provides that motorists adjust their behavior according to pedestrians and cyclists, by adapting their speed and giving priority.

A more radical application is represented by the experiments of the Dutch traffic engineer Hans Monderman, and aims at making road users coexist by reducing road regulations, especially priority rules, totally or partially. In fact the minimization of markings and signs, as well as traffic regulations, acts as a traffic calming element in the *principle of risk compensation* (Adams, 1985). However, this principle can be achieved only by an adequate road traffic design, suggesting to the user how to behave, and addressing them towards a pleasant and safe coexistence. Many informal road design instruments, such as geometrical measurement, road markings, materials and pavement, could influence the behavior and speed of users (Marceau et al., 2007). Moreover, street material and color have an effect on their behavior and their propensity to behave carefully.

Currently the choice of a particular shared space design does not take into account performance indicators like Level of Service or safeness. Appropriate micro simulation tools, which can reproduce the operation of shared spaces, are currently insufficient. However, such tools would ideally provide precise performance outputs, namely their efficiency (average road user delays and road capacity), safety (initial time-to-collision) and environmental impacts (emissions based on instantaneous speed and acceleration of vehicles) (Anvari et al., 2015).

The challenge of the research project MODIS (**M**ulti-m**od**al **I**ntersection **S**imulation) is to build a micro simulation framework, capable of simulating the movements of road users in shared spaces and calculating performance indicators, in order to evaluate the suitability of a particular solution. In the previous work (Pascucci et al., 2015) the fundamentals of a three-layered social force based approach were described, and simple conflict situations involving pedestrians and motorists were modeled.

In this work, the framework is extended by improving vehicle-pedestrian interactions, and implementing models for cyclists and groups of pedestrians. In Section 2 the background on shared space modeling is provided. Section 3 describes the data survey and typical road user behavior, focusing on the strategies to avoid conflicts. In Section 4 the problems in modeling shared spaces with a SFM are presented and the required modifications and extensions are explained. A detailed explanation of the framework is given in Section 5, while the results of the simulation framework are then visually compared to three representative observed situations involving cyclists, pedestrians and pedestrian groups in Section 6.