Simulating pedestrians and cars behaviours in a virtual city : an agent-based approach

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Introduction

Despite the central and fundamental role pedestrian walking plays within the urban transport system, it still remains a badly known transportation mode. Generally speaking, while most of the developed countries have been developing, for the last 40 years, a wide variety of sophisticated methods and tools aimed at studying urban mobility, only a few of them were really designed to deal with pedestrian movement, especially in interaction with the other transportation modes. Noticing the tremendous asymmetry that has been existing for long in the scientific literature between traffic flow and pedestrian movement, Weifeng and his colleagues [Weifeng, 2003] propose several explanations :

"*The reason may be that the pedestrian movement is more complex than vehicular flow. First, pedestrians are more intelligent than vehicles and they can choose an optimum route according to the environment around. Secondly, pedestrians are more flexible in changing directions and not limited to the "lanes" as in vehicular flow. Thirdly, the slight bumping is acceptable and need not be absolutely avoided as in traffic flow models. So the model developed for pedestrian movement should fully consider these differences in order to study the special phenomena in pedestrian movement. It is pity that till now, most pedestrian movement models are established based on the rules used for traffic flow and consider little of the special characteristics of pedestrian movement itself*"[pp. 634].

The key point we will try to defend here, is that pedestrian movement needs not only to be considered as a specific phenomenon. It also needs to be included in a much more global and complex perspective, the urban system as a whole. Pedestrian motion indeed occurs in an ever changing environment, defined by constraints and opportunities, but also nuisances and dangers. The SAMU prototype has been precisely designed to explore the behaviour of pedestrians in interaction with the motorized traffic, in a virtual city where most of the phenomenon can be mastered and studied. This idea of designing "virtual laboratories" [Batty and Torrens, 2001], within which "artificial societies"can be grown for example [Epstein and Axtell, 1995] has become very popular in the recent years and is largely related to two other fields, science of complex systems and agent based modelling. More, it is firmly embedded in a microscopic approach of urban mobility, where the world is represented as closely as possible in a one-to-one way, which means that "*people should be represented as people, cars should be represented as cars and traffic lights should be represented as traffic lights and not as, say, departure rates, traffic streams and capacities respectively*" [Nagel et al., 2000].

The SAMU prototype

While being fundamental steps, most of the micro-simulation approaches of pedestrian movement [Blue and Adler, 1998 ; Helbing et Monnar, 1997 ; Helbing et al., 2001 ; Batty, 2003 ; Haklay et al., 2001 ; Kerridge et al., 2001] have the drawback of relying on an excessive simplification of the urban environment (a corridor, a place or a room). Motivations and goals of pedestrians are also particularly simplified, reduced to the couple destination to reach / obstacles to avoid. Theses limitations encouraged other researchers to explore agent-based models of pedestrian movement [Batty, 2003 ; Haklay et al., 2001 ; Kerridge et al., 2001 ; Schweitzer, 2003 ; Zachariadis, 2005]. In this last family, each pedestrian/agent is defined by a set of capacities and tries to achieve a set of goals, interacting locally with its environment and with other agents.

The prototype SAMU[1] directly relies to that specific field, its originality being defined by its focus on interactions between pedestrian and traffic flows. Developed in NETLOGO[2], SAMU is an hybrid model, combining characteristics of both cellular automata and agent-based models. Cars and pedestrians are indeed defined as agents, situated on an active grid (Figure 1), with which they interact.

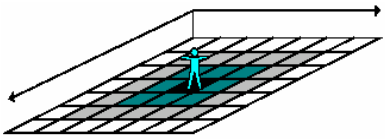

Figure 1 : the basic principle of SAMU

Then, agents have to perform specific tasks, interacting locally with other agents and with their environment. Figure 2 shows the prototype developed in order to observe and test these interactions, as well as emerging parameters, such as speed of cars or proportion of cars/pedestrians collisions.

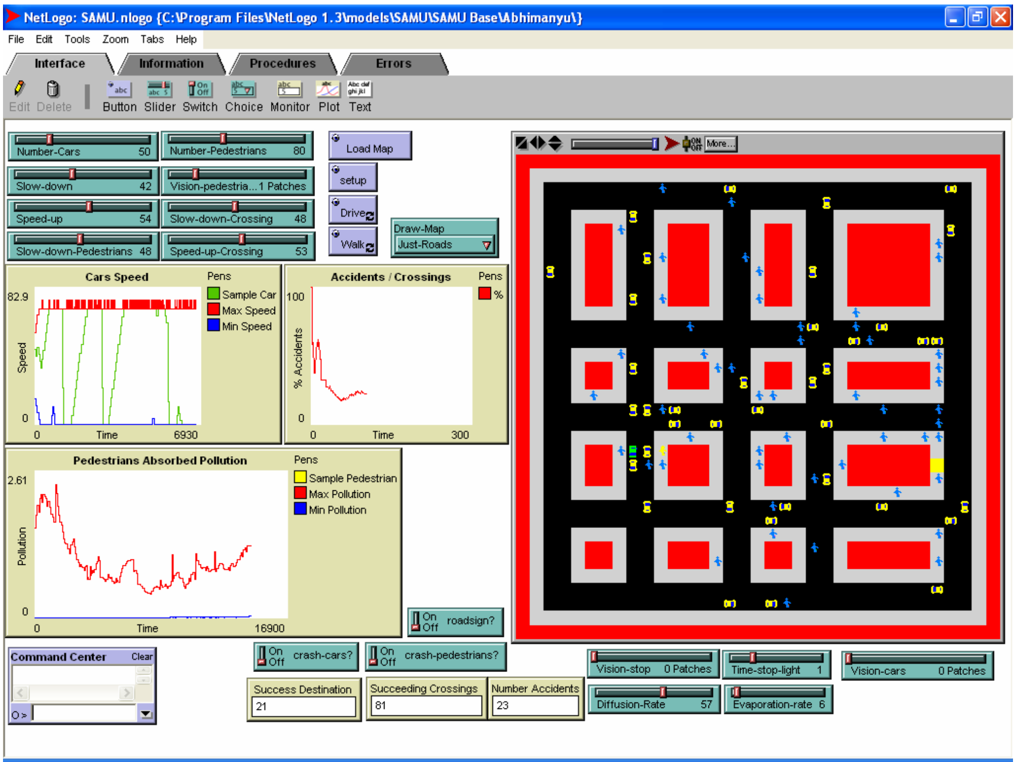

Figure 2 : The SAMU prototype

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[1] Simulation Agents et Modélisation Urbaine, http://www.univ-pau.fr/~banos/sma.html
[2] http://www.ccl.sesp.northwestern.edu/netlogo

Model Formulation

Our prototype SAMU, developed in Netlogo, integrates both cellular Automata and Agent-Based Modelling approaches to generate a new model of cars behaviours by appropriately modifying earlier NaSch/ChSch rules [Nagel and Schreckenberg, 1992] to take into account pedestrian and also turning movements. We also consider two-way traffic with turning movements to bring the model closer to the real world.

Following the prescription of the NaSch model, we allow the speed V of each vehicle to take one of the Vmax + 1 integer values V = 0, 1, 2….Vmax. For urban systems we do not want to have Vmax more than 70 km/h. So we are taking maximum speed as 3 (22.5 m/s as each cell is 7.5 m in length as in NaSch model). Suppose Vn is the speed of the nth vehicle at time t while moving in any direction (different from NaSch/ChSch/BML model where vehicles move either towards east or towards north and number of cars is fixed on a given road). To emphasize the effect of turning movements and pedestrians we are considering only unsignalized intersections in our model and also we want each car to stop at the intersection and decide regarding the turning movements to get homogeneity. The above assumption is true considering the fact that drivers become more cautious and reduce their speed at intersections to avoid any kind of collisions with other vehicles. At each discrete time step $t \rightarrow t+1$, the arrangement of N vehicles is updated in parallel according to the following “rules” :

Step 1: Acceleration

If Vn < Vmax, the speed of the nth vehicle is increased by one, i.e., Vn→ Vn+1.

Step 2: Deceleration (due to other vehicles, intersections, or pedestrians)

Suppose Dn is the gap in between the nth vehicle and the vehicle in front of it, Pn is the distance between the same car and the closest intersection in front of it (note here intersection not signal, which makes the model more general) where the car has to make a decision about turning, and D is the minimum gap between the car under consideration and the pedestrian in front of it on the road (if any).

Now, If min(Dn, Pn, D) ≤ Vn

and if min(Dn, Pn) < D,

then Vn→min(Dn – 1, Pn)

else Vn→D – 1 (the motivation for this choice comes from the fact that to avoid accident, the car will stop one cell before the pedestrian)

Step 3: Randomization

If Vn > 0, the speed of the car under consideration is decreased randomly by unity (i.e, Vn→Vn – 1) with probability p ($0 \leq p \leq 1$); p the random deceleration probability is identical for all the vehicles, and does not change during updating.

Step 4: Movement

Each vehicle moves forward with the given speed i.e. Xn→Xn + Vn, where Xn denotes the position of the nth vehicle at any time t.

The major changes are made in step 2 which reflects the interaction among vehicles and pedestrians. Step 4 shows there are no more north-bound or east-bound vehicles, the speed of each car being updated simultaneously without any specific classification. While being a work in progress, SAMU already provides an ergonomic platform useful to test the behaviour of the system under different configurations of parameters. Anyway, reaching such a modelling level, without being flooded with microscopic details, requires an ad-hoc procedure. Crucial principles like reductionism and parsimony [Batty and Torrens, 2001] may therefore constitute main guidelines, in our quest for the identification of the micro-specifications sufficient to generate macrostructures of interest [Epstein, 1999].

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