# A REPRESENTATION OF MOTORBIKE DOMINATED TRAFFIC USING CELLULAR AUTOMATA

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## 1. Introduction

Up to now, large numbers of traffic models and simulations have been developed, however, mainly for the lane-based traffic and still lacked for motorbike dominated traffic of some developing countries such as Vietnam, Thailand, etc... In these countries, motorbike component is more than 70% and the lane-based rule is not strictly complied. Motorbikes can travel with more freedom than other modes therefore they can advance using small space between vehicles. Besides, being the most unsafe mode in the traffic, their behaviours are affected by surrounding vehicles. These behaviours cause the differences in using road space between normal lane-based traffic and non lane-based traffic. For these reasons, this study aims to develop a network model using Cellular Automata method (CA); to represent this type of traffic in order to have tool to evaluate ITS measures in these countries.

Conventional traffic model can be separated into microscopic or macroscopic models. Microscopic approach considers time-space behaviour of individual drivers, however, its parameters are difficult to calibrate; whilst macroscopic approach deals with collective flow and patterns then the interaction among individual vehicle is ignored. Cellular automata models belong to microscopic approach but they use crude microscopic parameters to obtain correct macroscopic patterns[1)]. Therefore, in dealing with network modelling in considered mixed traffic situation, CA approach which can give fast and effective performance [1)] is chosen in this study.

## 2. Methodology

This modified CA model is being developed for the mixed traffic with 3 representative vehicle-classes which are significantly different in their specifications: such as length, width or speed. A representative road stretch (link) in the model is 3.75m width and 400m length, unidirectional traffic. The lattice chosen is a 2D square grid of 0.25mx0.25m with the time step of 1/20 second. Therefore the minimum speed is derived as 5m/s. Each line paralleling to road direction is defined as a “virtual lane”. From above settings, several parameters are conversed into CA unit as in Table 1.

Table 1: Parameters of model

| Vehicle Type | Maximum speed | | Dimension | | | |
|---|---|---|---|---|---|---|
| | cells/time step | m/s | Width | | Length | |
| | | | cells | m | cells | m |
| Motorbike | 3 | 15 | 3 | 0.75 | 8 | 2 |
| Car | 6 | 30 | 6 | 1.5 | 15 | 3.75 |
| Bus | 4 | 20 | 10 | 2.5 | 40 | 10 |

[*] Key words: motorbike dominated traffic, Traffic Cellular Automata models

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In making the short term plan, the driver's thinking process can be simplified as: first scanning surrounding area to have information of current driving environment. Based on that, he will make decision to choose his driving direction (following or lane changing). Together with safety checking where the speed and safety criteria are obtained, finally, the vehicle's position is updated after the moving action. Mechanism in one time step of the simulation is shown in Figure 1.

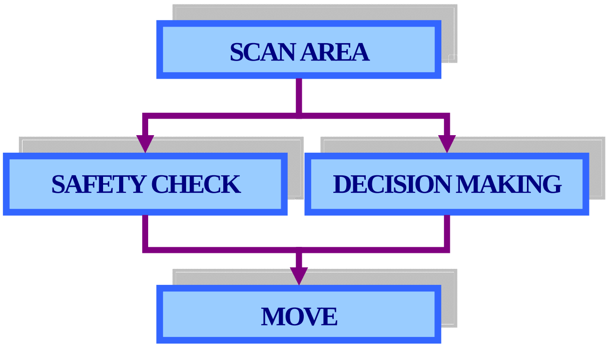


Figure 1: Mechanism of one time step simulation

Above process is represented in CA model as one evolution of each vehicle in the traffic stream from one time step to another time step. This evolution is described by the local transition rules which are defined based on observable phenomena of traffic flow and several assumptions made on driver behaviours[6]. These rules reflect car following and lane changing behaviour[1]. Within the scope of this model, the term "virtual lane" changing, which is used instead of lane-changing, explains any change in the lateral position of a vehicle. At every time step, longitudinal position is increased by its speed calculated in current step; and lateral position is adjusted to the left or right by number of 1 cell to the width of vehicle from current position as long as it does not jump out of the two road marking lines. The updated rule can be written as below:

$$(1): x(t) = x(t-1) + v(t)$$

$$(2): y(t) = \begin{cases} \min(y(t-1) + vehicle's\ width; road\ width) & if \quad move\ to\ left \\ \max(y(t-1) - vehicle's\ width; 0) & if \quad move\ to\ right \\ y(t-1) \quad if \quad go\ straight \end{cases}$$

Formula (1) describes the longitudinal position where:

$$(*): v(t) = \max(v_{left}^{safe} \vee v_{right}^{safe} \vee v_{straight}^{safe}, 0)$$

$v_{left}^{safe}, v_{right}^{safe}, v_{straight}^{safe}$ : Speed if vehicle moves to the left, right side or straight, respectively.

Changing direction to the left, right or straight depends on where the preferred "virtual lane" is. This lane is determined by Utility function which takes into consideration possible reasons of lane changing. Details of this function will be explained in next chapter.

"Virtual lane" changing behaviour is performed based on two parts which are the reasons to change and safety criteria[3]. Both are differentiated between car/bus and motorbike. For a road stretch, assumptions are given on the possible reasons of this behaviour. "Virtual lane" preference depends on: local traffic regulation, turning direction, surrounding vehicles.

Within a road stretch (without any effect of bus stop, intersection…), as referred from Vietnamese Traffic Law, Cars and buses have right to travel on the left; the lower speed vehicles including motorbikes should travel on the right side. But lane-based rule, in fact, does not effectively work in Vietnam cities traffic, especially, in motorbike drivers, the focused object of this study. In free flow traffic, motorbike drivers can freely use all road space and in congestion, lane division can not be observed. These facts imply that the driving decision of drivers in mixed traffic is also significantly affected by surrounding vehicles. E.g., motorbike drivers are often observed to avoid following (or even side by side) a bus since buses are perceived to be big obstacles and dangerous.

The situation in intersection approach segment, both intersections with or without clear turning split, is that the turning direction forces the driver [4,5] to change lane from a certain distance to the intersection. The distance in this model is fixed as 30 m.

Dealing with city network, the assumptions are:

- Vehicle enters next link with the same order as arriving at the stop line. This is because drivers tend to detour other than spending time waiting.
- Each vehicle is assumed to travel in an own virtual link. Using this link length traversing time of a vehicle can be calculated.
- First vehicles will traverse though intersection with higher speed than the followers. According to Hien NGUYEN[5) ] has proved that the discharge rate variation depends on traffic patterns at the intersection. Therefore the traversing speeds of vehicles though intersections are not constant.

## 3. Utility function and decision making rule

Utility function shows the variation of preference degree that a vehicle perceives at every "virtual lane" at a certain time. Utility value describes how the driver is attracted by each position over the cross section. As mentioned in previous part, the Utility function takes all the possible reasons of lane changing as its parameters. Variables of this function and their explained factors are shown in Table 2. Ranges of each factor are currently assigned default values. Formula of the function is written as:

$$U(i) = \{(front\_gap + front\_speed) \times Front\_factor + (back\_gap + back\_speed) \times Back\_factor\} \times Lane\_factor \times Turning\_factor$$

Where $U(i)$ : Utility of virtual lane $i$

An example of utility function's result is illustrated as in Figure 3. The vehicle will choose the position where not only the utilities are higher than in current position but also the number of consecutive higher utility cells must not be smaller than vehicle' s width.

$$P \text{ is a preferred lane} \Leftrightarrow \forall U(P \pm k) \geq U(i)$$

*Where: k: integer; k= 0÷vehicle' width ("+": range at the left side; and "-": rang at the right side)*

*i: current virtual lane*

The preference lane is the most left or most right boundary of those consecutive cells.

Table 2: Variables and factors of Utility function

| Variable | Factor |
|---|---|
| Speed, vehicle type | Lane_factor |
| Front vehicle speed+gap; type | Front_factor |
| Back vehicle speed+gap; type | Back_factor |
| Turning direction | Turning_factor |

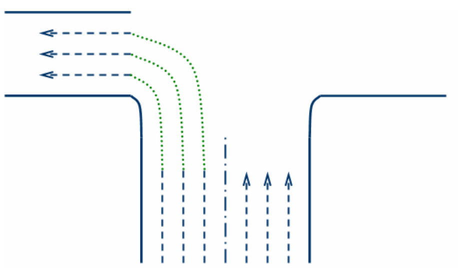

Figure 2: Turning order and virtual link assumption

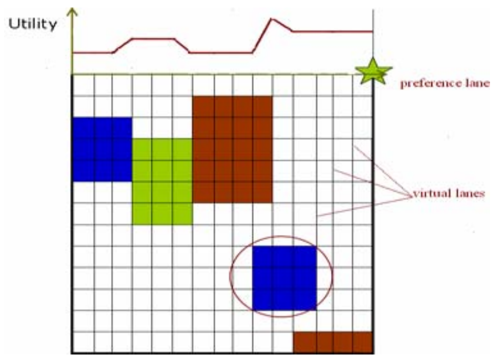


Figure 3: Illustration of Utility function

## 4. Prototype application

To investigate the possibilities of such a model, we have implemented a prototype. This first application shows already realistic driving behavior among all three vehicle types and is the basis for further developments.

All in all, we could proof the feasibility of such a model and in the next step it will be calibrated and validated with video footage from Vietnam.

Figure 4: An intersection approach in Hanoi, Vietnam

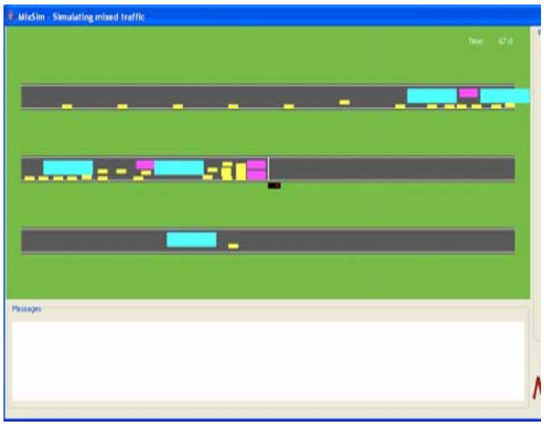

Figure 5: Model prototype

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