Using Ego-Centered Affordances in Multi-Agent Traffic Simulation

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ABSTRACT

To improve the validity of traffic simulations in urban and suburban areas, we propose to consider the driving context and the driver behavior in terms of space occupation. We endow agent driver with an ego-centered representation of the environment. This representation permits the agent to take a decision in terms of space occupation. Our agent driver model is based on the concept of affordances - the ways in which an agent can interact with its environment. First, we use the concept of affordances to identify the possible actions, in terms of space occupation, afforded by the environment. Second, we use an ego-centered representation of the situation around the agent, composed by the identified affordances. The proposed driver model was implemented with ArchiSim and the experiments show that this model makes traffic more fluid.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence-multiagent systems

General Terms

Algorithms, Experimentation

Keywords

Multi-agent simulation; affordances; traffic simulation; virtual lanes

1. INTRODUCTION

In road traffic management, road space occupation is a well known research problem. In urban areas with a high traffic density context, a bad management of the road space occupation may lead to several negative emergent effects like road congestion. The road is often decomposed in lanes and in several countries the road space decomposition should be respected by drivers. But this is not always the case. For instance many European governments are studying the dynamic readaptation of road space and its influence on the traffic.

Multi-Agent Systems (MAS) allow the simulation of complex phenomena that cannot easily be described analytically. They are often based on the coordination and interaction of agents that lead to the emergence of the simulated phenomenon [11]. MAS provide thus a solution to the traffic simulation problems, the traffic management, the traffic signal control, etc. [1, 5, 23]. Several multi-agent solutions have been proposed to study the road space occupation and the related emergent phenomena [12, 13]. In these models, the lanes used by drivers are defined by the road markings. These models do not consider the observed phenomena of road space occupation such as filtering maneuvers between vehicles or dynamic allocation of lanes. Moreover, Bonte [2] and Lee [15] proposed solutions for the particular case of two-wheels. However, the proposed solutions cannot be generalized to other vehicles. They are developed for one particular type of driver and cannot be applied to other situations such as deadlocks related to a particular event or toll stations.

In this paper, the aim is to model the behavior related to the phenomena of road space occupation, particularly in urban areas with a high traffic density context or specific events. Our model focuses on situations such as filtering maneuvers between vehicles (two-wheels), the readaptation of road space, the specific events (stranded vehicles or improperly parked), the dynamic allocation of lanes, etc. In some situations, the presence of road markings does not prevent drivers from readapting the road space according to their goals and context. Each driver overloads the road structure, defined by the road markings, by constructing his/her own ego-centered representation which meets his/her goals. Drivers can have different ego-centered representation for the same "physical" configuration. To deal with such phenomena, agent driver should be able to build an environment representation, taking into account the traffic context as well as individual characteristics, for example, the accepted gap

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to the regulation. We introduce, in this paper, a novel approach and we endow the agents with an ego-centered representation of the environment that permits the agent to take a decision in terms of space occupation. Our approach is based on the concept of affordances - the ways in which an agent can interact with its environment. Affordances are a theory from ecological psychology that describes how humans and animals can perceive the possible actions that the environment affords them [8]. Note that the concept of affordances has been already used in MAS [9, 20]. However the affordances have been considered as static properties of the environment which the situated agent can perceive.

The paper is organized as follows. Section 2 presents the related work and our motivations for the ego-centered representation. Section 3 explains the concept of affordances and the advantages of using it to study road space occupation practices. Section 4 describes our affordance-based agent model for the context of the traffic simulation. Section 5 presents the implementation of the model and discusses the experimental results. We conclude with a summary of our contribution and a presentation of our perspectives.

2. RELATED WORK

We are interested to reproduce the observed practices in terms of road space occupation, particularly in urban areas with a high traffic density context or specific events (urgency vehicles, stranded vehicles). The drivers do not always use the existing road configuration given by physical lanes defined by the road marking. They may occupy the free space according to their goals and their context. To improve heterogeneous traffic simulation, we need to understand the behavior of the different types of drivers. There has been some empirical studies [16] which aim to understand the motorcycle behavior and the properties of mixed flow.

Several multi-agent traffic simulation models were introduced to study the behavioral traffic simulation. In these models, drivers consider the road space according to the physical lanes and they are always positioned in the middle of their lanes [5, 12, 13]. They do not consider the observed phenomena of road space occupation. Thus, the resulting simulations do not reproduce real situations. Furthermore, Fellendorf *et al.* [7] use VISSIM, which is a commercial simulation tool based on mathematical models, to describe the continuous lateral movement for the case of heterogeneous traffic situations. The driver chooses the lateral position where he has the maximum longitudinal time-to-collision. To find this position, the driver divides the available road width in virtual lanes. These virtual lanes are constructed from the right and left sides of the preceding vehicles on the road, including some lateral safety distance. In our opinion, those parameters are not sufficient because the choice of the target lateral position is only based on an instantaneous evaluation. [2, 15] have proposed simulation models for the particular case of two-wheels vehicles. Lee's model [15] is based on the car-following model of Gipps [10] to describe both the moving of cars and two-wheels with some modifications for the motorcycles kinematic parameters to provide most suitable oblique movement. These interaction rules are integrated in an agent-based simulation model. The latter takes into account a limited number of parameters (of the vehicle ahead longitudinally or laterally) and does not allow a great anticipation of the traffic around the driver. Bonte *et al.* [2] introduced the concept of virtual lanes. They considered a systematic and geometric decomposition in virtual lanes of the space, the resulting dynamic number can thus be very high.

To provide a generic solution that considers the driver practices in terms of space occupation, two theories were proposed to deal with the representation of the environment: allo-centered and ego-centered representations [3, 24]. In ego-centered representations, spatial relations are generally directly related to the agent that builds a representation using a reference system with terms such as, for example, left, right, front, or back. When the context changes, all the spatial relations should be updated. Whereas, an allo-centered representation locates points within a framework external to the holder of the representation and independent of his/her position. Allo-centered representations are more stable but are more difficult to acquire. In addition, the number of the spatial relations is much higher since all the relations among different objects in the environment are considered.

The human driver "discovers" the situations as he/she moves. He/She needs to know what happens around him/her to make decision (go straight, changing lane to the left or to the right). From this point of view, the ego-centered representations are more intuitive in the context of traffic simulation, for which we need to have a contextual and dynamic representation of what is happening around the agent. Furthermore, the ego-centered representation is suitable to dynamic contexts because the number of relations to update is lower than the case of allo-centered representation.

El Hadouaj *et al.* [12] use an ego-centered environment representation that is composed of physical lanes given by the road marking. This representation does not permit to identify free space on the road and cannot reproduce the observed practices of road space occupation in the simulation like the behavior of two-wheels vehicles. The idea is to have an environment representation which takes into account the physical constraints of the environment, the context and the driver goals. We propose to use the concept of affordances to determine the possible actions afforded by the environment. Our ego-centered representation is composed by the identified affordances (the space occupation possibilities). For example, if a driver can not go straight toward (due to a lane closure), he/she will not necessarily add this lane to his/her representation of the environment. We can also consider the filtering behavior of the motorcycles: if there is a sufficient space between two queues of vehicles, the emergent lane should be integrated to his/her ego-centered environment representation because it affords him/her a possible action.

We present a novel approach to deal with the space occupation issue in the case of multi-agent traffic simulation. There are two key elements in our approach. First, we use the concept of affordances to identify the possible actions, in terms of space occupation, afforded by the environment. Second, we use an ego-centered representation of the situation around the agent.

3. AFFORDANCES

The theory of Affordances [8] is based on ecological psychology, which argues that knowing is a direct process. Affordances were described by Gibson [8] as action possibilities or opportunities for action that humans and animals can perceive in the environment. This description strongly suggests a set of specific design requirements to manage the interactions between an agent and its environment. The agent needs to perceive possible actions or opportunities for action directly in the environment.

Many researchers underlined that Gibson's theory is insufficient to explain perception because it neglects the processes of cognition [18, 20]. Those authors consider that affordances are the results of the mental interpretation of things, based on people's past knowledge and experiences, which are applied to the perception of these things. Raubal [20] used an extended theory of affordances within a functional model for affordance-based agent. It supplements Gibson's theory of perception with elements of cognition, situational aspects and social constraints. It has also been shown that integrating the affordance theory into agent architectures is an elegant solution to the problem of providing both rapid scenario development and the simulation of individual differences in perception, culture and emotion [4].

The concept of affordances has been largely used, especially in the domain of robotics and for problems related to way finding and for simulation of military operations [17, 19, 22]. This concept has been applied in the context of pedestrian steering [14] but has not been, to our best knowledge, used for the simulation of road traffic. It is suitable to the road space occupation. Affordances permit to identify the possible actions afforded by the interaction of the perceived entities and the environment in terms of space occupation possibilities. We propose thus an agent driver model for the space occupation issue based on the concept of affordances. The affordances allow the agent to build an ego-centered environment representation which takes into account the space occupation opportunities and facilitates thus the agent decision.

4. AFFORDANCE-BASED DRIVER MODEL

In our modeling of affordances, we use an extended version of this concept. It has been enriched with cognition. The affordances depend on the environment constraints as well as the mental capabilities of the agent. So, we consider the "situational" interpretation of the environment by the agents. To identify opportunities afforded by the interaction of perceived entities and the environment, the agent takes into account the context, the properties of the other agents and its individual properties (capabilities, intentions, goals, behavioral properties like the distance to the regulation[1]).

Within the framework of our application, an affordance corresponds to a possibility of space occupation resulting of the relationship between the physical environment and the perceived entities. Therefore, we consider the perceived properties of those entities (position, speed, type, etc.) and the individual characteristics of the agents (capabilities, distance to the regulation, type, width, etc.). The affordances identified by an agent may be different from those identified by another agent. The agent reasoning model is split into three steps following the Perception-Decision-Action loop model of decision making (see Figure 1).

[1]The distance to the regulation or to the norms is specified in a random manner during the agent initialization, it gives the degree of respect of the norm and ensures heterogeneity among agents.

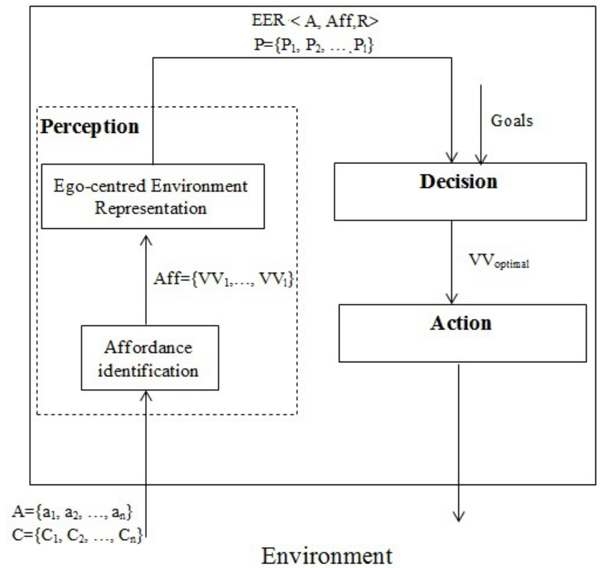

Figure 1: Agent model

4.1 Perception

Let $A = \{a_1, a_2, ..., a_n\}$ be a subset of all agents perceived by Agent a_i, at a given vision distance. Let $C = \{C_1, C_2, ..., C_n\}$ be a subset of the perceived characteristics of the other agents like the position, the type, the speed, etc. Each C_i is a set of properties describing each $a_i \in A$ and is given by $C_i = \{c_{1i}, c_{2i}, ..., c_{mi}\}$.

Let $\mathit{Aff} = \{VV_1, ..., VV_l\}$ be the set of affordances identified by Agent a_i around it. Those affordances result from the interactions of the perceived agents with the road configuration. The determination of affordances requires a cognitive process of perceived information to identify what are the possibilities afforded to the agent in terms of space occupation. This process verifies if an identified affordance corresponds really to a possible action. It is done with a payoff function, noted *payoff*, which allows to evaluate one potential possibility and determine if it can be a possible action.

This first step generates an ego-centered representation of the environment named EER_{a_i}. It is composed by the identified affordances and a set of affordances' properties P. Those affordances correspond to the space occupation possibilities. Each affordance VV_i is characterized by a set of properties given by $P_i = \{p_{1i}, p_{2i}, ..., p_{qi}\}$. This representation corresponds to an explicit mental representation of the situation and permits, therefore, to evaluate affordances and make a decision. Note that the sets of each ego-centered representation EER_{a_i} depend on the agent context. The details of this process are given in the next sections.

4.1.1 Affordance identification

An affordance corresponds to a space occupation possibility resulting from the interaction among the perceived entities and the road configuration. Typically, drivers move through the environment by following traffic lanes. In most traffic simulation models these traffic lanes correspond to the physical one which are defined by the road markings.

To improve the driver model, we suppose that the agents do not always use the physical lanes. The space occupation relies on the possibilities afforded by the environment, the characteristics of the perceived entities (position, speed, etc.) and the individual agents characteristics. These space occupation practices are not normative because the agents do not always follow the road marking. The representation of individual characteristics of agents (for example, distance to the norm, type of the vehicle, etc.) allows to have heterogeneous behaviors. For example, one space does not offer the same opportunities to an agent driving a two-wheels vehicle and an agent driving a truck. Moreover, one space does not afford the same opportunities to an agent with a normative behavior (do not consider inter-queues spaces as a possibility) and an agent with non normative one. For our model, we focus on this notion of traffic lanes for modeling the space. Therefore, affordances correspond to the possible virtual lanes. The latter have several characteristics such as width, depth (distance to the obstacle), average speed, speed of the walls (for example the speeds on the adjacent lanes), etc.

In the context of our application, we assume that the number of affordances cannot exceed 5. The affordances correspond to the following possibilities:

- Stay on its own lane
- Go to left towards an adjacent lane
- Go to right towards an adjacent lane
- Go to left to reach one space more to the left
- Go to right to reach one space more to the right

The two last possibilities represent "reachable" opportunities to the right or left, beyond the adjacent lanes. These lanes are not necessarily doubly adjacent (adjacent to adjacent lanes). They indicate lanes that are reachable by a series of changing lane maneuvers which may be sometimes unfavorable.

This choice is based on the following analysis. In a given traffic situation with interaction, the driver have the choice between staying on his/her lane and adapting to the constraint or changing lane (to the left or to the right). Further, to perform his/her changing lanes maneuvers, he/she needs to have information on what is happening in longitudinal (on his/her own lane) and in lateral (lanes directly adjacent to the left and to the right). In addition, a driver needs to have information beyond the surrounding environment in order to detect the most favorable options unreachable directly, but through iterations of maneuvers. Lane change can be an immediate solution to the constraint or a transitional step towards this goal, if the driver tries to reach a favorable lane crossing unfavorable ones.

The set $Aff = \{VV_1, VV_2, ..., VV_l\}$ gives the list of identified affordances. Each affordance corresponds to a possible virtual lane. The affordances are identifies by browsing the space around the agent from the closest environment to the farthest one.

We describe the different steps to determine the list of affordances available to the agent. From the list of perceived agents (ordered according to their lateral position from the right edge of the road to the left edge), the agent identifies the set of virtual intervals $IV = \{iv_1, iv_2, ..., iv_m\}$. A virtual interval iv_i is characterized by a width l and is defined either by the available space between the two vehicles or a vehicle and the edge of the road either by the space occupied by a vehicle. The intervals are ordered according to their starting and ending positions. From the list of identified virtual intervals, the agent identifies the list of affordances by browsing the intervals from the closest to the farthest (in terms of lateral position of the agent and the starting and ending positions of each interval). To do this, it starts by identifying and characterizing its immediate environment (its own lane) then its adjacent environment (adjacent lanes to the left and to the right) and finally its distant environment or non-adjacent (non-adjacent lanes to the left and to the right).

Immediate environment: The agent browses the set IV and identifies its own interval iv_k. This interval is transformed into a lane l_k by defining the above-mentioned parameters such as the depth (distance to the obstacle on the considered lane), the speed, density, etc. This lane is then added to the affordance set Aff. This new affordance corresponds to the action "stay on its own lane and go straight".

Adjacent environment: From its immediate environment (its own lane), the agent checks the space to the left and to the right to identify the possible affordances. The agent starts by evaluating the first interval. If the agent considers that this lane is more profitable, it adds this possibility to its list of affordances. Otherwise it merges this lane with the next one (if there is no physical marking through this interval) or it merges intervals until road marking. The agent affects so this new lane to its affordance list.

The evaluation mechanism is based on the lane properties identified above. Each agent has a choice between two actions: stay on its lane or change. This evaluation is performed through a function that compares the current velocity of the agent and the estimated velocity it could have on the target lane. The agent selects the lane which improves its speed. It estimates the speed of the identified lane and optionally adds it to the affordance list. This evaluation function is given by the difference between the two velocities[2]:

$$payoff(vc_{a_i}) = \tau * v_{a_i}(l_k) - vc_{a_i} \quad (1)$$

where a_i represents an agent, l_k is the lane k, $v_{a_i}(l_k)$ is the expected agent velocity on the lane l_k, vc_{a_i} is the agent current velocity and $\tau \in [0, 1]$ reflects the social acceptance of the filtering practice that differs according to the vehicle type (motorcycle, car, bus, etc.). $v_{a_i}(l_k)$[3] depends on the following parameters:

- $f_{a_i}(l_k)$: reflects the traffic flow characteristics of the lane l_k and depends on the lane density and on the lane average speed,
- $g_{a_i}(l_k)$: reflects the wall effect of the lane l_k and depends on the closeness of the walls and their stability in terms of speed,
- $h_{a_i}(l_k)$: is related to the individual characteristics of each agent and translates its distance to the regulation (normative and non-normative behavior).

[2] The choice of this function is completely empirical, we have chosen the parameters that affect the behavior of the agent based on psychological studies.

[3] The expected agent velocity on the lane l_k is given by the weighted sum of the parameters mentioned below.

The evaluation function is positive when the target lane is relevant for the agent (in terms of speed). This estimation takes into account the lane characteristics (width, depth, etc.), the wall characteristics (stability, proximity) and the individual agent characteristics, especially the distance to the norm.

Distant environment: For not immediate adjacent affordances, we propose to evaluate the lane, by browsing the road space from the immediate adjacent lane to the edge of the road (laterally to the left and to the right) and select the lane if its characteristics are better than the current lane (the browse is done on the set IV). Such a lane allows the agent to expect a profit, according to its own criteria and that depends on individual characteristics. The result of this step is a set of affordances corresponding to all the opportunities identified by the agent.

4.1.2 Affordance-based ego-centered representation

After identifying the list of affordances, the agent builds its ego-centered representation of the environment based on the detected affordances. Let EER_{a_i} be the environment ego-centered representation. EER_{a_i} is defined by the tuple $< A, Aff, R >$:

- $A = \{a_1, a_2, ..., a_n\}$ is a subset of all agents perceived by Agent a_i,
- $Aff = \{VV_1, VV_2, ..., VV_l\}$, with $l \leqslant 5$, denotes the set of identified affordances. Those affordances may be different from physical lanes initially defined by the road marking,
- $R = \{r_{a_i}(w_k)/w_k \in A \cup Aff\}$ is the set of relations. Each $r_{a_i}(w_k)$ establishes a binary relation between the agent a_i and each agent a_k from A reflecting the spatial relation between the two agents (to its right, to its left, front, back, etc.) or a binary relation between the agent a_i and each virtual lane VV_k of Aff reflecting the relation between the agent and the considered lane (the agent lane, the adjacent lane to the left, the adjacent lane to the right, etc.).

The identified virtual lanes are characterized by some properties. The width, depth (distance to the obstacle or lane closure), density, average speed are examples of those properties. We also take into account in our model parameters related to the wall effect that has an impact on the agent decision. The wall effect may be related to the infrastructure characteristics (lane width, the walls of a tunnel, etc.) or to the road context (the effect of the presence of trucks on adjacent lanes, the speeds variability on adjacent lanes, etc.).

We retain the following characteristics: the speed of each wall (it is the speed of the slowest vehicle of the lane which correspond to the wall or a speed of 0 in the case of a roadside), the stability of walls (given by the difference between the average speeds of each wall and we postulate that the more the speeds of the right and left walls are identical the more the wall effect can be considered as stable) and the proximity of the walls (space between the vehicle and the edges). These characteristics have an impact on the applied lateral position and speed.

4.2 Decision and Action

The ego-centered environment representation allows the agent to take a decision by choosing the optimal affordance. The result (or output) of the decision mechanism is a possible virtual lane with some properties like width, position on the road space, speed, speeds of lane walls. Those properties give a future lateral position of the agent and a possible lateral speed.

With the generalization of the virtual lanes as well as the enrichment of lane properties, we expect that the alternative to choose a virtual lane (inter-queues) will not be systematic and particularly for automobiles, trucks and bus, where "tolerance" associated with the use of such lanes is low as well as the gain in terms of travel time. For these users, it will be more favorable in case of specific events (presence of a vehicle badly parked, vehicle in an emergency). The filtering maneuver will be more suitable to two-wheels because of greater tolerance and a significant gain in terms of travel time. The proposed solution is also expected to improve the validity of the model for situations with an important number of lanes, in particular the consideration of "complex" tolls.

From the affordance-based ego-centered environment representation, the agent selects the affordance to adopt. It computes a fitness (score, interest value) for each affordance of Aff. This fitness quantifies the relative "strength" or "attractiveness" of all affordances, based on the target goals of the agent and its representation of the environment. Let $F_{aff}(VV)$ be the fitness.

$$F_{aff}(VV_i) = f(p_{1i}, p_{2i}, ..., p_{qi}, goal) \tag{2}$$

where the function $f(.)$ is defined such that $F_{aff}(VV)$ provides a numeric value indicating the strength (an expected utility) of a particular affordance. It is given by a weighted sum of the affordance parameters $p_{1i}, p_{2i}, ..., p_{qi}$ such as width of the lane, average speed, etc.

The choice of the optimal affordance is achieved through an evaluation of all identified affordances to determine the best one. The final output of the system is the affordance (space occupation possibility) VV_i associated with the optimal value $F_{aff}(VV_i)$. Optimality is defined by maximizing $f(.)$.

$$VV_{optimal} = arg \max F_{aff}(VV_i) \tag{3}$$

Once a decision has been made to adopt an affordance, the action must then be performed in the world. Note that the action can take time and performing action of adopted affordance is not immediately after the decision. The agent must verify the premises of the adopted affordance and can cancel the decision or make it possible with some specific actions.

5. IMPLEMENTATION AND EXPERIMENTS

Our model was implemented in a behavioral traffic simulation tool based on a multi-agent system, ArchiSim [6]. We carried out several experiments to validate our model. ArchiSim and the experimental results are described in the following sections.

5.1 ArchiSim: a traffic simulation tool

ArchiSim is a behavioral traffic simulation tool. It uses a neat simulation of road traffic based on psychological researches on the driver behavior [21]. The traffic is considered as an emergent phenomenon resulting from the actions and interactions of the various road actors (e.g. car drivers, pedestrians, road operators). Vehicle drivers are represented by agents. The core of the ArchiSim architecture is a process capable of providing, upon request, a symbolic description of the context of each agent. This "view server" contains all data related to the simulated environment as a description of the network, road equipment and the users evolving there. This process does not interfere in the decision-making of each agent; it is only responsible for delivering information. The decision is based on the agent knowledge of the dynamic context.

5.2 Results

There are many validation methods of traffic simulations: (a) the comparison with real data about the flow, the average speed of vehicles, the average speed at certain points, the time to travel, etc. (b) the opinion of psychologists or domain experts about the traffic, the behaviors, etc. (c) the user opinion during experiments. In the case of cars, some studies give the average speeds, the heaviness, the road occupation, etc. on itineraries thanks to sensors lay down the road and/or with equipped vehicles. Unfortunately, in the case of motorcycles, official studies about the average speed or their time to travel are not available. The observation of the motorcycle behavior is the alone possible validation.

To evaluate the individual behaviors of the agents in terms of space occupation, we use different scenarios where the agents are in situations of traffic suitable for observing the desired behavior. For the first scenario, we compare the behavior of a motorcycle driver in the reference model (the model of ArchiSim without virtual lanes) and in our model. For the second scenario, we compare the results of simulations to real data collected on real itinerary of 31 kilometers (19 miles). Indeed, we compare the behavior of a car driver and a motorcycle driver in terms of speeds, times to travel and space occupation behavior.

5.2.1 Road situation with a traffic light

We consider a road with 2 physical lanes. This road measures 1km long. We put a traffic light on this road at 800m and we perform simulations with a limited number of vehicles (20 vehicles) in order to verify the behavior of filtering maneuvers of motorcycles at the traffic light. We compare the simulations with the reference model (the model of ArchiSim without virtual lanes) and simulations with our model (affordance-based model).

Figure 2 shows that in the case of our model (right of Figure 2) the agent driving two-wheels chooses at the time step 1253 to fit and filter between the two lines of vehicles, moving to the head of a queue and stops at the traffic light (step 2501). Whereas, on the left of Figure 2 (reference model), we note that at step 3937, the agent stills behind the queue of the stopped vehicles. The behavior of motorcycle shown on the right of Figure 2 (in our model) results from the affordance based ego-centered environment representation. The motorcycle agent detects the possibility of the emergent virtual lane (between the two queues of vehicles) afforded by the interaction of the other agents with the physical road structure. This kind of behavior does not appear in the reference model (ArchiSim without the affordance-based model), as the lanes correspond to the physical ones. These two physical lanes are occupied by vehicles in front. Therefore, the two-wheeler driver gets stuck behind stopped vehicles until the light turns on green, it has not another opportunity. This kind of behavior does not always correspond to the two-wheels' behavior in an actual traffic situation. So our model reproduces behaviors that can be often observed in reality.

Our series of experiments compares the speeds of the motorcycle in both the affordance-based model and the reference model (without the virtual lanes). Figure 3 shows the speed curve for the motorcycle (with the affordance-based model and without). Between steps 0 and 1200, the motorcycle accelerates more in the case of our model than the reference model. This behavior is the result of using the virtual lane in our model, whereas it is blocked behind a line of slower vehicles in the case of the reference model. Between steps 1200 and 3000 the variation of the speed of motorcycle is the same in the two cases: the motorcycle breaks to stop at the red traffic light. At the step 3000, the light moves to green, the motorcycle accelerates faster in the case of our model than the reference model. It is at the head of the queue, in the first case, whereas in the second case, it is blocked behind a line of vehicles.

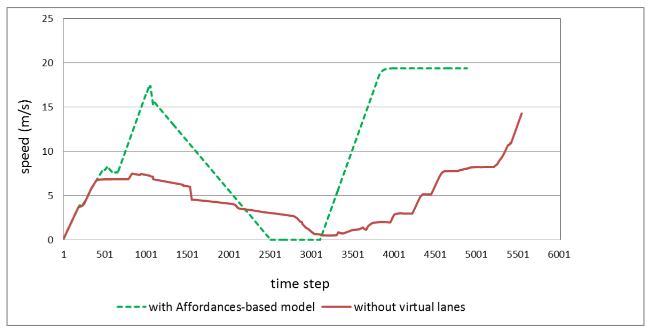

Figure 3: Speed curve of the motorcycle

5.2.2 Road situation with heavy traffic

In the second scenario, we consider a road situation with heavy traffic. We reproduce one real itinerary of 31km long with departmental roads, national roads and highway. For this itinerary, we have data collected by the ADEME[4]. Those data concern: travel time, average speeds and numbers of stops according to the vehicle type (car and motorcycle). First, we compare the results of our model with the reference model, to evaluate the impact of our agent model. Then we compare our results to real data. The traffic is composed by different types of vehicles: cars, buses, motorcycles and trucks. The real data and the results of simulations (with our model and the reference model) are summarized in Table 1.

We focus on the behavior of a car and a motorcycle generated with the same characteristics for this itinerary to study the impact of our model. The real data show that the travel time of motorcycle is half of the travel time of the car. It is not the case for the data of the reference model, where the travel times are roughly equal. This is due to the fact that the behavior is the same for cars and motorcycles. The latter use the physical lanes given by the road marking.

[4]The Environment and Energy Management Agency

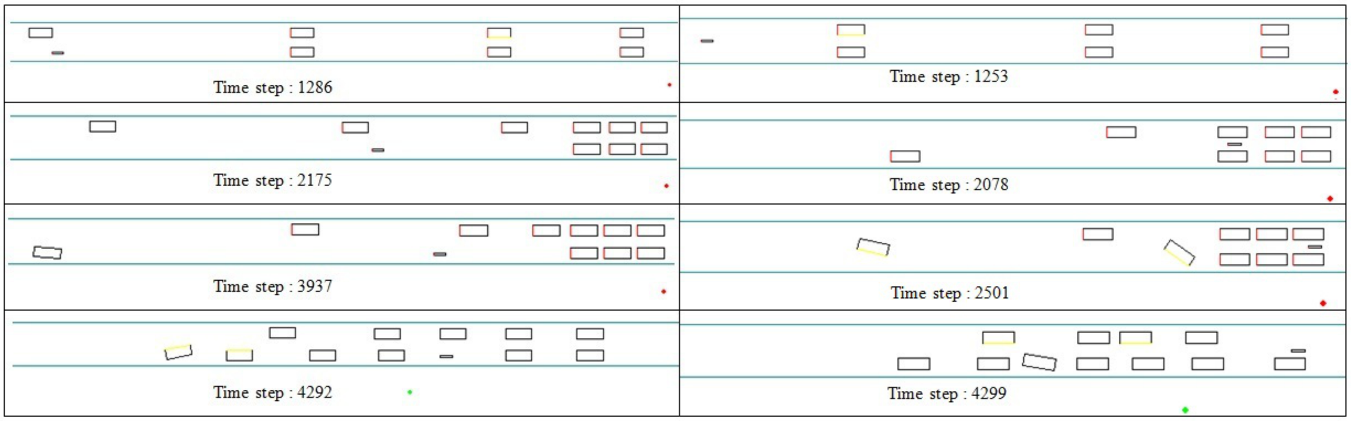

Figure 2: Comparing the behavior of motorcycle with the reference model and with affordance-based model

	vehicle type	travel time	average speed (km/h)	number of stops
Real Data	Car	1h 27min 10sec	21.18	78
	Motorcycle	44min 23sec	42.58	23
Reference Model	Car	54min 21sec	34.32	151
	Motorcycle	52min 58sec	35.11	137
Affordances-based Model	Car	58min 47sec	23.52	91
	Motorcycle	32min 10sec	43.09	35

Table 1: Real and Experimental measurement on a route of 31 kilometers

We compare our results to the reference ones. The difference between the car travel time and the motorcycle one has been improved, the motorcycle takes less time for the same journey. The motorcycle average speed is higher than the car average speed. We can also observe that the number of stops of the the motorcycle is lower than the number of stops of the car. So, the affordance-based model allows the agent driving a motorcycle to identify the virtual lanes afforded by the environment. Because of their size, motorcycles tend to use more virtual lanes than other types of vehicles. Their travel time and number of stops are lower than those of the cars.

Note that we observe the same trends, when comparing the obtained results (our model) to the real data. The difference between the simulation results and the actual ones is related to the calibration problem of the simulation. We have indeed no data to adjust precisely the flow or speed of the used vehicles.

We can conclude that our model takes into account the fact that the filtering practice is more tolerated for the motorcycle driver than for the car driver. The motorcycle takes less time than the car for a same journey. The choice of virtual lanes is not systematic; it depends on the lane characteristics as well as the vehicle characteristics and the agent individual characteristics. Our model is generic because it is not specific to one kind of driver. The behavior heterogeneity results from the different driving contexts and the individual driver characteristics coupled with generic rules.

6. CONCLUSION AND PERSPECTIVES

We are interested in the traffic simulation through a behavioral approach based on multi-agent systems. Our work intends to extend the validity of traffic simulation in urban and suburban areas, with a better consideration of the heterogeneity of the vehicles and driver behaviors in terms of anticipation positioning on the lane and space occupation. We proposed, in this paper, a new agent model based on an ego-centered representation of the environment. This representation allows the agent to take a decision in terms of space occupation. Our approach is based on the concept of affordances - the ways in which an agent can interact with its environment. Affordances permit to identify the possible actions afforded by the interaction of the perceived entities and the environment in terms of space occupation possibilities. In the context of our application, an affordance corresponds to a possible virtual lane.

We implemented our model with the traffic simulation tool ArchiSim. We validated some individual behaviors for specific situations. We also experimented our model for more complex situations. We compared the results of our model to real data. We find thus the same trends. In our model, the difference between the car travel time and the motorcycle one has been improved. The travel time of motorcycle is nearly half of the travel time of the car.

The obtained results are promising. But some improvements are needed to have a more complete model. We need more calibrations in order to limit the gap to the real data. One first perspective is to introduce cooperative behavior of agents. This kind of behavior can be observed in certain situations such as the presence of emergency vehicles where vehicles spread apart to let the latter pass or sometimes in the case of the motorcycles filtering behavior. Furthermore, it is interesting to compare our model with other general approaches for such heterogeneous contexts. However, to compare models, we need to implement them in the same tool and run experiments in the same context. It is an interesting issue but it is time consuming.

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