Towards a Truck-driver Model using a Hysteresis based Analysis and Verification Approach

(Extended Abstract)

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ABSTRACT

The complexity of human behaviors makes their modeling very difficult. To build a model that reproduce many concurrent aspects of those behaviors, we propose to use a test-driven like methodology. To validate this methodology, we reuse a car driver model and build a truck driver model by considering relevant aspects. We analyze, test and verify the model by using the hysteresis phenomena appearing in driver behaviors.

Categories and Subject Descriptors

I.6.0 [**SIMULATION AND MODELING**]: General; I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems

General Terms

Design

Keywords

Agent-based simulations, Test-driven, Hysteresis, Traffic, Truck

1. INTRODUCTION

Multi-agent simulation provides powerful tools to reproduce and study human and social behaviors. These behaviors show simultaneously reactive and deliberative properties. Furthermore, agent-based models are usually created to study emergent macroscopic phenomena, which are the results of the agent interactions. Therefore to validate the properties of those models, most of the attention is dedicated to the macroscopic view, and not to the individual one. Thus creating an adequate model is a non trivial task, because the desired output of the simulation is not directly specified in the model [1]. Moreover when a model produces the adequate emergent phenomena, it is generally not clear which modeling hypotheses are responsible for it [3].

Traffic simulation illustrates all of those issues since agent based models reproduce the driver behaviors, and most of the validation work is done on macroscopic properties such as traffic density, throughput and flow velocity.

In this work we propose to produce a model of the behavior of truck drivers, which are known to have a significant impact on traffic congestions, by focusing on individual properties of the behavior. We introduce a test-driven methodology to develop the truck model. The model we base our work on is ARCHISIM [2] which provides a car model. This methodology consists in identifying and specifying required aspects of the behavior in order to verify that the produced model matches those requirements. We present one iteration on the property, identification and specification, model adjustment and verification loop.

2. HYSTERESIS BASED ANALYSIS

To study and specify the desired behavior of truck, we focus on hysteresis phenomena — *i.e.* the lag of the reaction compared to its cause — in behavior. This lag is represented in a two dimensional space. The two considered values are the gap head of the current vehicle and its speed. The gap head of the vehicle is assimilated to a constraint applied to the vehicle, and its speed is its reaction when it is subject to a constraint as illustrated in Figure 1. Most models from traffic literature assume a direct relation between those values. Therefore, for a given constraint, the studied vehicle tries to get a stable speed. Those states are called *stable*

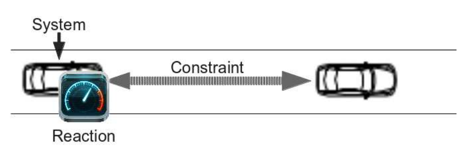

Figure 1: Subject to a constraint, a vehicle needs to adapt its speed to maintain safety. The constraint is quantified as the gap head (Δx), and the reaction is the speed ($\dot{x}$).

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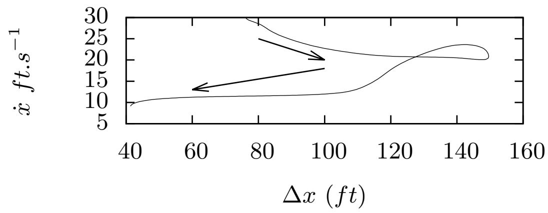

Figure 2: Hysteresis observed for the vehicle number 2851 (truck) in the US101_0750-0805 dataset.

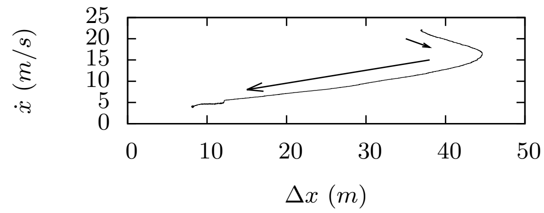

Figure 3: Simulated truck behavior during a deceleration phase.

states and represent the traveling strategy of the driver in a stable traffic (i.e. a traffic without perturbation such as stop and go waves). When the vehicle is in a non stable traffic, the related constraint varies according to accelerations and decelerations of its predecessor. Analysis of the evolution of the state of the vehicle in the gap-speed plan allows to identify its behavior. Acceleration phases below equilibrium states and deceleration phases above reflects the lag of the reaction of the driver (hysteresis). Deviations from this scheme reflects that the studied driver manages to adapt and anticipate the speed change it has to operate.

This analysis method is consistent with the widely accepted psychological framework proposed by J. Michon [4]. This framework proposes to analyze the behavior as the aggregation of three layers : 1) the strategic layer that manages long term strategy, that influences the equilibrium states; 2) the maneuver layer that deals with short term actions, it influences the position of the hysteresis loop (below or above the equilibrium states, rotation direction . . .); 3) the control layer responsible for low level actions. This layer influences the magnitude of the hysteresis phenomena.

3. TOWARDS A TRUCK MODEL

We use the hysteresis based analysis method to study truck behavior from observed data provided by the NGSIM project (`http://ngsim-community.org`).

We focus on truck behavior during deceleration phases. Observation shows that most trucks exhibit strong anticipation capabilities, required by their limited dynamic capabilities. Figure 2 illustrates two phases : 1) decrease of the speed and increase of the gap show that the predecessor still goes faster; 2) deceleration of the predecessor with stronger braking capabilities reducing the available gap. In similar situations, none of the simulated vehicles can reproduce such behavior. As mentioned previously, deviation from regular hysteresis reflects the influence of maneuver layer of the behavior. Therefore only this aspect of the model is altered.

During deliberation phase, the truck agent computes its acceleration based on the behavior of surrounding vehicles. For each slower vehicle down the road (constraint), the agent evaluates the needed acceleration to reach its stable following position. This stable position is reached when the current agent speed is equal to the constraint speed, and when the gap between the two vehicles is equal to the security distance — a stable state — proposed by the strategic level:

$$\begin{cases} x_c(\tau) - x_a(\tau) = \mathcal{G} \\ \dot{x}_c(\tau) = \dot{x}_a(\tau) \end{cases} \tag{1}$$

where τ is the time when the agent reaches the stable following situation, $x_a(\tau)$ its position when the state is reached and $\dot{x}_a(\tau)$ its velocity at this time. $x_c(\tau)$ and $\dot{x}_c(\tau)$ respectively represent the position and velocity of the constraint. $\mathcal{G}$ is the safe gap between the two vehicles:

$$\mathcal{G} = \Delta x_{\text{safe}}(a) + \sum_{i \in \mathcal{B}} \text{length}(i) + \Delta x_{\text{safe}(i)} + \text{length}(c)$$

where $\mathcal{B}$ is the set of vehicles between the agent and its target constraint (c). length(i) is the length of the i^{th} vehicle, and $\Delta x_{\text{safe}}(i)$ is the gap the agent believes the i^{th} agent will adopt at time τ. The acceleration γ the vehicle adopts in order to reach the target state (Equation 1) is given by:

$$\gamma = \frac{[v_c(0) - v_a(0)]^2}{2\,[-x_c(0) + x_a(0) + \mathcal{G}]} \tag{2}$$

We assume that c adopts a constant speed. The remaining aspects of the maneuver layer in Archisim are not modified. So an agent selects the strongest constraint down the road and adapts its acceleration according to it.

Given those modifications of the model, we are able to reproduce the major aspects of the hysteresis loop from Figure 2 as shown in Figure 3. Moreover, we are able to reproduce important properties of traffic flow such as local capacity drop around truck in unstable traffic that tend to degrade the traffic situation.

This work shows that a test driven approach that focuses on specific aspects of the behavior helps to reproduce sophisticated human behaviors and the resulting emergent phenomena. Further validation is needed to highlight the improvement of the resulting model over the original approach.

4. REFERENCES

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