Analysis of Lane Level Dynamics for Emergency Vehicle Traversal

(Extended Abstract)

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ABSTRACT

Slow moving traffic in heavily populated cities, can many times result in loss of lives due to emergency vehicles not being able to reach their destination hospitals on time. In this paper, we assume the usage of inter vehicular communication to optimize the lane level dynamics for an Emergency Vehicle Agent (EVA), traversing a multi lane stretch of road in an urban traffic setting. In particular, we present the Fixed Lane Strategy (FLS) and the Best Lane Strategy (BLS) for EVA traversal. FLS is a simple strategy that acts as a good baseline while BLS is a sophisticated strategy that can adapt to varying traffic patterns.

Keywords

Lane Level Dynamics, Emergency Vehicles, Traffic Simulation, Intelligent Transportation Systems, SUMO - Simulation of Urban Mobility

1. INTRODUCTION

Recent advances in the field of **Intelligent Transportation Systems (ITS)** makes it increasingly likely that vehicles in the near future will be equipped with advanced systems that allow inter vehicular communication. This is being made possible using VANETS (vehicular ad hoc networks), a key component of ITS. Vehicle to vehicle (V2V) communication will allow for several innovative methods of urban traffic management. In this paper, we will study one application of this technology that can improve the traversal time of Emergency Vehicles (EVs). Note that we only assume usage of inter-vehicular communication system (V2V) but not the usage of any other road side infrastructure. We perform our analysis using a free and open microscopic traffic simulation suite named **Simulation of Urban MObility (SUMO)** [1]. We use its rich feature set to simulate a variety of realistic traffic scenarios, introduce the EV modeled as an Agent (EVA) into the environment and allow its behavior to play out in the simulation.

Much of the previous work on this topic has focused on developing techniques to identify better lanes for vehicles in general. There are lane changing models that are used by vehicles in microscopic traffic simulation suites like SUMO [3]. However they do not focus on EVAs, which need specialized routing strategies to take advantage of the fact that other vehicles make way for EVAs and also to account for the accurate information about other vehicles such as speed, vehicle position, etc., available due to ITS assumptions.

The works that do focus on better routing of EVAs, describe the best path to be taken by the EVA but do not describe the actual traversal details (like lane selection/ changing), once a stretch of road in the path is identified. In this paper, we focus specifically on the lane level dynamics for an EVA. In particular, we describe the **Fixed Lane Strategy (FLS)** and **Best Lane Strategy (BLS)**, and the improvements they provide. While FLS is a simple strategy that acts as a good baseline, BLS is a sophisticated strategy that can adapt to varying traffic patterns. Unlike prior works, where the decision to traverse on a lane(s) is based on the presence of a faster leader(s), BLS uses a utility function which by including average speeds, slowest speeds and normalized free space considers both the possibility of an immediate faster lane and the clearing time of other vehicles.

2. THE STRATEGIES

We now describe the FLS and BLS strategies that would enable an EVA to handle better lane level dynamics while traversing on a multi-lane stretch of road. These strategies only specify the lane that the EVA should travel in while the low-level dynamics of traversal namely speed, acceleration/deceleration and the dynamics involved in changing the lane for the EVA are handled by SUMO. Another task these strategies perform is to identify the appropriate vehicles to send lane change requests.

2.1 The SUMO strategy

For purposes of modeling EVA traversal behavior using SUMO, we perform the following extension: In real-world, EVAs have sirens and lights to indicate other vehicles to make way. To model this into SUMO, we add communication on top of the SUMO default strategy. This will allow EVA to send lane change requests to vehicles on its current lane up to a distance, c_d in front of it. We assume that all lane change requests sent will reach the intended vehicles and vehicles will try to clear immediately upon receiving them. Similar communication facility is assumed for FLS and BLS strategies (not to model the effect of sirens/lights

Appears in: *Proceedings of the 15th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2016), J. Thangarajah, K. Tuyls, S. Marsella, C. Jonker (eds.), May 9–13, 2016, Singapore.*

but) due to the availability of V2V communication. Availability of communication in SUMO provides an advantage to the EVA since in real traffic scenarios sirens may not always be heard or drivers may not always know the lane to clear until the EVA is in sight. Also, the SUMO strategy includes the simulator's state of the art lane change model which has been shown to compare favorably against other competing models described in [3]. Hence, the SUMO strategy we use for bench-marking is expected to be favorable to the EVA in terms of travel time.

2.2 The Fixed Lane Strategy (FLS)

FLS is a baseline strategy that is based on the following idea: the EVA identifies the lane, that is fastest on an average, based on prior information and picks that as the fixed lane for its entire journey. Assuming a right handed driving system, in most cases leftmost lane is the fastest, as faster vehicles tend to move on the left lanes while the slower ones move on the right lanes (the vice-verse typically holds true for left handed driving systems). When using FLS the EVA therefore moves to the leftmost lane from its current position and then tries to clear out the vehicles from that lane.

2.3 The Best Lane Strategy (BLS)

In BLS, the EVA calculates the utilities of the current lane and the other lanes using the utility computation function described below and then takes a decision to switch if it is beneficial to do so. Similar to FLS the EVA tries to clear out vehicles from the lane it currently is in. Also, the EVA can get the information about the speed and position of vehicles upto the **communication distance (c_d)**.

We envision utility u_l, of a lane l, to be a function of the following factors: (a) Normalized speed of the slowest vehicle, calculated as (speed/maximum possible speed) and denoted by $\frac{a}{m}$ (since traffic on a lane eventually moves at speed of the slowest vehicle). (b) Normalized average speed (many times a vehicle(s) might be temporarily slow since it is just about to change a lane or near an intersection i.e., give some weight to average rather than decide entirely on temporary phenomenon), $\frac{b}{m}$, calculated as (average speed/maximum possible speed), and (c) Normalized free space (since not all vehicles may be able to switch lanes immediately after a clear lane message is received), an approximation computed as $\frac{n-c}{n}$, where c is the number of vehicles present on the lane l upto distance c_d, and n is the maximum number of vehicles that can be on the lane upto c_d. To compute n we assume an average length for vehicles which makes the computation an approximation. Here, m , maximum possible speed, is the speed limit of the road (different lanes can have additional speed restrictions). Combining the terms:

$$u_l = w_a * \frac{a}{m} + w_b * \frac{b}{m} + w_c * \frac{n-c}{n} \quad (1)$$

where w_a, w_b, w_c are the weights of each of the terms. At the beginning of the simulation an EVA starts on the lane with maximum value of u_l. Utilities are recomputed every t seconds and lane changes happen when the utility of the best lane u_b, exceeds the utility of the current lane u_c, by at least δ to compensate for lane switching overheads:

$$u_b - u_c > \delta \ (\mathit{Condition\ for\ lane\ change})$$

In addition to the above described strategies, we also model the **Empty road baseline (ERB)** strategy. The ERB strategy acts as a lower bound on the EVA traversal time and captures the time taken by the EVA when there are 0 vehicles on the road apart from the EVA.

3. EXPERIMENTAL RESULTS

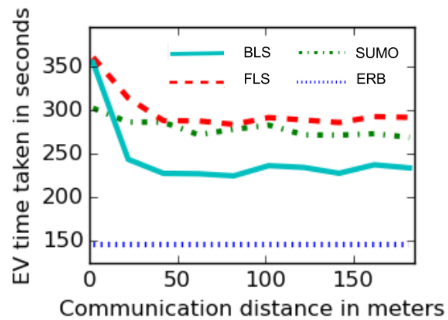

Figure 1: Variation with communication distance, c_d

For purposes of this experiment, we modeled an urban traffic environment corresponding to a densely populated city namely New York City. We tested on a wide range of lane speeds, calibrated using data from a data set providing us with actual traffic speeds of a comprehensive set of roads in New York city available from the City of New York Department of Transportation [2]. Our results in Figure 1 are an average of our simulations for a 2 km representative stretch of a road. The experiment shows how the four different strategies ERB, SUMO, FLS and BLS perform when c_d changes. The figure shows the different values picked for the parameter c_d on the x-axis (in meters) and the time taken by the EVA on the y-axis (in seconds).

FLS, BLS and SUMO strategies gain advantage from an increase in c_d as the EVA can send lane change requests to farther vehicles. BLS gains additional advantage as it also uses the information about speed and position of other vehicles present in different lanes upto distance c_d, to compute better lanes. However, increasing the distance to greater than say 75 meters, does not lead to much better computation of utilities since additional vehicles may not add much to the existing information. Overall we can conclude that, for realistic distances involving single hop communication, BLS performs significantly better than FLS and SUMO strategies (e.g., 18.90% and 16.42% improvement at $c_d = 100$ meters).

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