2019 Third IEEE International Conference on Robotic Computing (IRC)

Probabilistic Interaction-Aware Occupancy Prediction for Vehicles in Arbitrary Road Scenes

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***Abstract*—This paper drafts a new interaction-aware approach to predict road user occupancy through vehicle-specific probabilities of presence. Instead of presenting another behavior prediction approach which tries to predict the most likely vehicle positions, the aim is to determine the likelihood of all feasible vehicle positions, called probability of presence. Thus the occupied area derived from this probability of presence blocks less space compared to existing approaches in the field of occupancy prediction. For this purpose, based on a physical model the future presence areas of a vehicle are fully calculated in a discrete consideration. Each movement possibility is evaluated taking into account the statistically typical driver behavior and interactions with static and dynamic objects. This gives rise to a qualified prediction of the future behavior of vehicles which blocks less space compared to all feasible future vehicle positions, like demonstrated in the numerical example.**

***Index Terms*—occupancy prediction, behavior prediction, autonomous vehicles, advanced computing applications**

I. INTRODUCTION

The future relevance of autonomous driving cars, trucks and buses entails far-reaching research efforts in the academic sector as well as in the automotive industry. According to human drivers [1], autonomous vehicles as well require a strategy to handle the uncertain behavior of other traffic participants. This motivation leads to the development of the behavior and motion prediction research field, with the aim to predict as exactly as possible the unsafe behavior of other road users, e.g [2]. Even though the prediction quality of some approaches is impressive, a sufficient safety is currently not ensured during autonomous driving. Therefore, additional approaches which calculate the occupancy prediction of road users have been established, e,.g. [3]. This predicted occupancy correspond under certain limitations to all feasible positions of the vehicle, depending on implementation arbitrary road networks, traffic rules and the interaction between vehicles are considered. Thereby the safety for autonomous driving should be ensured. However, the occupied prediction areas, especially in unstructured traffic are typically oversized, because the very unlikely but feasible vehicle positions are also considered in the occupied prediction. Therefore, this demo paper presents the draft of an interaction aware motion prediction approach with the aim to determine the vehicle occupancy. This means, instead of trying to predict the likely positions, the aim is to evaluate all feasible vehicle positions with a likelihood, called probability of presence. Thus the occupied area derived from this probability of presence blocks less space compared to all feasible positions by ignoring the very unlikely areas without neglect the safety requirements.

To knowledge of the authors, this is the first work which draft an approach for determining occupancy prediction by calculating the likelihood of all feasible positions. Therefore, two new basic requirements are introduced: *Gap-less prediction* - It must be ensured that probable presence locations in the occupancy area are not rejected due to an incomplete prediction. *No limitation to predefined maneuver or predefined environments* - The more unstructured/chaotic road traffic is, the more predominate the risk of an incorrect prognosis due to the incompleteness of the considered maneuver set or the limitation to structured/predefined environments (intersection, roundabout, lane markings).

II. APPROACH

A. Physical Model

The aim of the draft method presented in this paper is to be able to make a situation-generic, area-based prediction to determine the occupancy of the considered vehicle. To achieve this, all possible locations in the forecast period must be taken into account based on the current position. In the implementation presented, this is realized via sufficiently precise discretization of presence areas in the form of a trajectory array. To this end, trajectories are not derived from maneuvers, but are determined by a suitable physical model. The general validity of this model ensures that it applies to all situations. In figure 1-a.) a suitable parameter free kinematic model is used to calculate trajectories for all consider lateral acceleration ($a_y \in [-3\frac{m}{s^2} + 3\frac{m}{s^2}]$ with $\Delta a_y = 0.1\frac{m}{s^2}$).

B. Acceptance Distribution

Once the potential future presence areas have been determined, the second step is to evaluate them in accordance with the driver's behavior. Therefore, the three different acceptance values are calculated for each calculated trajectory. Whereby each acceptance value quantifies a relevant influence on the future behavior and assesses whether a driver fully accepts a trajectory (value is 1) or completely avoids

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978-1-5386-9245-5/19/$31.00 ©2019 IEEE
DOI 10.1109/IRC.2019.00081

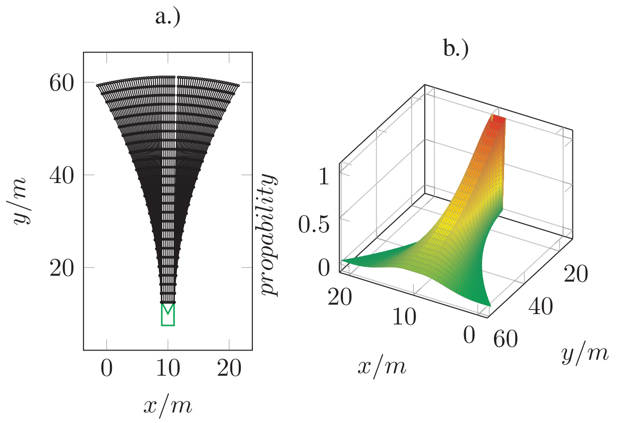

Fig. 1. vehicle state: $v_{l,Veh0} = 19.4\frac{m}{s}, x_{l,Veh0} = 10m, y_{l,Veh0} = 10m$ a.) predicted position of the vehicle - b.) probabilities of presences)

it (value is 0). The overall behavior can be determined by combining the following three acceptance distributions.

Statistically typical driver behavior - This acceptance distribution is intended to reflect statistically typical driver behavior. This should result on the one hand in a prediction as clear as possible in situations without static- and dynamic objects and on the other hand evaluate atypical behavior for now by a lower acceptance.

Relevant structural elements of road traffic (e.g. lane markers) and static objects - To quantify the influence, the driver is assumed to avoid static objects and structural elements of road traffic proportional to their traverse-ability. Accordingly, every static object is defined by a polygonal line and a weight that quantifies the traverse-ability in a value range of 0 to 1. e.g. no traversable static objects 1, solid road marking 0.8, dashed road marking 0.1.

Mutual influence of dynamic objects - Obviously, the behavior of driver is influenced by other road users. Accordingly, mutual interactions are also taken into account by an acceptance distribution. The conceptual basis for this is the assumption that drivers inherently want to avoid collisions with other vehicles, so that the global collision risk falls below a defined threshold.

C. Probability of presence

The questions ”Where can the vehicle go” and ”Where does the driver want to go” are answered with the possible future presence areas and the acceptance distribution. In the last step of the method, this information is combined by assigning every trajectory the associated value of the acceptance distribution. Afterwards every time step in the prediction is normalized which results in the probability of presence. Thus, figure 1-b.) shows the probability of presence for a exemplary normal distributed acceptance distribution.

III. NUMMERICAL EXAMPLE

This inner-city situation was chosen as an example because it represents a combination of structured and unstructured environments. The entry and exit points are similar to crossroads (structured). However, the roundabout clearly has multiple lanes without lane markings (unstructured). The behavior of the blue vehicle (Figure 2-b) is considered. Due to the vehicles entering the roundabout the likely lane-change maneuver towards the center is predicted correctly. Accordingly, the occupancy of areas of an increased probability of presence e.g. $P_l > 0.1$ (figure 2-b orange and magenta framed area) is significantly less, compared to all feasible positions (figure 2-b gray framed area).

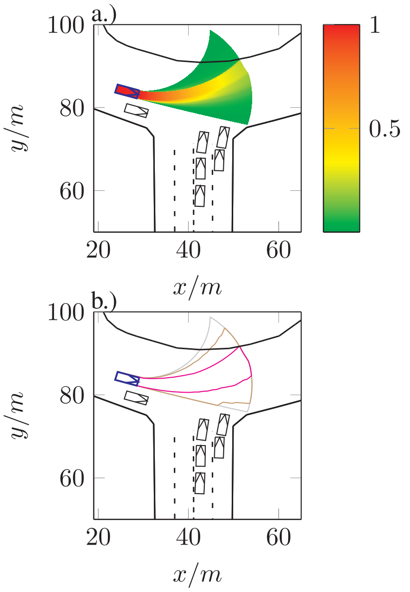

Fig. 2. a.) Situation including lane markings, not evaluated vehicles in black and the probability of presence P_l of the evaluated blue vehicle - b.) Situation including occupied areas in gray $P_{safety} = 0$, in orange $P_{safety} = 0.01$, in magenta $P_{safety} = 0.1$

IV. CONCLUSION

This paper drafts a new interaction-aware approach for predicting road user behavior through vehicle-specific probabilities of presence. In the last chapter, the correct prediction was demonstrated and shows the differences in the occupied area size, between all feasible future positions and all likely future positions. Particularly in unstructured environments, the approach presented in this paper is able to predict the behavior correct and enables the derivation of an occupancy predictions with acceptable area sizes. In the future it is planned to evaluate the dataset on real world data and present the approach more detailed.

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