

SILA: An Incremental Learning Approach for Pedestrian Trajectory Prediction

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Abstract

The prediction of pedestrian motion is challenging, especially in crowded roads and intersections. Most of the current approaches apply offline methods to learn motion behaviors, but as a result, they are not able to learn continuously and typically do not generalize well to new environments. This paper presents Similarity-based Incremental Learning Algorithm (SILA) for pedestrian motion prediction with the ability of improving the learned model over the time as data is obtained incrementally. To keep the model size efficient, the motion primitives learned from the new data are compared with the previously known ones, and similar motion primitives are fused while novel motion primitives are added to the model. Results show that the SILA model growth rate is about 1/3 that of an incremental approach that does not fuse motion primitives. SILA is evaluated on different datasets and scenarios including intersections and busy streets. The results show that, even though SILA learns incrementally, it performs comparably to (and sometimes outperforms) state-of-the-art algorithms in pedestrian prediction. Additionally, SILA learning time only depends on the size of the data added incrementally, which makes SILA more efficient in terms of time and space compared to batch learning.

1. Introduction

Safe navigation of autonomous vehicles in urban environments requires accurately predicting motions of other moving agents, including cars, cyclists and pedestrians. Pedestrian motion prediction is challenging as compared to other agents, as the rules are less clear and more frequently violated. Moreover, pedestrian behavior is also complicated by their interactions with other road users.

Machine learning techniques have been used to model complex pedestrian motion behavior by incorporating contextual features [1–3] and/or the interaction between other road users [4–8]. However, most of these techniques

are limited to offline (batch) setting. The offline setting becomes impractical when training data is incrementally available or when the autonomous agent has to explore new environments. Batch learning does not have the option of learning *incrementally* and hence, limits the generalization of the pre-trained model to new pedestrian behaviours and environments. Moreover, incremental learning provides the flexibility of learning new behaviors using relatively fewer data points as opposed to learning from scratch. Such a setup is significantly more efficient and better suited to autonomous driving applications where there is a need for real-time learning. The need to maintain pedestrian privacy might further limits the possibility of storing past data and re-learning from the past and new data combined (batch learning). Instead, if an agent can learn incrementally, its prediction model can be improved continually from new streams of data or “few-shot” examples without the need to access past data. Additionally, incremental learning enables systems with limited resources to process big data gradually in scenarios where offline learning is impractical. Although there has been a lot of work in incremental learning in different domains [9–11], there are very few prior works on incremental learning of pedestrian behaviors.

This paper presents a Similarity-based Incremental Learning Algorithm (SILA) for incremental learning of motion primitives for pedestrian motion prediction. To the best of our knowledge, the only prior work on incremental learning for pedestrian motion prediction is presented by Vasquez *et al.* [12] and is based on Growing Hidden Markov Models (GHMMs). Similar to other Markovian approaches, GHMMs depend on goal estimation for inferring pedestrian intent which requires complete un-occluded trajectories for training. However collecting such datasets is impractical in busy and crowded domains such as intersections, campus areas and shopping centers, where often a part of the pedestrian trajectory is occluded by obstacles and other agents.

In another work, Chen *et al.* [13] combined the merits of Markovian-based and clustering-based methods for the task of pedestrian trajectory prediction. In their approach, trajectories are segmented based on motion primitives learned us-

