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Trajectory Reconstruction Using Reinforcement Learning

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Preface

A few years ago, I would have never thought I would be at the place I am now, neither personally, nor professionally—and not even physically! After a 3 year-long chain of serendipitous events, now I sit, writing the final words of this thesis. Submission of this thesis marks the end of an important chapter in my life—perhaps the most important thus far. I am really grateful for having had the chance to study this program at KU Leuven; the past two years have definitely changed me for the better.

Personal notes aside, I would like to express my gratitude to my promotor, Prof. Tampère, whose manner of thinking/articulation has guided/influenced me throughout these two years, and whose key insights have always set me on the right path. I would like to also thank my assessor, Prof. Bruyninckx, whose thought-provoking remarks triggered an important change in my thinking during this thesis. I was fortunate to have Ali and Anne as my daily supervisors, who accompanied me throughout the ups and downs of this thesis; I would like to especially thank them for putting aside time in their busy schedules to give multiple feedbacks on my text.

Lastly, I would like to thank my loved ones, who accompanied and supported me; they know that without them life would have been much less pleasant during these busy months.

And a final note for you, dear reader, I hope you enjoy reading this text—or at the very least, the insights from this thesis can stand you in good stead.

Nikzad Rezaie

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Abstract

It has been widely observed that lane changing maneuvers (LCMs) give rise to safety issues and many undesired traffic flow phenomena. Despite its significance, the study of LCMs is hampered by the lack of long, lane-level trajectory data. Such data is hard to collect, and only a handful of reconstruction methods exist for this purpose. This thesis seeks to fill this gap by providing a reconstruction method for matched loop detector (LD) observations from two successive LD stations.

The method reconstructs longitudinal trajectories by fitting unique cubic splines on the upstream and downstream LD observations. Then, it uses reinforcement learning (RL) to approximate the position of LCMs along the splines. To realize this reconstruction task, first, the feasibility conditions of a trajectory set between two successive LD stations are defined. Then, based on the defined feasibility conditions, two RL formulations are proposed: one based on single-agent RL (SARL), and the other based on multi-agent RL (MARL).

The LD observations originate from a busy 5-lane weaving area on the R1 ring of Antwerp, Belgium. This thesis specifically focuses on a 3-lane, 216-meter segment directly upstream of the entry gore. From this segment, three data samples are considered, all spanning over a congested period during a morning peak. Several training and test cases are considered based on these samples.

The results strongly suggest that the MARL formulation outperforms the SARL formulation. The MARL results on all training cases and smaller test cases are near-optimal. In larger test cases, the results may deviate from optimality.

The main contribution of this thesis is in the potential generalizability of the proposed method, which can enable the reconstruction of large volumes of trajectory data through training on a small representative sample. Three major barriers to generalizability are identified: cubic splines artifacts, violation of the Markov property, and handling of multiple feasibility conditions with a single-objective framework. Future research directions are dedicated to resolving these barriers.