Road regulation sensing with in-vehicle sensors

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Abstract The purpose of this research work is twofold. The first problem it attempts to address is the inference of regulators that control the traffic (i.e. traffic signs, traffic lights) for enriching maps with new features. The second is related with how we can assist the drivers by communicating the previously mined information in the context of driving safety. As data sources, we use in-car sensors which are accessed through CAN-Bus (spatial data and dynamic features of motion). We introduce the notion of *road-regulation sensing* and propose unsupervised methods for mining a subset of common traffic regulators. For detecting anomalous driving behaviour resulted from the violation of the valid local regulations, a probabilistic spatio-temporal approach is proposed based on modelling the routes at the places of interest (here, traffic regulators).

1 Introduction

As navigation devices nowadays have become an important assistant tool for the drivers due to the ever increasing mobility needs and the complexity that the constantly evolving road network introduces, it is getting apparent the requirement of up-to-date maps that reflect the *real* topological and topographical features of the

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In: A. Comber, B. Bucher and S. Ivanovic (Eds.): Proceedings of the 3rd AGILE Phd School, Champs sur Marne, France, 15-17-September-2015, published at http://ceur-ws.org

road network. According to [7], roads change by as much as 15% a year, a fact that further highlights the importance of the map update process.

Mapping with survey equipment is a time and cost expensive procedure which makes frequent map updates prohibitive. For this reason, researchers have tried to overcome these restrictions by using crowd-sourced GPS traces captured by everyday vehicles with simple GPS devices or through User Generated Content (UGC), enabling that way mass-market mapping (e.g. OpenStreetMap) based on affordable GPS receivers, home computers, and the Internet [4]. A wide range of different methods has been proposed for automating the map construction process [1, 5, 8] and for improving the existing road data by harnessing incoming new information from GPS traces [9, 10]. A less explored though, from the *sensing* point of view, category of road-related features is that of road regulators (e.g. traffic signs, lights), which plays an important role in driving safety. The purpose of this research work is twofold. The first problem it attempts to address is the inference of regulators that control the traffic for enriching maps with new features. The second is related with how we can assist the drivers by communicating the previously mined information in the context of driving safety. In the next section we discuss existing approaches that tackle these problems, revealing their drawbacks and highlighting the robustness of trajectory analysis oriented methods.

2 Existing approaches

Beyond the manual entry of road regulators in map databases, most of the existing methods for mining them are based on computer-vision and rely on cameras [2, 3]. As a result, in environments where the traffic is regulated by rules which haven't the form of a visual sign (e.g. slight rise in road level), such approaches will fail to recognize the regulation context of road network or different components have to be built for the recognition of each individual case of regulators. On the other hand, nowadays, vehicles are equipped with thousands of electronics that monitor different functions of car's units and therefore vast opportunities and challenges can emerge from exploiting these data. In the context of regulation sensing, processing data from multiple cars in incremental way can reveal such information that on one hand it could be difficult to be recovered with traditional methods and on the other hand it can enrich the digital maps with accurate and up-to-date semantics. Consequently, a basic question that motivates this research has to do with how data derived from CAN-Bus can be processed so that the result of such a fusion to contribute to a new map layer which can be regularly and automatically updated.

3 Regulation-aware navigation: significance and applications

The recovered traffic rule set, except of enriching the map content with contextual information, can be likewise used for other applications. Contextual information is important when Advanced Driving Assistance Systems (ADAS) assess in real-time the risk of vehicles' collision. Lefèvre et al.[6] show that by taking into account contextual information such as the intersection layout, the presence of other vehicles and the traffic rules, false alarms of ADAS can be reduced, due to an overall better interpretation of the predicted driving behaviour of the traffic participants. Furthermore, modelling the typical behaviour of dynamical features of movement (e.g. speed, acceleration) in form of prototypical sequences of activity patterns, categorization of the observed behaviour is feasible.

Under this framework, maps that include road rules and embed spatio-temporal models of driving behaviour can provide *regulation-aware* navigation [11]. Driver's observable behaviour is categorised as compliant to the rules or violating based on the behaviour model of the route he follows and which has been earlier acquired in an *unsupervised* and *dynamic* way. By unsupervised model learning, we mean that no previous training is needed for acquisition of the spatial-behaviour model, whereas by the term dynamic we refer to the frequent update of the model, so that it can reflect the most possible current driving patterns. In the next section we summarize the proposed approach.

4 Proposed approach

Fig. 1 depicts the proposed framework for mining the regulation related information and then communicating it to drivers through a process of rule-sensing and motion-behaviour modelling along routes, coupled with a component that analyses driver's behaviour in accordance to the local rule context. Since the traffic rules we aim to extract are located at intersections, we consider data samples taken from a radius r that covers all the road segments that cross the intersections. Motion-behaviour patterns are detected and then modelled along the paths that cross the same areas. In brief, final aim is to build spatio-temporal models which describe *how* drivers are moving along road segments. Our assumption is that given roads' geometry and rules, vehicles move in accordance to them, that is, in a structured way. Exactly this hidden structure is what we want to recover from data containing spatial and dynamic features; data attributes at our disposal are: *position (latitude, longitude), speed, acceleration, steering wheel angle, brake (boolean), blinkers (right, left, each taking boolean values) and gear indicator*.

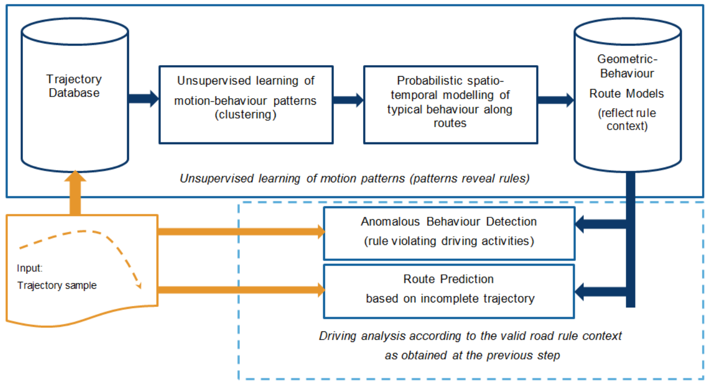

Fig. 1 Overview of the proposed system

5 Conclusions

At this article a general framework for road regulation sensing coupled with a violating behaviour detection system was proposed, underlining the possible applications it can have in the context of map enrichment and driving safety. Beyond testing the proposed methods, a number of topics for further investigation has already been arisen. For example, how often and when should the rule-sensing procedure be repeated so that rules are getting extracted in a *dynamic* way? Could the accuracy of the sensing component be increased by fusion of *active learning* camera-captured content and dynamical features of motion and how?

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