Where do bicyclists interact with other road users? Delineating potential risk zones in HD-maps.

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1 INTRODUCTION

International crash statistics indicate a decrease of bicycle crashes, but at a slower pace compared to total crash numbers. The share of crashes with involved cyclists is above the modal share (see [1] for an overview). Depending on sources, types of analyses, and geographic regions, crash statistics suggest high rates of single-bike crashes and crashes between cyclists and other vulnerable road users (VRUs) [2], while cars are opponents in more than half of all fatal crashes in the European Union [3]. The design of the road environment is of particular relevance for crash risks. A study from London found three times higher injury odds for cyclists at intersections [4]. Connected and automated vehicles (CAV) are frequently said to increase the safety level in road traffic since they are less prone to human errors [5]. This might hold true in transport systems with little complexity, such as highways [6]. However, when it comes to complex situations in multimodal systems with multiple interactions between different road users, such as intersections in urban environments, existing solutions are not sufficient yet in terms of protecting VRUs.

We identified two fundamental flaws in the (over-) simplistic conclusion of increasing traffic safety by increasing the amount of CAVs at the current level of system maturity and reliability. First, to operate correctly, CAVs rely on technology-based communication protocols such as vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication. This requires every entity in traffic (X) to be connected and reporting its current position as well as intended route. However, VRUs are not yet connected to such systems due to technical and ethical reasons. Therefore, they cannot be adequately embedded in V2X systems. Second, CAVs use a wide range of active and passive sensors, which form a technological base to detect and estimate the location, movement and intention of road users. However, sensors and the computational units fed with the sensed information are not bulletproof to malefaction or a cyber-attack leading to the risk of misinterpreted information. In addition, the amount of data that needs to be processed is paramount. Intelligent spatial filters could cut down this amount dramatically and thus reduce the probability of errors.

In order to contribute to the safety of VRUs in the interplay with CAVs in current systems, we propose a geo-spatial model, which delineates potential interaction risk zones from high definition (HD) maps and enriching these zones with additional information. These enriched risk zones are then provided as standardized OGC web service, which can be integrated in V2X systems. With this, we contribute to the visibility, and thus the safety of VRUs in connected transport systems. From a methodological point of view, the proposed model is a first step in integrating spatial context and semantic information explicitly into V2X communication.

2 PROPOSED WORKFLOW

Within the nationally funded research project Bike2CAV, which revolves around safety of VRUs, particularly bicyclists, in connected transport systems, we developed a geo-spatial model and analysis workflow for identifying and enriching interaction zones.

In order to navigate autonomously on roads, CAVs rely on high precision GNSS to locate themselves on high definition maps (HD-map). A HD-map is a highly accurate, three-dimensional data model, which describes the road space at the level of lanes. Each lane in the real world is represented by two enclosing borderlines. This results in two-dimensional, geo-referenced entities, describing the shape (geometry) of the respective lane and additional attributes, such as access rights or direction of flow [7]. Our approach is to translate these HD-maps into features in a geographical information system (GIS), where they can then be overlayed, further analyzed and enriched with additional data. The workflow consists of the following steps:

1) integrate and translate the HD-map into a GIS environment
2) identify interaction zones between lanes based on access and turning information using spatial analysis
3) map national crash statistics onto the identified interaction zones
4) provide access to the enriched interaction zones via OGC services published to the internet

The resulting interaction zones are areas in the road spaces where two or more lanes spatially overlap. In these zones, different road users might interact. The probability for potentially risky interactions is then deduced from national crash reports. We used the relative distribution of crash patterns and translated them into clustered scenarios, such as right turning car intersects with a bicyclists crossing in straight direction. The probability of the different types of interactions was then mapped on the interaction zones in the HD-map, considering access rights and turning relations.

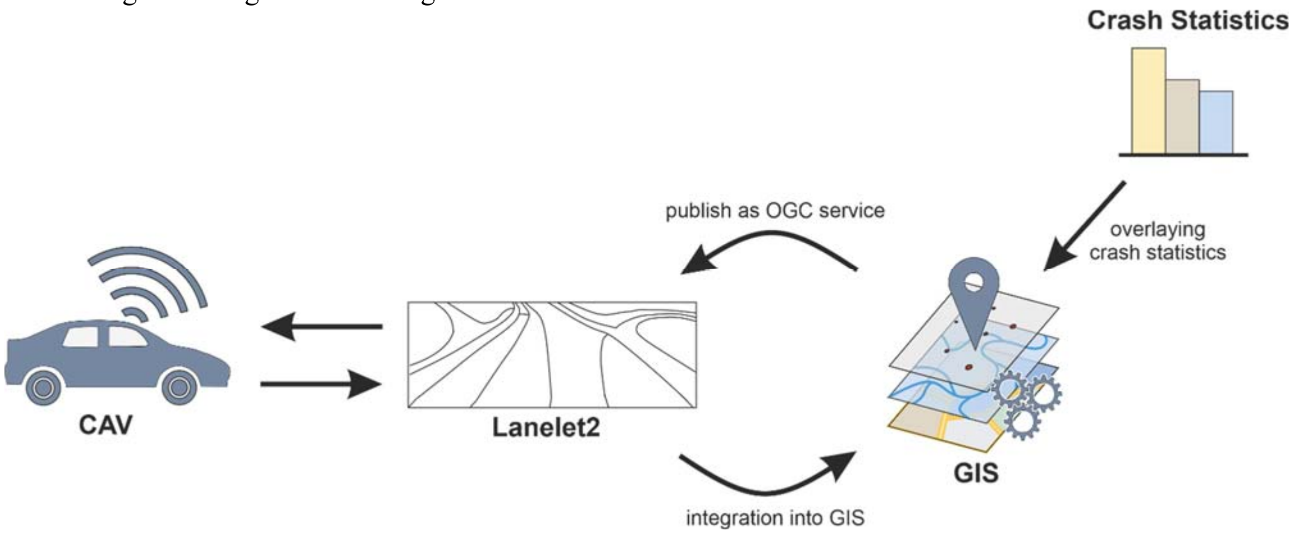

Figure 1: Proposed workflow to derive risk zones by mapping national crash statistic on interaction zones.

3 RESULTS

By applying the outlined workflow, a general probability for risky interactions can be mapped on the interaction zones. This makes the potential risk of specific turning relations within intersections spatially visible. CAVs can access and use this information in real time via OGC services published to the internet. The workflow has been implemented on two test intersections. One represents a four-legged, high volume intersection in the city of Salzburg (Austria) whereas the other covers a three-legged intersection in a rural area. Our approach identifies potentially dangerous interaction zones and indicates the statistically derived possibility of a collision. Making areas where dangerous interactions occur visible to CAVs prior to a recognition with onboard sensors, increases the perception of VRUs within the domain of connected transport systems. Thus, the risk for a crash can be reduced. Moreover, the enriched interaction zones serve as cost efficient and intelligent spatial filters for onboard sensors of CAVs. Another potential application of the identified interaction zones is to adapt the physical condition of intersections. Knowing about dangerous interactions within intersections, gives planners and decision makers the opportunity to adapt the layout of intersections, or optimize the phases of traffic lights in order to mitigate the crash probability.

In a next step of the Bike2CAV research project, the derived interaction zones will be evaluated using real world trajectories from VRUs on the demo intersections. This allows comparing the derived crash statistics with the actual behavior of cyclists and pedestrians in order to assess the correctness of the workflow.

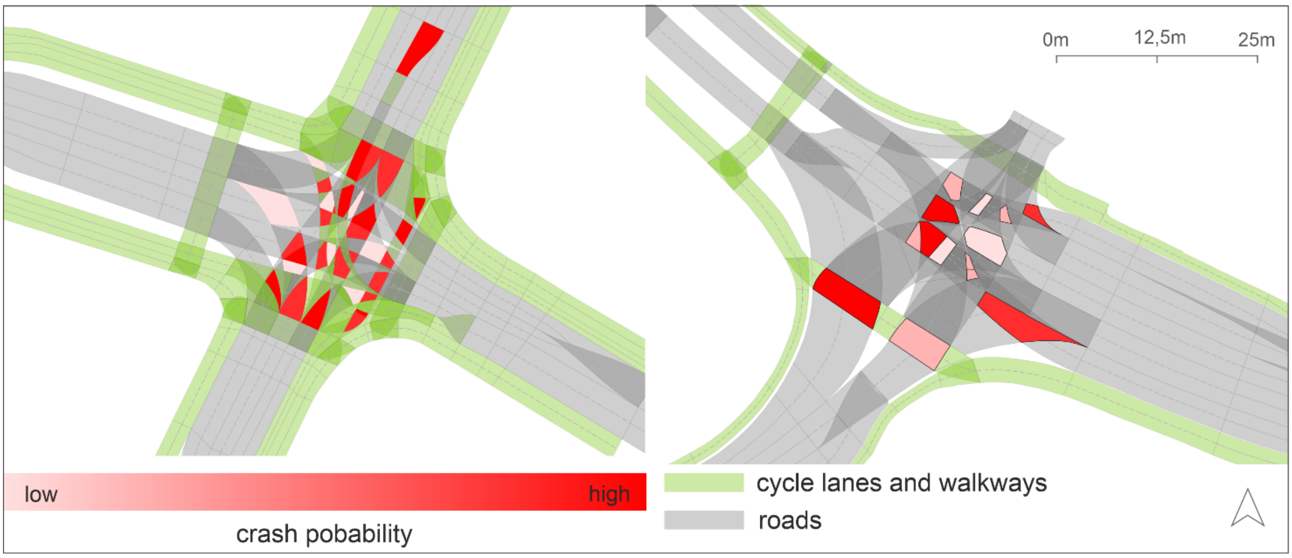

Figure 2: Enriched HD-map displaying the crash probability for the interaction zones within the two test intersections.

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