Predicting the intention of cyclists

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1 INTRODUCTION

In 2014, more than 2.000 cyclist were killed in traffic accidents in the EU, many more were seriously injured [1]. In total the cyclists make 8% of all road fatalities in the EU [2]. Most of the cyclist accidents are collisions with a vehicle [1]. The SaveCAP project [3] showed that a cyclist airbag (impact mitigation) and collision avoidance systems (e.g. forward collision warning (FCW), speed adaptation (SA), Autonomous Emergency Braking or AEB) are two complementary ways to improve cyclist safety. The industry focusses on the development of cyclist-FCW-AEB and advanced versions thereof [4,5]. The first versions already on the market use on-board cameras and radar technology. The AEB-system must perform optimally and only intervene in case of an imminent collision while minimizing the false positives. The algorithm development is a challenging task, due to the relative high speed of the cyclists (needing earlier detection), the scenario types (mainly crossing scenario), the cyclist maneuverability (compared to vehicles) and the difficulty to determine the intention of the cyclist. For a reliable and accurate collision risk prediction such systems require on-time cyclist detection, a highly accurate position with respect to the car, intention and trajectory prediction. Judging the intention of a cyclist is a difficult task. Cyclists do not always indicate a change of direction by making a hand gesture, and there is no official way to indicate stopping or starting. From a human behavior study [6], using video data from a camera mounted on the front of a bicycle, it seems hard to predict if a cyclist ahead will turn left or go straight ahead based on purely visual cues (position, speed, head movement, leaning, and pedaling). However, certain factors such as head movements and the speed of the cyclist ahead increased the reliability of the predictions.

The objective of this study is to determine the features that predict cyclist intentions, and based on these features develop an algorithm predicting their intentions (stop, turn, straight). The study results can be used for the development of collision avoidance systems as well as for automated driving systems.

2 METHOD

Since a bicycle cannot suddenly stop or turn like a pedestrian, the kinematics of the bicycle give an indication of the intention. Also, a cyclist has a destination in mind and most often anticipates on the situation. To understand and be able to predict the cyclist behaviour, the kinematics of a bicycle were measured during various maneuvers at intersections. An instrumented bicycle measured the following signals: wheel speed, roll angle, steering angle, velocity, acceleration, and peddling frequency.

First, a test series was performed in a controlled environment with only predefined traffic. Four volunteers participated, 3 male and 1 female. The instrumented bicycle and a volunteer cycling during a controlled test are shown in Figure 1a and 1b. The cyclists were instructed what maneuver to make at the intersection beforehand: A) stop, B) turn right, C) straight ahead, as shown in Figure 1c an 1d. There was only one other road user involved; a car driver that was instructed such that a crossing scenario or a turning right scenario was generated, as shown in Figure 1c and d. In total 75 successful tests (meaning no signal lost) were performed.

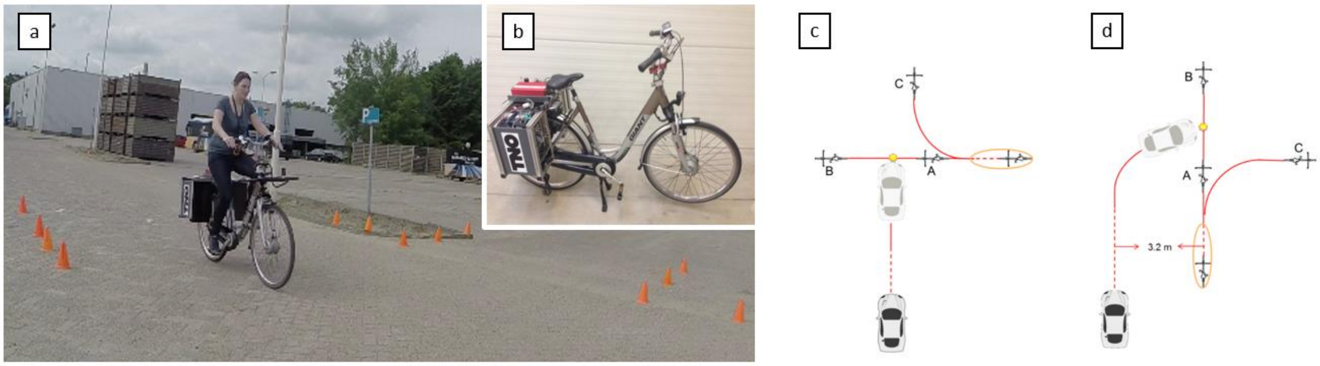
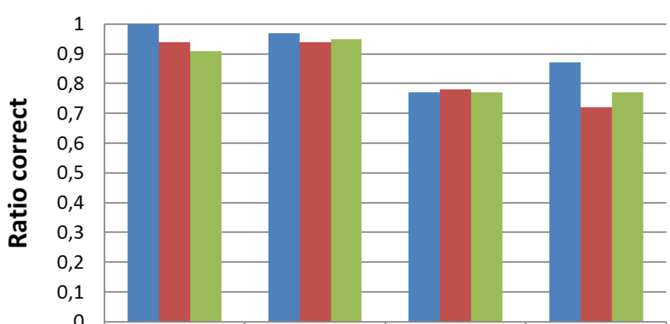


Figure 1: Volunteer cycling in controlled test environment (a); instrumented bicycle (b); cyclist crossing scenario (c); cyclist turning right scenario (d)

Based on the measured signals an algorithm was developed that estimates the cyclist intention in advance of the actual maneuver (stopping, turning right, going straight ahead without stopping). The algorithm uses a hidden Markov model in which each maneuver is associated with a distinctive manifold [7,8]. Model parameters are learned using the modified Baum-Welch method used in [8] after observing new maneuvers. The algorithm allows for online model refinement (parameters adapt based on historical data of the cyclist).

In order to validate the cyclist intention prediction algorithm, a second test series was performed in a naturalistic environment including other traffic participants with a new instrumented bicycle, and other volunteers (3 male and 1 female). The location that was selected was a busy, equal priority crossing in the Dutch village Son. The cyclist were asked to execute the same three maneuvers extended with one more maneuver: turning left. The cyclists were instructed to cycle certain routes, such that at the crossing the maneuver was a result of the destination that the cyclist had in mind and the traffic at the crossing (stop for traffic from the right side).

3 RESULTS AND ANALYSIS



	0.5 s	1.0 s	1.5 s	2.0 s
Stop	1	0,97	0,77	0,87
Straight	0,94	0,94	0,78	0,72
Turn	0,91	0,95	0,77	0,77

Figure 2: Results of cyclist intention prediction algorithm based on first test series (30 stop, 21 straight, 24 turn).

Based on the first test series, the results of the intention prediction algorithm are shown in Figure 2. The algorithm is trained by 75 cases. The figure shows the ratio of correct intention predictions (1=all predictions are correct) for the three distinguished maneuvers (stop, straight, turn) as function of time before the actual maneuver takes place (respectively 2.0, 1.5, 1.0 and 0.5 seconds). For example, in the cases the cyclist stops the algorithm predicts 2.0 s before the maneuver starts in 87% of the cases that the cyclist is going to stop. For 0.5 s in advance of the stop maneuver the algorithm predicts all of the cases correct. The validation of the algorithm using the kinematic data resulting from the second test series, which took place in a naturalistic environment, as input showed promising results.

4 CONCLUSIONS

From the first test series it was concluded that the cyclists motion profiles are affected by the scenarios, however their intention based on the developed algorithm using bicycle kinematics can be predicted 1s ahead correctly in at least 94% of the cases. Validation of the intention prediction algorithm using bicycle kinematics from cyclists in a naturalistic environment showed promising results.

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