Fuzzy logic as a model of an actor-driver in simulator scenarios

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I. INTRODUCTION

Simulation tests are being increasingly used in the ongoing development of motor vehicles and infrastructure. One of the avenues of development of this research is to examine the possibility of testing various Advanced Driver Assistance Systems (ADAS) in a safe environment, but with the addition of a real human driver. In order to make such simulation tests as accurate as possible, the traffic in the scenario under investigation must correspond closely to the behaviour of vehicles in real world traffic situations. In the virtual environment, these vehicles are represented as objects with strictly programmed motion and reactions to the vehicle being driven by a human. To disrupt the monotony of these algorithms, the authors created a fuzzy logic module as part of an algorithm that simulates the behaviour of other drivers on the road. In this way, vehicle motion programming was transformed into simulating the response of the actor-drivers. Adding a certain amount of randomness has allowed for the reproduction of behaviour by different types of driver, such as careful, optimal and aggressive. The results of simulations and simple ADAS and driver responses are also presented here.

II. METHODS

Composition of a scene

The simulated scenario is composed of different traffic areas (Fig. 1), around which wraps almost 8 km of highway. In the centre of the highway ring there are some rural roads. There is a small city, with downtown, uptown and industry districts. All of these elements have a big impact on the sensors' field of view or camera image because they affect the lighting conditions. Also, every area has its own speed limitation and rules. Cars in the scenario must navigate through intersections and roundabouts, and some of the roads also require lane changes.

Fig. 1. Simulation scenario overview.

Fuzzy Logic controller of an actor-driver

Although a simulation scenario is projected for driver testing, it also contains cars that are controlled by a computer to produce a more realistic scenario. In order to provide more adequate and realistic car behaviour, the human module was developed and applied.

This module has a fuzzy logic element that allows us to set the type of driver in each car. There are three driver types – careful, optimal and aggressive. In addition, each of these types can behave according to different workload levels – low (bored), optimal (focused on the road), and high (talking on mobile).

Driver "intput" can be treated as a function of various conditions [3-4], so, to simplify it, driver reactions were divided into three categories: Vision, Reaction Time, and Hearing (Understanding the environment). They are responsible for estimating distance, and self and others' velocities (Visual), for time needed to take physical action, such as braking or accelerating (Reaction Time), and for recognising signs on the road and attending to communications from the car (Hearing).

For each set "driver type – workload level", values for reactions were determined through fuzzy logic. As an output, nine sentences describing those sets were compiled, in the pattern: "If the driver is … and the workload

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level is …, then Vision is …, Reaction Time is … and Hearing is …". The following membership functions are based on the literature [2] and on experience.

The optimal driver with optimal workload level was chosen to be the driver with the most perfect parameters. Then, according to the driver's reactions, ADAS were modified. The verification of the human module was tested with the one, selected ADAS, i.e. Adaptive Cruise Control (ACC) [1]. Particular actions selected were: estimating the velocity of the actor-car; estimating the speed of the leading car; and estimating the distance between car equipped with ACC and leading car. The same actions were taken into account as an output signal from sensors in car steering using ACC block. To make this system more realistic, it was decided that, according to the values of action parameters from the "driver – workload" sets, the estimated distance and velocities would be read as different from the "perfect" values from the sensor. The algorithm changes the parameters and makes them random.

The wide range of input parameters allowed for a full spectrum of different types of driver. Applying the random driver types into the car scenarios, the virtual environment became more realistic, with proper characteristics.

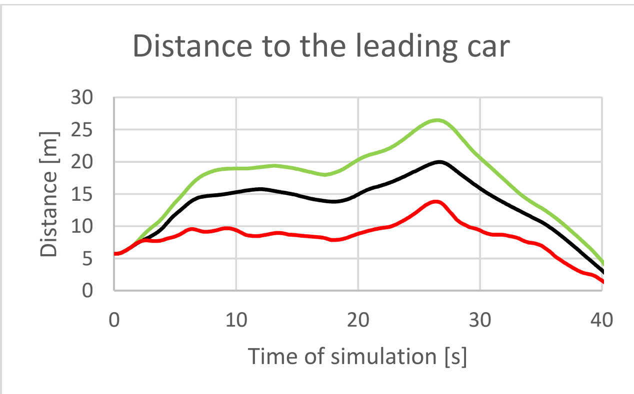

Fig. 2. Distance between tested cars (green – careful, black – optimal, red – aggressive) and leading car.

III. INITIAL FINDINGS

First simulations of the fuzzy logic actors show the difference in behaviour between optimal ACC controller and selected types of driver. As was expected, the careful driver is a bit slower and uses smaller acceleration rates, while the aggressive actor has quicker and more frequent changes of acceleration and higher velocity (Fig. 2). During the Human in the Loop (HITL) simulation, the driver can therefore react to the behaviour of other road users in a more natural way, because the actors are behaving in more human, less predictable way.

IV. DISCUSSION

Actors equipped with a behaviour algorithm based on the fuzzy logic module can improve the realism of HITL simulations (Fig. 3). As a result, the workload of the human driver should be higher during the simulation because he/she needs to be more careful, due to the unpredictable movement of other road users in the scenario (Fig. 4). This sort of 'disorder' in the actors' movements should be the next challenge for the ADAS tested in simulators.

Fig. 3. Mini-simulator station.

Fig. 4. Simulation with careful (green), optimal (black) and aggressive (red) driving modules.

V. ACKNOWLEDGEMENTS

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