Using a Fuzzy Ranking Method for an Adaptive Cruise Control System

M. Saniee [1], J. Habibi [1], M. Fathy [2], A. Rahmani [2], S. H. Davarpanah [2], A. Mirzaei [2]
PhD student, Assistant Prof., Associate Prof., Assistant Prof., MS student, MS student
1. Sharif University of Technology
2. Iran University of Science and Technology
saniee@ce.sharif.edu

Abstract. This paper presents a fuzzy system for Adaptive Cruise Control as a Driver Assistant System in the intelligent vehicles. The main advantage of the suggested system is its simplicity. To test the designed system, a simulation tool is implemented. By using the described tool, we can analyze the operation of the implemented Adaptive Cruise Control system in a simulated highway. Results show an acceptable performance of the developed fuzzy system.

1 Introduction

During the last decade, intensive research and development effort has been made by the car manufacturers and their suppliers in order to bring to the market Advanced Driver Assistance Systems (ADAS). These systems improve comfort, safety and mobility. Adaptive Cruise Control (ACC) is one of the first examples of such systems to be introduced in the market [1-3].

The algorithm used in the ACC system plays an important role in the final system's performance. On the other hand, as ACC system is a Real-Time system, the complexity of the used decision making algorithm in the ACC system, should be considered. The less complexity of the used decision making algorithm will result the higher performance of the ACC system. In this paper, we proposed a new method, which is capable of controlling the cruise of an intelligent vehicle, using a considerable simple fuzzy rule based system. Although the structure of the suggested fuzzy system is very simple, results show an acceptable operation of the ACC system. The described results are obtained from an implemented simulation tool. This tool is capable of modeling the operation of a vehicle in a simulated highway and generating the results of the simulation.

2 Adaptive Cruise Control (ACC)

The high-profile driver assistant product is adaptive Cruise Control (ACC). ACC senses slower vehicles ahead and adjusts speed to establish a safe following distance, resuming the desired speed when the way ahead is clear [2].

ACC is a typical driver assistant system designed for comfort. Its use is restricted to given areas (highways) and given operational conditions (between a minimum $V_{\min}$ and a maximum $V_{\max}$ operational speed, with limited braking and acceleration capabilities).

3 Simulation Tool

To test the operation of the implemented fuzzy ACC system and measure the system's performance, we have constructed a simulation tool. By this tool, we can test the decision-making system in different traffic situations. Fig. 1 shows the simulated highway of the implemented tool.

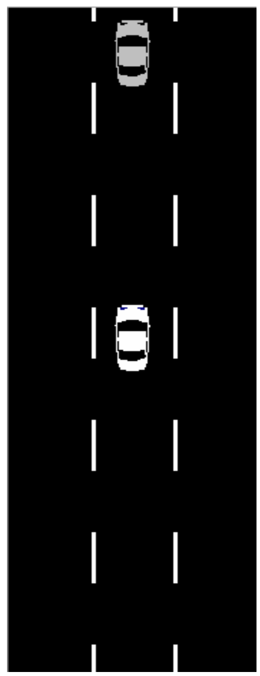


Fig. 1. Simulated highway. The white vehicle is the intelligent vehicle. The gray vehicle is the environment vehicle.

The software is also capable of generating the results related to the operation of the intelligent vehicle. The outputs of this software are the graphs which are shown in this paper.

4 Developed Fuzzy System

The developed fuzzy system uses the singleton fuzzifier, the product inference engine and the center average defuzzifier [4], [5].
The method in this paper is introduces a new concept, which is called Concession Method. According to this method, a fuzzy system assigns a concession to all of the operations in each time. The operation, which has got the maximum concession, is then chosen. This cycle will be continued until the system reaches to a predefined goal or is being stopped manually. In the ACC system, we determined 3 actions each time. These actions are:

- Increasing the acceleration of the intelligent vehicle
- Doing no changes to the acceleration of the intelligent vehicle
- Decreasing the acceleration of the intelligent vehicle

The fuzzy system assigns a concession to each of the actions above and chooses the action that has got the maximum concession.

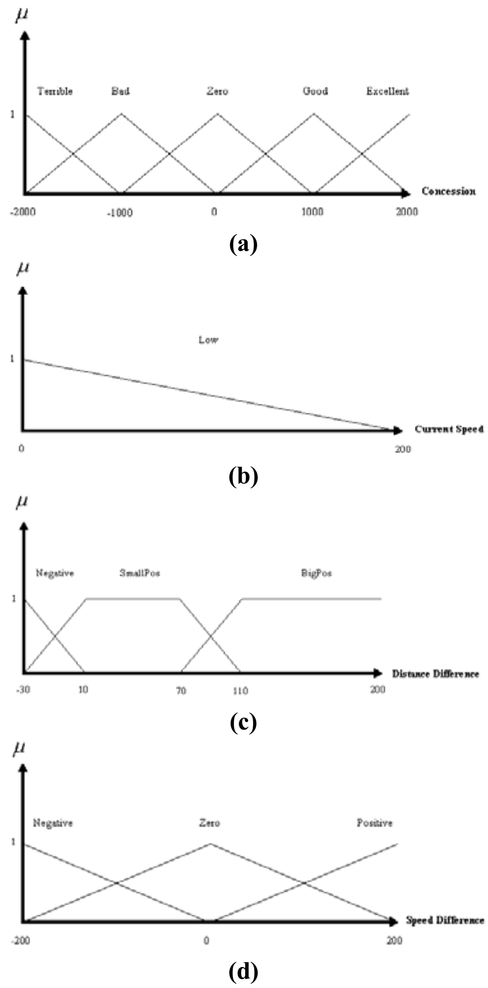


Fig. 2. Linguistic variables which the implemented fuzzy system is using them. (a) Concession. (b) Current Speed. (c) Distance Difference. (d) Speed Difference.

The system uses four linguistic variables. These variables are Concession, Current Speed, Distance Difference and Speed Difference (Fig. 2). Distance Difference means the difference between the safety distance and the vehicle ahead. Safety distance is the distance that should be considered by the intelligent vehicle. Speed Difference is the difference between the Current Speed and the Desired Speed.
The knowledgebase of the fuzzy system consists of 4 fuzzy rules. These rules are:

- **IF** Distance Difference **is** Small Positive **AND** Current Speed **is** Low **THEN** Concession **is** Excellent
- **IF** Distance Difference **is** Negative **THEN** Concession **is** Terrible
- **IF** Speed Difference **is** Zero **THEN** Concession **is** Excellent
- **IF** Speed Difference **is** Positive **THEN** Concession **is** Terrible

The system can control the cruise of the intelligent vehicle properly. This fact will be concluded from the tests in the next part of this article.

5 Simulation Results

We have prepared 3 tests to examine the operation of the intelligent vehicle. These tests will be discussed below:

- **Test 1:** In this test we want to test the operation of the decision-making system, when there is no vehicle in the highway. In all of these tests, the desired speed of the intelligent vehicle is 60 km/h and its initial speed is 0 km/h. The result of this test is presented in the Fig. 3.

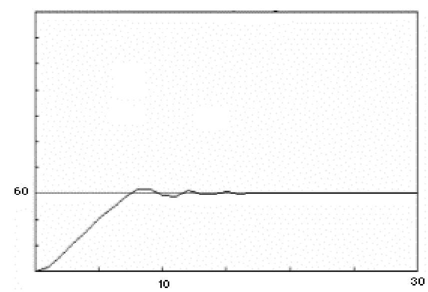


Fig. 3. The speed chart of the intelligent vehicle according to the test 1. This chart shows the speed convergence of the intelligent vehicle to the desired speed.

The vertical axes in the speed charts in this part are the speed values. The horizontal axes are the time values in second. In the distance charts, the vertical axes are the distance values in meter. The horizontal axes are the same as the speed charts. The speed chart shows the intelligent vehicle's speed during the simulation. This chart also shows the desired speed. The distance chart shows the distance of the vehicle ahead to the intelligent vehicle. This chart also shows the safety distance.

- **Test 2:** The goal of this test is to examine the operation of the ACC system when a vehicle with the speed of 50 km/h, comes from the ahead of the intelligent vehicle and then increases its speed to 70 km/h. The results of this test are presented in the Fig. 4.

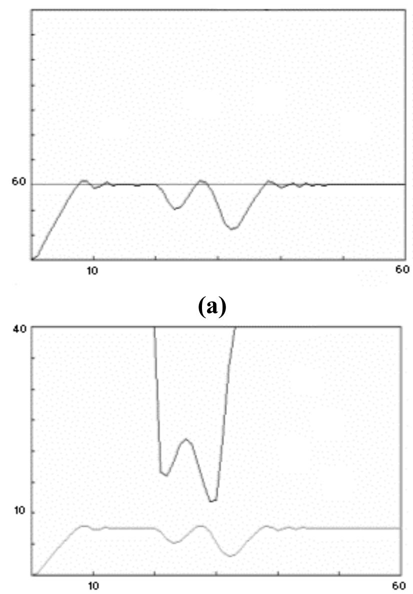
- **Test 3:** This test examines the operation of the ACC system when a vehicle with the speed of 50 km/h, comes from the ahead of the intelligent vehicle and remains on this speed to the end of the simulation. The results of this test are presented in the Fig. 5.

Theses results show the acceptable operation of the developed ACC system. It is important to focus on this fact that the developed fuzzy system in this paper is very simple.

6 Conclusions

In this paper a new method to develop the ACC system, was introduced. The main advantage of the proposed method is that it could implement all of the ACC system capabilities, using a considerable simple fuzzy system. The discussed fuzzy system is simple in all of fuzzy systems aspects, such as:

- **Fuzzifier:** The fuzzifier used is the singleton fuzzifier, which is one of the simplest fuzzifiers.
- **Inference Engine:** The product inference engine is one of the simplest fuzzy inference engines.

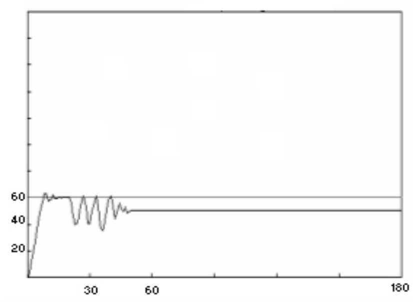


(b)

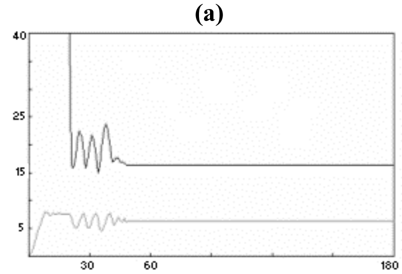
Fig. 4. The charts of the intelligent vehicle according to the test 2. The speed chart shows the speed convergence of the intelligent vehicle to the desired speed after a disturbance. The distance chart shows that the intelligent vehicle considers the safety distance. (a) Speed chart. (b) Distance chart.

- **Defuzzifier:** The fuzzy system uses the center average defuzzifier, which has a simple and logical operation.
- **Fuzzy Rules:** The rules used are very simple. The number of these rules is four, which is wonderful for such a fuzzy system.
- **Linguistic Variable:** The linguistic variables of the proposed fuzzy system are really simple. Because they use a few number of membership functions.

Theses results show the capability of the concession method to develop the fuzzy ACC system. This method can also be used in the other kinds of application.
The system has some problems near its capabilities. The most remarkable problem is the existamce of a slight oscillation or overshoot in speed, which will translate to passenger discomfort. Refining the capabilities of the presented system by cancelling such a problems will be considered for our future work.



(a)



(b)

Fig. 5: The charts of the intelligent vehicle according to the test 3. The speed chart shows the speed convergence of the intelligent vehicle to 50 km/h. The distance chart shows that the intelligent vehicle converges its distance to the preceding vehicle. (a) Speed chart. (b) Distance chart.

References

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