Cognitive Agent-Based Accident Avoidance System

Faisal Riaz
Department of Computer Science & Information Technology, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42
fazi_ajku@yahoo.com

Abdul Ghafoor
Department of Computer Science & Information Technology, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42

Yasir Mehmood
Department of Computer Science & Information Technology, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42

Naeem Ratyal
Department of Electrical Engineering, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42

Iram Zamir
Department of Computer Science & Information Technology, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42

Ujala Siddique
Department of Computer Science & Information Technology, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42

Hina Iqbal
Department of Computer Science & Information Technology, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42

Anila Arbab
Department of Computer Science & Information Technology, Mirpur University of Science & Technology, AJK, Pakistan
College Rd, New Mirpur City, Azad Jammu and Kashmir 10250
Phone: +92-5827-961040 / 42

Abstract

Distracted driving is a growing problem that leads to many deaths in the world. Causes of distraction are speeding, eating, texting, drinking, answering phone calls, reading billboards, adjusting vehicle equipment, and attending to passengers. These deaths could be prevented by a cognitive agent-based collision detection and auto collision avoidance (CABCD-CA) system. In order to reduce accidents caused by distraction, this paper presents a (CABCD-CA) system. The research is two-fold, first designed as a fuzzy inference system, which takes distraction, speed, and distance as input and produces the chances of an accident using fuzzy logic. Then, different probabilities of accidents are provided to the cognitive agent, which, in turn, performs appropriate collision avoidance manoeuvrers. The agent-based simulation of the CABCD-CA system is validated using VOMAS agent approach. Extensive testing has proved the success of the proposed system for avoiding collisions due to the distraction of the human driver.

Keywords: Cognitive Agent, Distraction, Fuzzy Logic, VOMAS Agent.

1. Introduction

Human distraction is one of the main causes of road accidents. According to Chana and Singhal (Chan & Singhal, 2013), distracted driving is a growing problem in the world and causes a high number of accidents. It can cause many deaths that could otherwise be prevented, especially in the younger generation of drivers (Foss & Goodwin, 2014). Distraction occurs when drivers divert their attention from the driving task to focus on some other activity (Foss & Goodwin, 2014). According to the Australian National Crash In-depth Study (ANCIS) (Beanland, Fitzharris, Young, & Lenné, 2013), it is concluded that distraction is the second largest cause of accidents due to inattention (Gidron, Gaygısız, & Lajunen, 2014). Distractions influenced by the advancement of technology, especially text messaging or talking on the cell phone with someone, can require a combination of visual, manual, and cognitive attention from the driver, thus making these types of distractions particularly dangerous (Chan & Singhal, 2015). There are many types of distractions.

There are three different types of distractions; (a) visual distraction, (b) manual distraction, and (c) cognitive distraction (Simons-Morton, Guo, Klauer, Ehsani, & Pradhan, 2014). Visual distraction means that drivers have their eyes off the road, is operating the vehicle entertainment system, adjusting vehicle equipment, or viewing roadside billboards (Foss & Goodwin, 2014). Visual distraction involves taking one's hands off the wheel whereas cognitive distraction means that driver has his mind off the road when he/she is text messaging, talking on the phone, conducting a hands-free mobile conversation, or conversing with passengers (Chan & Singhal, 2015).

Other than above causes, distractions also include lack of concentration, adjusting vehicle equipment, viewing outside people/objects/events, talking to passengers, drinking, smoking, eating, etc. (Lansdown, Stephens, & Walker, 2015). According to the United States Department of Transportation, "Text messaging while driving increases a crash risk 23 times higher than driving while not distracted". Despite these statistics, more than 37% of drivers have admitted to sending or receiving text messages while driving, and 18% admit to doing so regularly (Lisetti & Nasoz, 2005).

Results from (Lansdown et al., 2015) also examine that electronic device use (6.7%) was the most common single type of distracted behaviour, followed by adjusting vehicle controls (6.2%) and grooming (3.8%). Most distracted driver behaviours were less frequent when passengers were present. However, loud conversation and horse play were quite common in the presence of multiple peer passengers (Lansdown et al., 2015). These conditions were associated with looking away from the road, the occurrence of serious events, and, to a lesser extent, rough driving (high g-force events) (Lansdown et al., 2015). Driver distraction is predicted to be one of the leading causes of motor vehicle accidents. In 2011, it accounted for 10% of all fatal crashes and 17% of injury crashes (Administration, 2012) (NHTSA, 2013). In a recent review by Young and Salmon (2012), secondary task distraction is suggested to be a contributing factor in at least 23% of all accidents (Nourzad, Salvucci, & Pradhan, 2014).

2. Method

In this section the details of the adapted method have been provided. First of all detailed literature review has been performed to identify the main causes of driver distraction. For this purpose authentic journals of high reputed publishers have been selected. One of the examples is the accident analysis and prevention journal by Taylor and Francis. We selected this journal because it provides more authentic information regarding the subject under discussion. Then in second step, literature review regarding existing collision avoidance, detection and avoidance systems. In the next step, fuzzy logic (Mamdani Inference System) has been employed to compute the different levels of driver distraction. It is important to mention that fuzzy logic is a tool, which can be utilized to generate the quantitative values of qualitative terms like Low Distraction and High Distraction. Because the computer softwares need quantitative values instead of qualitative terms, hence the fuzzy logic has been employed. In the continuation of the research, the second type of simulation experiments has been performed using fuzzy logic to compute the chances of accidents using the different levels of driver distraction. The output was again in quantitative values, which were then provided to the agent based simulation tool known as NetLogo. In the last the validation of the results has been performed using Virtual Overlay Modelling Agent (VOMAS) under the guidelines of the validation method propose by Niazi et al.(Niazi, Siddique, Hussain, & Kolberg, 2010).

3. Literature Review

We have performed two-fold literature reviews. The first fold of literature review helps us in identifying the main causes of distraction. The second fold of literature review helps us in studying the existing collision detection and avoidance systems.

In (Lansdown et al., 2015), it is discussed that if young drivers keep their eyes on the road and prefer secondary tasks, then crash risk increases because of distraction. In (Simons-Morton et al., 2014), it is discussed that driver distraction occurs if the driver performs physical tasks (including eating, drinking, or manipulating dashboard controls) or auditory/visual diversions (e.g., loud music or looking at a smart phone screen), or cognitive activities (e.g., talking on a phone or to a passenger). In (Lansdown et al., 2015), systematic reviews of several driver distractions are given. In (Cuenen et al., 2015), it is elucidated that distraction occurs due to inattention and it may impact driving performance. Also, the effect of distraction on driving performance of older drivers has been checked. The aim was to investigate whether attention capacity has a moderating effect on older drivers' driving performance during visual distraction and cognitive distraction. In (Chan & Singhal, 2013, 2015), it is discussed that driver distraction is one of the leading causes of motor vehicle accidents. Roadside billboards contain negative and positive emotional contents and lead to non-attentive driving behaviour. The impact of emotion-related auditory distraction on driving is also discussed. The causes of distraction and the results of the literature review are given in Table 1.

In (Gidron et al., 2014), an intelligent car interface is designed by facilitating natural human interaction with the drivers so that he/she will be aware of their emotional state while driving. In this way, the distractions can be avoided. Riaz and Niazi (Riaz & Niazi, 2017a) have proposed emotions enabled cognitive autonomous agent for efficient rear-end collision avoidance, which is installed in an autonomous vehicle. Riaz and Niazi (Riaz & Niazi, 2016) have also proposed a comprehensive survey regarding different collision avoidance techniques. A validated fuzzy logic inspired driver distraction evaluation system for road safety using artificial human driver emotion has been proposed by Riaz et al. (Riaz et al., 2018). This paper provides a solution to compute driver distractions and then using them to tailor an efficient road collision avoidance system. Riaz and Niazi (Riaz & Niazi, 2017b) have proposed an efficient collision avoidance system between autonomous vehicles and human driven vehicles using Richardson's arms race model.

Table 1. The Causes of distraction

Causes	Result
Speeding	Distraction
Eating	
Texting	
Drinking	
Attending to phone calls	
Reading billboards	
Adjusting vehicle equipment	
Interacting with passengers	

In paper (Nourzad et al., 2014), they propose a system combination modelling framework that integrates a cognitive model of distraction and an agent-based traffic simulation model and validates it by using existing experimental data sets. The authors have developed a database of distraction types and, from that database, they calculated profile time of distraction and that profile time used an agent-based traffic simulation modelling.

4. Proposed Work

We have given an agent-based assistant system that alerts distracted human drivers to avoid accidents. As we know, while driving, the human driver gets distracted because of different things mentioned above. In order to save human lives and avoid road accidents in this work, we tried to make a cognitive system which will check the crisp values of chances of accidents obtained from the fuzzy inference system and then generate alarms and take action on whether to reduce speed or to apply breaks to avoid accidents.

4.1. Proposed Sim-connector Design

In the first phase, using fuzzy logic, we have calculated the rate of distraction by taking all the causes of accidents as input. These values of distraction are then given to the fuzzy inference system, which then calculates the chances of accidents.

The Figure 1 shows how two simulators are joined using Sim-Connector. Firstly, the value of speed, distraction, and distance are given to the fuzzy inference system to generate crisp values of chances of accidents. These crisp values are then given to an agent-based model using Sim-Connector, which makes decisions on the basis of these values.

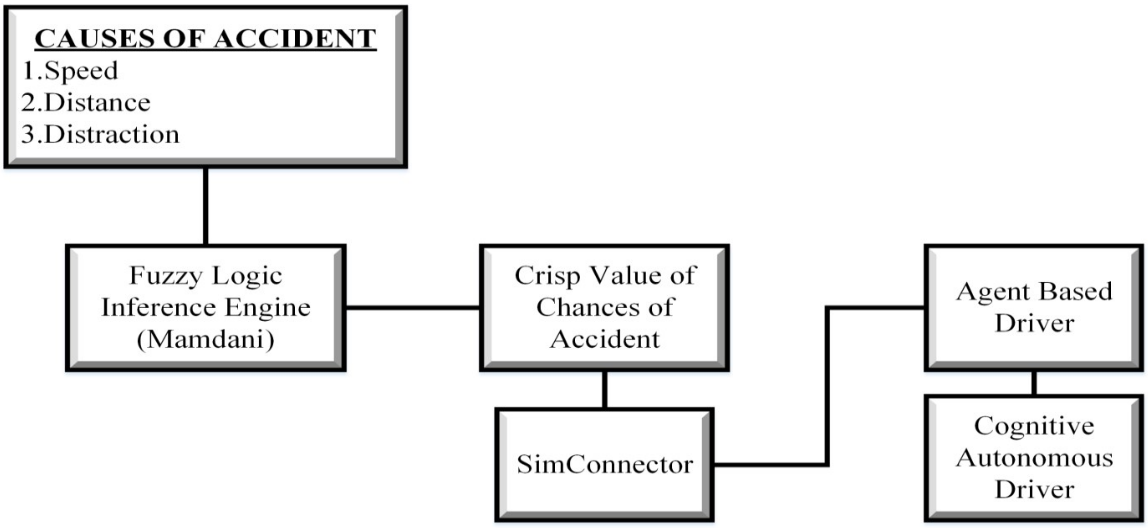

Figure 1. Proposed Sim-Connector design

4.2. Proposed Validation Method

In the second phase, we proposed a distributed accident alerting system using an agent modelling tool, i.e., Netlogo; a system which generates alerts for drivers by making intelligent decisions based on the values of chances of accident retrieved from the fuzzy inference system. Using the Sim Connector approach, the accident detection system (the fuzzy inference system) simulation model is connected to the distributed accident alerting system. The proposed system can also take action on whether to slow down the speed or to use breaks, if the human driver does not respond to the alerts.

VOMAS: a Virtual Overlay Multi-Agent System. This overlay multi-agent system can be comprised of various types of agents, which form an overlay on top of the agent-based simulation

model that needs to be validated. Other than being able to watch and log, each of these agents contains clearly defined constraints, which, if violated, can be logged in real time.
For the validation of our cognitive agent-based accident avoidance system using VOMAS approach we use design invariant, which are;

1. If the pre-condition that "Rear end distance between both autonomous vehicles is decreasing" is TRUE, then the variation in the distance of autonomous vehicles would result in a post condition of "give alert accordingly".

If the pre-condition that "Rear end distance between both autonomous vehicles is Equal to threshold" is TRUE, then the variation in the distance of autonomous vehicles would result in a post condition of "breakdown".

Flow Chart:

1. Start moving cars followed one by another.
2. Make a decision based on "Chance of Accident".
3. Calculate chances of accident.
4. If chance of accident is less than or equal to 80%, it generates an alarm.
5. Otherwise:
6. If chance of accident is greater than 80%, it will take a break.

The Figure 8 shows the flowchart of an agent-based system, which checks the chances of accidents. When the chance of an accident is less than or equal to 80%, it generates an alarm and when these chances increases and are above 80%, it will take the break.

5. Simulation and Results

In this section, details regarding simulation and results have been provided.

5.1. Simulation-1 to Compute Distraction Reason

We constructed a Mamadani-based Fuzzy Inference System (FIS) for calculating the different intensity levels of distraction using the causes of distraction presented in Table 1.

The Figure 2 shows the fuzzy inference system, which takes different causes of distraction as input and generates the values of distraction, which we use later as input in other fuzzy inference systems that will generate chances of accidents.

5.1.1. Simulation-1 results:

The table 2 describes the results, which determine the value of distraction. The values of eating, drinking, adjusting vehicle equipment, physical impairments are used as inputs as the major causes of distraction.

5.1.2. Verification of simulation-1 results:

As can be seen from the membership function of eating, the value of eating (0.139) lies in the Very Low category. In the same way the value of drinking, which is 0.175, lies in the Very Low category, the value of adjusting vehicle equipment, which is 0.355, also lies in the Very Low category, the value of physical impairments 0.657 lies in the average category. The output is 0.175, which lies in the Very Low values of distraction. From the membership function, it also lies in the Very Low category; hence the value of distraction is Very Low.

Table 2. Simulation-1 results

Eating	Drinking	Adjusting Vehicle Equipment	Physical impairments	Value of Distraction
0.139 V.Low	0.175 V.Low	0.355 V.Low	0.657 Average	0.175 V.Low
0.355 Average	0.615 (High)	0.187 V.Low	0.232 Low	0.187 Low
0.584 Average	0.657 High	0.139 Low	0.49 Average	0.657 Average
0.584 Average	0.657 Average	0.777 Average	0.187 Low	0.777 High
0.729 V.High	0.416 Average	**0.657 High**	0.88 V.High	0.861 V.High

Table 3. Input and output of fuzzy logic inference system

Input		Output
Speed	Fuzzy logic inference system	Chances of accident
Distance		
Distraction		

In the same way that the value of eating is (0.355) from the membership function, it lies in the Average category. The value of drinking, which is 0.615, lies in the Very High category, the value adjusting vehicle is 0.187, and it lies in the Very Low category, and the value of physical impairment, 0.232, lies in Average categories, then the output of fuzzy inference of these five inputs is 0.187, which lies in the Low category, hence the value of distraction is Low.

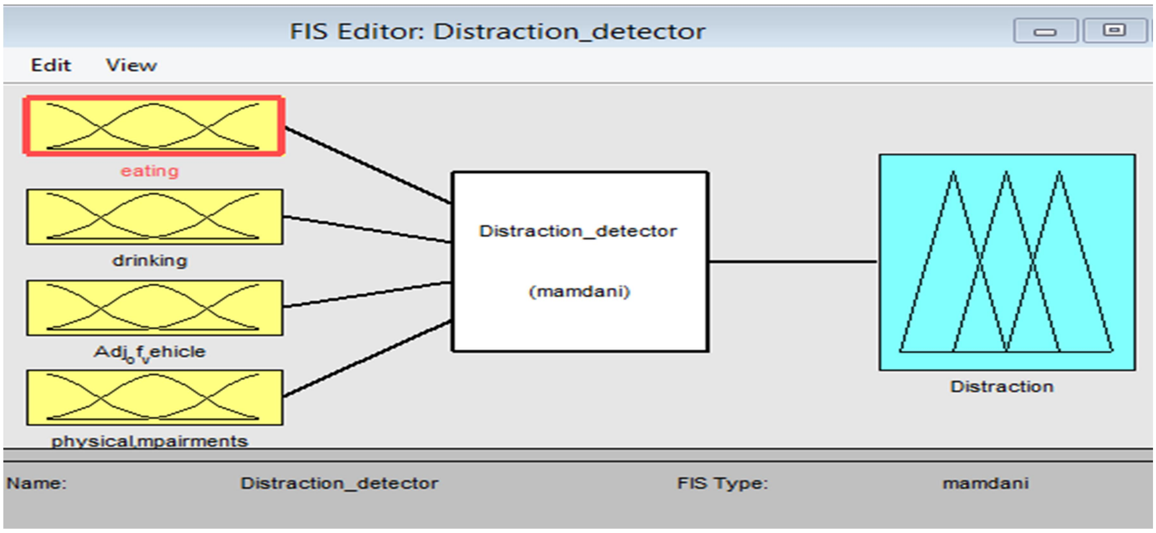

Figure 2. Distraction Detection

Also, when the value of eating is (0.584) from the membership function, it lies in the Average category, the value of drinking, which is 0.657, lies in the High category, the value adjusting vehicle is 0.139 lies in the Very Low category, and the value of physical impairment 0.49, which lies in the Average category. So, the output of fuzzy inference of these five inputs is 0.657, which lies in the Average category, hence the value of distraction is Average.

Similarly, when the value of eating is (0.584) from the membership function, it lies in the Average category. The value of drinking, which is 0.657, lies in the Very High category, the value of adjusting vehicle equipment is 0.777, which lies in the Very Low category, and the value of

physical impairment, 0.187, lies in the Average category. So, the output of fuzzy inference of these five inputs is 0.777, which lies in the Low category, hence the value of distraction is High.
Similarly, when the value of eating is (0.729) from the membership function, it lies in the Very High category. The value of drinking, which is 0.416, lies in the Average category, the value of adjusting vehicle equipment is 0.657, which lies in the High category, and the value of physical impairment, 0.88, lies in the Very High category. Therefore, the output of fuzzy inference of these five inputs is 0.861, which lies in the Very High category, hence the value of distraction is Very High.

5.2. Simulation-2 to Compute Chances of Accident

In simulation-2, we constructed a fuzzy inference system in MATLAB, which takes the input speed, distance, and distraction and generates an output in the form of chances of accidents. We set a membership for each input and then set different rules. According to these rules, we verify the results.

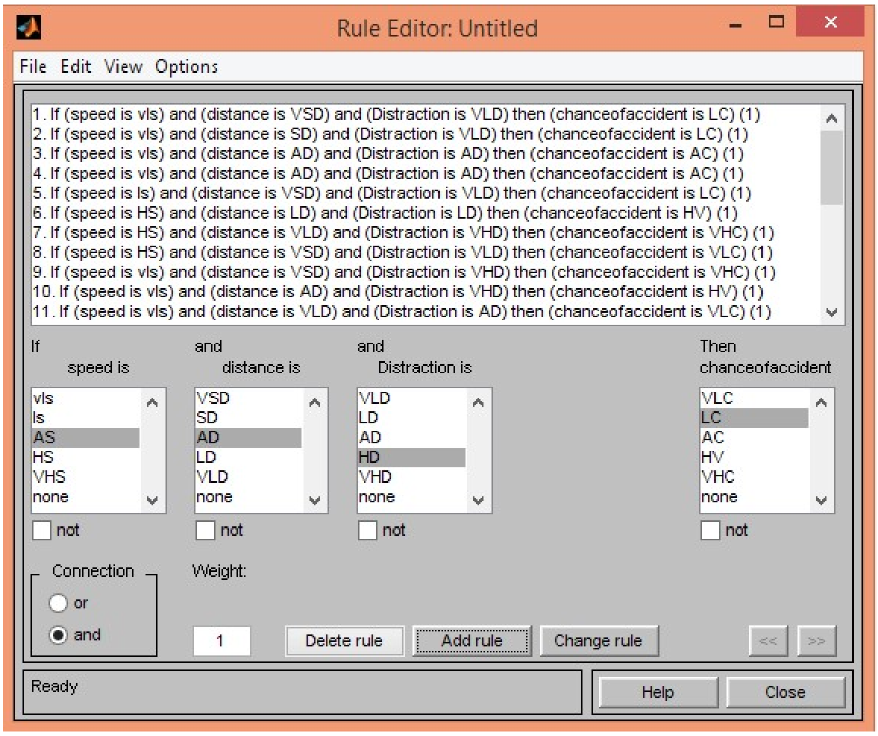

Figure 3. Rule Editor.

5.2.1. Input and output of fuzzy logic

The fuzzy logic inference system takes the input like speed, distance, and distraction and produces an output using the fuzzy logic inference system about the chances of accident.

5.2.2. Membership functions of fuzzy logic

Figure 3 shows the membership function editor in which we set the membership function for each input: speed, distance, and distraction in Very Low, Low, Average, High and Very High categories. According to member functions, output variables "chance of accidents" plotted to demonstrate the range of accidents.

5.2.3. Rule editor of fuzzy logic inference system

We set rules for the three inputs, speed, distance, and distraction. Figure 4 shows the rules that are set using fuzzy logic on the basis of which system generates chances of accidents (output).

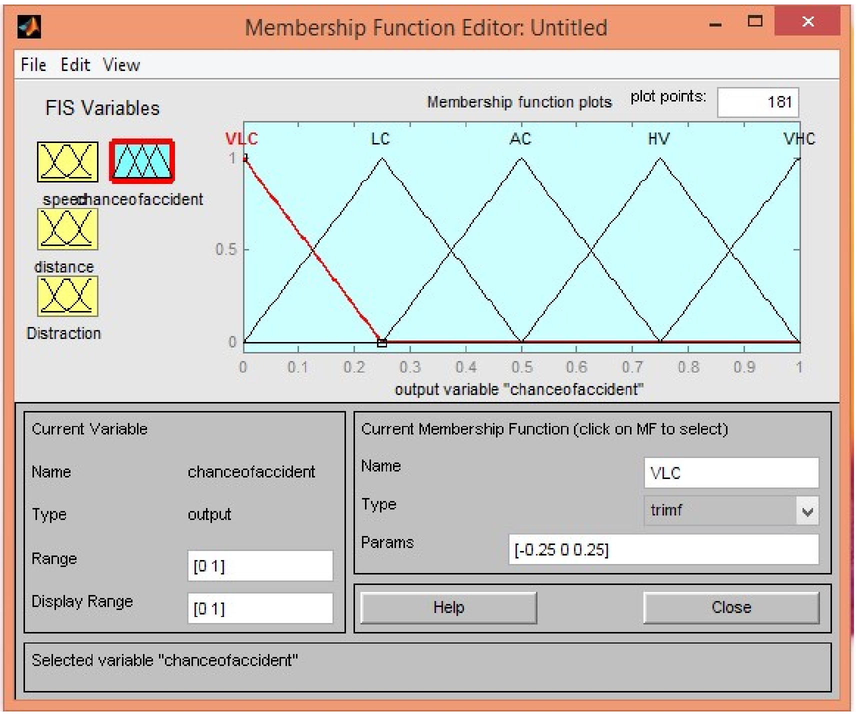

Figure 4. Membership function editor

5.2.4. Simulation-2 Results

Table 4 describes the results, which determine the chances of accidents. The values of speed, distance, and distraction are used as input, which gives the output of chances of accidents. Membership is set for each input and then set different rules. According to these rules, we verify these results.

Table 4. Chances of accident results based on input factors

Inputs			Output	Chances of Accident
Speed	Distance	Distraction		
0.416Average	0.139 V. Low	0.175 V. Low	0.118	V. Low
0.355 Low	0.615 High	0.187 Low	0.232	Low
0.584 Average	0.657 High	0.657 Average	0.490	Average
0.416 Average	0.741 High	0.777 High	0.751	High
0.729 V. High	0.139 V. Low	0.861V. High	0.880	V. High

5.2.5. Verification of simulation-2 results

As can be seen from the membership function of speed, the value of speed (0.416) lies in the Average category. In the same way the value of distance, which is 0.139, lies in the Very Low category. The value of distraction, which is 0.175, also lies in the Very Low category. The output of fuzzy inference of these three inputs is 0.118. From the membership function, it also lies in the Very Low category; hence chances of accidents are Very Low.

In the same way, when the value of speed is 0.355 from the membership function, it lies in the Low category. The distance, which is 0.615, also lies in the High category and the distraction is 0.187, which lies in the Low category. The output of fuzzy inference of these three inputs is 0.232, which lies in the Low category; hence the chances of accidents are Low.

Also, when the value of speed is 0.584, which lies in the Average category and the distance, which is 0.657, lies in the High category and the value of distraction (0.657) lies in the Average category then the output is 0.490, which lies in the Average category, hence the chances of accidents are Average.

Likewise, when the value of speed is 0.416, which lies in the Average category and the value of distance is 0.741, which lies in the Long Distance category, and the value of distraction is 0.777, which lies in High, then the output of fuzzy inference is 0.751 from the membership function which lies in the High category. Hence, the chances of an accident are high.
Similarly, when the value of speed is 0.729, which lies in the Very High category and the value of distance is 0.139, which lies in the Short Distance category, and the value of distraction is 0.861, which lies in Very High, then the output of fuzzy inference is 0.880 from the membership function which lies in the Very High category. Hence, the chances of an accident are Very High.

5.3. Simulation-3 Validation for Agent-based System

We designed an agent-based model in NetLogo Simulator. The Figure given below 5 is the interface view of the agent-based model in NetLogo.

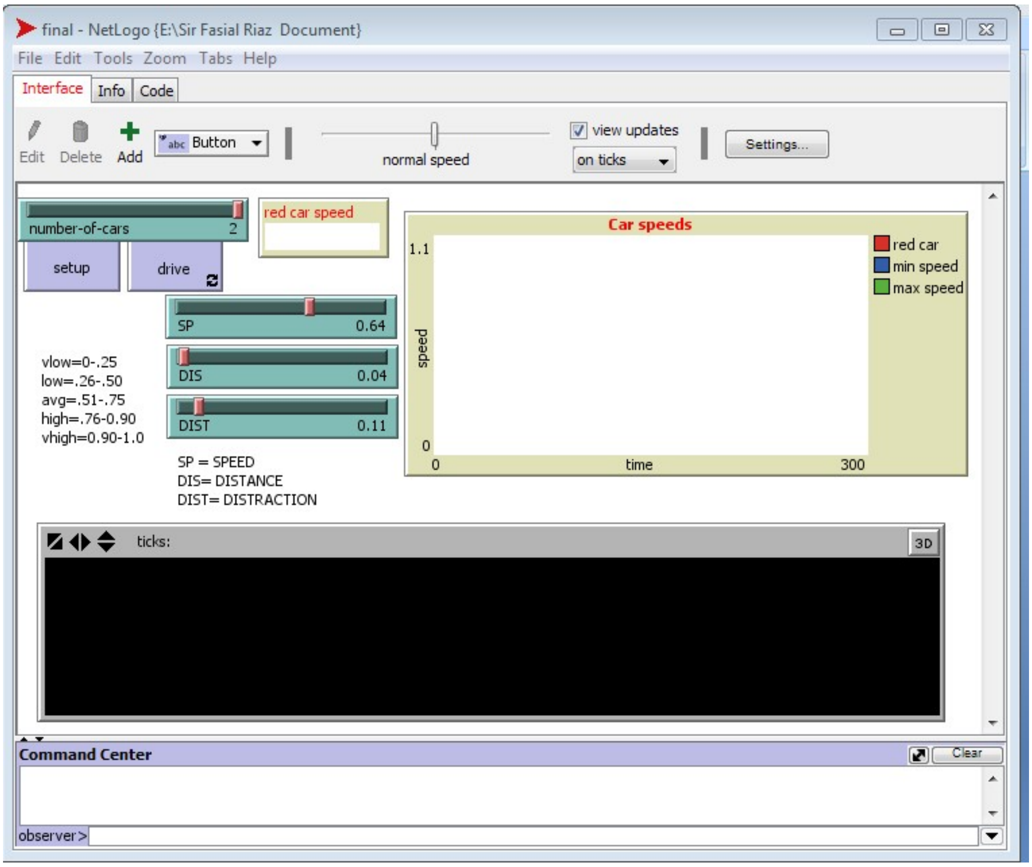

Figure 5. User interface of agent-based model system.

Figure 6 shows that the cognitive agent give alerts or generates an alarm when the chances of accidents are in the Very High range (as 0.90). Figure 7 shows that the cognitive agent "takes a break" when it notices that the chances of an accident are Very High (as 1.0).

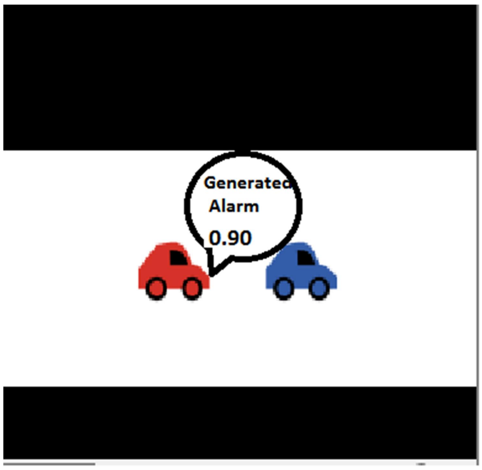

Figure 6. Alert for high range accident chances.

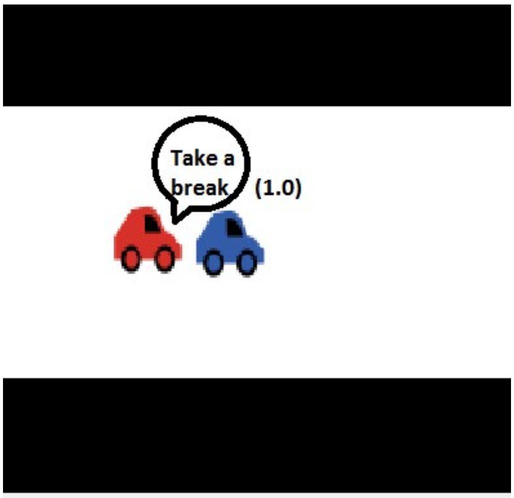

Figure 7. Take break action for very high range accident chances.

6. Discussion

Existing studies have mostly investigated the causes of distraction and verify that the distraction is due to speeding, eating, texting, drinking, attending to phone calls, reading billboards, adjusting vehicle equipment, and interacting with passengers while driving. In (Nourzad et al., 2014) (Seyed Hossein Hosseini Nourzad, Dario D. Salvucci and Anu Pradhan, 2014), they have developed a database of distraction types. From that database, they calculated profile time of distraction and that profile time was used in agent-based traffic simulation modelling. Whereas, we have used fuzzy logic to calculate chances of accidents using speed, distance, and distraction (values of rate of distraction calculated by using fuzzy inference system) and used five variables of each parameter (Very Low, Low, Average, High, Very High) and we also proposed the agent-based accident detection and avoidance system, which not only determines the chances of accidents using fuzzy logic but then takes action to avoid accidents. We have used the Sim-Connector approach in order to connect two simulations (fuzzy inference system and NetLogo simulation) and validated our system using VOMAS agent.

7. Conclusion

Distracted driving is the leading cause of accidents. In order to reduce accidents due to distraction, in this paper, we presented an accident detection and cognitive agent-based accident by cognitive agent-based collision detection and an auto collision avoidance system (CABCD-CA). This system involves two steps. In the first step, we constructed a fuzzy inference system, which uses distraction, speed, and distance as input and using fuzzy logic produces chances of accidents.

Then we provided these values of chances of accident to the cognitive agent, which then performed the collision avoidance process. We validated the system using VOMAS approach. Different invariants are designed to perform the validation using extensive testing showing that the system works successfully and performs accident avoidance due to distraction of human drivers.

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Faisal Riaz (b. Oct 2, 1980) is a PhD candidate at Iqra University, Pakistan and currently serving as an Assistant Professor in the dept. of computer sciences, Mirpur University of Science and Technology, Azad Kashmir, Pakistan. His research interests are Vehicular Cyber Physical Systems, Cognitive Radio, Affective Computing, and Agent Based Modelling. He has more than 31 research publications in various national/international research journals and conferences. He is the author of two books as well. Furthermore, he is heading Intelligent Transport Systems Lab at Mirpur University of Science and Technology (MUST), AJ&K Pakistan. Under the banner of ITS lab, he has developed the first Autonomous Vehicle of Pakistan. He is the reviewer of many well reputed journals. He has served as a technical program committee member in many international IEEE conferences. His reviewing profile can be viewed over https://publons.com/author/742771.

Abdul Ghafoor (b. September 1, 1972) received his Master of Computer Science (2003) from University of Azad Jammu & Kashmir, Muzaffarabad, MSCS in Computer Science (2013) from Iqra University, Islamabad Campus. Now he is lecturer in Department of Computer Science & Information Technology (CS&IT), Mirpur University of Science and Technology, (MUST). His current research interests include different aspects of Software Engineering, Ad Hoc and Wireless Networking.

Yasir Mehmood (b. March 9, 1975) received his Master of Computer Science (2005) from University of Azad Jammu & Kashmir, Muzaffarabad, MSCS in Computer Science (2009) from FAST-National University of Computer and Emerging Sciences, Islamabad. He is currently working towards the Ph.D. degree at the department of Computer Sciences, FAST-National University of Computer and Emerging Sciences, Islamabad. Currently, he is working as an Assistant Professor in Department of Computer Science & Information Technology, Mirpur University of Science and Technology. His research interest includes optimization using Computational Intelligence and Swarm Intelligence techniques.

Dr. Naeem Iqbal Ratyal received Ph.D degree in Electrical Engineering from Capital University of Science & Technology (CUST), Pakistan in 2016. His research interests are 3D face recognition, image processing and computer vision. He is currently working as an assistant professor in the department of electrical engineering, Mirpur University of Science & Technology (MUST), Azad Kashmir, Pakistan.