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Relationship between the Traffic Parameters and Road Traffic Accidents using Fuzzy Logic Designer in Matlab: A Case Study of Uganda's Road Traffic Accidents

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Abstract – Road traffic accidents in Uganda continue to increase with increasing parameters like population, cars owned. The accidents mainly increase due to driver errors. Strictness on the driving lessons in driving schools have been put in place; however, even the experts in driving, keep making errors. Driving while tired or under the influence of alcohol, are some of the reasons why accidents increase. In this study, fuzzy logic has been used to simulate the relationship between the traffic parameters and road traffic accidents. The results have shown that the traffic parameters increase the road traffic accidents. It was simulated that with no parameters in place, a vehicle is at 62 percent chance of moving, that is, 38 percent accident chance in case the driver moves, while with parameters in place; the motion chance reduces to 48.2 percent; that is, 51.8 percent accident chance in case the driver moves.

Keywords – Fuzzy Logic, Traffic Lights, Traffic Parameters, MATLAB.

I. INTRODUCTION

Traffic on roads consists of pedestrians, vehicles, ridden or herded animals using the road as a means of transportation. Heavy traffic including congestion can be observed on urban roads all over the world. Since space for new roads is very limited, it is necessary to improve the exploitation of the existing network (Schafer, 2002). Traffic light is a signaling device that helps in indicating when it may be safe to drive, ride, or walk using the universal colour code. This however, does not cater for the learners or experts in driving. Hence the many accidents on the roads. On top of that, there is illiteracy among the drivers and other road users (Okaka W. a., 2018), (Okaka W. a., 2019), (Okaka W. a., 2019).

In Uganda specifically, 25,729 crashes occurred on Ugandan roads in 2016, involving 59,077 individuals with 7,558 fatalities (Muni, 2020). This is more than twice the number of fatalities reported by the police for 2016 (3,502) but lower than the estimate from the 2018 Global Status Report (12,036). The fatal road traffic injuries (RTI) rate in Kampala District is still almost twice as high as the global rate of 17.4 per 100,000 (Ario, 2020). In addition, vulnerable road users and young adult males were the most affected category. The RTI motorcycle contribution rose steadily from 2009 to 2017 (24.5 percent to 33.9 percent) (Vaca, 2020). While the total number of crashes dropped from 22,461 to 13,244 between 2010 and 2017, the proportion of fatal RTIs increased from 14.7 percent to 22.2 percent. Reducing congestion and waiting time will lessen the number of accidents (Kanungo, 2014). The project can be augmented for coordination control which places traffic signals on a coordinated system so that drivers encounter long strings of green lights. This will also provide data for future road design and construction or where improvements are required and which are urgent like which junction has higher waiting times. However, this only focuses on the waiting time. Additional measures that

incorporate the role of private operators managing highway toll roads (Nduhura, 2021). This outcome is important as it provides policy implications that can be implemented to reduce deaths due to road traffic accidents that are currently on the rise. The measures devised to mitigate Road Traffic Injuries (RTI) in an emerging city like Kampala should study thoroughly the patterns of traffic and population flow to help to optimize the use of available resources for effective road safety planning, injury prevention and sustainable transport systems (Balikuddembe, 2020).

In this paper, fuzzy logic is used to study the relationship between the traffic parameters and road traffic accidents. Fuzzy logic is an approach to variable processing that allows for multiple values to be processed through the same variable; unlike the Boolean logic that uses “1” and “0” outputs, fuzzy logic has an output that is an integral from “0” to “1”, that is, [0,1] (Moraga, 2005), (Dingle, 2011). The fuzzy logic can be accessed through MATLAB using the Fuzzy Logic Designer application.

II. MATERIALS AND METHODS

2.1. Materials

In this work, the following materials were used but not limited to: MATLAB software, Fuzzy Logic Designer application. (Kulkarni, 2007) concentrated on the minimizing of the traffic delays but does not look at other traffic parameters. (Atapattu, 2010), (Noviyantono, 2012) only looked at the traffic system based on fuzzy logic that reduces on the traffic congestions. (Poletajew, 2016), (Abiyev, 2017) further looked at reduction of the numbers of vehicles in the cross-roads in the shortest time possible. Therefore, the method used in this study focused on understanding the relationship between the traffic parameters and accidents using fuzzy logic.

The schematic diagram in Figure 1: Fuzzy logic architecture shows the fuzzy logic architecture used in setting the rules and identify the crisp inputs and outputs.

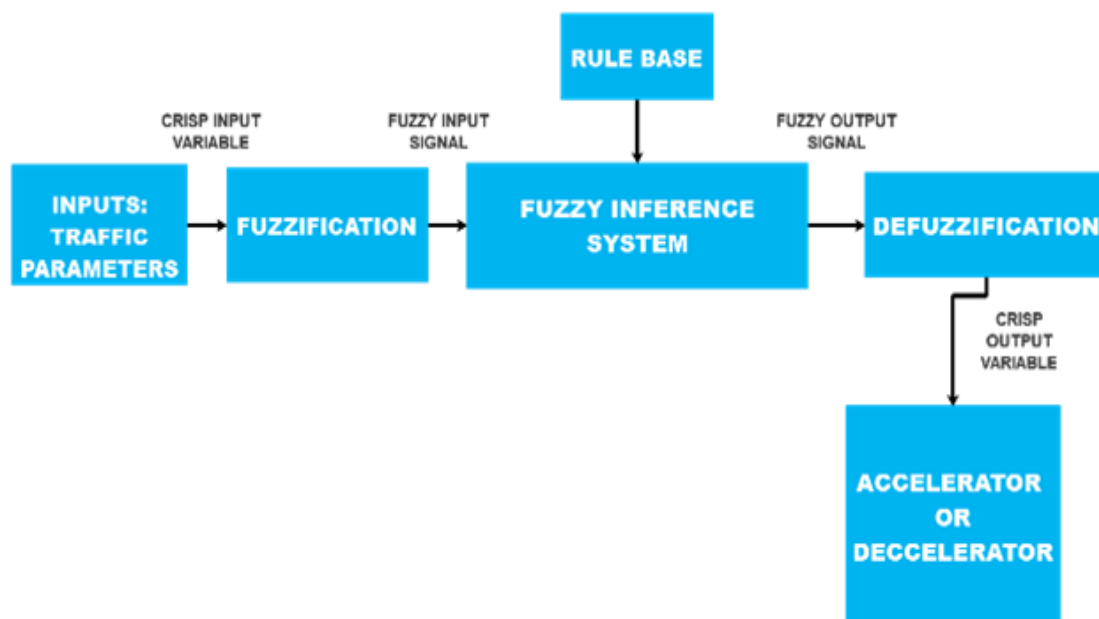


Fig. 1. Fuzzy logic architecture.

Figure 2 shows the fuzzy architecture in Fuzzy Logic Designer application with three inputs (traffic lights, approaching car, approaching person), Mamdani type inference and output (motion).

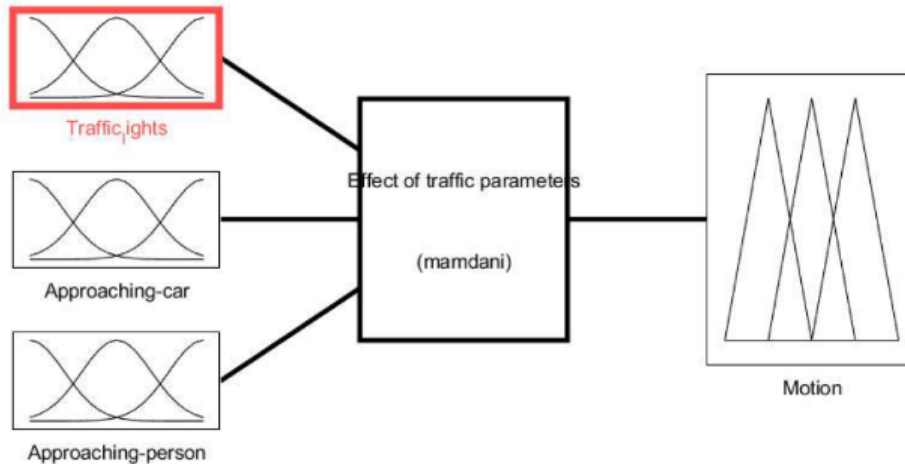


Fig. 2. Fuzzy architecture in fuzzy logic designer.

Figure 3 shows the three membership functions of the traffic lights consisting of the red, orange, and green. Figure 4 and 5 show the four membership functions of the approaching car and approaching person respectively, namely: left-lane, in-front, right-lane, and clear. Figure 6 shows the three membership functions of the motion, namely: stop, get-ready, and go.

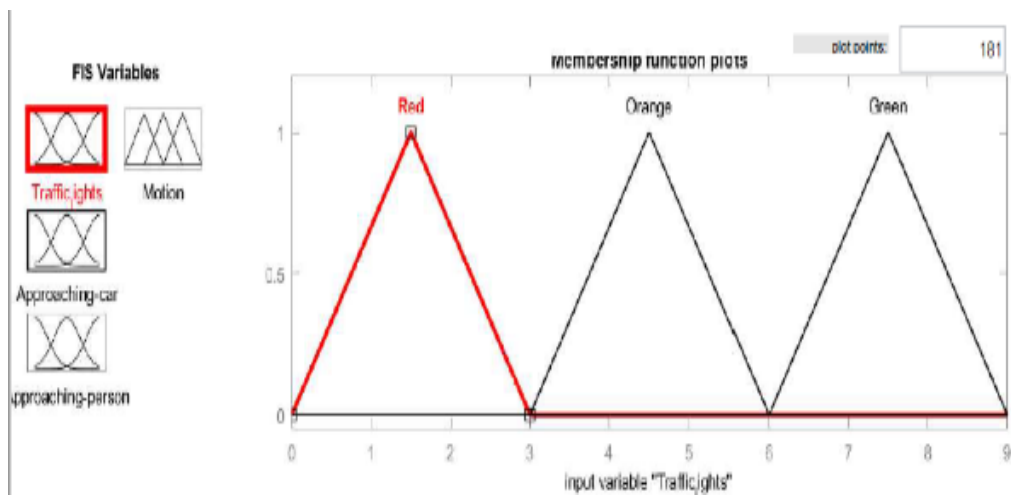


Fig. 3. Traffic light (Input) membership function.

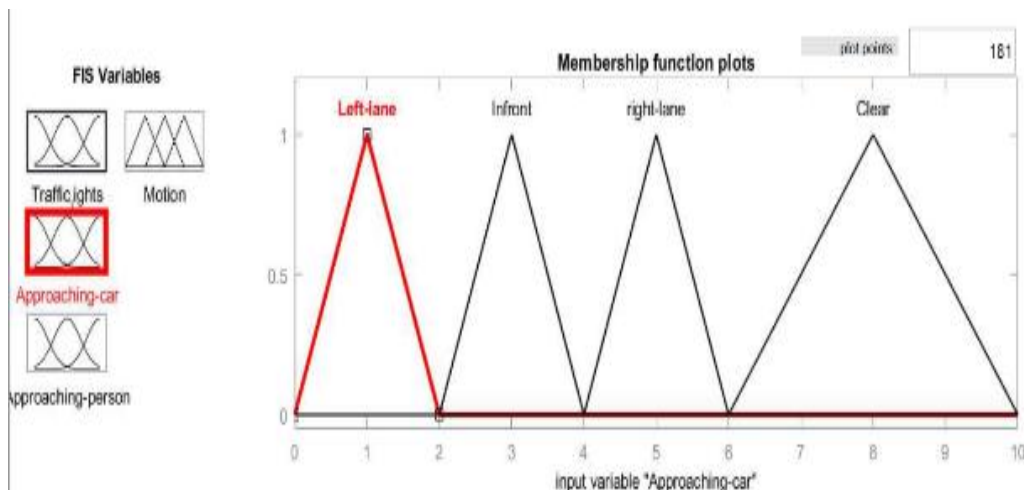


Fig. 4. Approaching car (Input) membership function.

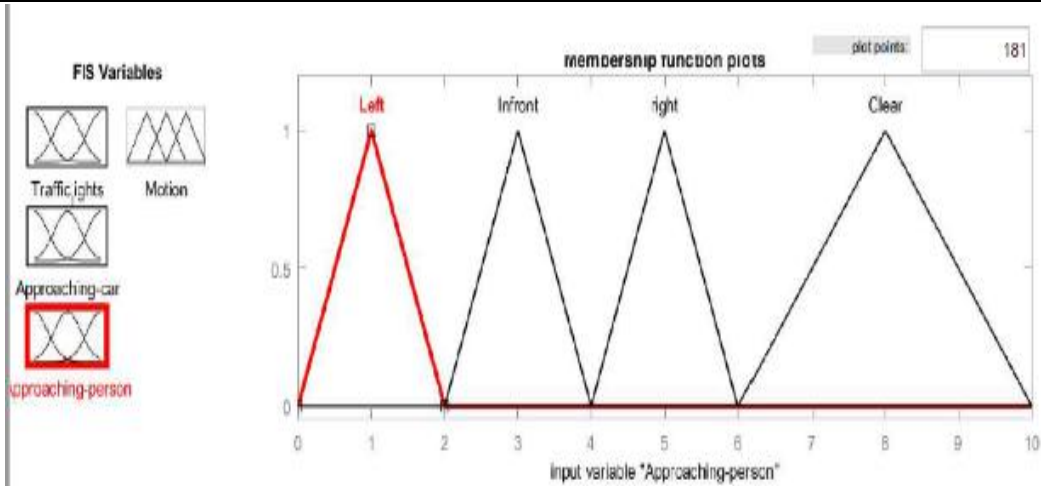


Fig. 5. Approaching person (Input) membership function.

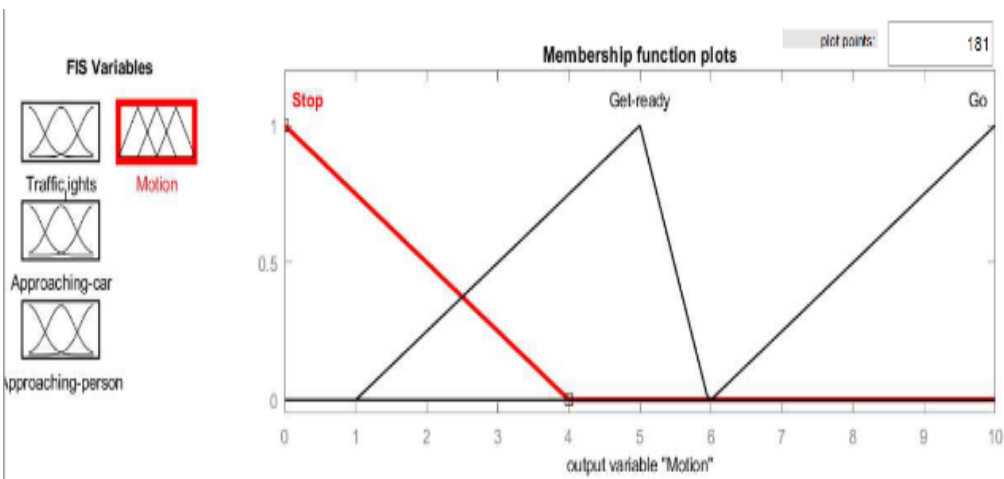


Fig. 6. Motion (Output) membership function.

Figure 7 shows the rule base consisting of 49 rules in the Fuzzy rule editor. The rules are what are used in determining the relationship between the traffic parameters and road traffic accidents.

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34. (Traffic_lights==Green)((Approaching-car==Left-lane)((Approaching-person==infront)=>(Motion=Get-ready)
35. (Traffic_lights==Green)((Approaching-car==Left-lane)((Approaching-person==right)=>(Motion=Get-ready)
36. (Traffic_lights==Green)((Approaching-car==Left-lane)((Approaching-person==Clear)=>(Motion=Get-ready)
37. (Traffic_lights==Green)((Approaching-car==Infront)((Approaching-person==Left)=>(Motion=Get-ready)(1)
38. (Traffic_lights==Green)((Approaching-car==Infront)((Approaching-person==Infront)=>(Motion=Get-ready)(1)
39. (Traffic_lights==Green)((Approaching-car==Infront)((Approaching-person==right)=>(Motion=Get-ready)(1)
40. (Traffic_lights==Green)((Approaching-car==Infront)((Approaching-person==Clear)=>(Motion=Get-ready)(1)
41. (Traffic_lights==Green)((Approaching-car==right-lane)((Approaching-person==Left)=>(Motion=Get-ready)
42. (Traffic_lights==Green)((Approaching-car==right-lane)((Approaching-person==Infront)=>(Motion=Get-read
43. (Traffic_lights==Green)((Approaching-car==right-lane)((Approaching-person==right)=>(Motion=Get-ready)
44. (Traffic_lights==Green)((Approaching-car==right-lane)((Approaching-person==Clear)=>(Motion=Get-ready)
45. (Traffic_lights==Green)((Approaching-car==Clear)((Approaching-person==Left)=>(Motion=Get-ready)(1)
46. (Traffic_lights==Green)((Approaching-car==Clear)((Approaching-person==Infront)=>(Motion=Get-ready)(1)
47. (Traffic_lights==Green)((Approaching-car==Clear)((Approaching-person==right)=>(Motion=Get-ready)(1)
48. (Traffic_lights==Green)((Approaching-car==Clear)((Approaching-person==Clear)=>(Motion=Go)(1)
49. (Traffic_lights==Green)=>(Motion=Go)(1)

```

Fig. 7. Fuzzy rule editor.

III. RESULTS AND DISCUSSION

The terminologies used in the caption of the figures, traffic light, approaching car, and approaching person are input parameters used as the crisp input variables. Green, orange, and red are linked to the traffic light; right-lane, infront, and left-lane (a car/ person approaching the vehicle with the fuzzy logic system), clear implies that

there is no approaching car or person, none implies that no approaching car or person is expected to approach the car with the system.

The traffic lights are displaying the green colour (implying go) in Figure 8 and orange colour in Figures 9, however, the motion of the car has less than 50 percent (48.2 percent) chance of moving.

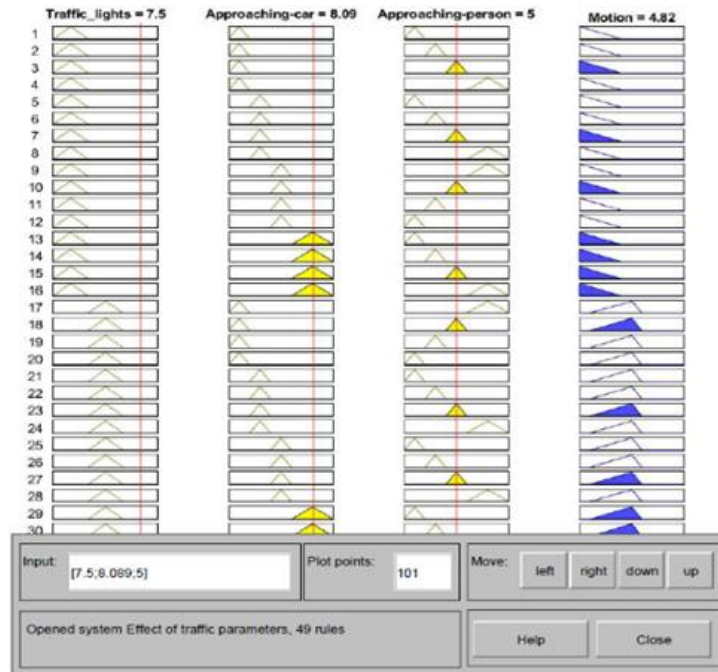


Fig. 8. Traffic light = green, Approaching car = clear, Approaching person = right-lane, Motion = 4.82.

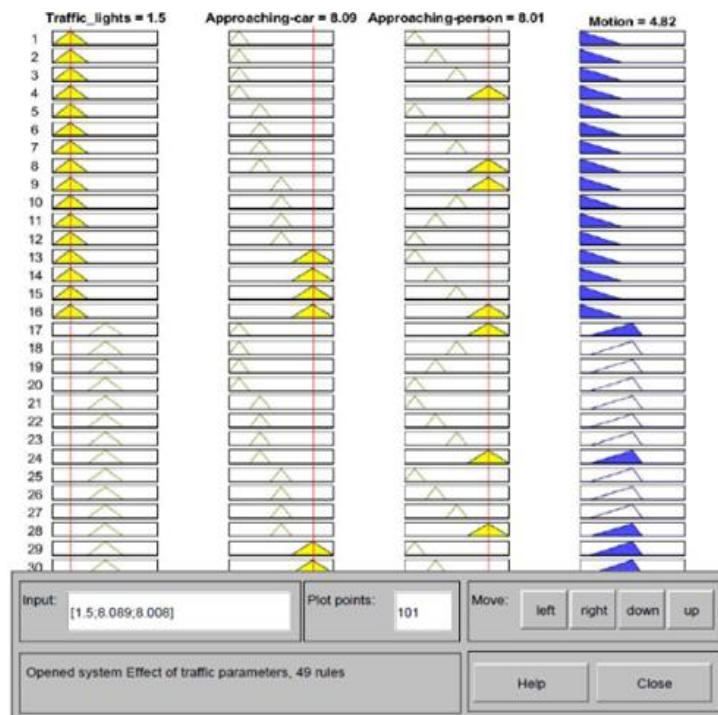


Fig. 9. Traffic light = red, Approaching car = clear, Approaching person = clear, Motion = 4.82.

When the traffic lights turned to red in Figure 10, with approaching car and person on the left-lane, the chance reduced to 28 percent chance of motion/ acceleration. When the traffic light turned to green with a scenario

where there is no expected approaching car or person, the chance of the car accelerating or starting increased to 62.1 percent as shown in Figure 11.

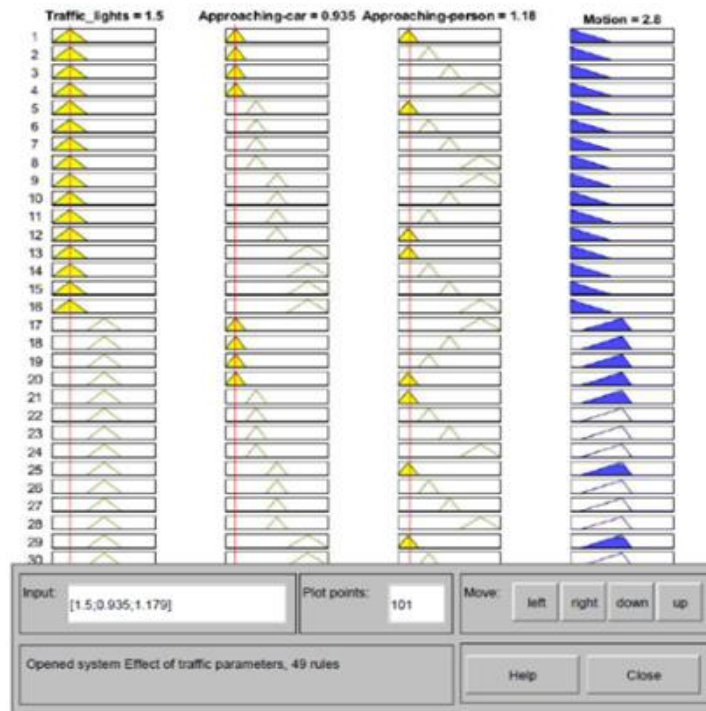


Fig. 10. Traffic light = red, Approaching car = left-lane, Approaching person = left-lane, Motion = 2.8.

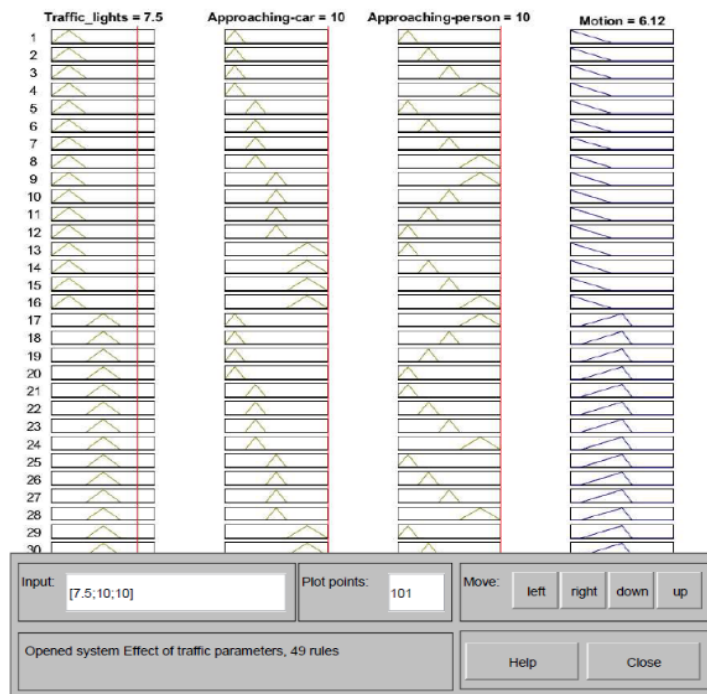


Fig. 11. Traffic light = green, Approaching car = None, Approaching person = None, Motion = 6.12.

Figures 12 and 13 show the surface plot with dark blue for a region where the car stops, light blue for a region where the car gets ready to start motion, yellow is a region where a car can start moving however only when there is no approaching car/ person (between 6 to 9) and the traffic light is green. This region can clearly be seen at the T-junction of the yellow region.

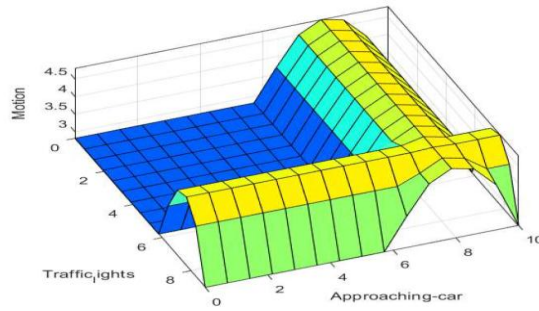


Fig. 12. Surface plot showing the 3D graph of motion, traffic lights, approaching car.

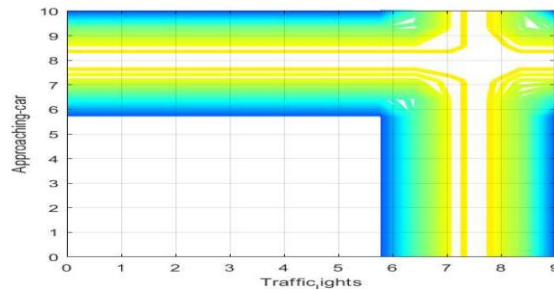


Fig. 13. Surface contour plot showing the 2D graph of approaching car against traffic lights.

This therefore implies that the more parameters are put in place, the riskier it is for road accidents to increase.

IV. CONCLUSION

The fuzzy logic results have shown that the traffic parameters increase the road traffic accidents. It was simulated that with no parameters in place, a vehicle is at 62 percent chance of moving, while with parameters in place, the motion chance reduces to 48.2 percent. Therefore, future researchers can design a system that uses fuzzy logic in automated vehicles to help in reducing the road traffic accidents. This can be done with the input of computer vision to detect approaching cars and person; to help in determining the parameters' speed, flow, and densities.

APPENDIX



Fig. 14. Traffic light = green, Approaching car = left-lane, Approaching person = right-lane, Motion = 4.82.

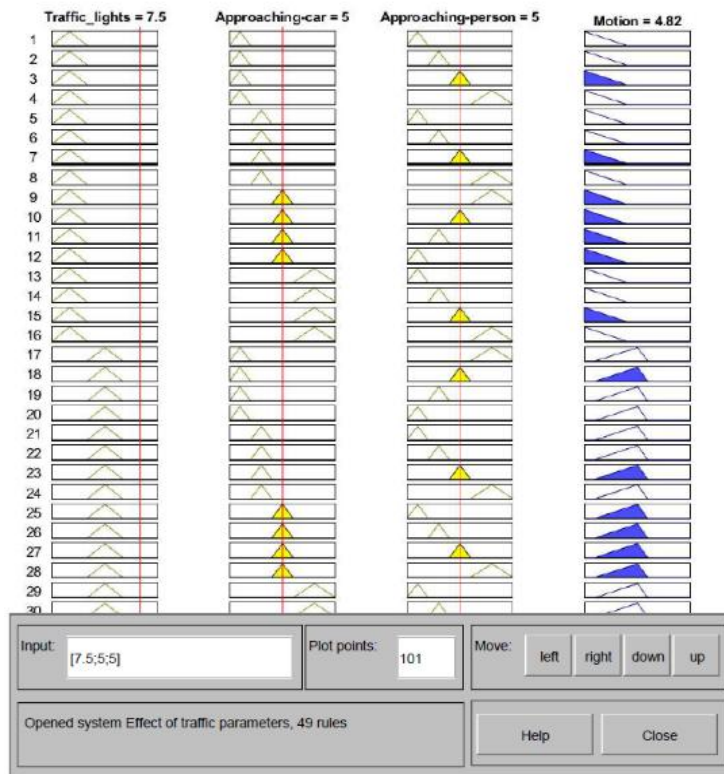


Fig. 15. Traffic light = green, Approaching car = right-lane, Approaching person = right-lane, Motion = 4.82.

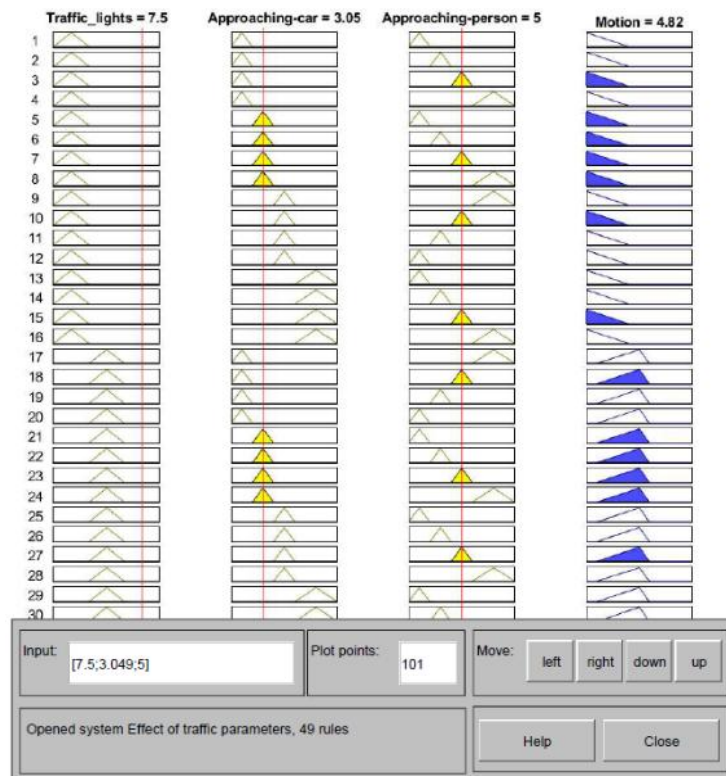


Fig. 16. Traffic light = green, Approaching car = infront, Approaching person = right-lane, Motion = 4.82.

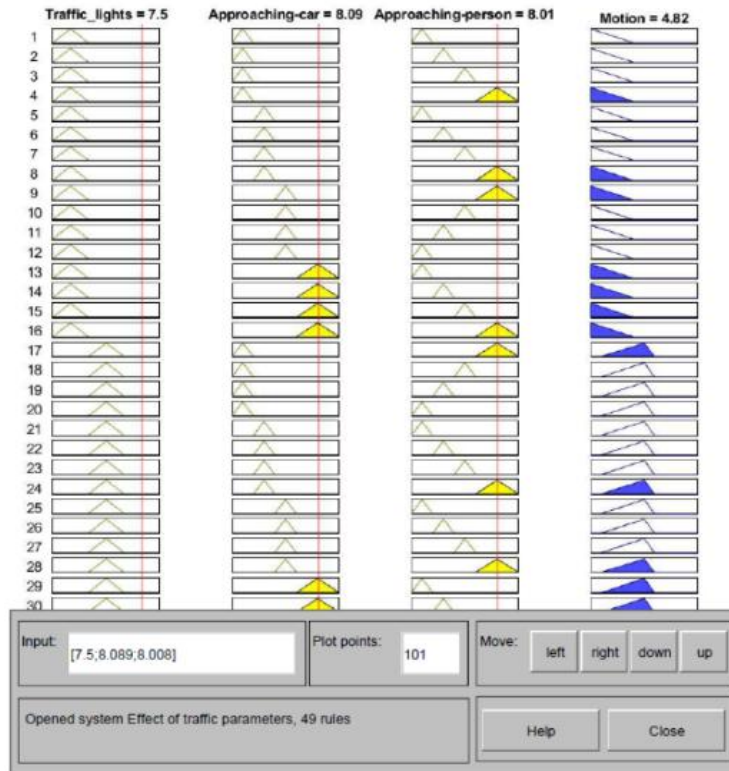


Fig. 17. Traffic light = green, Approaching car = clear, Approaching person = clear, Motion = 4.82.

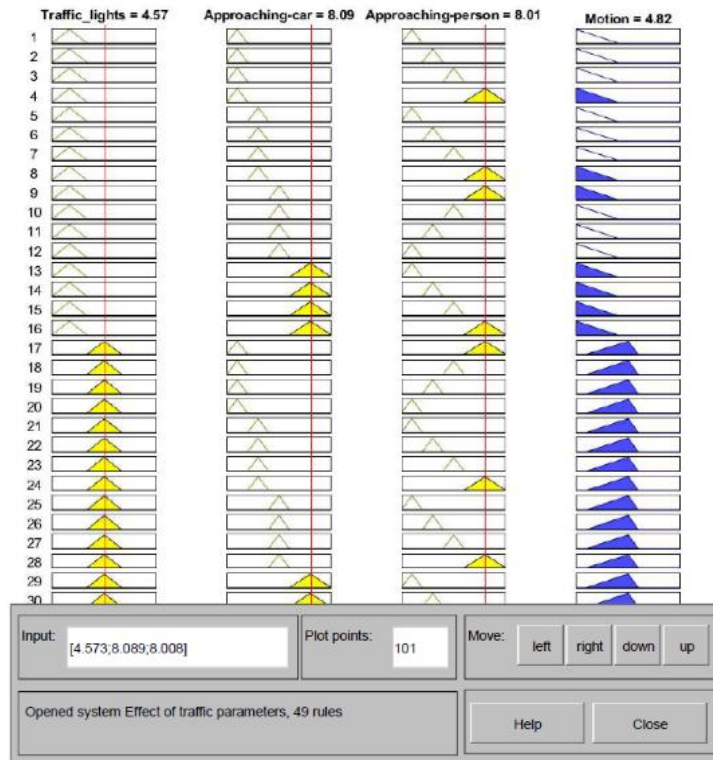


Fig. 18. Traffic light = orange, Approaching car = clear, Approaching person = clear, Motion = 4.57.

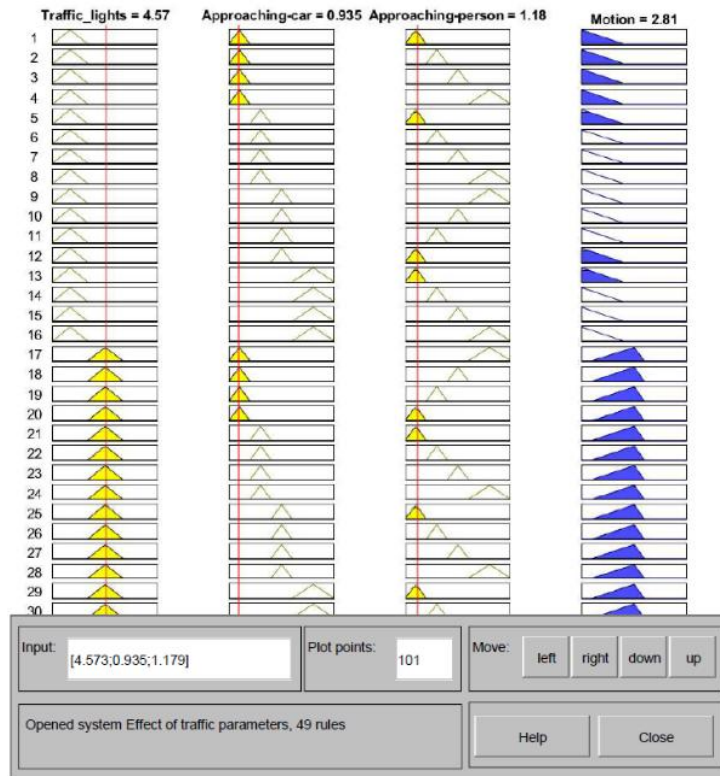


Fig. 19. Traffic light = orange, Approaching car = left-lane, Approaching person = left-lane, Motion = 2.81.

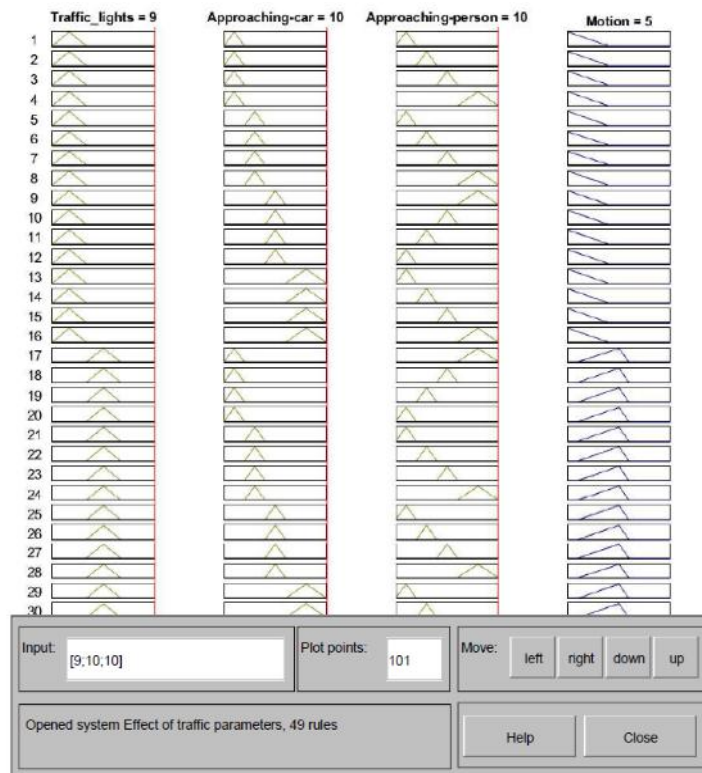


Fig. 20. Traffic light = None, Approaching car = None, Approaching person = None, Motion = 5.

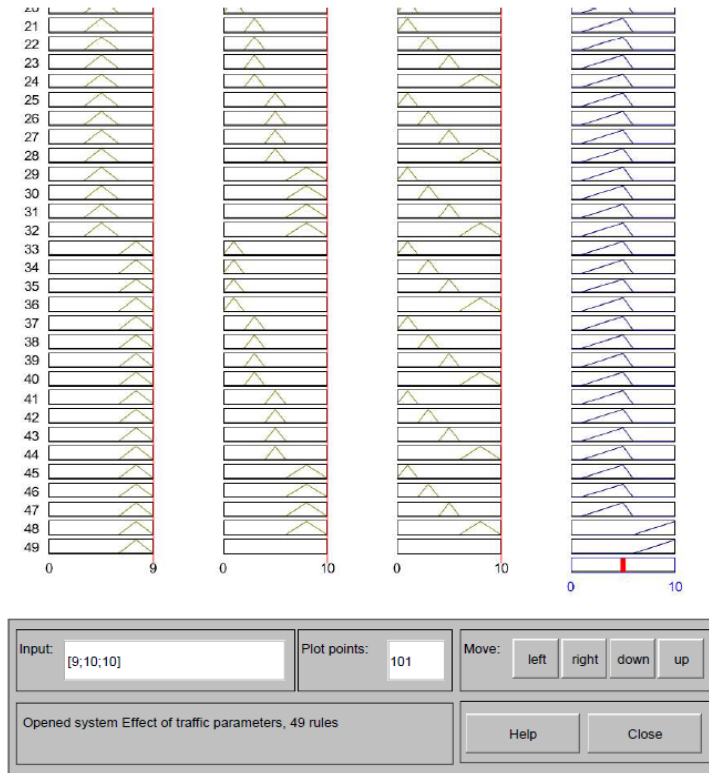


Fig. 21. Traffic light = None, Approaching car = None, Approaching person = None, Motion = 5.

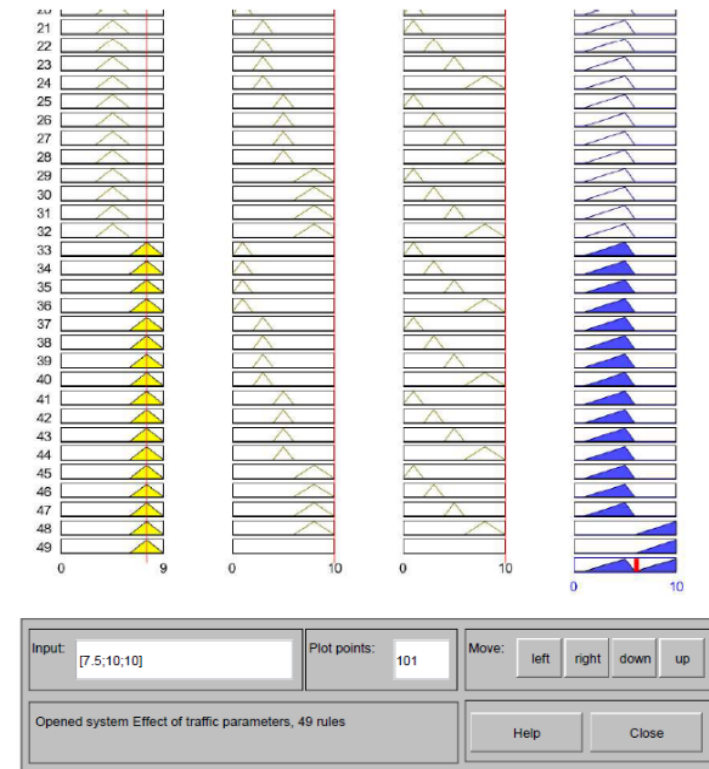


Fig. 22. Traffic light = green, Approaching car = None, Approaching person = None, Motion = 6.12.

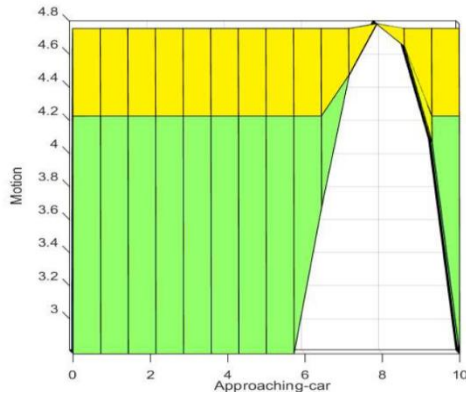


Fig. 23. Surface plot showing the graph of motion against approaching car.

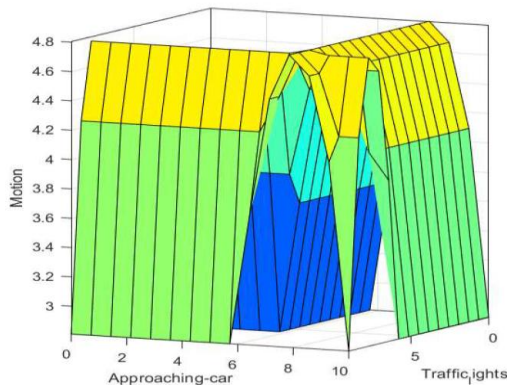


Fig. 24. Surface plot showing the 3D graph of motion, approaching car, traffic lights.

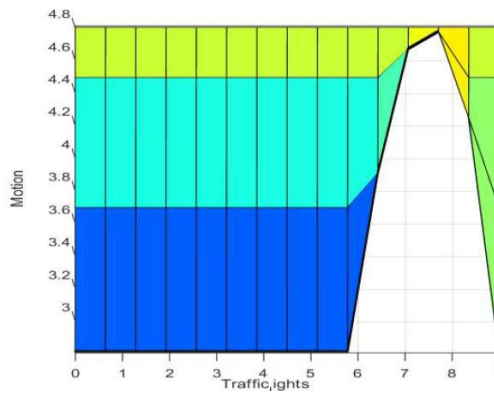


Fig. 25. Surface plot showing the graph of motion against traffic lights.

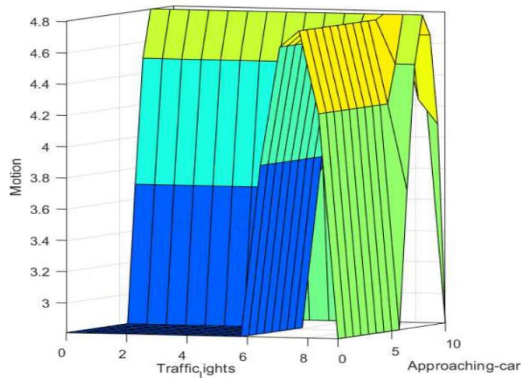


Fig. 26. Surface plot showing the 3D graph of motion, traffic lights, approaching car.

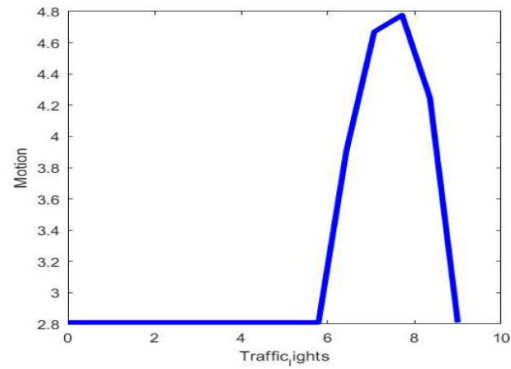


Fig. 27. Surface plot showing the graph of motion against traffic lights.

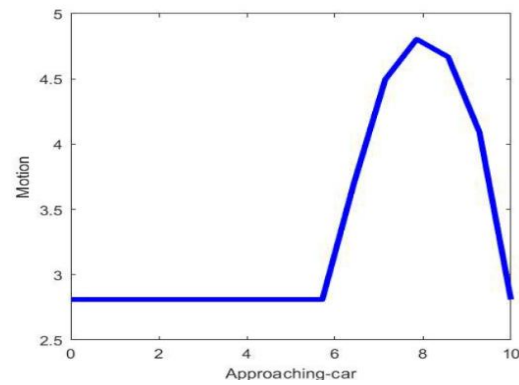


Fig. 28. Surface plot showing the graph of motion against approaching car.

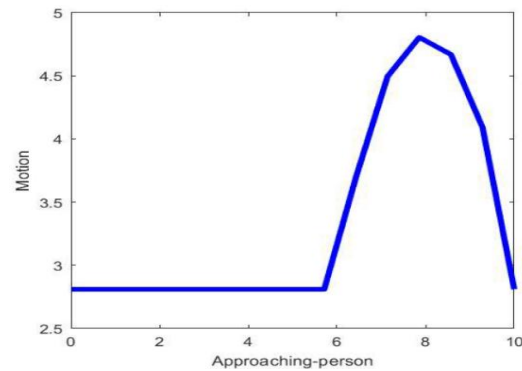


Fig. 29. Surface plot showing the graph of motion against approaching person.

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