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Fuzzy Expert System

PLANNING AND APPROXIMATE REASONING - EXERCISE 2

JOSEP FAMADAS ALSAMORA / JORDI RIU VICENTE

UNIVERSITAT ROVIRA i VIRGILI

URV | Facultat de Informàtica

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1. Introduction

In this document we present the results of our project, which is devoted to design a fuzzy expert system.

The system controls the light intensity of a car required and the safety distance between it and the car in front. It takes into account environmental variables such as rain intensity, lightness, fog and tires pressure.

The system uses the Mamdani inference procedure and the Center of Area as defuzzification method.

To design this system, we have used the fuzzyTECH software.

2. Input variables

In this system we have considered 4 different input variables. The first 3 are given and we have decided the fuzzy sets of the fourth one.

2.1. Rainfall

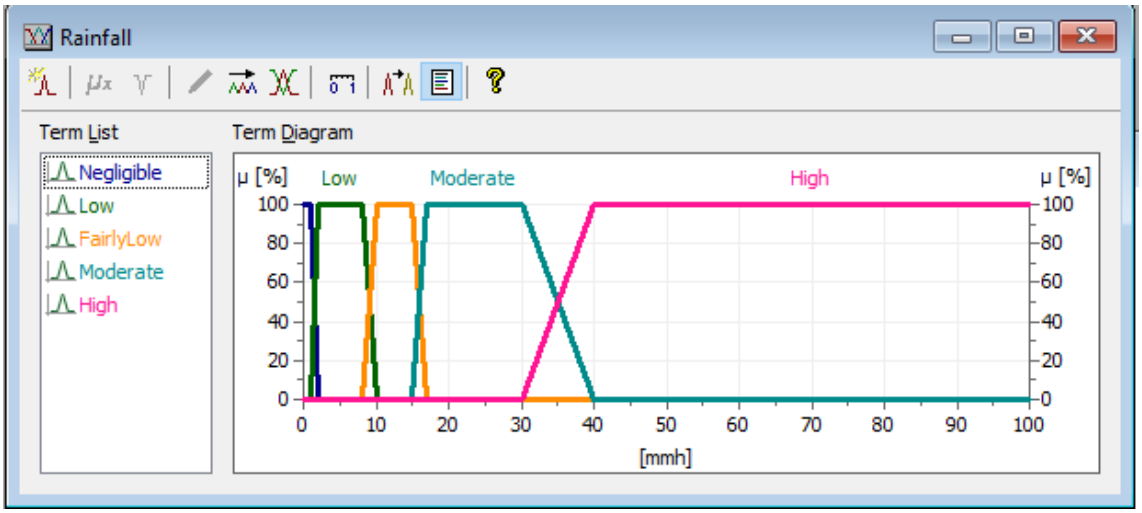

Figure 1: Rainfall fuzzy sets

2.2. Lightness

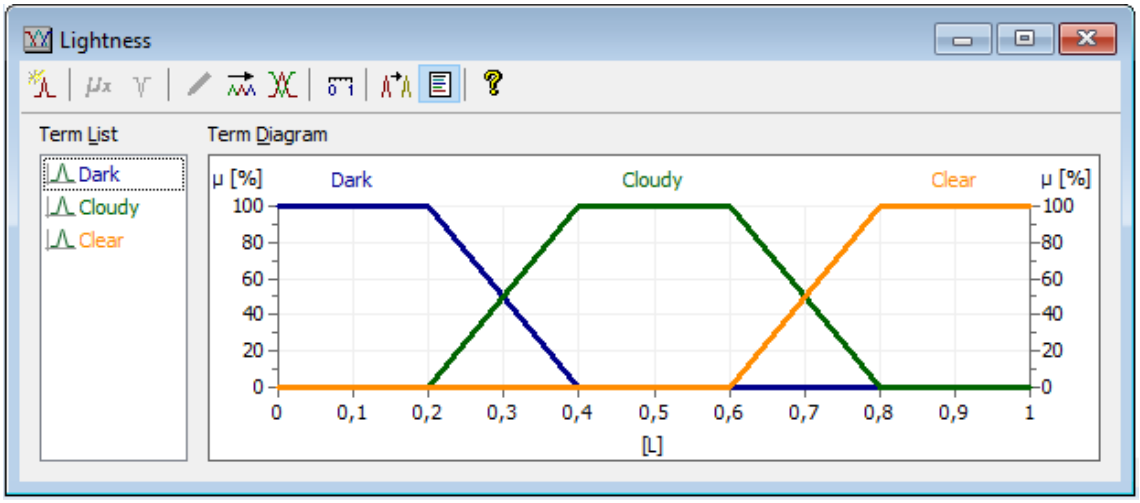

Figure 2: Lightness fuzzy sets

2.3. Fog

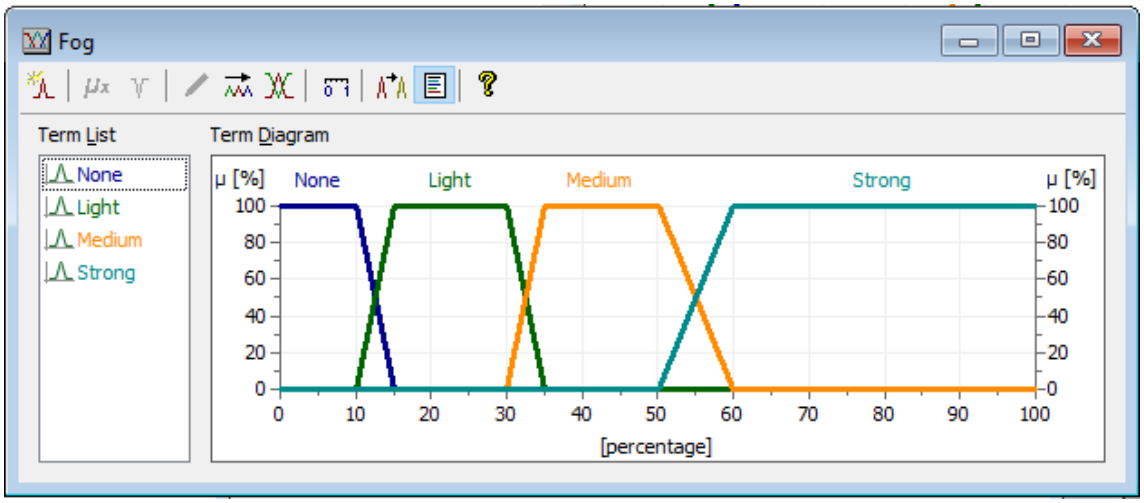

Figure 3: Fog fuzzy sets

2.4. Tires pressure

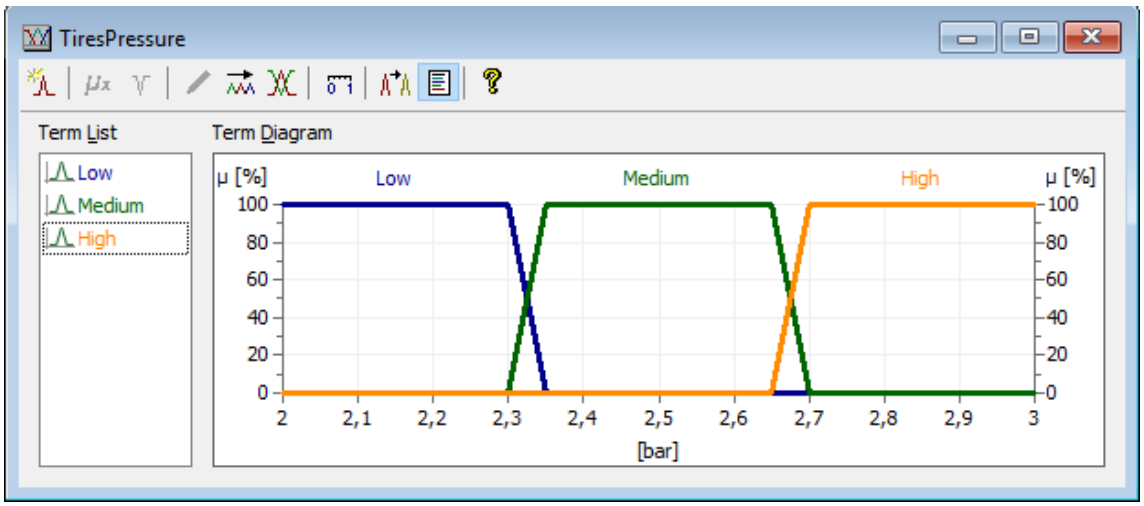

Figure 4: Tires pressure fuzzy set

For this variable we have considered three equal fuzzy sets and for the values in barometers we have looked it up on the internet for real data.

3. Output variables

For each one of the 2 previously mentioned output variables we have defined their fuzzy sets and created a block of rules. There is also an intermediate variable (Visibility level) that has its own sets and rules.

3.1. Visibility Level

3.1.1. Fuzzy sets

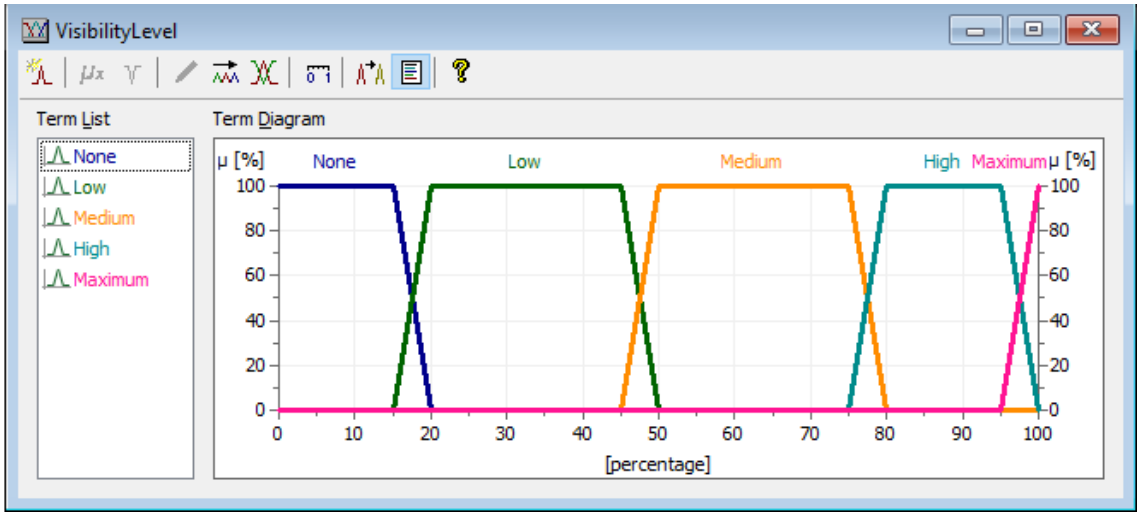

Figure 5: Visibility level fuzzy sets

For the visibility we have considered 5 different fuzzy sets because it is an intermediate variable and we wanted the system to consider as much options as possible.

As it can be seen in *Figure 5* the sets are not equal. Low and Medium visibility are the biggest ones because we thought that in real life they are the most common visibility levels. On the other hand, Maximum visibility is something that nearly ever happens so it is really short.

3.1.2. Rules

In *Figure 6* can be appreciated the rules for the Visibility level. To design them we have considered that the fog is the most significant issue to visibility. For this reason, if it is strong there is no visibility. Apart from this, the combination of maximum rain level (High) and minimum lightness (Dark) also gives no visibility. Due to the fact that these two rules admit some uncertainty in one or more parameters, they do not have a 100% degree of support.

For the rest of the rules we have followed a logic procedure decreasing the visibility level as the fog and rain intensity increased and the lightness decreased.

	Name	If	And	And	Operators	Then	With
B1	RB1	1	2	3	Min / Max	1	
B1.G1	Rules	Rainfall	Lightness	Fog		VisibilityLevel	DoS [%]
B1.G1.R1				Fog.*Strong*	=>	VisibilityLevel.*None*	80
B1.G1.R2		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100
B1.G1.R3		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R4		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R5		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R6		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R7		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R8		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R9		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R10		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R11		Rainfall.*Low*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100
B1.G1.R12		Rainfall.*Low*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R13		Rainfall.*Low*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R14		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R15		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R16		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R17		Rainfall.*Low*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R18		Rainfall.*Low*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R19		Rainfall.*Low*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R20		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R21		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R22		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R23		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R24		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R25		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R26		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R27		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R28		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R29		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R30		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R31		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R32		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R33		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R34		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R35		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Low*	100
B1.G1.R36		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R37		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*None*	100
B1.G1.R38		Rainfall.*High*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R39		Rainfall.*High*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R40		Rainfall.*High*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R41		Rainfall.*High*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*Low*	100
B1.G1.R42		Rainfall.*High*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R43		Rainfall.*High*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R44		Rainfall.*High*	Lightness.*Dark*		=>	VisibilityLevel.*None*	90

Figure 6: Visibility level rules

3.1.3. Dependences

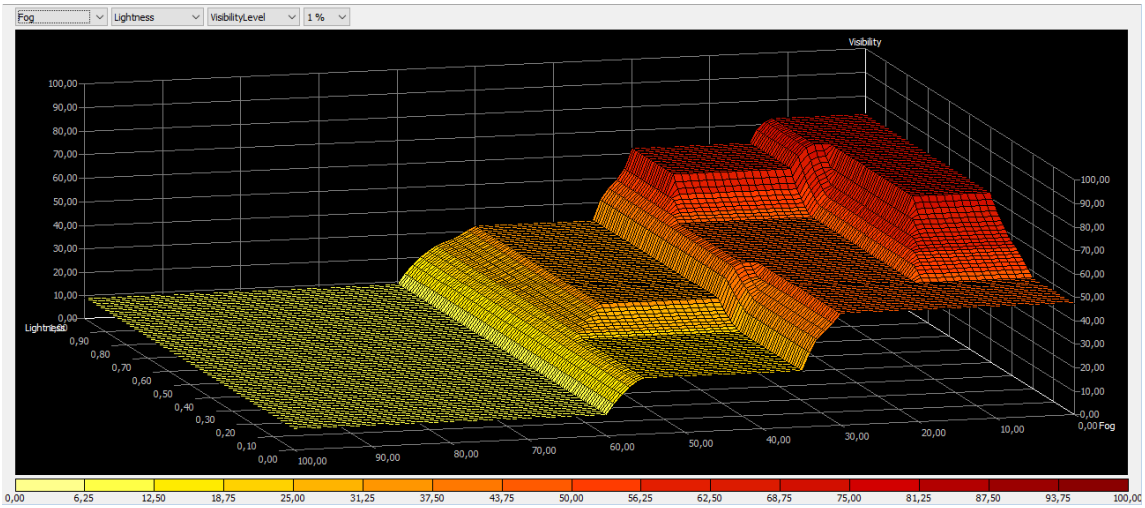

Figure 7: Visibility Level (Vertical) as a function of Fog (Horizontal) and Lightness (Depth)

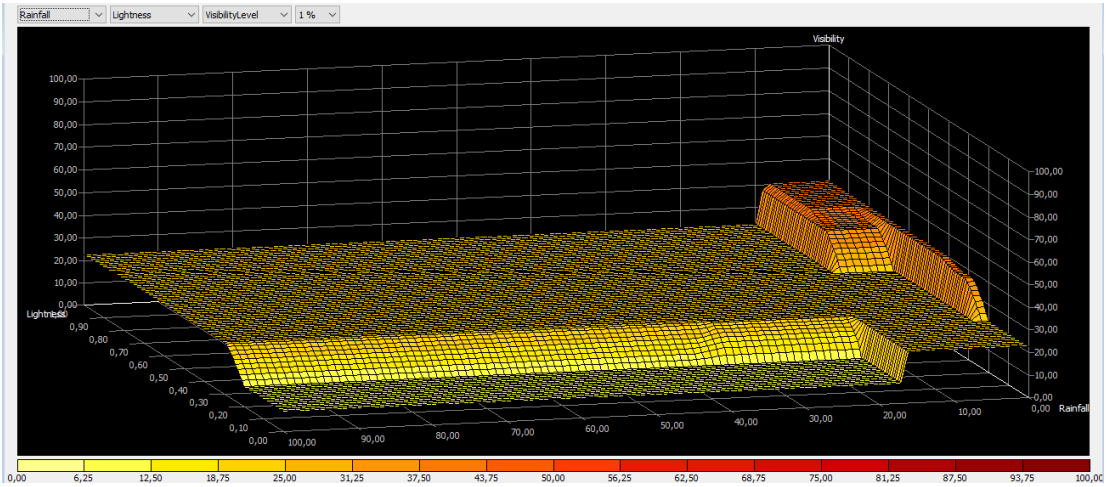

Figure 8: Visibility Level (Vertical) as a function of Rainfall (Horizontal) and Lightness (Depth)

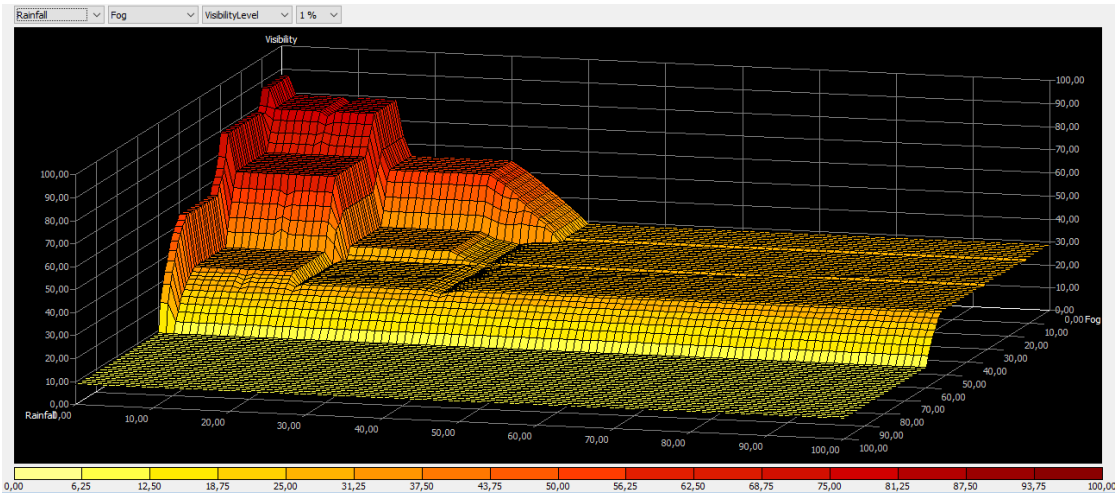

Figure 9: Visibility Level (Vertical) as a function of Rainfall (Horizontal) and Fog (Depth)

3.2. Light Instruction

3.2.1. Fuzzy sets

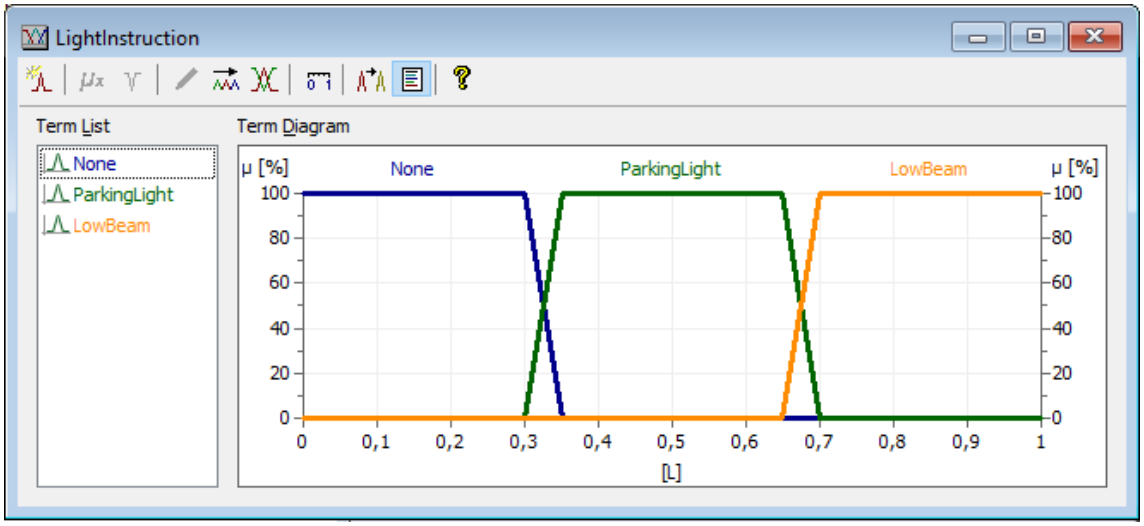

Figure 10: Light Instruction fuzzy sets

For the first output variable we have designed 3 equispaced sets. They represent not having the lights on, having just the Parking Lights (which are just to help other cars to see you) and the Low Beam light which allow you to better see the environment.

3.2.2. Rules

For these rules we just made the assignment minimum visibility with maximum light, the other way around and Medium visibility with parking light.

The intermediate levels between the maximum or minimum and the medium (Low and High), have been assigned to the higher and lower lights but with less degree of support.

	Name	If	Operators	Then	With
B3	RB2		Min / Max		
B3.G1	Rules	VisibilityLevel		LightInstruction	DoS [%]
B3.G1.R1		VisibilityLevel.*None*	=>	LightInstruction.*LowBeam*	100
B3.G1.R2		VisibilityLevel.*Low*	=>	LightInstruction.*LowBeam*	70
B3.G1.R3		VisibilityLevel.*Medium*	=>	LightInstruction.*ParkingLight*	100
B3.G1.R4		VisibilityLevel.*High*	=>	LightInstruction.*None*	70
B3.G1.R5		VisibilityLevel.*Maximum*	=>	LightInstruction.*None*	100

Figure 11: Light Instruction rules

3.2.3. Dependences

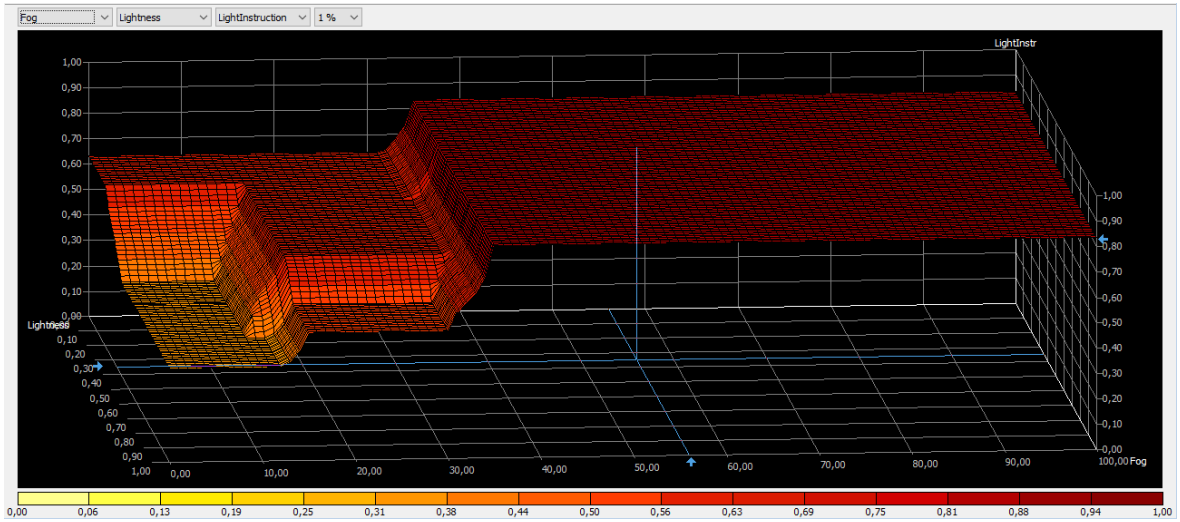

Figure 12: Light Instruction (Vertical) as a function of Fog (Horizontal) and Lightness (Depth)

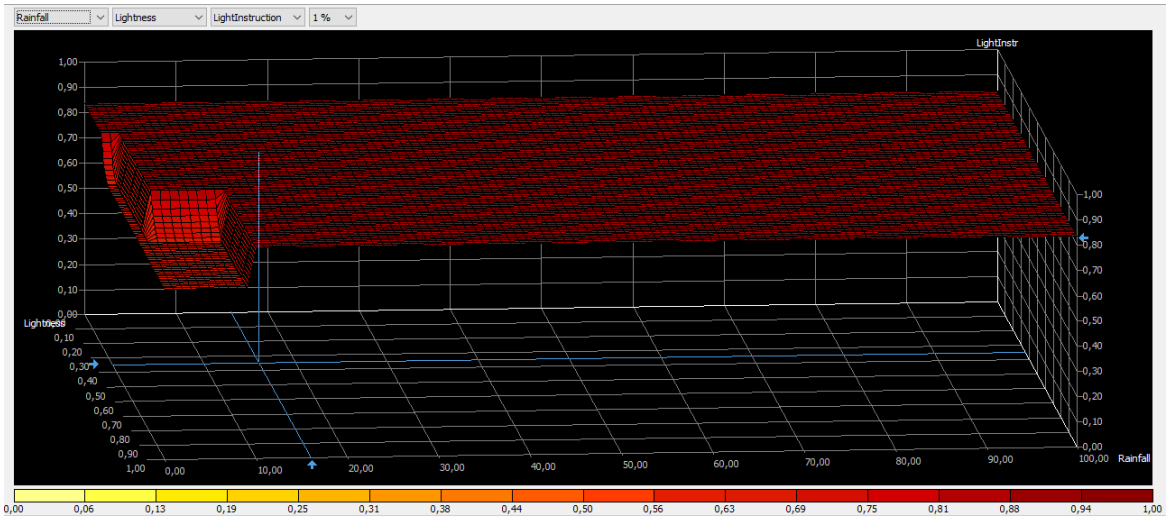

Figure 13: Light Instruction (Vertical) as a function of Rainfall (Horizontal) and Lightness (Depth)

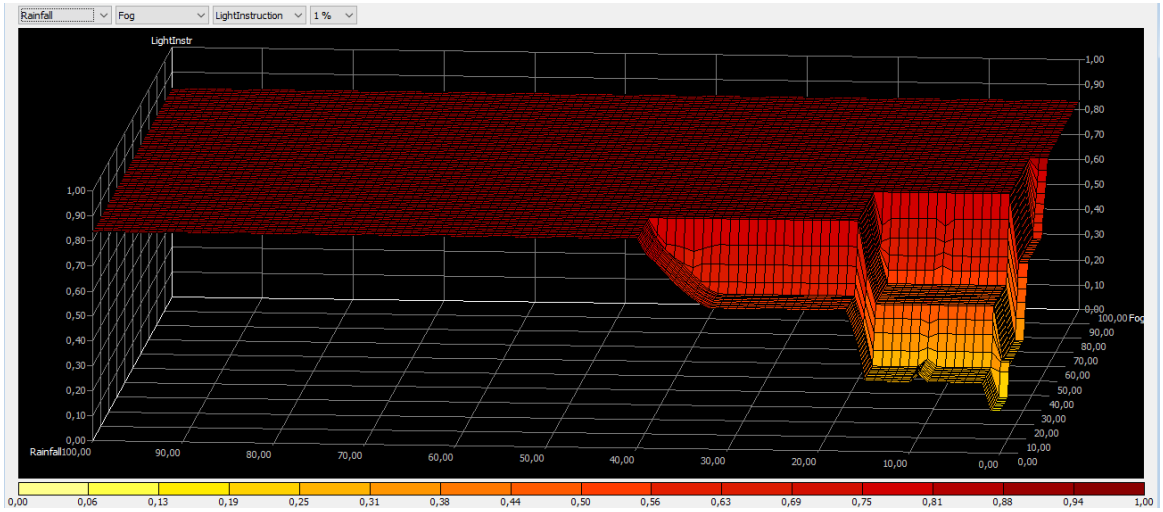

Figure 14: Light Instruction (Vertical) as a function of Rainfall (Horizontal) and Fog (Depth)

3.3. Front Car Distance

3.3.1. Fuzzy sets

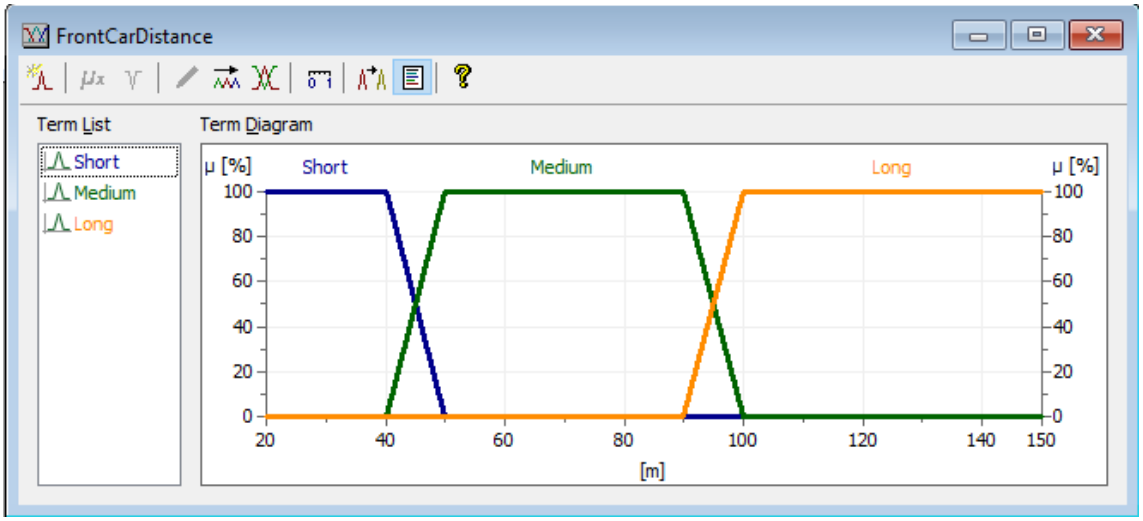

Figure 15: Front Car Distance fuzzy sets

For the front car distance, we have also used 3 different fuzzy sets. To define the range for such sets, we have taken into consideration that we are not controlling nor using the speed of the car when computing this value, and therefore we have given the short fuzzy set a smaller weight (Area) than the long fuzzy set. By doing this, we would like to displace the CoA towards the long fuzzy set to make sure we are driving safely.

3.3.2. Rules

For the Front Car Distance rules, we have taken into consideration what has the harder effect in the braking distance is the wet floor, so if the rain intensity is high, one should maintain the maximum possible distance from the front car. Also, with none visibility the driver must be as far as possible from the next vehicle. We have not given much importance to the tires pressure, and for the extremes (high visibility – low rain and the other way around) we have not considered it for the decision. In the intermediate levels of rain and visibility we thought that a lower pressure on the tires would make it easy to brake.

	Name	If	And	And	Operators	Then	With
B2	RB3	1	2	3	Min / Max	1	
B2.G1	Rules	VisibilityLevel	Rainfall	TiresPressure		FrontCarDistance	DoS [%]
B2.G1.R1			Rainfall.*High*		=>	FrontCarDistance.*Long*	100
B2.G1.R2		VisibilityLevel.*None*			=>	FrontCarDistance.*Long*	100
B2.G1.R3		VisibilityLevel.*Low*	Rainfall.*Moderate*		=>	FrontCarDistance.*Long*	100
B2.G1.R4		VisibilityLevel.*Maximum*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	80
B2.G1.R5		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R6		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R7		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R8		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R9		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R10		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R11		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R12		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R13		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R14		VisibilityLevel.*High*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	100
B2.G1.R15		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R16		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R17		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R18		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R19		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R20		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R21		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R22		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R23		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R24		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R25		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R26		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R27		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R28		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R29		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R30		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R31		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R32		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R33		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R34		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R35		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100
B2.G1.R36		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R37		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R38		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R39		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R40		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R41		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100
B2.G1.R42		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R43		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Long*	100
B2.G1.R44		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100

Figure 16: Front Car Distance rules

3.3.3. Dependences

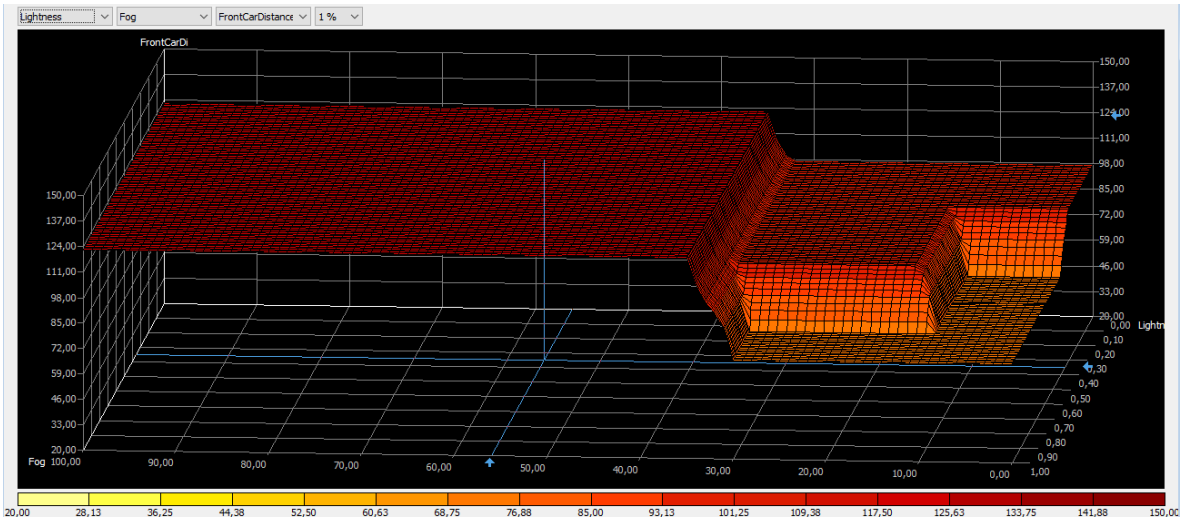

Figure 17: Front Car Distance (Vertical) as a function of Fog (Horizontal) and Lightness (Depth)

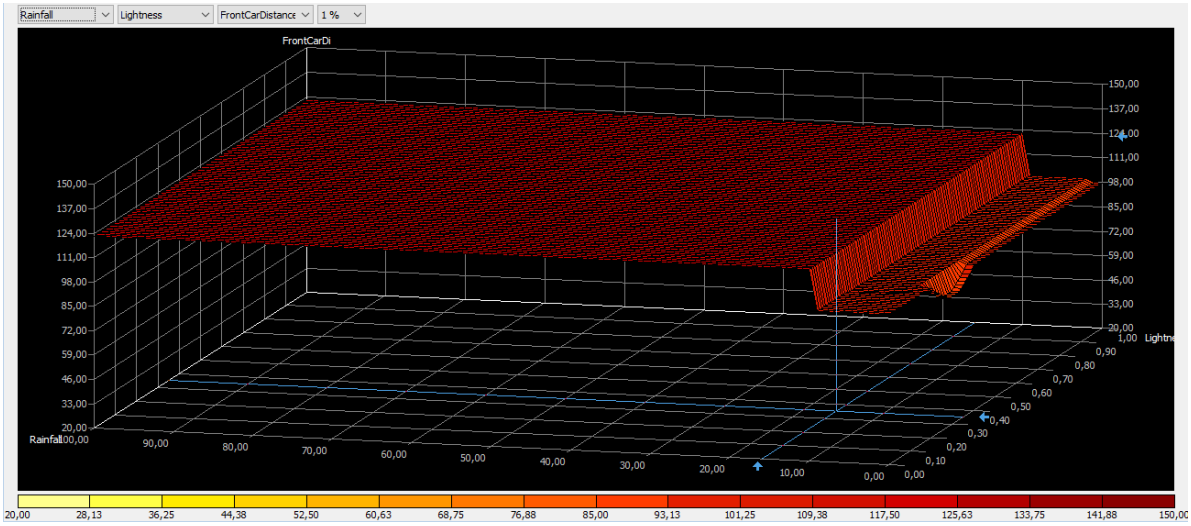

Figure 18: Front Car Distance (Vertical) as a function of Rainfall (Horizontal) and Lightness (Depth)

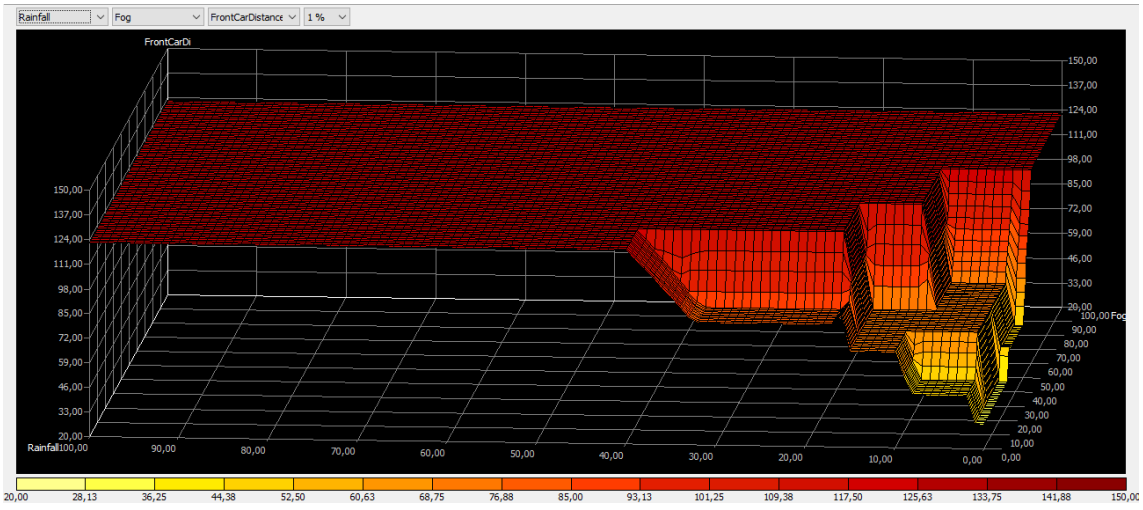

Figure 19: Front Car Distance (Vertical) as a function of Rainfall (Horizontal) and Fog (Depth)

4. System testing

In order to test the system, we have thought of 3 different real-life situations, one with good conditions, another with medium and a last one with bad environmental conditions.

4.1. Situation 1

4.1.1. Values

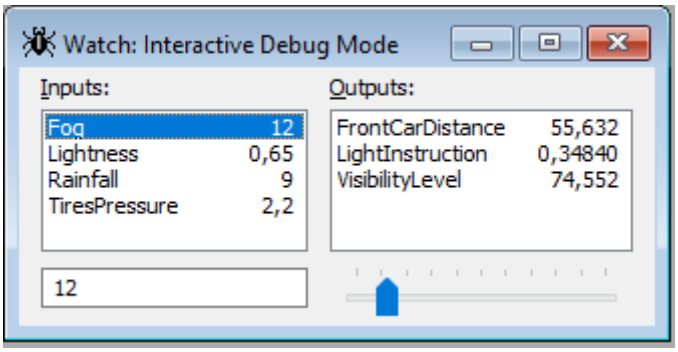

Figure 20: Situation 1: Values for the inputs and outputs

4.1.2. Input sets

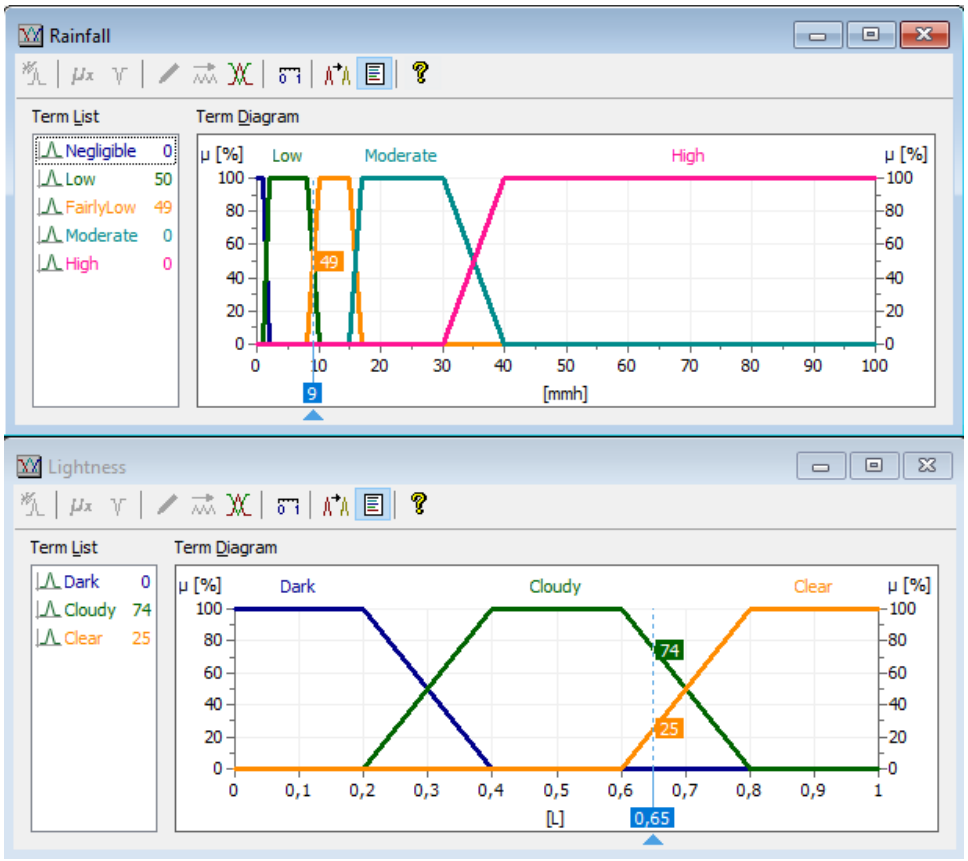

Figure 21: Situation 1: Rainfall and Lightness fuzzy sets memberships

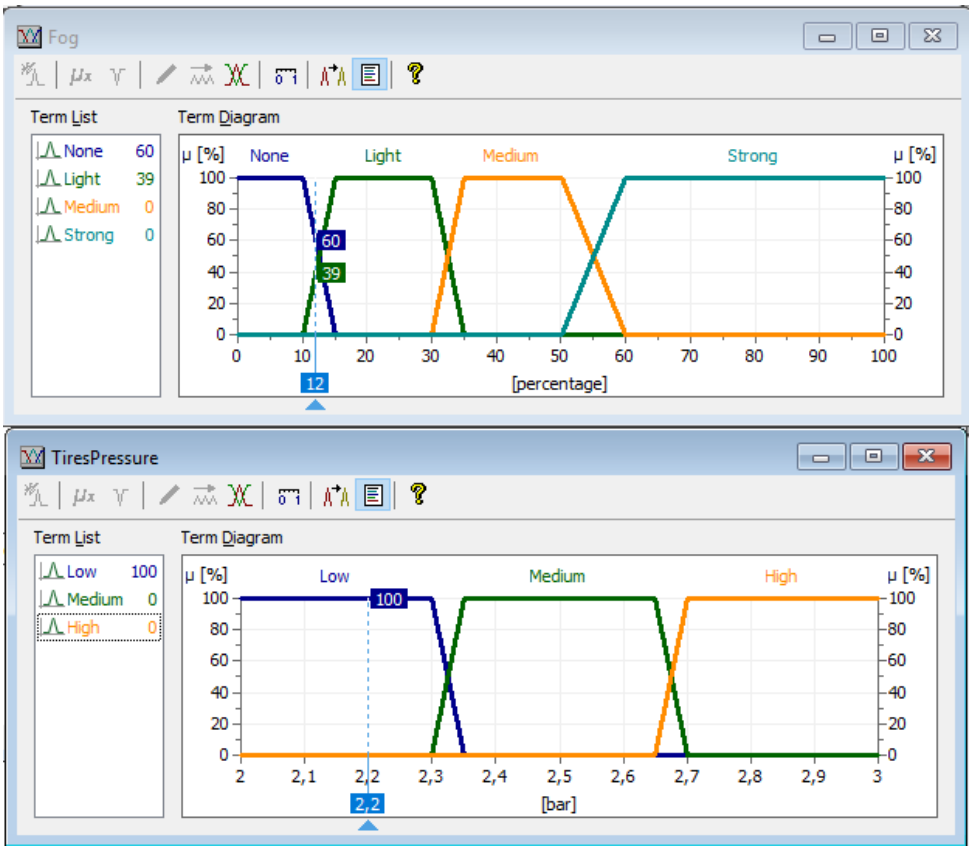

Figure 22: Situation 1: Fog and Tires Pressure fuzzy sets memberships

4.1.3. Rules activation

	Name	If	And	And	Operators	Then	With
B1	RB1	1	2	3	Min / Max	1	
B1.G1	Rules	Rainfall: 9	Lightness: 0,65	Fog: 12		VisibilityLevel: 74,552	DoS [%]
B1.G1.R1				Fog.*Strong*	=>	VisibilityLevel.*None*	80
B1.G1.R2		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100
B1.G1.R3		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R4		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R5		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R6		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R7		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R8		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R9		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R10		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R11		Rainfall.*Low*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100
B1.G1.R12		Rainfall.*Low*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R13		Rainfall.*Low*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R14		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R15		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R16		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R17		Rainfall.*Low*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R18		Rainfall.*Low*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R19		Rainfall.*Low*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R20		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R21		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R22		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R23		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R24		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R25		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R26		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R27		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R28		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R29		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R30		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R31		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R32		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R33		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R34		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R35		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Low*	100
B1.G1.R36		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R37		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*None*	100

Figure 23: Situation 1: Visibility level rules block (In red the activated rules)

	Name	If	Operators	Then	With
B3	RB2	1	Min / Max	1	
B3.G1	Rules	VisibilityLevel: 74,552		LightInstruction: 0,3484	DoS [%]
B3.G1.R1		VisibilityLevel.*None*	=>	LightInstruction.*LowBeam*	100
B3.G1.R2		VisibilityLevel.*Low*	=>	LightInstruction.*LowBeam*	70
B3.G1.R3		VisibilityLevel.*Medium*	=>	LightInstruction.*ParkingLight*	100
B3.G1.R4		VisibilityLevel.*High*	=>	LightInstruction.*None*	70
B3.G1.R5		VisibilityLevel.*Maximum*	=>	LightInstruction.*None*	100

Figure 24: Situation 1: Light Instruction rules block (In red the activated rules)

	Name	If	And	And	Operators	Then	With
B2	RB3	1	2	3	Min / Max	1	
B2.G1	Rules	VisibilityLevel: 74,552	Rainfall: 9	TiresPressure: 2,2		FrontCarDistance: 55,632	DoS [%]
B2.G1.R1			Rainfall.*High*		=>	FrontCarDistance.*Long*	100
B2.G1.R2		VisibilityLevel.*None*			=>	FrontCarDistance.*Long*	100
B2.G1.R3		VisibilityLevel.*Low*	Rainfall.*Moderate*		=>	FrontCarDistance.*Long*	100
B2.G1.R4		VisibilityLevel.*Maximum*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	80
B2.G1.R5		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R6		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R7		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R8		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R9		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R10		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R11		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R12		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R13		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R14		VisibilityLevel.*High*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	100
B2.G1.R15		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R16		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R17		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R18		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R19		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R20		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R21		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R22		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R23		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R24		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R25		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R26		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R27		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R28		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R29		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R30		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R31		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R32		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R33		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R34		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R35		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100
B2.G1.R36		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R37		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100

Figure 25: Situation 1: Front Car Distance rules block (In red the activated rules)

4.1.4. Output sets

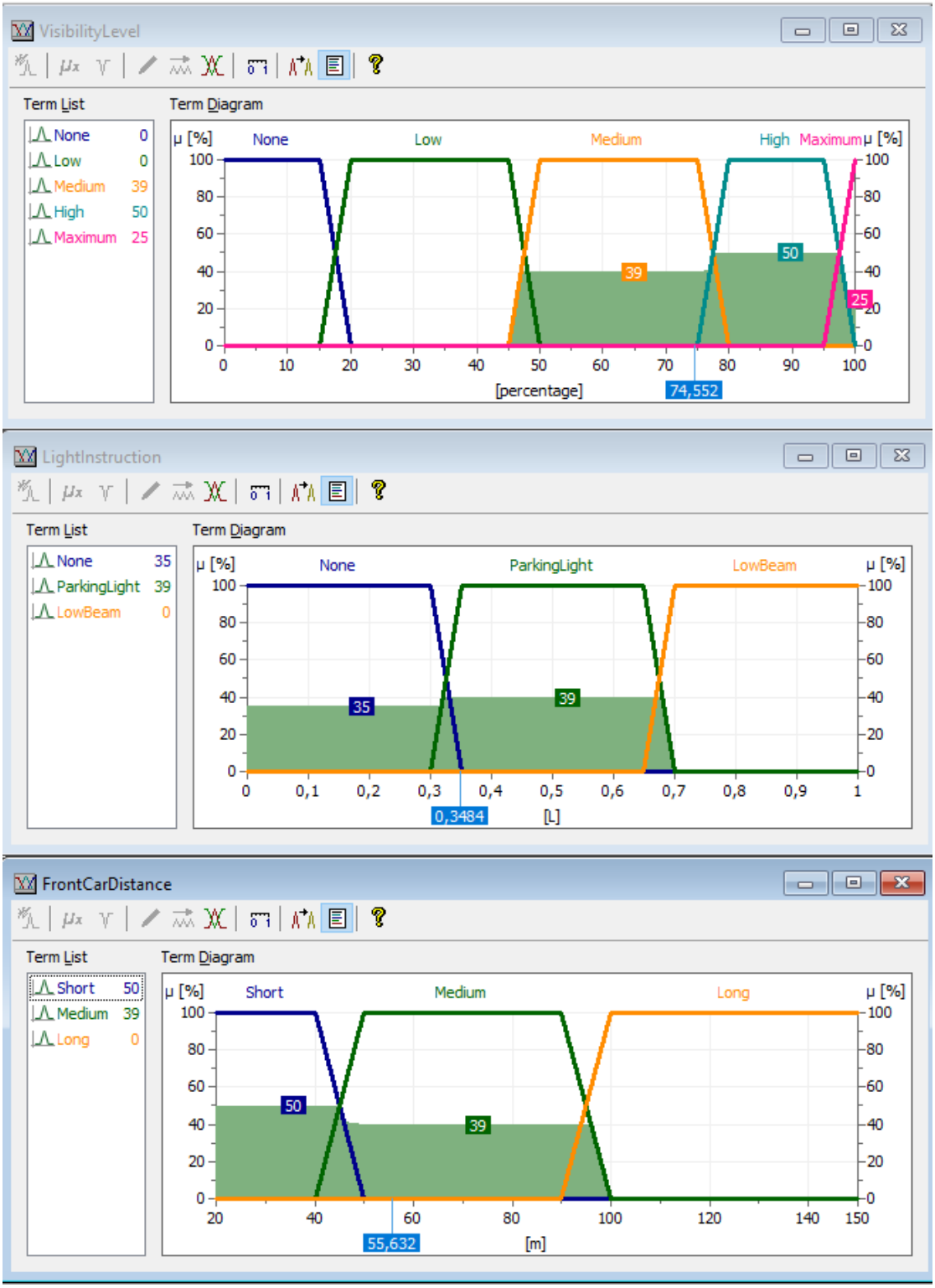

Figure 26: Situation 1: Output variables fuzzy sets memberships

4.2. Situation 2

4.2.1. Values

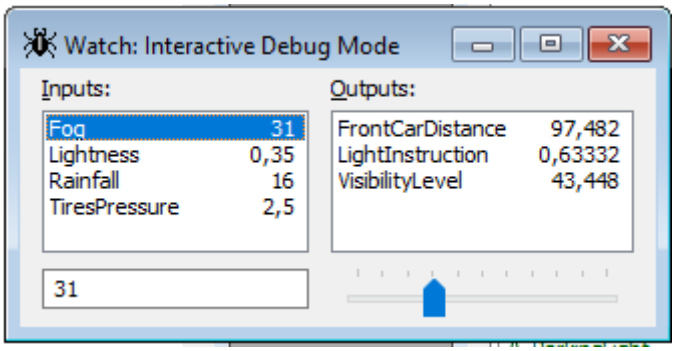

Figure 27: Situation 2: Values for the inputs and outputs

4.2.2. Input sets

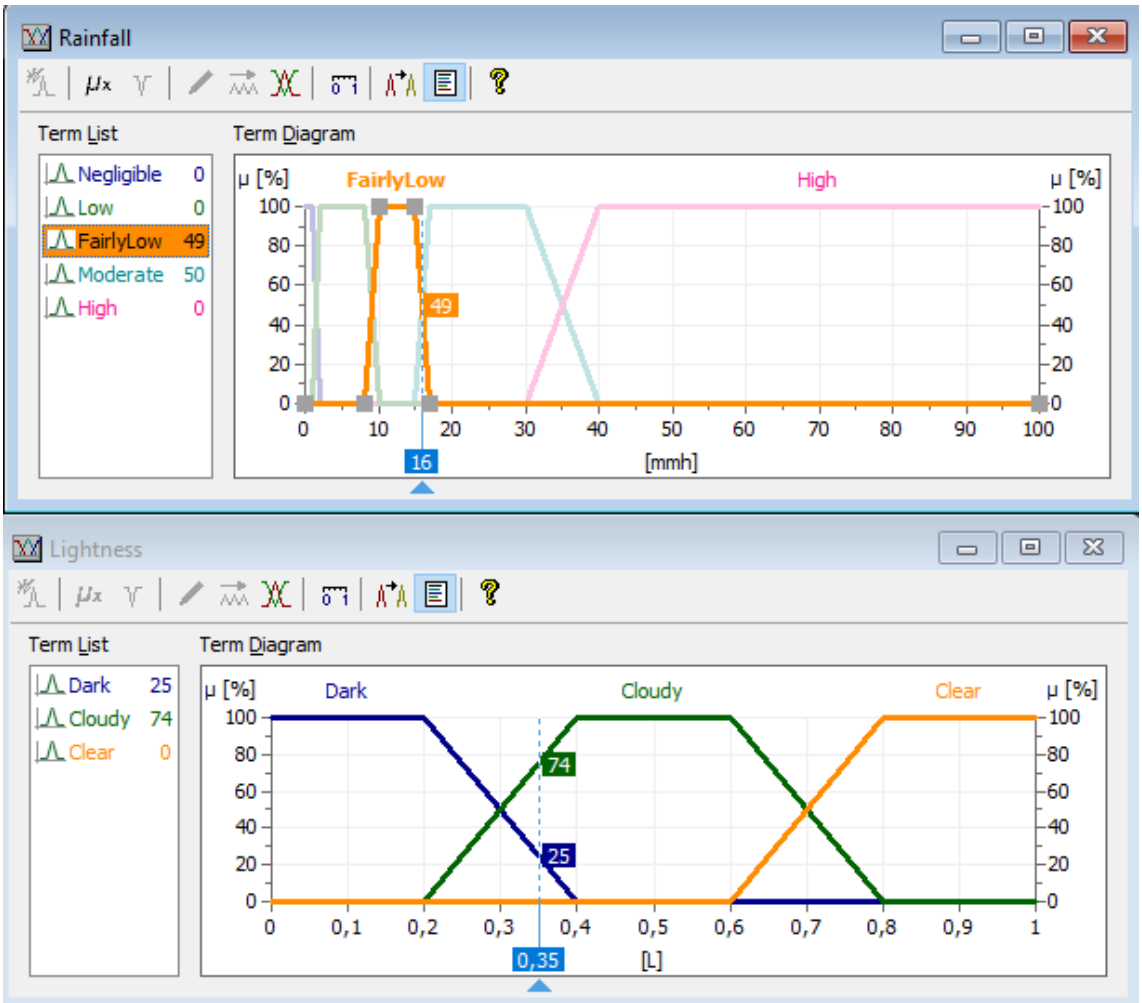

Figure 28: Situation 2: Rainfall and Lightness fuzzy sets memberships

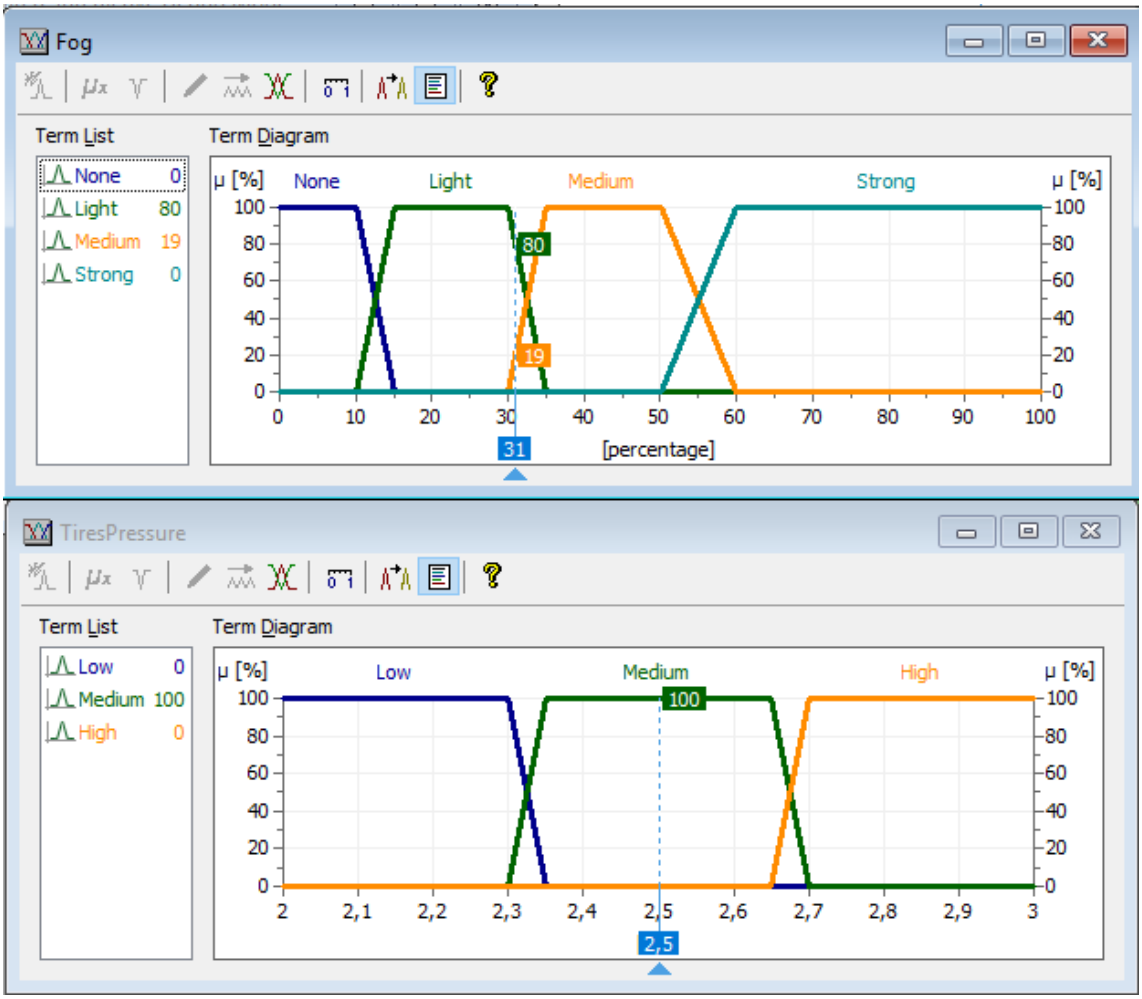

Figure 29: Situation 2: Fog and Tires Pressure fuzzy sets memberships

4.2.3. Rules activation

	Name	If	And	And	Operators	Then	With
B1.G1	Rules	Rainfall: 16	Lightness: 0,35	Fog: 31		VisibilityLevel: 43,448	DoS [%]
B1.G1.R1				Fog.*Strong*	=>	VisibilityLevel.*None*	80
B1.G1.R2		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100
B1.G1.R3		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R4		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R5		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R6		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R7		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R8		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R9		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R10		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R11		Rainfall.*Low*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100
B1.G1.R12		Rainfall.*Low*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100
B1.G1.R13		Rainfall.*Low*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100
B1.G1.R14		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R15		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R16		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R17		Rainfall.*Low*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R18		Rainfall.*Low*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R19		Rainfall.*Low*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R20		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R21		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R22		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R23		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100
B1.G1.R24		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R25		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R26		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R27		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R28		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R29		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R30		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100
B1.G1.R31		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R32		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*Medium*	100
B1.G1.R33		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R34		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100
B1.G1.R35		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Low*	100
B1.G1.R36		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Low*	100
B1.G1.R37		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*None*	100
B1.G1.R38		Rainfall.*High*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Medium*	100

Figure 30: Situation 2: Visibility level rules block (In red the activated rules)

	Name	If	Operators	Then	With
B3	RB2	1	Min / Max	1	
B3.G1	Rules	VisibilityLevel: 43,448		LightInstruction: 0,63332	DoS [%]
B3.G1.R1		VisibilityLevel.*None*	=>	LightInstruction.*LowBeam*	100
B3.G1.R2		VisibilityLevel.*Low*	=>	LightInstruction.*LowBeam*	70
B3.G1.R3		VisibilityLevel.*Medium*	=>	LightInstruction.*ParkingLight*	100
B3.G1.R4		VisibilityLevel.*High*	=>	LightInstruction.*None*	70
B3.G1.R5		VisibilityLevel.*Maximum*	=>	LightInstruction.*None*	100

Figure 31: Situation 2: Light Instruction rules block (In red the activated rules)

	Name	If	And	And	Operators	Then	With
B2	RB3	1	2	3	Min / Max	1	
B2.G1	Rules	VisibilityLevel: 43,448	Rainfall: 16	TiresPressure: 2,5		FrontCarDistance: 97,482	DoS [%]
B2.G1.R1			Rainfall.*High*		=>	FrontCarDistance.*Long*	100
B2.G1.R2		VisibilityLevel.*None*			=>	FrontCarDistance.*Long*	100
B2.G1.R3		VisibilityLevel.*Low*	Rainfall.*Moderate*		=>	FrontCarDistance.*Long*	100
B2.G1.R4		VisibilityLevel.*Maximum*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	80
B2.G1.R5		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R6		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R7		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R8		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R9		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R10		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R11		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R12		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R13		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R14		VisibilityLevel.*High*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	100
B2.G1.R15		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R16		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R17		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R18		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R19		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R20		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R21		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R22		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R23		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R24		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R25		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R26		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R27		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R28		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R29		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R30		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R31		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R32		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R33		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R34		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R35		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100
B2.G1.R36		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R37		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R38		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R39		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R40		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R41		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100
B2.G1.R42		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R43		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Long*	100
B2.G1.R44		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100

Figure 32: Situation 2: Front Car Distance rules block (In red the activated rules)

4.2.4. Output sets

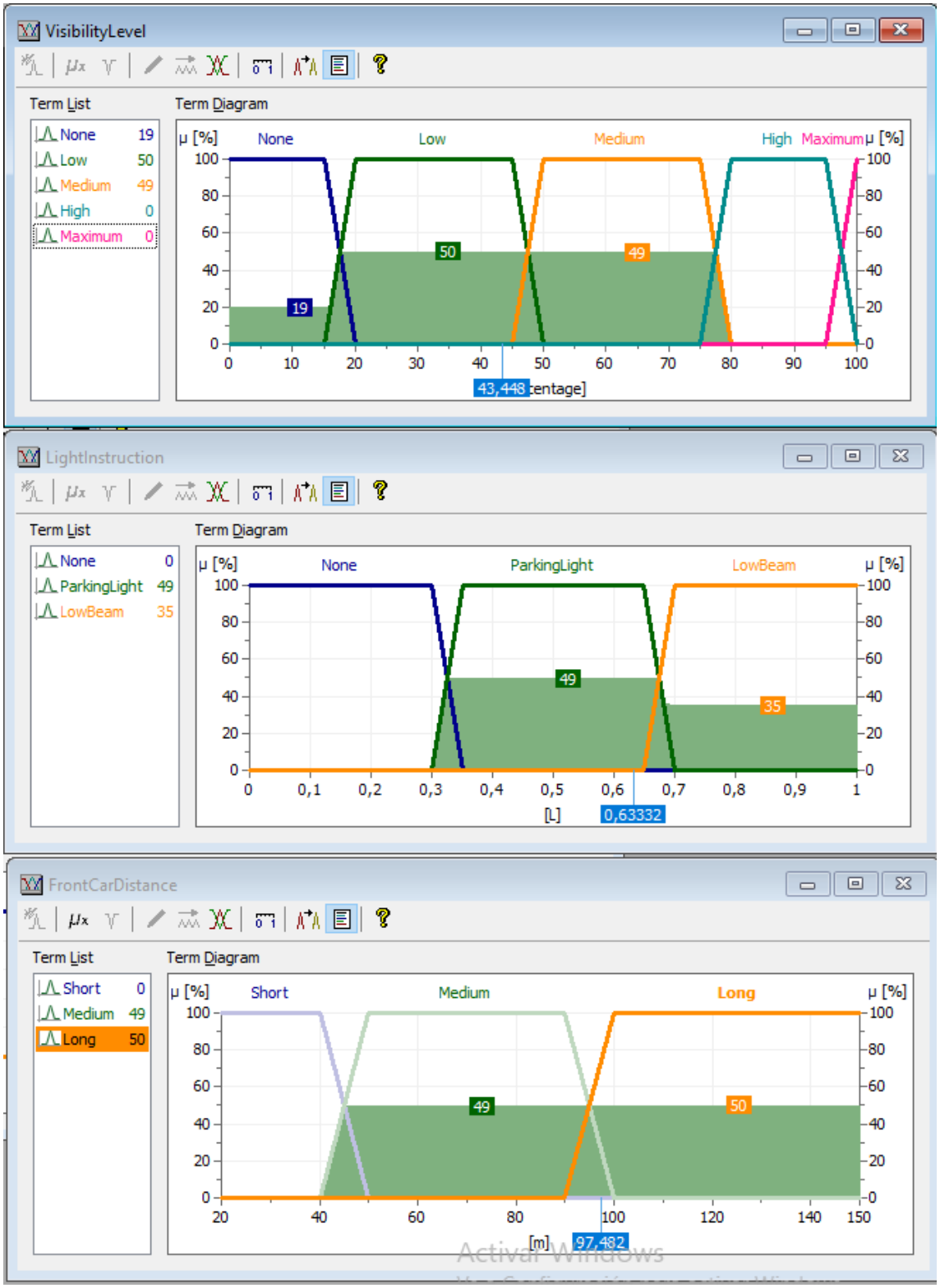

Figure 33: Situation 2: Output variables fuzzy sets memberships

4.3. Situation 3

4.3.1. Values

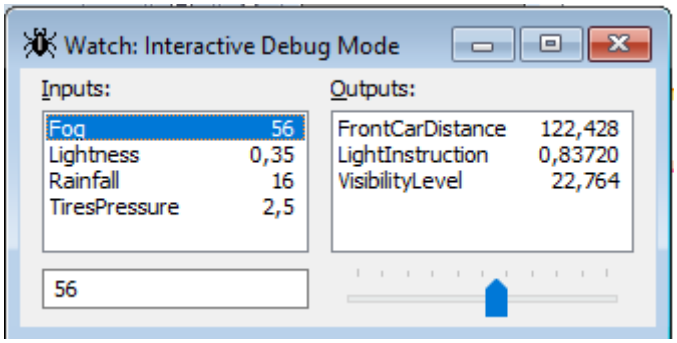

Figure 34: Situation 3: Values for the inputs and outputs

4.3.2. Input sets

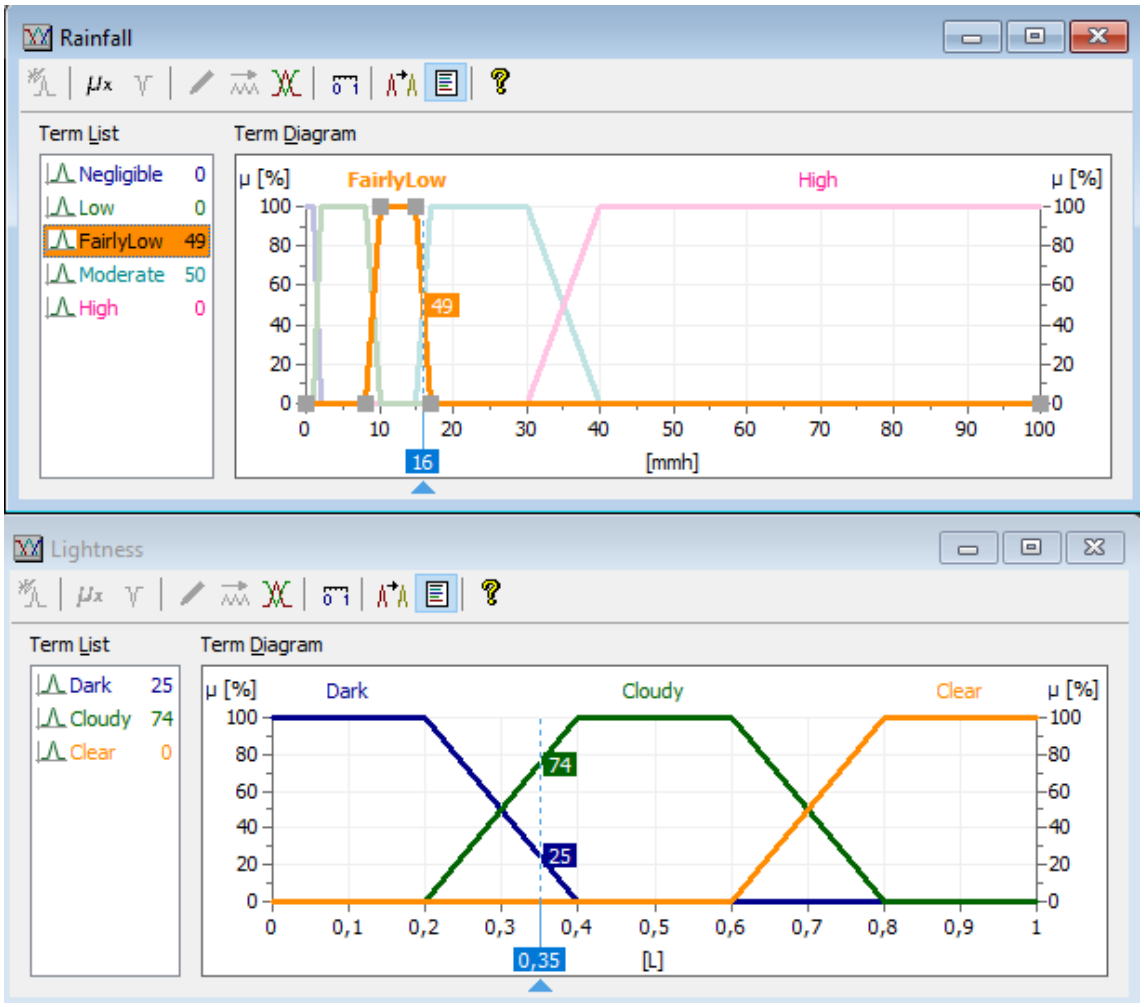

Figure 35: Situation 3: Rainfall and Lightness fuzzy sets memberships

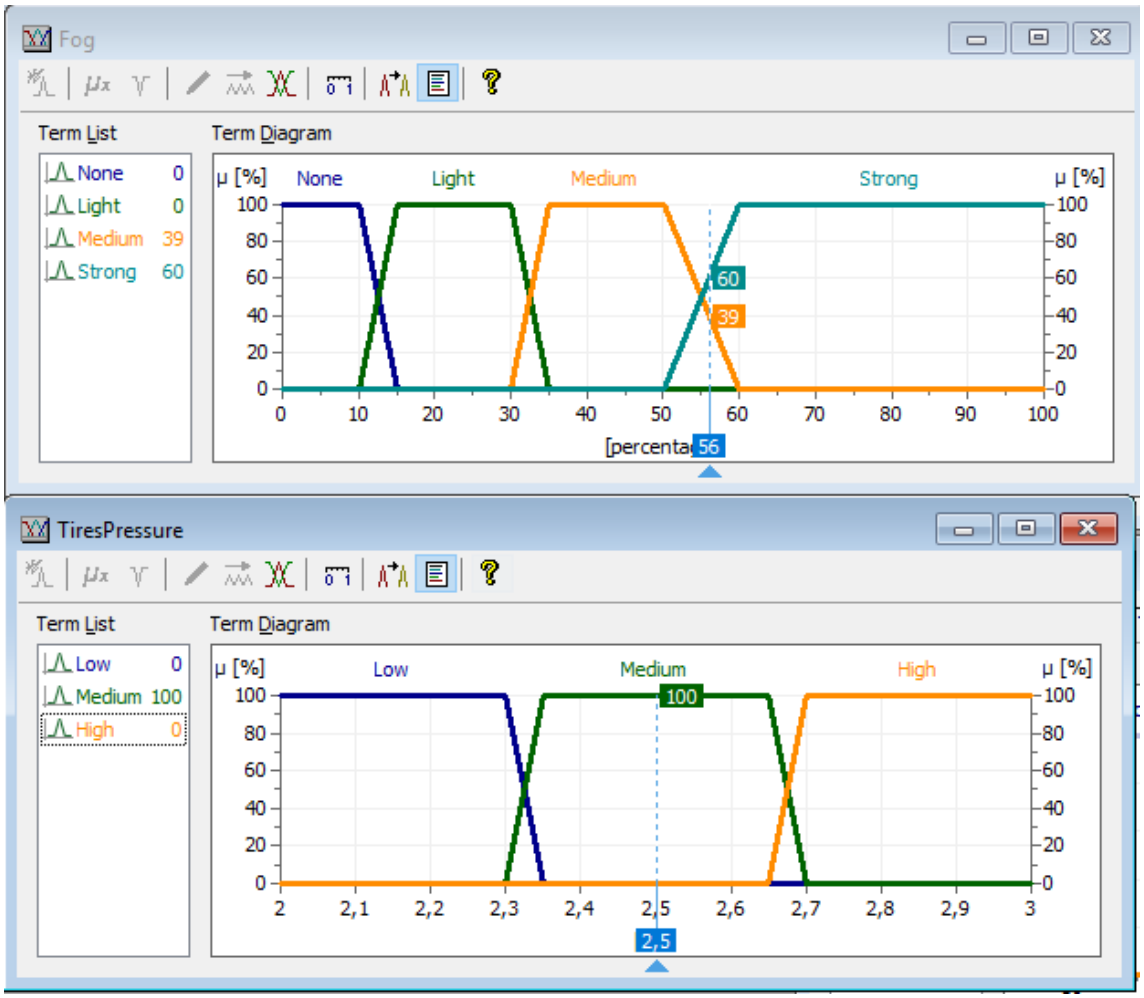

Figure 36: Situation 3: Fog and Tires Pressure fuzzy sets memberships

4.3.3. Rules activation

	Name	If	And	And	Operators	Then	With	C
B1.G1	Rules	Rainfall: 16	Lightness: 0,35	Fog: 56		VisibilityLevel: 22,764	DoS [%]	
B1.G1.R1				Fog.*Strong*	=>	VisibilityLevel.*None*	80	
B1.G1.R2		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100	
B1.G1.R3		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100	
B1.G1.R4		Rainfall.*Negligible*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R5		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100	
B1.G1.R6		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*High*	100	
B1.G1.R7		Rainfall.*Negligible*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R8		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*High*	100	
B1.G1.R9		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R10		Rainfall.*Negligible*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R11		Rainfall.*Low*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Maximum*	100	
B1.G1.R12		Rainfall.*Low*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*High*	100	
B1.G1.R13		Rainfall.*Low*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R14		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100	
B1.G1.R15		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R16		Rainfall.*Low*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R17		Rainfall.*Low*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R18		Rainfall.*Low*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R19		Rainfall.*Low*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R20		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*High*	100	
B1.G1.R21		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R22		Rainfall.*FairlyLow*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R23		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*High*	100	
B1.G1.R24		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R25		Rainfall.*FairlyLow*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R26		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R27		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R28		Rainfall.*FairlyLow*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R29		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*None*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R30		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Light*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R31		Rainfall.*Moderate*	Lightness.*Clear*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R32		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*None*	=>	VisibilityLevel.*Medium*	100	
B1.G1.R33		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Light*	=>	VisibilityLevel.*Low*	100	
B1.G1.R34		Rainfall.*Moderate*	Lightness.*Cloudy*	Fog.*Medium*	=>	VisibilityLevel.*Low*	100	
B1.G1.R35		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*None*	=>	VisibilityLevel.*Low*	100	
B1.G1.R36		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Light*	=>	VisibilityLevel.*Low*	100	
B1.G1.R37		Rainfall.*Moderate*	Lightness.*Dark*	Fog.*Medium*	=>	VisibilityLevel.*None*	100	

Figure 37: Situation 3: Visibility level rules block (In red the activated rules)

	Name	If	Operators	Then	With
B3	RB2	1	Min / Max	1	
B3.G1	Rules	VisibilityLevel: 22,764		LightInstruction: 0,8372	DoS [%]
B3.G1.R1		VisibilityLevel.*None*	=>	LightInstruction.*LowBeam*	100
B3.G1.R2		VisibilityLevel.*Low*	=>	LightInstruction.*LowBeam*	70
B3.G1.R3		VisibilityLevel.*Medium*	=>	LightInstruction.*ParkingLight*	100
B3.G1.R4		VisibilityLevel.*High*	=>	LightInstruction.*None*	70
B3.G1.R5		VisibilityLevel.*Maximum*	=>	LightInstruction.*None*	100

Figure 38: Situation 3: Light Instruction rules block (In red the activated rules)

	Name	If	And	And	Operators	Then	With
B2	RB3	1	2	3	Min / Max	1	
B2.G1	Rules	VisibilityLevel: 22,764	Rainfall: 16	TiresPressure: 2,5		FrontCarDistance: 122,428	DoS [%]
B2.G1.R1			Rainfall.*High*		=>	FrontCarDistance.*Long*	100
B2.G1.R2		VisibilityLevel.*None*			=>	FrontCarDistance.*Long*	100
B2.G1.R3		VisibilityLevel.*Low*	Rainfall.*Moderate*		=>	FrontCarDistance.*Long*	100
B2.G1.R4		VisibilityLevel.*Maximum*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	80
B2.G1.R5		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R6		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R7		VisibilityLevel.*Maximum*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R8		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R9		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R10		VisibilityLevel.*Maximum*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R11		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R12		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R13		VisibilityLevel.*Maximum*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R14		VisibilityLevel.*High*	Rainfall.*Negligible*		=>	FrontCarDistance.*Short*	100
B2.G1.R15		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R16		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R17		VisibilityLevel.*High*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R18		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R19		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R20		VisibilityLevel.*High*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R21		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R22		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R23		VisibilityLevel.*High*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R24		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R25		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Short*	100
B2.G1.R26		VisibilityLevel.*Medium*	Rainfall.*Negligible*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R27		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Short*	100
B2.G1.R28		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R29		VisibilityLevel.*Medium*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R30		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R31		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R32		VisibilityLevel.*Medium*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R33		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R34		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R35		VisibilityLevel.*Medium*	Rainfall.*Moderate*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100
B2.G1.R36		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R37		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R38		VisibilityLevel.*Low*	Rainfall.*Negligible*	TiresPressure.*High*	=>	FrontCarDistance.*Medium*	100
B2.G1.R39		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R40		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*Medium*	=>	FrontCarDistance.*Medium*	100
B2.G1.R41		VisibilityLevel.*Low*	Rainfall.*Low*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100
B2.G1.R42		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*Low*	=>	FrontCarDistance.*Medium*	100
B2.G1.R43		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*Medium*	=>	FrontCarDistance.*Long*	100
B2.G1.R44		VisibilityLevel.*Low*	Rainfall.*FairlyLow*	TiresPressure.*High*	=>	FrontCarDistance.*Long*	100

Figure 39: Situation 3: Front Car Distance rules block (In red the activated rules)

4.3.4. Output sets

Figure 40: Situation 3: Output variables fuzzy sets memberships

5. Manual calculation

For this part of the project we have selected the first situation and calculated its value for the visibility level manually to check that it coincides with the one provided by the fuzzyTECH.

	Set 1	*Membership 1*	*Set 2*	*Membership 2*
Rainfall	Low	50.5	FairlyLow	49.5
Lightness	Cloudy	74.5	Clear	25.5
Fog	None	60.5	Light	39.5

Table 1: Situation 1: Input sets and its membership values

	Rainfall	*Lightness*	*Fog*	*Min*	*Dos (%)*	*Visibility Level*
Rule 11	Low – 50.5	Clear – 25.5	None – 60.5	25.5	100	Maximum
Rule 12	Low – 50.5	Clear – 25.5	Light – 39.5	25.5	100	High
Rule 14	Low – 50.5	Cloudy – 74.5	None – 60.5	50.5	100	High
Rule 15	Low – 50.5	Cloudy – 74.5	Light – 39.5	39.5	100	Medium
Rule 20	FairlyLow – 49.5	Clear – 25.5	None – 60.5	25.5	100	High
Rule 21	FairlyLow – 49.5	Clear – 25.5	Light – 39.5	25.5	100	Medium
Rule 23	FairlyLow – 49.5	Cloudy – 74.5	None – 60.5	49.5	100	High
Rule 24	FairlyLow – 49.5	Cloudy – 74.5	Light – 39.5	39.5	100	High

Table 2: Situation 1: Rules activated for the visibility level

Once all the activated rules have given their output values, for each visibility level set we selected the maximum membership, which are:

$$Maximum = \max(25.5) = 25.5\ \%$$

$$High = \max(25.5, 50.5, 49.5, 39.5) = 50.5\ \%$$

$$Medium = \max(39.5, 25.5) = 39.5\ \%$$

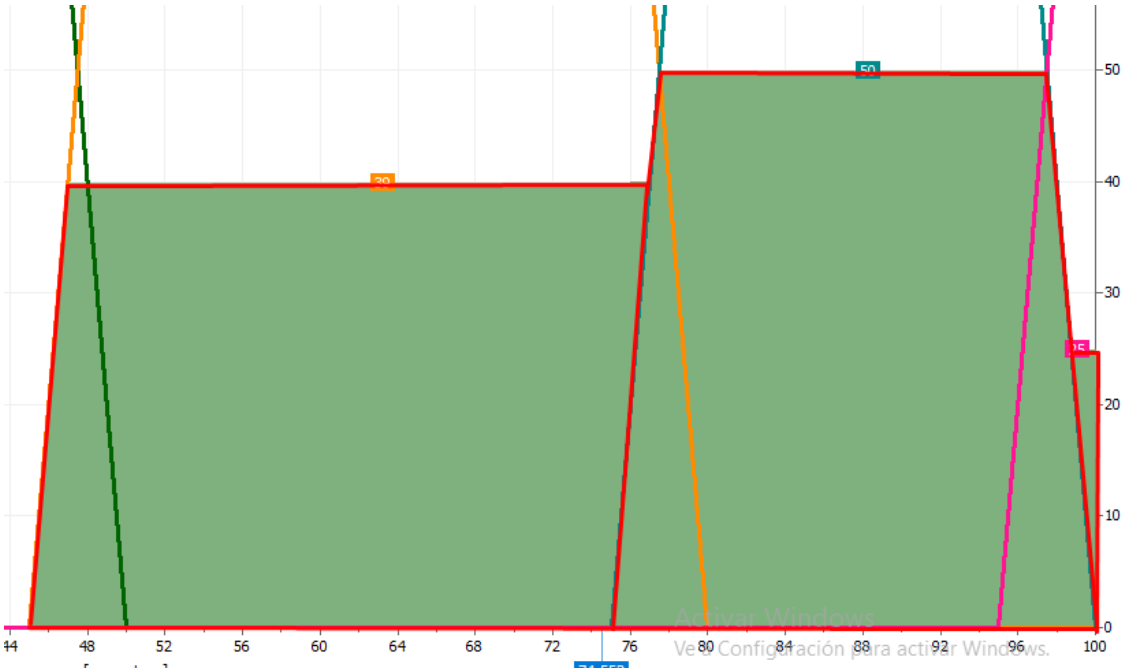

Figure 41: Situation 1: Activated Visibility level fuzzy sets with their memberships (From left to right: Medium, High, Maximum)

Finally we divided the final figure in 3 subfigures to compute their areas

$$A_{Parallelogram} = 30 * 39.5 = 1185$$

$$A_{Trapezoid} = \frac{(25 + 20) * 50.5}{2} = 1136.25$$

$$A_{Triangle} = \frac{1 * 25}{2} = 12.5$$

$$A_{Total} = 1185 + 1136.25 + 12.5 = 2333.75$$

With this, the CoA will be the value of the x-axis of the figure for which the area covered between the left side of the figure and such point is equal to half the total Area (1166.875).

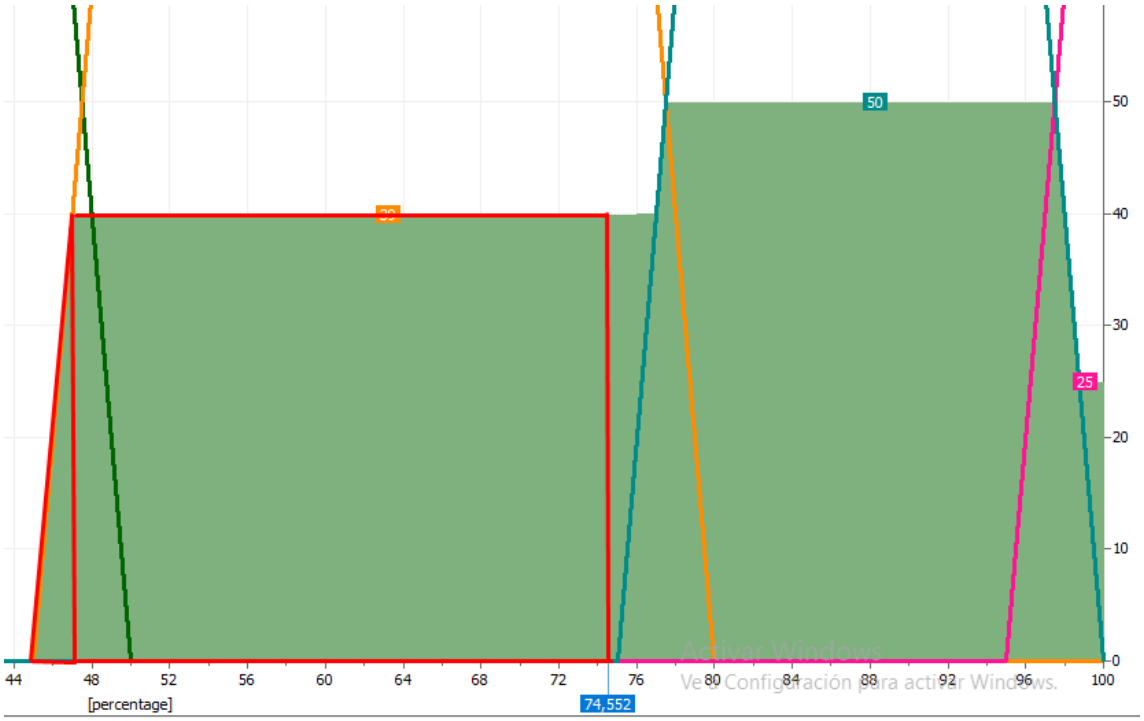

Figure 42: Situation 1: Area where half of the total area has been covered

The area of the left triangle is 39.5, so we still have to cover 1127.375. With the height of 39.5, the base of the rectangle that covers this area is 28.54, which added to the 47 where the rectangle starts yields 75.54 as the CoA of the figure, which is our final defuzzified value for the variable VisibilityLevel. The difference between the value computed by hand and the one yield by the program of is due to the fact that for the input variables, the membership value we were given by the program did not sum 100 (e.g. Rainfall 49 and 50), which we corrected by giving half point to each of them.

6. Degree of support variation

In this part, to check the utility of the degree of support (DoS) we have selected the Situation 1, and played with the DoS of the Front Car Distance rules.

As we expected, changing the DoS of a rule that does not give the maximum output does not affect the final result.

On the other hand, reducing the DoS of the rule that provides the maximum value for a set of the output variable, reduces the corresponding membership to that set until it reaches the value of the second most dominant rule for the same set, which will be now the dominant one.

In our case, we first reduced the DoS of rule 18 which gives a value of 49 to 90%. Therefore, the membership value of the output to set FrontCarDistance.Short changed from 49 to 44. But, if we reduce the DoS of that rule to 75%, the output value becomes 37 which is lower than the one given by the rule 27 (with a value of 39) and it will become the maximum value.

(Just to explain this example we have reduced to 0 the rule 15 because it gave a value of 50 and we could not compare it to the value of 49 of the rule 18 by changing the DoS).

7. Tires pressure to determine Safe distance

In the next three figures we can observe the influence of the tires pressure respect to the other 3 inputs variables. In the first and third images, the three levels of tire pressure can easily be appreciated but in the second one, the safety distance do not differentiate whether the pressure is High or Medium.

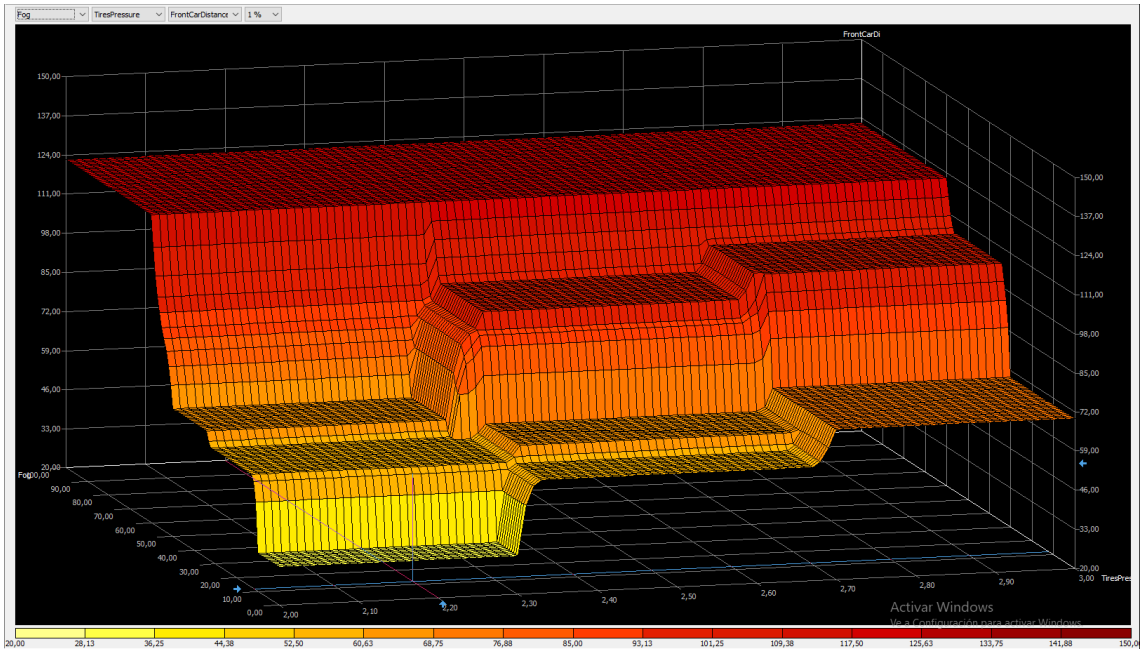

Figure 43: Front Car Distance (Vertical) as a function of Tires pressure (Horizontal) and Fog (Depth)

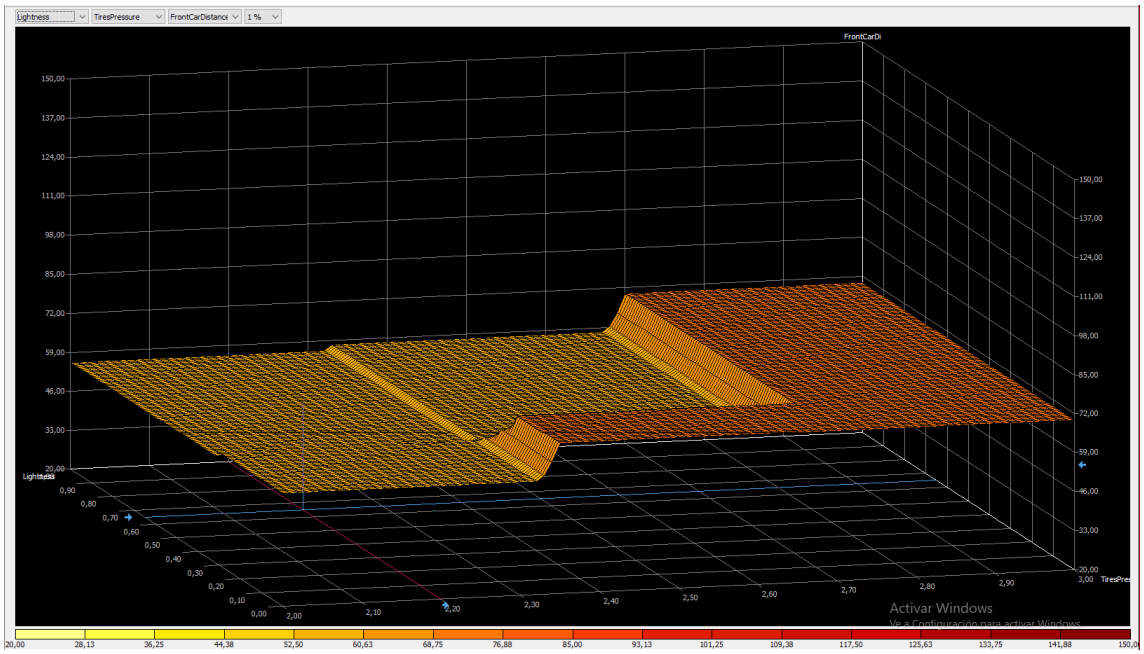

Figure 44: Front Car Distance (Vertical) as a function of Tires pressure (Horizontal) and Lightness (Depth)

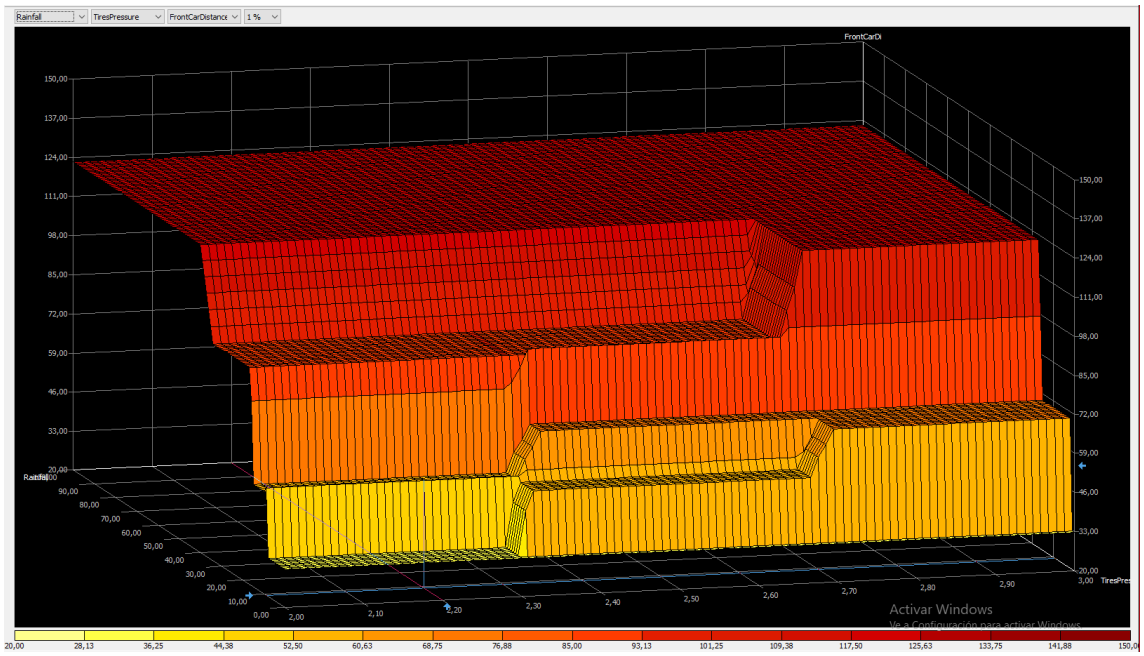

Figure 45: Front Car Distance (Vertical) as a function of Tires pressure (Horizontal) and Rainfall (Depth)