Fuzzy Expert System

PLANNING AND APPROXIMATE REASONING - EXERCISE 2
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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

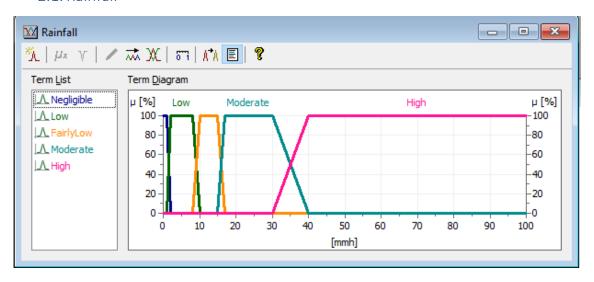


Figure 1: Rainfall fuzzy sets

2.2. Lightness

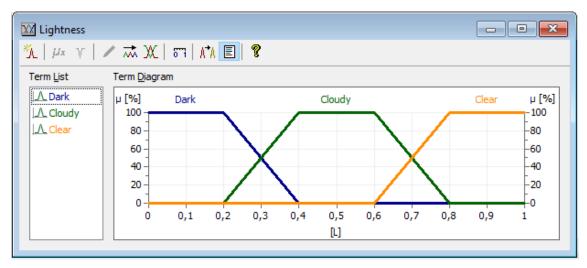


Figure 2: Lightness fuzzy sets



2.3. Fog

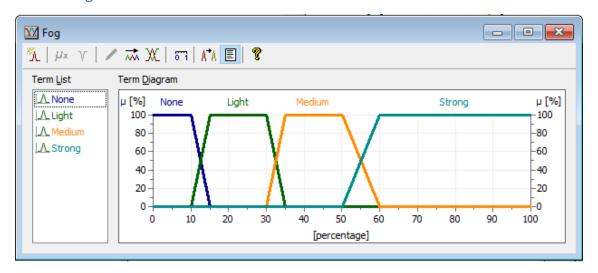


Figure 3: Fog fuzzy sets

2.4. Tires pressure

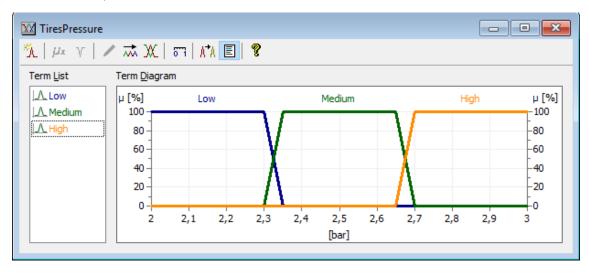


Figure 4: Tires pressure fuzzy set

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

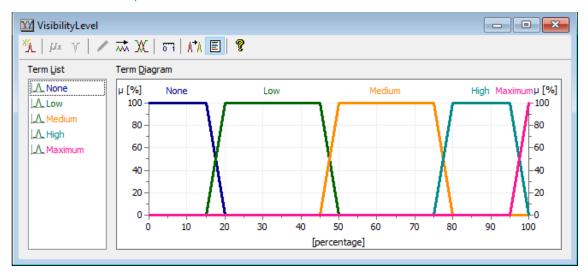


Figure 5: Visibility level fuzzy sets

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 If	And	And	Operators	Then	With
.Ø	B1	RB1	1	2	3	Min / Max	1	
<i>I</i> >	B1.G1	Rules	XX Rainfall	XX Lightness	XX Fog		₩ VisibilityLevel	DoS [%]
Ø	B1.G1.R1				LA Fog_Strong	=>	△ VisibilityLevel_None	80
Ø	B1.G1.R2		A Rainfall_Negligible	Lightness.Clear	. Fog.None	=>	⚠ VisibilityLevel_Maximum	100
Ø	B1.G1.R3		A Rainfall_Negligible	Lightness.Clear	. Fog_Light	=>	△ VisibilityLevel.High	100
0	B1.G1.R4		A Rainfall_Negligible	Lightness.Clear	. Fog.Medium	=>	⚠ VisibilityLevel_Medium	100
0	B1.G1.R5		A Rainfall_Negligible	Lightness.Cloudy	. Fog_None	=>	△ VisibilityLevel_High	100
0	B1.G1.R6		A Rainfall_Negligible	Lightness.Cloudy	. Fog_Light	=>	△ VisibilityLevel_High	100
0	B1.G1.R7		A Rainfall_Negligible	Lightness.Cloudy	. Fog.Medium	=>	⚠ VisibilityLevel_Medium	100
.0	B1.G1.R8		A Rainfall Negligible		None	=>		100
.0	B1.G1.R9		A Rainfall Negligible	Lightness_Dark	Light	=>	⚠ VisibilityLevel_Medium	100
.0	B1.G1.R10		A Rainfall Negligible	-	Fog_Medium	=>	△ VisibilityLevel Low	100
0	B1.G1.R11		A Rainfall Low	△ Lightness Clear	None	=>	△ VisibilityLevel Maximum	100
0	B1.G1.R12		△ Rainfall Low	△ Lightness Clear	Light	=>		100
.0	B1.G1.R13		△ Rainfall Low	△ Lightness Clear	. Fog.Medium		△ VisibilityLevel Medium	100
.0	B1.G1.R14		△ Rainfall Low	△ Lightness Cloudy	Fog_None	=>		100
.0	B1.G1.R15		△ Rainfall Low	△ Lightness Cloudy	<u>-</u>	=>	△ VisibilityLevel Medium	100
.0	B1.G1.R16		△ Rainfall Low	△ Lightness Cloudy		=>		100
.0	B1.G1.R17		△ Rainfall Low	△ Lightness Dark	∴ Fog_None	=>	∴ VisibilityLevel_Medium	100
.0	B1.G1.R18		△ Rainfall Low	△ Lightness Dark	. Fog_Light	=>	△ VisibilityLevel Medium	100
.0	B1.G1.R19		△ Rainfall Low	△ Lightness Dark	. Fog.Medium		△ VisibilityLevel Low	100
.0	B1.G1.R20		A Rainfall_FairlyLow	△ Lightness Clear	∴ Fog_None	=>	∆ VisibilityLevel_High	100
	B1.G1.R21		⚠ Rainfall_FairlyLow		Fog_Light	=>	△ VisibilityLevel_Medium	100
.0	B1.G1.R22		⚠ Rainfall_FairlyLow		⚠ Fog.Medium		△ VisibilityLevel Low	100
.0	B1.G1.R23		⚠ Rainfall_FairlyLow	△ Lightness Cloudy	<u> </u>	=>	△ VisibilityLevel_High	100
.0	B1.G1.R24		⚠ Rainfall_FairlyLow		-	=>	△ VisibilityLevel_Medium	100
.0	B1.G1.R25		A Rainfall_FairlyLow				△ VisibilityLevel.Low	100
.o	B1.G1.R26		A Rainfall FairlyLow		△ Fog_None	=>	△ VisibilityLevel_Medium	100
.o	B1.G1.R27		A Rainfall_FairlyLow		⚠ Fog_Light	=>	△ VisibilityLevel_Medium	100
.o	B1.G1.R28		A Rainfall_FairlyLow		∴ Fog Medium		△ VisibilityLevel Low	100
.v I	B1.G1.R29		A Rainfall_Moderate	-	∴ Fog_None	=>	△ VisibilityLevel_Medium	100
.v I	B1.G1.R30		A Rainfall_Moderate		∴ Fog_Light	=>	△ VisibilityLevel_Medium	100
.v .0	B1.G1.R31		A Rainfall_Moderate		∴ Fog_Medium		△ VisibilityLevel.Low	100
.v I	B1.G1.R32		A Rainfall_Moderate			=>	△ VisibilityLevel_Medium	100
0	B1.G1.R33		A Rainfall_Moderate			=>	△ VisibilityLevel Low	100
.v .v	B1.G1.R34		A Rainfall_Moderate				△ VisibilityLevel.Low	100
.v .v	B1.G1.R35		A Rainfall_Moderate					100
.o	B1.G1.R36				∴ Fog_None ∴ Fog_Light	=>		100
				-		=>		
0	B1.G1.R37		A Rainfall Moderate		Fog_Medium		△ VisibilityLevel_None	100
.Ø 19	B1.G1.R38		A Rainfall High	Lightness Clear		=>	△ VisibilityLevel Medium	100
.0	B1.G1.R39		A Rainfall High	Lightness Clear		=>	△ VisibilityLevel Low	100
.0	B1.G1.R40		A Rainfall_High	Lightness.Clear			∴ VisibilityLevel.Low	100
.0	B1.G1.R41		A Rainfall_High	Lightness Cloudy		=>	∴ VisibilityLevel.Low	100
.0	B1.G1.R42		A Rainfall High	△ Lightness Cloudy		=>	△ VisibilityLevel Low	100
.0	B1.G1.R43		A Rainfall High	△ Lightness Cloudy			△ VisibilityLevel Low	100
.Ø	B1.G1.R44		A Rainfall High	△ Lightness Dark		=>	∴ VisibilityLevel_None	90

Figure 6: Visibility level rules



3.1.3. Dependences

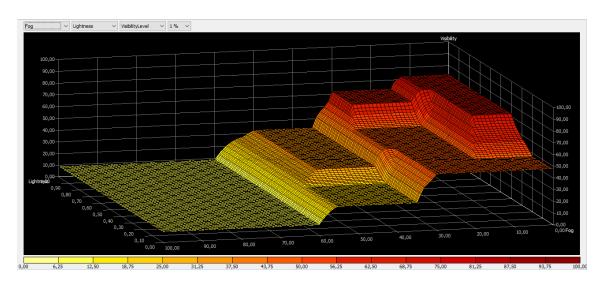


Figure 7: Visibility Level (Vertical) as a function of Fog (Horizontal) and Lightness (Depth)

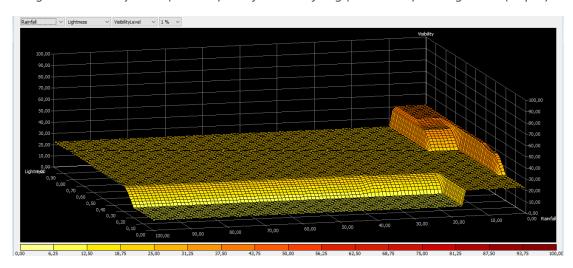


Figure 8: Visibility Level (Vertical) as a function of Rainfall (Horizontal) and Lightness (Depth)

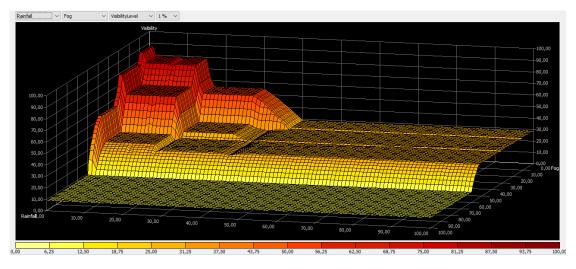


Figure 9: Visibility Level (Vertical) as a function of Rainfall (Horizontal) and Fog (Depth)



3.2. Light Instruction

3.2.1. Fuzzy sets

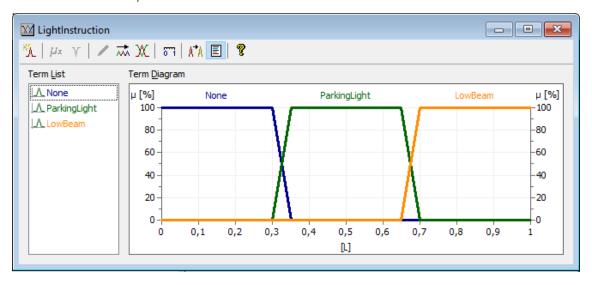


Figure 10: Light Instruction fuzzy sets

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	iii If	Operators	Then	With
.Ø ▶	B3	RB2		Min / Max		
.0	B3.G1	Rules	☆ VisibilityLevel		☆ LightInstruction	DoS [%]
.0	B3.G1.R1			=>		100
.0	B3.G1.R2			=>	△ LightInstruction LowBeam	70
.0	B3.G1.R3			=>	$\bot A$ LightInstruction_ParkingLight	100
.0	B3.G1.R4			=>	△ LightInstruction None	70
.0	B3.G1.R5			=>	△ LightInstruction None	100

Figure 11: Light Instruction rules



3.2.3. Dependences

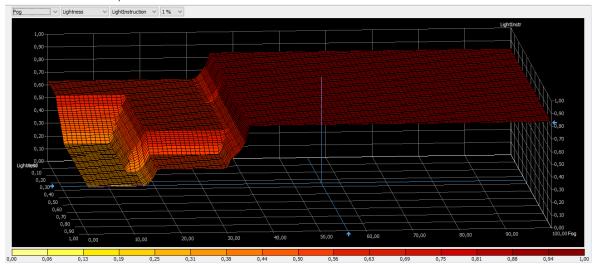


Figure 12: Light Instruction (Vertical) as a function of Fog (Horizontal) and Lightness (Depth)

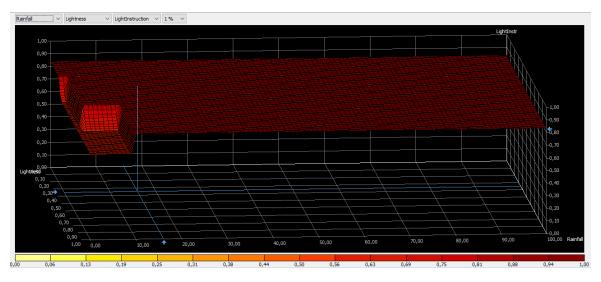


Figure 13: Light Instruction (Vertical) as a function of Rainfall (Horizontal) and Lightness (Depth)

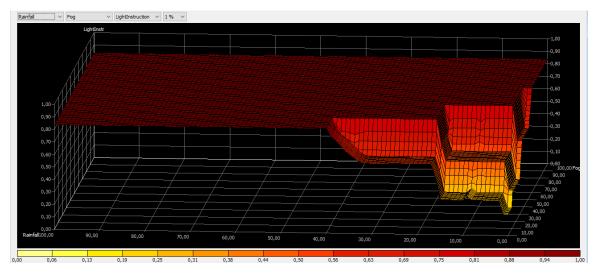


Figure 14: Light Instruction (Vertical) as a function of Rainfall (Horizontal) and Fog (Depth)



3.3. Front Car Distance

3.3.1. Fuzzy sets

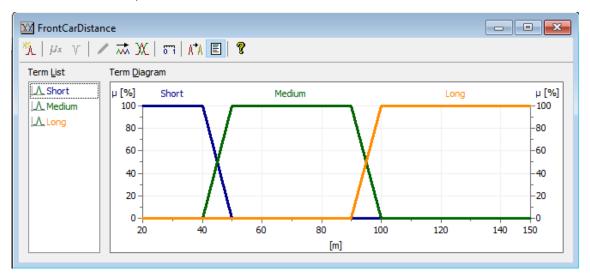


Figure 15: Front Car Distance fuzzy sets

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		lf	And	t	And	t	Operators	The	en	With
0	B2	RB3	1		2		3		Min / Max	1		
<i>0</i>	B2.G1	Rules	XX	VisibilityLevel	χχ	Rainfall	ÌΩ	TiresPressure		XX	FrontCarDistance	DoS [%
Ø	B2.G1.R1				ļΛ	Rainfall.High			=>	LΛ	FrontCarDistance_Long	10
0	B2.G1.R2		IΛ	VisibilityLevel_None					=>	LΛ	FrontCarDistance_Long	10
0	B2.G1.R3		ĪΛ	VisibilityLevel_Low	L	Rainfall_Moderate			=>	LΛ	FrontCarDistance_Long	10
0	B2.G1.R4			VisibilityLevel_Maximum	ļΛ	Rainfall_Negligible			=>		FrontCarDistance_Short	8
0	B2.G1.R5		ΙΛ	-	_	Rainfall_Low	lΛ	TiresPressure.Low	=>		FrontCarDistance_Short	10
	B2.G1.R6		ΙΛ	-		Rainfall_Low	LΛ	TiresPressure_Medium		_	FrontCarDistance.Short	10
	B2.G1.R7		ΙΛ			Rainfall_Low		TiresPressure_High	=>	LA	FrontCarDistance.Medium	10
0	B2.G1.R8		1	-		Rainfall_FairlyLow		TiresPressure_Low	=>	_	FrontCarDistance.Short	10
0	B2.G1.R9			VisibilityLevel_Maximum		Rainfall_FairlyLow		TiresPressure_Medium			FrontCarDistance.Short	10
0	B2.G1.R10		IV	-		Rainfall_FairlyLow		TiresPressure_High	=>	_	FrontCarDistance.Medium	10
0	B2.G1.R11			VisibilityLevel.Maximum		Rainfall_Moderate		TiresPressure_Low	=>		FrontCarDistance.Short	10
0	B2.G1.R12		ΙΛ	-	IΛ	Rainfall_Moderate		TiresPressure_Medium		IA.		10
.v .v	B2.G1.R13		17	•	17			TiresPressure.High	=>	14		10
.v .0	B2.G1.R13			•	_		12/	ineriesule.nig/l			FrontCarDistance.Meaturn FrontCarDistance.Short	10
			-	VisibilityLevel.High		Rainfall_Negligible	1 A	TiresPressure_Low	=>	-		
.0	B2.G1.R15			VisibilityLevel.High	14				=>	-	FrontCarDistance.Short	10
.0	B2.G1.R16		1		1	Rainfall_Low	1			-	FrontCarDistance.Short	10
.0	B2.G1.R17		1		1	Rainfall_Low	1		=>	-	FrontCarDistance.Medium	10
.0	B2.G1.R18		1		1	Rainfall_FairlyLow		TiresPressure_Low	=>		FrontCarDistance.Short	10
.0	B2.G1.R19			VisibilityLevel. High	1	,		TiresPressure_Medium			FrontCarDistance.Medium	10
.0	B2.G1.R20			VisibilityLevel.High	1	Rainfall_FairlyLow		TiresPressure_High	=>	_	FrontCarDistance.Medium	10
.0	B2.G1.R21			VisibilityLevel.High	ΙΛ.	Rainfall_Moderate		TiresPressure_Low	=>		FrontCarDistance_Short	10
.0	B2.G1.R22			VisibilityLevel.High	ΙΛ.	Rainfall_Moderate		TiresPressure_Medium	=>	1	FrontCarDistance_Medium	10
.0	B2.G1.R23		ĪΛ	VisibilityLevel.High	ļΛ	Rainfall.Moderate	ļΛ	TiresPressure.High	=>	1	FrontCarDistance_Medium	10
.0	B2.G1.R24		ļΛ	VisibilityLevel.Medium	ļΛ	Rainfall_Negligible	ļΛ	TiresPressure_Low	=>	ļΛ	FrontCarDistance_Short	10
.Ø	B2.G1.R25		ļΛ	VisibilityLevel.Medium	ļΛ	Rainfall_Negligible	ļΛ	TiresPressure.Medium	=>	ļΛ	FrontCarDistance_Short	10
.Ø	B2.G1.R26		ļΛ	VisibilityLevel.Medium	ļΛ	Rainfall_Negligible	ļΛ	TiresPressure.High	=>	ļΛ	FrontCarDistance.Medium	10
Ø.	B2.G1.R27		ĬΛ	VisibilityLevel.Medium	ļΛ	Rainfall_Low	ĺΛ	TiresPressure.Low	=>	1	FrontCarDistance_Short	10
0	B2.G1.R28		ĺΛ	VisibilityLevel.Medium	ļΛ	Rainfall_Low	ĺΛ	TiresPressure.Medium	=>	1	FrontCarDistance.Medium	10
.0	B2.G1.R29		ĪΛ	VisibilityLevel_Medium	ļΛ	Rainfall_Low	ĺΛ	TiresPressure.High	=>	ļΛ	FrontCarDistance.Medium	10
0	B2.G1.R30		ļΛ	VisibilityLevel_Medium	ļΛ	Rainfall.FairlyLow	ĺΛ	TiresPressure.Low	=>	ļΛ	${\bf Front Car Distance.} {\it Medium}$	10
Ø	B2.G1.R31		ļΛ	VisibilityLevel_Medium	ļΛ	Rainfall_FairlyLow	ĺΛ	TiresPressure.Medium	=>	ļΛ	${\bf Front Car Distance.} {\it Medium}$	10
ø	B2.G1.R32		ļΛ	VisibilityLevel.Medium	ļΛ	Rainfall_FairlyLow	ļΛ	TiresPressure.High	=>	ļΛ	${\bf Front Car Distance.} {\it Medium}$	10
ø	B2.G1.R33		ļΛ	VisibilityLevel_Medium	ļΛ	Rainfall_Moderate	ļΛ	TiresPressure_Low	=>	ļΛ	${\sf Front Car Distance.} \textit{Medium}$	10
ø	B2.G1.R34		ļΛ	VisibilityLevel_Medium	ļΛ	Rainfall_Moderate	ļΛ	TiresPressure_Medium	=>	ļΛ	${\sf Front Car Distance.} \textit{Medium}$	10
ø	B2.G1.R35		ļΛ	VisibilityLevel_Medium	ļΛ	Rainfall_Moderate	ļΛ	TiresPressure.High	=>	ļΛ	FrontCarDistance_Long	10
Û	B2.G1.R36		ļΛ	VisibilityLevel_Low	ļΛ	Rainfall_Negligible	ļΛ	TiresPressure_Low	=>	ļΛ.	FrontCarDistance.Medium	10
ø	B2.G1.R37		LΛ	VisibilityLevel_Low	LΛ	Rainfall_Negligible	LΛ	TiresPressure_Medium	=>	L	FrontCarDistance.Medium	10
0	B2.G1.R38		ļΛ	VisibilityLevel_Low	ļΛ	${\bf Rainfall.} Negligible$	ļΛ	TiresPressure.High	=>	ļΛ	${\sf Front Car Distance.} \textit{Medium}$	10
.0	B2.G1.R39		ļΛ	VisibilityLevel_Low	ļΛ	Rainfall_Low	ļΛ	TiresPressure_Low	=>	1	FrontCarDistance.Medium	10
ø	B2.G1.R40		ļΛ	VisibilityLevel_Low	ļΛ	Rainfall_Low	ļΛ	TiresPressure_Medium	=>	1	FrontCarDistance.Medium	10
Ø	B2.G1.R41		ΙΛ	VisibilityLevel_Low	ļΛ	Rainfall_Low	ļΛ	TiresPressure_High	=>	L	FrontCarDistance.Long	10
0	B2.G1.R42			VisibilityLevel_Low	ļΛ	Rainfall_FairlyLow	ļΛ	TiresPressure_Low	=>	IV	FrontCarDistance.Medium	10
0	B2.G1.R43		ΙΛ	VisibilityLevel_Low	ļΛ		ļΛ	TiresPressure.Medium	=>	L	FrontCarDistance.Long	10
0	B2.G1.R44			VisibilityLevel_Low	LΛ	Rainfall_FairlyLow	LΛ	TiresPressure. High	=>		FrontCarDistance_Long	10

Figure 16: Front Car Distance rules



3.3.3. Dependences

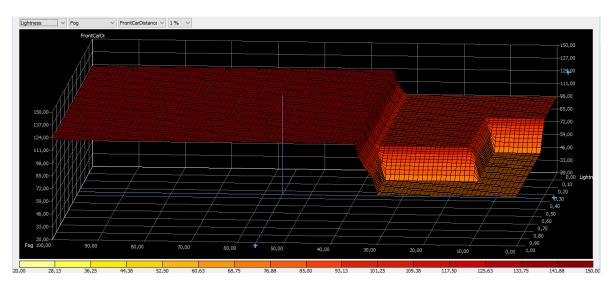


Figure 17: Front Car Distance (Vertical) as a function of Fog (Horizontal) and Lightness (Depth)

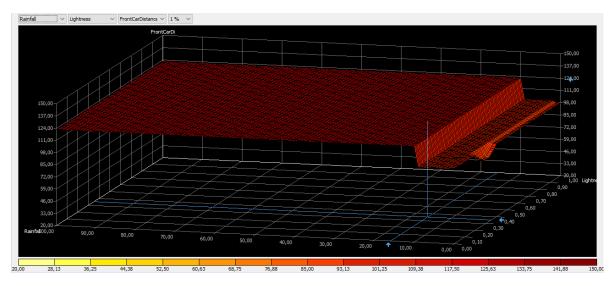


Figure 18: Front Car Distance (Vertical) as a function of Rainfall (Horizontal) and Lightness (Depth)

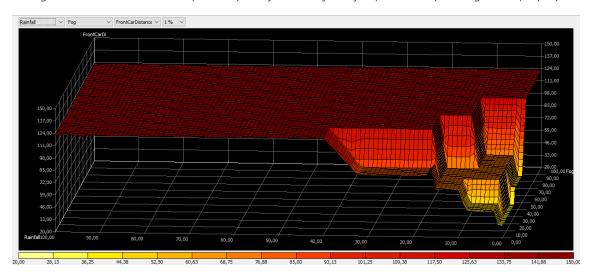


Figure 19: Front Car Distance (Vertical) as a function of Rainfall (Horizontal) and Fog (Depth)



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

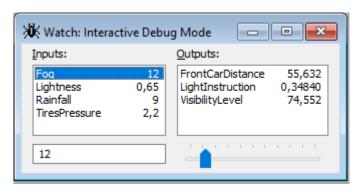


Figure 20: Situation 1: Values for the inputs and outputs

4.1.2. Input sets

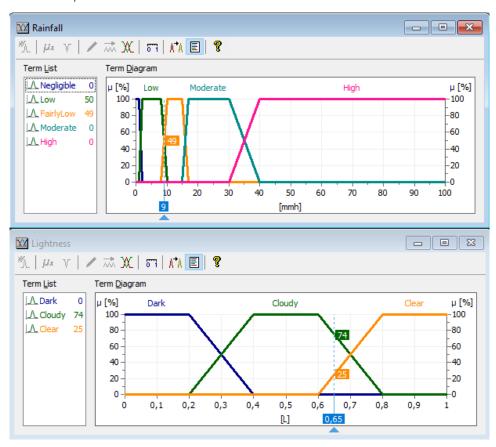


Figure 21: Situation 1: Rainfall and Lightness fuzzy sets memberships



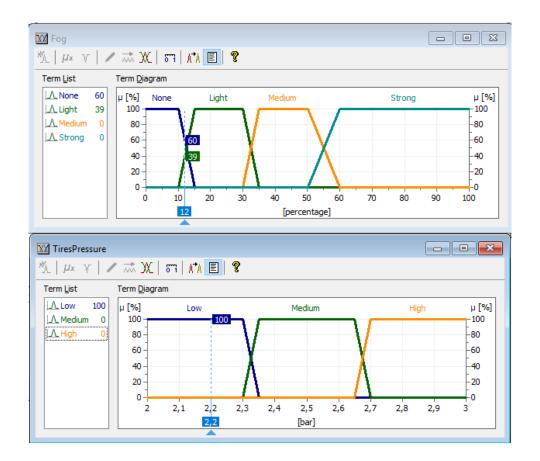


Figure 22: Situation 1: Fog and Tires Pressure fuzzy sets memberships



4.1.3. Rules activation

		Name	iii If	And	And	Operators	Then	With
.0 >	B1	RB1	1	2	3	Min / Max	1	
.Ø	B1.G1	Rules	XX Rainfall: 9	XX Lightness: 0,65	*XX Fog: 12		∀isibilityLevel: 74,552	DoS [%
Ø	B1.G1.R1		_		L∆ Fog_Strong	=>	△ VisibilityLevel_None	8
Ø	B1.G1.R2		A Rainfall Negligible	Lightness.Clear	None	=>	△ VisibilityLevel_Maximum	10
ø	B1.G1.R3		A Rainfall Negligible	_		=>	⚠ VisibilityLevel.High	10
ø	B1.G1.R4		A Rainfall Negligible		Fog_Medium	=>	⚠ VisibilityLevel_Medium	10
0	B1.G1.R5		A Rainfall Negligible		None	=>		10
0	B1.G1.R6		A Rainfall Negligible	⊥A Lightness Cloudy		=>		10
0	B1.G1.R7		A Rainfall Negligible	⊥A ■Lightness Cloudy		=>	⚠ VisibilityLevel_Medium	10
0	B1.G1.R8		A Rainfall Negligible	Lightness_Dark	None	=>	⚠ VisibilityLevel.High	10
Ø	B1.G1.R9		A Rainfall Negligible		Fog_Light	=>	⚠ VisibilityLevel_Medium	10
0	B1.G1.R10		A Rainfall Negligible	△ Lightness Dark		=>	✓ VisibilityLevel Low	10
.Ø	B1.G1.R11		A Rainfall Low	Lightness.Clear		_ =>	∴VisibilityLevel_Maximum	10
Ø	B1.G1.R12		A Rainfall Low	⊥A_Lightness.Clear	⊥∆ Fog_Light	=>	\	10
ø	B1.G1.R13		A Rainfall Low	Lightness_Clear	. Fog.Medium	=>	⚠ VisibilityLevel_Medium	10
Ø	B1.G1.R14		A Rainfall Low	⊥A Lightness Cloudy		=>	\VisibilityLevel. <i>High</i>	III 10
Ø	B1.G1.R15		A Rainfall Low	△ Lightness Cloudy		=>	△ VisibilityLevel_Medium	10
Ø	B1.G1.R16		Rainfall_Low	⊥A Lightness.Cloudy	Fog_Medium	=>		10
Ø	B1.G1.R17		Rainfall_Low			=>		10
0	B1.G1.R18		Rainfall_Low	△ Lightness Dark	⊥∆ Fog_Light	=>		10
0	B1.G1.R19		Rainfall_Low	△ Lightness Dark	⊥∆ Fog.Medium	=>	VisibilityLevel.⊥ow	10
0	B1.G1.R20		A Rainfall FairlyLow			_ =>	⊥VisibilityLevel. <i>High</i>	10
ø	B1.G1.R21		A Rainfall FairlyLow	Lightness.Clear	⊥∆ Fog_Light	=>	△ VisibilityLevel.Medium	10
Ø	B1.G1.R22		Rainfall_FairlyLow	Lightness.Clear		=>		10
Ø	B1.G1.R23		A Rainfall FairlyLow	⊥∆ Lightness.Cloudy	⊥∆_ Fog. None	=>	△ VisibilityLevel. <i>High</i>	III 10
Ø	B1.G1.R24		A Rainfall FairlyLow	⊥∆ Lightness.Cloudy	L∆ Fog_Light	=>	\VisibilityLevel_Medium	10
ø	B1.G1.R25		A Rainfall FairlyLow	⊥Lightness.Cloudy	⊥∆ Fog.Medium	=>	△ VisibilityLevel.Low	10
Ø	B1.G1.R26		A Rainfall FairlyLow	△ Lightness Dark	⊥Fog_None	=>	△ VisibilityLevel.Medium	10
Ø	B1.G1.R27		A Rainfall FairlyLow	△ Lightness Dark	L∆ Fog_Light	=>		10
Ø	B1.G1.R28		A Rainfall FairlyLow	△ Lightness Dark	<u> </u>	=>		10
Ø	B1.G1.R29		A Rainfall_Moderate	⊥∆ _Lightness.Clear	⊥∆_ Fog. None	=>	△ VisibilityLevel Medium	10
Ø	B1.G1.R30		A Rainfall_Moderate	Lightness.Clear	L∆ Fog_Light	=>		10
Ø	B1.G1.R31		A Rainfall_Moderate	Lightness.Clear	Fog_Medium	=>	VisibilityLevel Low	10
Ø	B1.G1.R32		A Rainfall_Moderate	⊥ Lightness.Cloudy		=>		10
Ø	B1.G1.R33		A Rainfall Moderate	⊥ Lightness.Cloudy	L∆ Fog_Light	=>		10
Ø	B1.G1.R34		A Rainfall Moderate	Lightness.Cloudy	Fog_Medium	=>		10
Ø	B1.G1.R35		A Rainfall_Moderate	Lightness_Dark		=>		10
Ø	B1.G1.R36		A Rainfall_Moderate	△ Lightness Dark		=>		10
0	B1.G1.R37		△ Rainfall Moderate	Lightness_Dark		=>		10

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



	·	Name	iii If	Operators	Then	With
.0 ▶	B3	RB2		Min / Max		
.Ø	B3.G1	Rules	VisibilityLevel: 74,552		LightInstruction: 0,3484	DoS [%]
.0	B3.G1.R1			=>	LightInstruction_LowBeam	100
.Ø	B3.G1.R2			=>	LightInstruction_LowBeam	70
.0	B3.G1.R3			=>	LightInstruction Parking Light	100
.0	B3.G1.R4			=>	△ LightInstruction None	₌ 70
0	B3.G1.R5			=>	LightInstruction None	100

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

		Name	∭ If	And	And	Operators	Then	With
Ø >	B2	RB3				Min / Max		
ø	B2.G1	Rules	VisibilityLevel: 74,552	XX Rainfall: 9	XX TiresPressure: 2,2		FrontCarDistance: 55,632	DoS [%]
ø	B2.G1.R1			A Rainfall_High		=>		100
ø	B2.G1.R2					=>		100
ø	B2.G1.R3		△ VisibilityLevel_Low	A Rainfall_Moderate		=>		100
ø	B2.G1.R4			A Rainfall_Negligible		=>	A FrontCarDistance_Short	80
Ø.	B2.G1.R5			A Rainfall Low	TiresPressure_Low	=>	LA ■ FrontCarDistance Short	10
ø	B2.G1.R6			A Rainfall Low		=>	☐ FrontCarDistance_Short	10
ø	B2.G1.R7			A Rainfall Low		=>	☐ FrontCarDistance Medium	10
ø	B2.G1.R8		△ _VisibilityLevel_Maximum	A Rainfall FairlyLow	TiresPressure Low	=>	A ■ FrontCarDistance Short	10
Ø	B2.G1.R9		△ _VisibilityLevel_Maximum	A Rainfall FairlyLow		=>	☐ FrontCarDistance.Short	10
Ø.	B2.G1.R10			<u>∧</u> Rainfall_FairlyLow		=>	☐ FrontCarDistance Medium	10
ø	B2.G1.R11			A Rainfall_Moderate	TiresPressure_Low	=>	☐ FrontCarDistance_Short	10
0	B2.G1.R12			A Rainfall_Moderate		=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R13			A Rainfall_Moderate		=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R14			A Rainfall_Negligible		=>	☐ FrontCarDistance_Short	10
Ø	B2.G1.R15			A Rainfall Low	TiresPressure ⊥ow	=>	A FrontCarDistance_Short	10
Ø	B2.G1.R16			A Rainfall Low		=>	☐ FrontCarDistance_Short	10
Ø	B2.G1.R17			A Rainfall Low		=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R18			A Rainfall FairlyLow	TiresPressure ⊥ow	=>	FrontCarDistance.Short	_Ⅲ 10
Ø	B2.G1.R19			A Rainfall FairlyLow		=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R20			A Rainfall FairlyLow		=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R21			A Rainfall_Moderate	TiresPressure_Low	=>	A FrontCarDistance_Short	10
Ø	B2.G1.R22			A Rainfall_Moderate		=>	☐ FrontCarDistance Medium	10
ø	B2.G1.R23			A Rainfall_Moderate		=>	☐ FrontCarDistance.Medium	10
ø	B2.G1.R24			A Rainfall_Negligible	TiresPressure Low	=>	A FrontCarDistance_Short	10
ø	B2.G1.R25		△ VisibilityLevel_Medium	A Rainfall_Negligible		=>	☐ FrontCarDistance.Short	10
ø	B2.G1.R26			A Rainfall_Negligible		=>	☐ FrontCarDistance Medium	10
ø	B2.G1.R27			A Rainfall Low	TiresPressure_Low	=>	⚠ ■ FrontCarDistance_Short	_{III} 10
ø	B2.G1.R28			A Rainfall Low		=>	☐ FrontCarDistance.Medium	10
ø	B2.G1.R29			A Rainfall Low		=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R30			A Rainfall FairlyLow	TiresPressure ⊥ow	=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R31			A Rainfall FairlyLow		=>	☐ FrontCarDistance Medium	10
Ø	B2.G1.R32		△ VisibilityLevel Medium	A Rainfall FairlyLow		=>	☐ FrontCarDistance.Medium	10
0	B2.G1.R33		△ VisibilityLevel Medium	A Rainfall_Moderate	TiresPressure ⊥ow	=>	FrontCarDistance_Medium	10
0	B2.G1.R34			A Rainfall_Moderate	TiresPressure_Medium	=>	FrontCarDistance_Medium	10
Ø	B2.G1.R35			A Rainfall_Moderate		=>	☐ FrontCarDistance.Long	10
Ø	B2.G1.R36			A Rainfall_Negligible		=>	☐ FrontCarDistance Medium	10
0	B2.G1.R37		△ VisibilityLevel_Low	A Rainfall_Negligible		=>	FrontCarDistance_Medium	100

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



4.1.4. Output sets

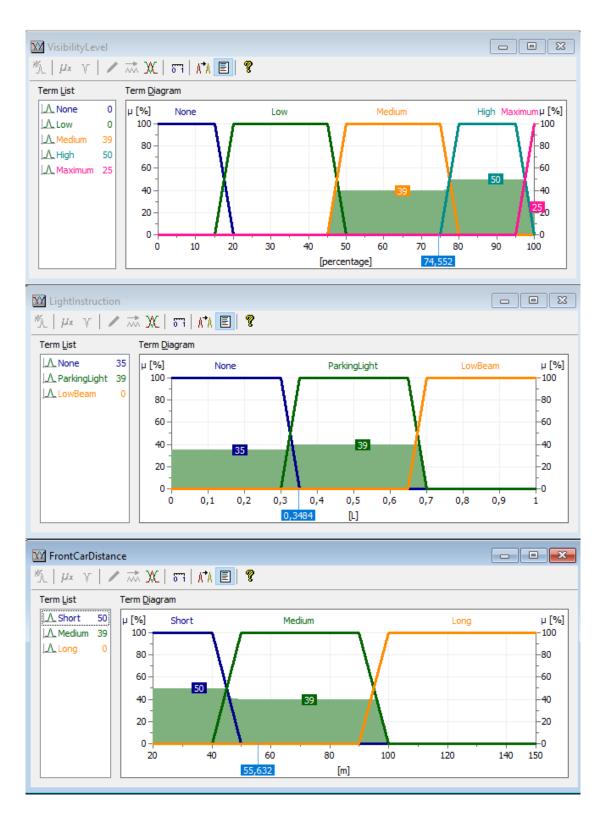


Figure 26: Situation 1: Output variables fuzzy sets memberships



4.2. Situation 2

4.2.1. Values

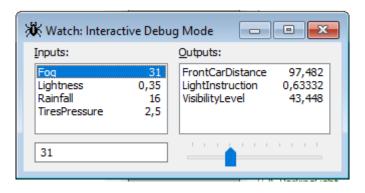


Figure 27: Situation 2: Values for the inputs and outputs

4.2.2. Input sets

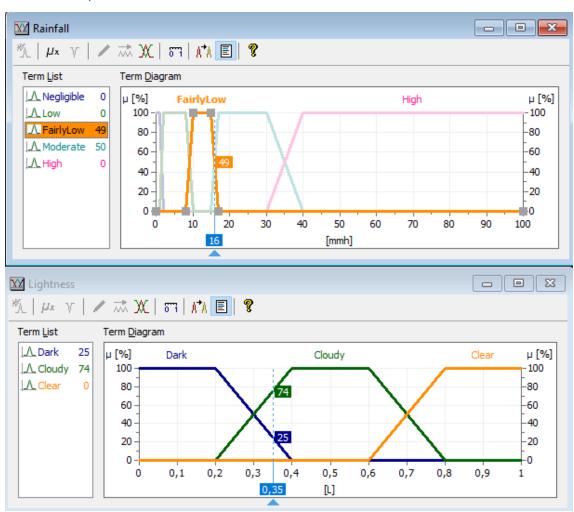


Figure 28: Situation 2: Rainfall and Lightness fuzzy sets memberships



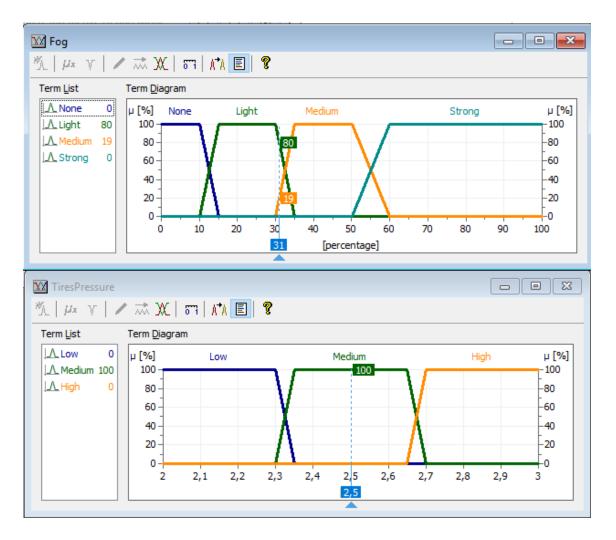


Figure 29: Situation 2: Fog and Tires Pressure fuzzy sets memberships



4.2.3. Rules activation

		Name	∭ If	And	And	Operators	Then	With
ØÞ.	B1.G1	Rules	XX Rainfall: 16	XX Lightness: 0,35	XX Fog: 31		∀ VisibilityLevel: 43,448	DoS [%]
.Ø	B1.G1.R1				△ Fog_Strong	=>		80
Ü	B1.G1.R2		A Rainfall_Negligible	△ Lightness.Clear	△ Fog_None	=>		100
.Ø	B1.G1.R3		A Rainfall Negligible	△ Lightness.Clear	Fog_Light	=>		100
Ũ	B1.G1.R4		A Rainfall Negligible	△ Lightness.Clear	Fog_Medium	=>		100
.Ø	B1.G1.R5		A Rainfall_Negligible	⊥ Lightness Cloudy	Fog_None	=>		100
.Ø	B1.G1.R6		A Rainfall Negligible	⊥∆ Lightness.Cloudy	Fog_Light	=>		100
0	B1.G1.R7		A Rainfall Negligible	⊥ Lightness. Cloudy	Fog_Medium	=>		100
Ø	B1.G1.R8		A Rainfall_Negligible	Lightness_Dark	Fog_None	=>	VisibilityLevel. <i>High</i>	100
.Ø	B1.G1.R9		A Rainfall Negligible	Lightness_Dark	Fog_Light	=>		100
0	B1.G1.R10		A Rainfall Negligible	Lightness_Dark	Fog_Medium	=>	✓ VisibilityLevel Low	100
ø	B1.G1.R11		A Rainfall Low	Lightness.Clear	Fog_None	=>		100
Ø	B1.G1.R12		A Rainfall Low	△ Lightness Clear		=>		100
Ø	B1.G1.R13		A Rainfall Low	△ Lightness.Clear	Fog_Medium	=>	△ VisibilityLevel.Medium	100
Ø	B1.G1.R14		△ Rainfall Low	⊥∆ Lightness.Cloudy	△ Fog_None	=>		100
.Ø	B1.G1.R15		△ Rainfall Low	⊥ Lightness. Cloudy	∆ Fog_Light	=>		100
Ø	B1.G1.R16		△ Rainfall Low	⊥ Lightness. Cloudy	Fog_Medium	=>	△ VisibilityLevel.Low	100
Ø	B1.G1.R17		A Rainfall Low	⊥ALightness_Dark	. Fog.None	=>		100
Ø	B1.G1.R18		<u> </u>	⊥ALightness.Dark		=>		100
Ø	B1.G1.R19		<u> </u>	△ Lightness Dark	Fog_Medium	=>	✓ VisibilityLevel.Low	100
ø	B1.G1.R20		A Rainfall FairlyLow	<u> </u>	△ Fog.None	=>		100
0	B1.G1.R21		A Rainfall FairlyLow	△ Lightness.Clear		=>		100
ø	B1.G1.R22		A Rainfall FairlyLow	△ Lightness.Clear	△ Fog Medium	=>	✓ VisibilityLevel.Low	100
Ø	B1.G1.R23		A Rainfall FairlyLow	⊥A Lightness.Cloudy	△ Fog.None	=>		100
ø	B1.G1.R24		A Rainfall FairlyLow	⊥ Lightness. Cloudy		=>	<u> </u>	III 100
ø	B1.G1.R25		<u> </u>	⊥ Lightness. Cloudy	Fog_Medium	_ =>		100
.Ø	B1.G1.R26		<u> </u>	\triangle Lightness Dark	. Fog.None	=>		100
ø	B1.G1.R27		A Rainfall_FairlyLow	\triangle Lightness Dark		=>		100
Ø	B1.G1.R28		<u> </u>	\triangle Lightness Dark	△ Fog Medium	_ =>	△VisibilityLevel.Low	100
Ø	B1.G1.R29		<u> </u>	△ Lightness.Clear	△ Fog.None	=>		100
Ø	B1.G1.R30		$A \longrightarrow Rainfall Moderate$	<u> </u>	▲ Fog_Light	=>		100
Ø	B1.G1.R31		$\bot A$ Rainfall Moderate	Lightness.Clear		=>	✓ VisibilityLevel.Low	100
Ø	B1.G1.R32		$\underline{\hspace{0.1cm}} \hspace{0.1cm} \blacksquare \textbf{Rainfall}. \hspace{0.1cm} \textit{Moderate}$	\bot Lightness.Cloudy	△ Fog_None	=>		100
Ø	B1.G1.R33		$A \longrightarrow Rainfall Moderate$	⊥A Lightness.Cloudy	▲ Fog_Light	=>	\VisibilityLevel.⊥ow	■ ■ 100
Ø	B1.G1.R34		\triangle Rainfall Moderate			_ =>		100
Ø	B1.G1.R35		A Rainfall Moderate	Lightness_Dark	△ Fog_None	=>	\A VisibilityLevel⊥low	100
Ø	B1.G1.R36		<u> </u>	Lightness_Dark		=>	△	100
Ø	B1.G1.R37			Lightness_Dark	Fog_Medium	_ =>	∴ VisibilityLevel_None	100
0	B1.G1.R38		A Rainfall_High	△ Lightness.Clear	Fog_None	=>		100

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



ℓ B3 RB2 Min / Maxℓ B3.G1 Rules	LightInstruction: 0,63332 DoS [9
	LightInstruction: 0,63332 DoS [5
. Ø B3.G1.R1	LightInstruction_LowBeam 1
. Ø B3.G1.R2	△ LightInstruction_LowBeam
. Ø B3.G1.R3	△ LightInstruction_ParkingLight 1
B3.G1.R4	△ LightInstruction_None
B3.G1.R5	△ LightInstruction_None 1

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



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

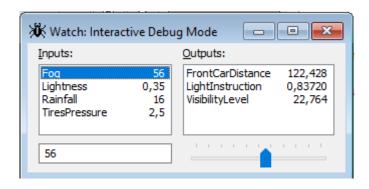


Figure 34: Situation 3: Values for the inputs and outputs

4.3.2. Input sets

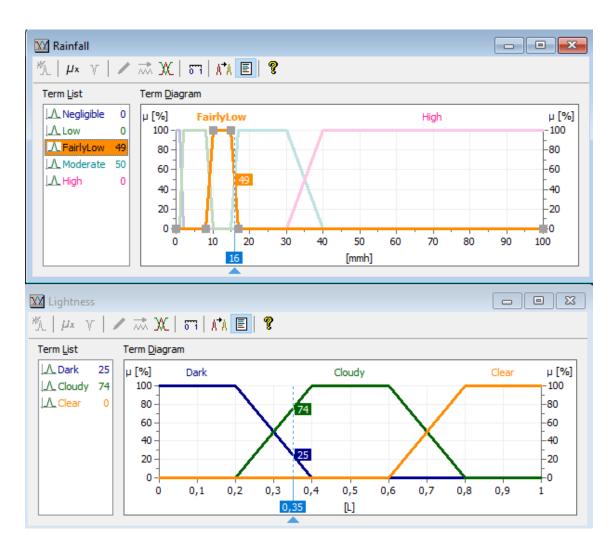


Figure 35: Situation 3: Rainfall and Lightness fuzzy sets memberships



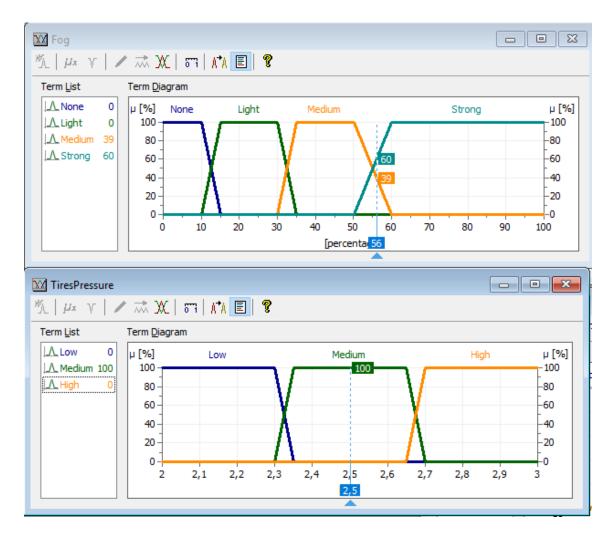


Figure 36: Situation 3: Fog and Tires Pressure fuzzy sets memberships



4.3.3. Rules activation

		Name	iii If		And		And	I	0	perators	Then		Wit	:h	(
.Ø >	B1.G1	Rules	XX	Rainfall: 16	XX	Lightness: 0,35	XΧ	Fog: 56			XX V	isibilityLevel: 22,764	DoS	S [%]	
.Ø	B1.G1.R1						ļΛ	Fog Strong	ı	=>	1	VisibilityLevel_None	li.	80	1
.Ø	B1.G1.R2		ļΛ	Rainfall_Negligible	ļΛ	Lightness.Clear	ļΛ	Fog.None		=>	1	VisibilityLevel_Maximum		100	Ī
.Ø	B1.G1.R3		ļΛ	Rainfall_Negligible	ļΛ	Lightness.Clear	ļΛ	Fog.Light		=>	ļΛ.	VisibilityLevelHigh		100)
.0	B1.G1.R4		ļΛ	Rainfall_Negligible	ļΛ	Lightness.Clear	ļΛ	Fog.Medium		=>	1	VisibilityLevel_Medium		100)
.Ø	B1.G1.R5		ļΛ	Rainfall_Negligible	ļΛ	Lightness.Cloudy	ļΛ	Fog.None		=>	ļΛ.	VisibilityLevelHigh		100)
.Ø	B1.G1.R6		ļΛ	Rainfall_Negligible	ļΛ	Lightness.Cloudy	ļΛ	Fog.Light		=>	ļΛ.	VisibilityLevelHigh		100)
.Ø	B1.G1.R7		ļΛ	Rainfall_Negligible	ļΛ	Lightness.Cloudy	ļΛ	Fog.Medium		=>	ļΛ	VisibilityLevel_Medium		100)
.Ø	B1.G1.R8		ļΛ	Rainfall_Negligible	ļΛ	_Lightness_Dark	ļΛ	Fog.None		=>	1	VisibilityLevelHigh		100)
.Ø	B1.G1.R9		ļΛ	Rainfall_Negligible	ļΛ	_Lightness_Dark	ļΛ	Fog.Light		=>	ļΛ	VisibilityLevel_Medium		100)
.Ø	B1.G1.R10		ļΛ	Rainfall.Negligible	ļΛ	_Lightness_Dark	ļΛ	Fog.Medium		=>	14	VisibilityLevel.Low		100)
.Ø	B1.G1.R11		ļΛ	Rainfall.Low	ļΛ	Lightness.Clear	ļΛ	Fog.None		=>	1	VisibilityLevel_Maximum		100)
.Ø	B1.G1.R12		ļΛ	Rainfall_Low	ļΛ	Lightness.Clear	ļΛ	Fog.Light		=>	ļΛ	VisibilityLevel_High		100)
.Ø	B1.G1.R13		ļΛ	Rainfall_Low	ļΛ	Lightness.Clear	ļΛ	Fog.Medium		=>	Į.A.	VisibilityLevel_Medium		100)
.Ø	B1.G1.R14		ļΛ	Rainfall.Low	ļΛ	Lightness.Cloudy	ļΛ	Fog.None		=>	1	VisibilityLevel_High		100)
.Ø	B1.G1.R15		ļΛ	Rainfall_Low	ļΛ	Lightness.Cloudy	ļΛ	Fog.Light		=>	IV	VisibilityLevel_Medium		100)
.Ø	B1.G1.R16		ļΛ	Rainfall.Low	ļΛ	Lightness.Cloudy	ļΛ	Fog.Medium		=>	14	VisibilityLevel_Low		100)
.0	B1.G1.R17		ļΛ	Rainfall_Low	ļΛ	_Lightness_Dark	ļΛ	Fog.None		=>	1	VisibilityLevel_Medium		100)
.Ø	B1.G1.R18		ļΛ	Rainfall.Low	ļΛ	_Lightness_Dark	ļΛ	Fog.Light		=>	1	VisibilityLevel_Medium		100)
.0	B1.G1.R19		ļΛ	Rainfall_Low	ļΛ	_Lightness_Dark	ļΛ	Fog Medium		=>	14	VisibilityLevel_Low		100)
.Ø	B1.G1.R20		ļΛ	Rainfall.FairlyLow	ļΛ	Lightness.Clear	ļΛ	Fog.None		=>	1	VisibilityLevel.High		100)
.Ø	B1.G1.R21		ļΛ	Rainfall.FairlyLow	ļΛ	Lightness.Clear	ļΛ	Fog_Light		=>	1	VisibilityLevel_Medium		100	J
ø	B1.G1.R22		ļΛ	Rainfall_FairlyLow	ļΛ	Lightness.Clear	ļΛ	Fog.Medium		=>	14	VisibilityLevel_Low		100)
ø	B1.G1.R23		ļΛ	Rainfall_FairlyLow	ļΛ	Lightness.Cloudy		Fog.None		=>	1	VisibilityLevel.High		100)
ø	B1.G1.R24		ļΛ	Rainfall_FairlyLow	ļΛ	Lightness.Cloudy	ļΛ	Fog.Light		=>	ļΛ	VisibilityLevel_Medium		100)
ø	B1.G1.R25		ļΛ	Rainfall_FairlyLow	ļΛ	Lightness.Cloudy	ļΛ	Fog.Medium		=>	14	VisibilityLevel_Low		100	1
0	B1.G1.R26		ļΛ	Rainfall_FairlyLow	ļΛ	Lightness Dark	ļΛ	Fog.None	Ī	=>	1	VisibilityLevel_Medium		100	ľ
.Ø	B1.G1.R27		ļΛ	Rainfall_FairlyLow	ļΛ	_Lightness_Dark	ļΛ	Fog.Light		=>	1	VisibilityLevel_Medium		100)
ø	B1.G1.R28		ļΛ	Rainfall_FairlyLow	ļΛ	_Lightness_Dark	ļΛ	Fog.Medium		=>	14	VisibilityLevel_Low		100	I
ø	B1.G1.R29		ļΛ	Rainfall Moderate	ļΛ	Lightness.Clear	ļΛ	Fog.None	Ī	=>	1	VisibilityLevel_Medium		100	,
ø	B1.G1.R30		ļΛ	Rainfall_Moderate	ļΛ	Lightness.Clear	ļΛ	Fog.Light		=>	1	VisibilityLevel_Medium		100)
.Ø	B1.G1.R31		ļΛ	Rainfall Moderate	ĪΛ	Lightness.Clear	ļΛ	Fog.Medium		=>	1	VisibilityLevel.Low		100)
ø	B1.G1.R32		ļΛ	Rainfall Moderate	ļΛ	Lightness.Cloudy		Fog.None		=>	īV.	VisibilityLevel_Medium		100)
ø	B1.G1.R33		ļΛ	Rainfall Moderate	ĪΛ	Lightness.Cloudy	ļΛ	Fog.Light		=>	ΙΛ.	VisibilityLevel.Low		100)
.Ø	B1.G1.R34		ļΛ	Rainfall Moderate		Lightness.Cloudy		Fog.Medium		=>	1	VisibilityLevel.Low		100	1
0	B1.G1.R35		ļΛ	Rainfall Moderate		_Lightness_Dark	ļΛ	Fog.None		=>	ΙΛ.	VisibilityLevel.Low		100	1
.Ø	B1.G1.R36		-	Rainfall Moderate		Lightness Dark	ĮΛ	Fog.Light		=>		VisibilityLevel.Low		100)
.0	B1.G1.R37			Rainfall Moderate		_Lightness_Dark		Fog.Medium		=>		_VisibilityLevel_None		100	٠
			-	-					100						ı

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



		Name	iii If	Operators	Then	With	(
.0 >	B3	RB2		Min / Max			
.Ø	B3.G1	Rules	VisibilityLevel: 22,764		LightInstruction: 0,8372	DoS [%]
.Ø	B3.G1.R1			=>	LightInstruction.LowBeam	_{III} 10	0
.Ø	B3.G1.R2			=>	LightInstruction.LowBeam	ա 7	0
.Ø	B3.G1.R3			=>	LightInstruction ParkingLight	10	0
.Ø	B3.G1.R4			=>	LightInstruction None	7	0
.Ø	B3.G1.R5			=>	△ LightInstruction None	10	0

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



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:

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



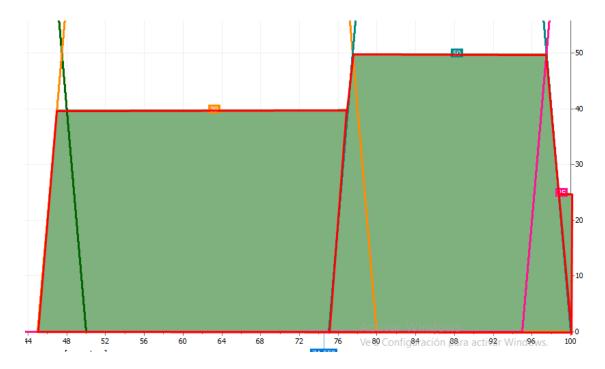


Figure 41: Situation 1: Activated Visibility level fuzzy sets with their memberships (From left to right: Medium, High, Maximum)

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).



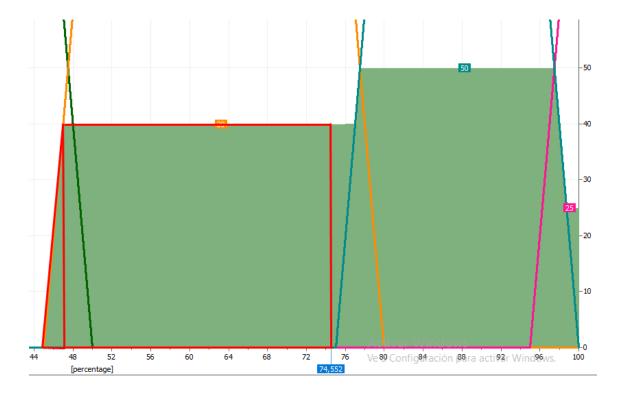


Figure 42: Situation 1: Area where half of the total area has been covered

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.

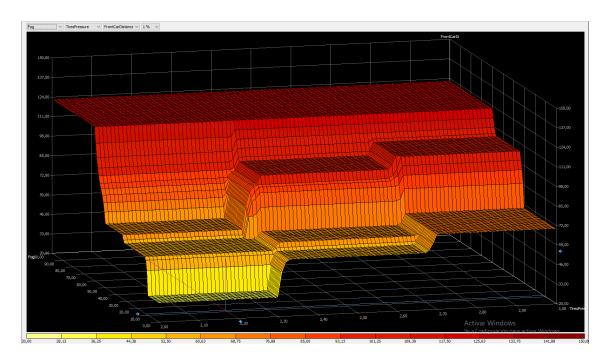


Figure 43: Front Car Distance (Vertical) as a function of Tires pressure (Horizontal) and Fog (Depth)



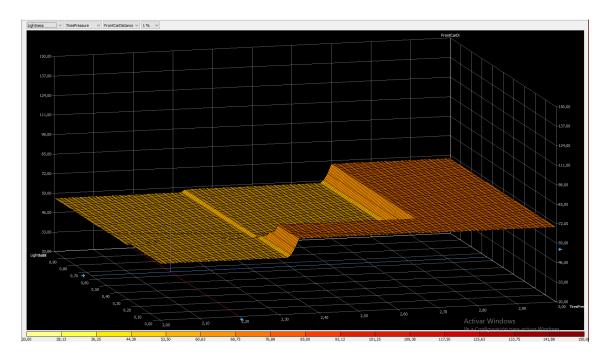


Figure 44: Front Car Distance (Vertical) as a function of Tires pressure (Horizontal) and Lightness (Depth)

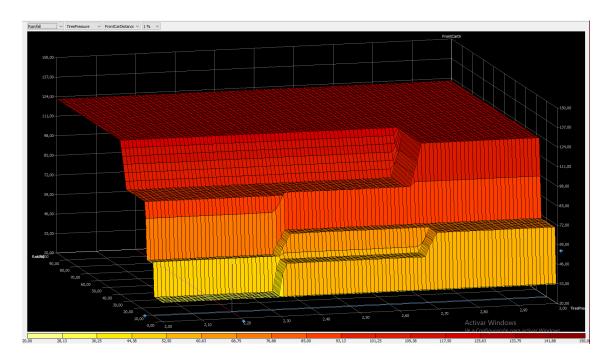


Figure 45: Front Car Distance (Vertical) as a function of Tires pressure (Horizontal) and Rainfall (Depth)

