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An Fuzzy-based Risk Reasoning Driving Strategy on VANET☆

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ABSTRACT

This paper proposes an Fuzzy-based Risk Reasoning Driving Strategy on VANET. Its first reasoning phase consists of a WC_risk reasoning that reasons the risk by using limited road factors such as current weather, density, accident, and construction, a DR_risk reasoning that reasons the risk by combining the driving resistance with the weight value suitable for the environment of highways and national roads, a DS_risk reasoning that judges the collision risk by using the travel direction, speed. and distance of vehicles and pedestrians, and a Total_risk reasoning that computes a final risk by using the three above-mentioned reasoning. Its second speed reduction proposal phase decides the reduction ratio according to the result of Total_risk and the reduction ratio by comparing the regulation speed of road to current vehicle's speed. Its third risk notification phase works in case current driving speed exceeds regulation speed or in case the Total_risk is higher than AV(Average Value). The Risk Notification Phase informs rear vehicles or pedestrians around of a risk according to drivers's response. If drivers use a brake according to the proposed speed reduction, the precedent vehicles transfers Risk Notification Messages to rear vehicles. If they don't use a brake, a current driving vehicle transfers a Risk Message to pedestrians. Therefore, this paper not only prevents collision accident beforehand by reasoning the risk happening to pedestrians and vehicles but also decreases the loss of various resources by reducing traffic jam.

☞ keyword : Efficient Vehicular Traffic Management, Fuzzy Reasoning, VANET, Collision Prevention

1. Introduction

Nowadays electronic equipments such as smart-phone, wearable equipments, and smart watches became miniaturized and had mobile communication capabilities. And various network structures are emerging with these equipments to provide various mobile services. Particularly, MANETs (Mobile Ad hoc Networks) enables short-range wireless communication by organizing dynamic network anytime with a variety of wireless terminal equipments without infrastructure and provides various services by communicating with terminals farther away than communication radius with multi-hop networking technology [1][2].

In 2004, Blum[3] applied MANET's merits to VANET (Vehicular Ad hoc Networks) and the VANET's research was spread far and wide[1]. VANET's applications are various and are being applied to new environment such as smart cities and recent ITS(Intelligent Transportation System). In order to improve the best safety in the smart city environment utilizing various vehicle information, drivers and pedestrians must have good judgement about a risk. That is, if drivers and pedestrians can take proper measures after sensing collision beforehand, they can improve their safety and an accident occurrence ratio can be reduced thanks to this. In addition, the traffic congestion, the second traffic accident, and the cost caused by the accident can be decreased[4].

This paper proposes An Fuzzy-based Risk Reasoning Driving Strategy on VANET. Its reasoning phase consists of a Risk Reasoning Phase, a Speed Reduction Phase, and a Risk Notification Phase. By using the three phases. the paper not only prevents collision accident beforehand by reasoning a risk happening to pedestrians and vehicles but also decreases the

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loss of various resources by reducing traffic jam.

The remainder of this paper is organized as follows. Chapter 2 discusses the related works on Fuzzy Theory. Chapte r3 proposes a risk reasoning driving strategy. Chapter 4 analyzes and estimates its performance. In the chapter 5, our conclusion is described.

2. Related Works

2.1 ITS

Intelligent transportation systems (ITS) are advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks[5].

Intelligent Transport Systems (ITS) include telematics and all types of communications in vehicles, between vehicles (e.g. car-to-car), and between vehicles and fixed locations (e.g. car-to-infrastructure). However, ITS are not restricted to Road Transport - they also include the use of information and communication technologies (ICT) for rail, water and air transport, including navigation systems. In general, the various types of ITS rely on radio services for communication and use specialized technologies[6].

Applying information technology to a country's transportation network delivers five key classes of benefits by: 1) increasing driver and pedestrian safety, 2) improving the operational performance of the transportation network, particularly by reducing congestion, 3) enhancing personal mobility and convenience, 4) delivering environmental benefits, and 5) boosting productivity and expanding economic and employment growth[7].

2.2 Fuzzy Theory

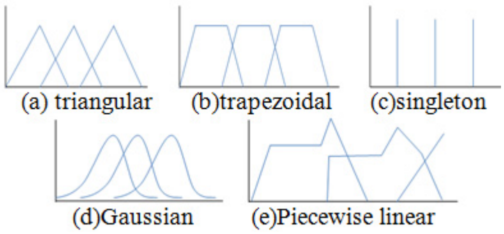
Fuzzy Set Theory was formalized by Lofti Zadeh in 1965[8]. Since its inception in 1965, the fuzzy set theory has advanced in a variety of ways and in many disciplines. Applications of this theory can be found, for example, in artificial intelligence, computer science, medicine, control engineering, decision theory, expert systems, logic, management science, operations research, pattern recognition, and robotics[9]. Specially, a Fuzzy Logic System can be defined as the nonlinear mapping of an input data set to a scalar output data[10,11]. A Fuzzy Logic System consists of four main parts: fuzzifier, rules, inference engine, and defuzzifier[12].

2.2.1 Linguistic variables

Linguistic variables are the input or output variables of the Fuzzy Logic System whose values are words or sentences from natural language, instead of numerical values. For example in the Fuzzy Logic System the linguistic variables are expressed as follows according to a patient's temperature. temperature(t)= {hypothermia, normothermia, mild fever, high fever}.

2.2.2 Membership function

Membership functions are used in the fuzzification and defuzzification steps of the Fuzzy Logic System. Membership functions can have several different shapes such as Figure 1 [8,10,11].



(Figure 1) Membership functions

The most commonly used shapes are triangular, trapezoidal, Gaussian and bell shaped membership function.

2.2.3 Fuzzification

A Fuzzy Logic system uses linguistic variables instead of numerical variables. The process of converting a numerical variable (real number or crisp variable) to a linguistic variable (fuzzy number) is called fuzzification. The simplest form of membership function is triangular membership function.

2.2.4 Defuzzification

The reverse fuzzification is called defuzzification. The use of a Fuzzy Logic System inference engine produces the output in a linguistic form. According to real world requirements, the linguistic variables have to be transformed to crisp output. Weighted average method is the best well-known defuzzification method for Sugeno type fuzzy controller [10,13].

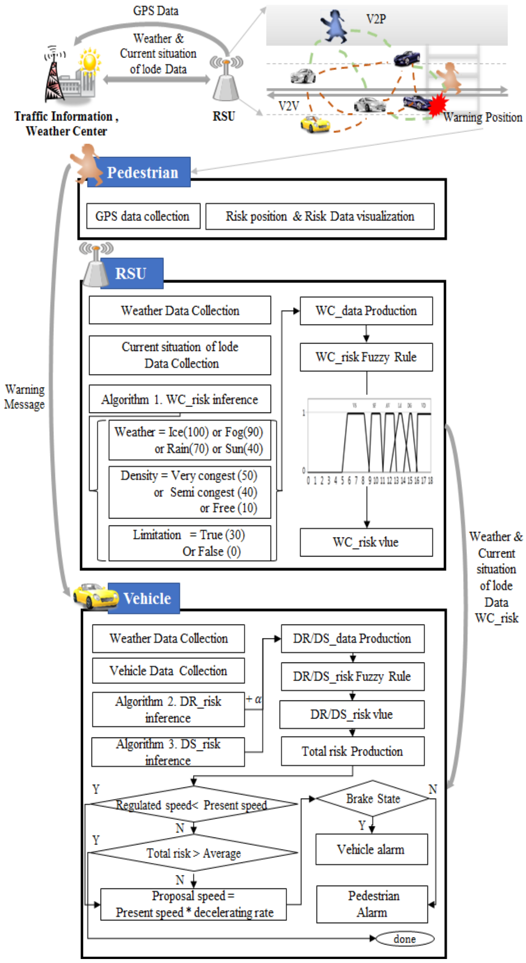
3. An risk reasoning driving strategy

3.1 Overview

Figure 2 shows the structure of risk reasoning eco-driving strategy based on fuzzy to prevent vehicle collision and consists of a RRP(Risk Reasoning Phase) based on Fuzzy, a SRP(Speed Reduction Phase), a RNP(Risk Notification Phase).

First, the RRP is based on Fuzzy rules and is made up of three steps as follows. The 1st step is CWS_risk (Current Weather and Situation of road_risk) which reasons the risk of road weather and situation RSU manages. The 2nd step is DR_risk(Driving Resistance_risk) which reasons the risk of driving resistance by using the information of their own vehicles and the weather information collected by RSU. The 3rd step is DS_risk(Distance and Speed_risk) which reasons the risk of distance and speed by using the external information collected from vehicles around and pedestrians. If the result of these reasons is decided, Total_risk is generated by applying a fuzzy theory to it again. The Total_risk is used for the SRP.

The SRP decides a reduction ratio according to the result of the Total_risk, and computes the proposed speed with the reduction ratio which is computed with the comparison of the regulation speed with the speed of current vehicles. Besides, the SRP computes a proposed speed even in case the total_risk of vehicles is above average. In the phase, the computed speed is transferred to drivers immediately and the RNP action is decided according to the driver's response about the speed.



(Figure 2) The flowchart of the proposed strategy

The RNP generates two kinds of notification messages. The first step generates a SRNM(Speed Reduction Notification Message) when the proposed speed reduction is above 15% and drivers reduced driving speed. The message is transferred to rear vehicles and a collision accident is prevented by abrupt stop. The second step generates a RSM(Risk Sensing Message) when case the proposed speed reduction is above 15% and drivers did not reduce driving speed. The message is transferred to pedestrians around and an expected collision accident area is informed of them. Therefore, this paper considers the various risks during driving, prevents the collision accident caused by driver's bad habit and overspeed, and saves fuel by managing of driving resistance and speed.

3.2 An RRP Design

3.2.1 The CWS_risk Reasoning

The Algorithm1 shows the WC_risk Reasoning of RSU proposed in this paper.

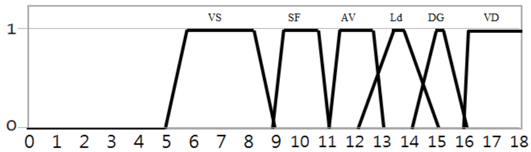
(Algorithm 1) WC_risk inference

```
1:WD=Weather data value //by Meteorological agency
  Switch (Weather data){
      case Ice:       WD = 100; break;
      case Fog:       WD = 90;  break;
      case Rain:      WD = 70;  break;
      case Sun:       WD = 40;  break;}
2: DD =Density data value
   Switch (Density data){
      case Very_congest:   DD = 50; break;
      case Semi_congest:   DD = 40; break;
      case Free:           DD = 10;  break;}
   LD = Limitation Data value
   Switch (Limitation Data){
      case True:      LD = 30; break;
      case False:     LD = 0;  break;}
3: WC_data = (WD+ DD+ LD)/10 //Lage(5~18)
4: WC_risk Fuzzy Rule
  if(WC_data >= 50 && WC_data < 90) then
   WC_risk = VS //Very Safety
  else if(WC_data <= 90 && WC_data < 110) then
   WC_risk = SF //Safety
  else if(WC_data <= 110 && WC_data < 130) then
   WC_risk = AV //Average
  else if(WC_data <= 120 && WC_data < 150) then
   WC_risk = Ld //Little danger
  else if(WC_data <= 140 && WC_data < 160) then
   WC_risk = DG // Danger
  else  WC_risk = VD //Very Danger
  endif
5: Make WC_risk Fuzzy set graph
6: WC_risk Production
```

First, RSU classifies the weather data collected from the weather center into snowy, misty, rainy, and fine weather and computes a risk baseline according to its classification baseline(1: WD computation)

Second, RSU transfers its location information to the Highway Department and receives the information of limitations such as density, construction, local event from the Highway Department. The RSU computes a risk baseline (DD and LD) on the basis of the received limitations.

Third, the RSU computes WC_data with WD, DD, and LD value and applies the result to a WC_risk Fuzzy Rule.



(Figure 3) The Fuzzy set Graph of WC_risk

Fourth, the WC_risk Fuzzy Rule is the “(4:)” of Algorithm1 and Figure 3 shows the WC_risk Fuzzy Graph generated by the result.

3.2.2 The DR_risk reasoning

The DR_risk reasoning of Vehicles proposed in this paper is computed on the base of the driving resistance of vehicles. The driving resistance consists generally of Rolling Resistance, Air Resistance, Acceleration Resistance, and Slope Resistance. In addition, the Highway is not influenced by road condition such as sloping roads, unpaved roads, and sand roads, but by Air Resistance, and Acceleration Resistance rather than Rolling Resistance and Slope Resistance. On the other hand, because vehicles can not drive faster in the national road than in the Highway, this case is influenced by Rolling Resistance and Slope Resistance rather than Air Resistance and Acceleration Resistance. The driving resistance of DR_risk provides 300% weight value for the resistance influencing the Highway and the National Road significantly. Algorithm2 shows the process of DR_risk reasoning.

First, Rolling Resistance is computed with “(2:), (3:)” in Algorithm2. For example, in the case of vehicle and road situation in the Table1, Rolling Resistance, F_R is computed in the following expression.

$$F_R = \mu_R \times W \times g$$
$$= 0.015 \times 1380_{kg} \times 9.8_{m/s^2} = 202.86_{[N]}$$

where, μ_R(=0.015) is the coefficient of dry asphalt, W(Weight) 1,380kg and g(Gravity acceleration) $9.8_{m/s^2}$.

(Algorithm 2) DR_risk inference

1: W: total mass; Θ : Slope;
g: acceleration of gravity; //9.8m/s2
μR: Rolling resistance coefficient;
μair: Air resistance coefficient;
A: Vehicle face area; p: Air density;
Vres :Traveling speed ;// m/s2
ε: Weight equivalent to rotating part;
TV:Types of Vehicle; //3 or 4
VG:Vehicle Gear; //1~4 Ar: Acceleration;
F(R): Rolling Resistance; F(Air): Air Resistance
F(Ar): Acceleration resistance;
F(Θ): Slope resistance; F(d): driving resistance;
2: Rolling resistance coefficient Production
if (road == dry_concrete or dry_asphalt) then
μ_R =0.015 //average : 0.01~0.02
else if (road == wet_concrete or wet_asphalt or gravel or tar) then μ_R=0.025
else if (road == Unpaved) then μ_R=0.05
else if (road == Farm or Sandy) then μ_R=0.25
endif
3: Rolling resistance Production : $F_R = \mu_R \times W \times g$
4: Air resistance coefficient Production
if (sharpe == 'sphere') then $\mu_{Air} = 0.47$
else if (sharpe == 'Half-sphere') then μ_{Air}=0.42
else if (sharpe == 'core') then μ_{Air}=0.50
else if (sharpe == 'general') then μ_{Air}=0.30
else if (sharpe == 'sports') then μ_{Air}=0.25
endif
5: Air resistance Production: $F_{Air} = \mu_{Air} \times A \times (\frac{p}{2}) \times (V_{res})^2$
6: Acceleration resistance coefficient Production
if (VG == 1) then{
if (TV == 3) then ε=0.8 else ε =0.7}
else if (VG == 2) then{
if (TV == 3) then ε =0.8 else ε =0.54;}
else if (VG == 4) then{
if (TV == 3) then ε =0.28 else ε =0.2}
else if (VG == 5) then{
if (TV == 3) then ε =0.11 else ε =0.1}
endif
7: $acceleration = \left(\frac{Target\,speed}{3600_s}\right) / Travel\,time$
8: Acceleration resistance Production
$F_{Ar} = W \times (1+\varepsilon) \times \left(\frac{acceleration_{m/s^2}}{g^2}\right)$
9: Slope resistance Production : $F_\theta = (W \times g \times \theta)/2$
10: Interim F(d) Value
$=((F_R + F_{Air} + F_{Ar} + F_\theta) \times V_{res})/1000$
11: $F_d = interim\,F_d\,Value + \alpha$
if (drive road == Express way) then
$\alpha = ((F_{Air} + F_{Ar}) \times 3)/1000$
else $\alpha = ((F_R + F_\theta) \times 3)/1000$
endif
12: DR_data = 36-F(d)
13: DR_risk Fuzzy Rule
if(DR_data >= 1 && DR_data < 15) then
DR_risk = VD // Very Danger
else if(DR_data <= 14 && DR_data < 20) then
DR_risk = Dg // Danger
else if(DR_data <= 20 && DR_data < 22) then
DR_risk = Ld // Little danger
else if(DR_data <= 21 && DR_data < 28) then
DR_risk = Av //Average
else if(DR_data <= 27 && DR_data < 30) then
DR_risk = Sf //Safety
else if(DR_data <= 29 && DR_data <= 35) then
DR_risk = VS //Very Safety
endif
14: Make DR_risk Fuzzy set graph
15: WR_risk Production

Second, the Air Resistance influenced by driving speed and air density is decided according to the Front cross section and shape. The expression for computing the Air Resistance is the (4:) and (5:) of Algorithm2. The coefficient of Air Resistance μ_{Air} is 0.42, because a vehicle type is Half-sphere. Air Resistance F_{Air} is computed in the following expression.

$$F_{Air} = 0.42 \times 1.89_{m^2} \times \frac{(1,202_{kg/m^3})}{2} \times 25_{m/s^2} = 298.2[N]$$

(Table1) The vehicle and road situation for the computation of driving resistance

Data	Value	Data	Value
W	1,380kg	Θ	4% (0.04)
g	$9.8_{m/s^2}$	Vres	$90_{km/h} = (25_{m/s^2})$
A	1.89_{m^2}	TV	4
p	$1,202_{kg/m^3}$	VG	2
Target speed	$10_{km/h}$	Travel time	3s
road	Dry_asphalt	sharpe	Half-sphere

Third, Acceleration Resistance is computed by using the weight equivalent to rotating part, an acceleration and a total weight, where acceleration means a speed for reaching target speed within target time. In the table1, because target speed is 10Km/h and given time is 3 second, acceleration is 0.93

by the (10,000m/s)/(3600s)/(3s). If the table1 has the second gear(VG) of 4 speed gearbox(TV) vehicle now, its weight(ε) equivalent to rotational part is 0.54. If this result is applies to "(8:)" in Algorithm2, Acceleration Resistance F_{Ar} is computed as follows.

$$F_{Ar} = 1{,}380 \times 1.54 \times \frac{0.93}{9.8_{m/s}} = 201.68[N]$$

Fourth, Slope Resistance is computed by using the slope of flat surface(Θ) and gravity as follows.

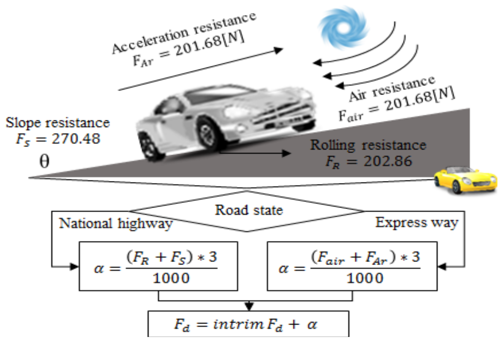
$$W \times g \times \Theta = 1{,}380kg \times 9.8_{m/s^2} \times 0.04 = 540.96[N]$$

But, this paper uses just 50% of Slope Resistance to reduce the difference between other resistance values. Therefore, Slope Resistance of Table1 becomes 270.48[N].

Fifth, the value of intermediate driving resistance is computed by using the following expression with Rolling, Air, Acceleration, Slope. Intermediate Driving Resistance $F_{(id)}$ is computed as follows.

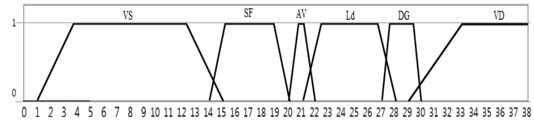
$$F_{(id)} = ((F_R + F_{Air} + F_{Ar} + F_\theta) \times V_{res})/1000$$

This intermediate driving resistance $F_{(id)}$ is added to the weight value and the result becomes the final driving resistance value. The weight value is decided according to the location of current vehicles. If the current vehicle is in the highway, the weight value becomes $\alpha = ((F_{Air} + F_{Ar}) \times 3)/1000$ on the basis of speed, If the current vehicle is in the national road, becomes $\alpha = ((F_R + F_\theta) \times 3)/1000$ on the basis of road environment. Figure 4 shows the process that the final driving resistance value is computed in the highway and national road.



(Figure 4) The computation of the final driving resistance value in the highway and national road

Sixth, if the final resistance is computed, the final driving resistance value is applied to the DR_risk Fuzzy Rule. The Fuzzy Graph to which DR_risk is applied is shown in Figure 5.



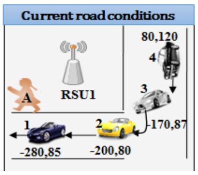
(Figure 5) The Fuzzy Set Graph of DR_risk

3.2.3 The DS_risk reasoning

The DS_risk reasoning of vehicles proposed in this paper reasons collision risk by using the collected location and speed data from vehicles around and pedestrians. Its operation is as follows.

First, a vehicle records their own location and speed information in real time and collects the location and speed information of vehicles and pedestrians around it through periodical Hello Packet.

Second, it generates the distance and speed data to apply to DS_risk Fuzzy rule by using both its own collected data and the data of vehicles and pedestrians around it.



ID	current position	moving direction	Speed
1	-280,85	-1,0	60
3	-170,87	1,0	65
4	80,120	0,-1	65
A	-290,93	0,-1	4

(Figure 6)The road situation including vehicles and pedestrians(Example)

Third, the distance data is computed by using the subtraction of the smaller value from the bigger one about the X axis or the Y axis each changing according to a moving direction of a vehicle, vehicles around. and pedestrians. For example, if the distance of the number1 vehicle from the number 2 vehicle in Figure6 is computed, only the X-axis changed according to a moving direction first is extracted. When the two vehicles compares two coordinate values of X-axis, the distance data becomes $80\{(-200)-(-280)=80\}$. because the coordinate value of the number 2 vehicle is the larger. The distance data computed in this way is applied to the DS_risk Fuzzy rule by using expression (1).

$$distancedata = 10 - \left(\frac{distance_{(x \text{ or } y)}}{10} \right) \qquad (1)$$

Fourth, a average speed value between vehicles or between a vehicle and a pedestrian becomes speed data.

Fifth, The generated distance and speed data is applied to a Fuzzy system.

Sixth, Each risk of the distance and the speed data applied to Fuzzy Rules are applied to DS_risk Fuzzy Rules again to compute DS_risk. Table2 shows the risk scope for the Fuzzy Rules of the DS_risk.

If the distance and speed data are applied to DS_risk Fuzzy Rules, total 20 Fuzzy Reasoning Rules are generated and a Fuzzy rule table is generated with average value of the minimal and maximal risk generated in each reasoning rule.

(Table 2) the risk scope for the Fuzzy rules of the DS_risk

Distance	Speed	Risk Scope
Low	Safety	0 ~ 4
Low	Very Danger	8 ~ 12
Medium	Safety	2 ~ 8
Medium	Danger	8 ~ 15
Little High	Safety	5 ~ 11
Little High	Little Danger	9 ~ 16
High	Safety	8 ~ 12
High	Very Danger	16 ~20

3.2.4 The total_risk reasoning

The Total_risk proposed in this paper is computed with WC_risk, DR_risk and DS_risk. First, to adjust the scope of three risks, 17 are added to the risk scope computed in the WC_risk and 15 is added the risk scope computed in the DS_risk. With this, the final risk scope is adjusted to 0~35 and applied to Total Fuzzy Rules.

(Table 3) The risk scope about Fuzzy Rules of the Total_risk

DS_risk	WC_risk	DR_risk	Risk Scope
VS	VS	AV	45 ~ 60
SF	DG	LD	64 ~ 72
AV	LD	DG	68 ~ 80
LD	VD	DG	75 ~ 85
VD	DG	VD	82 ~ 104

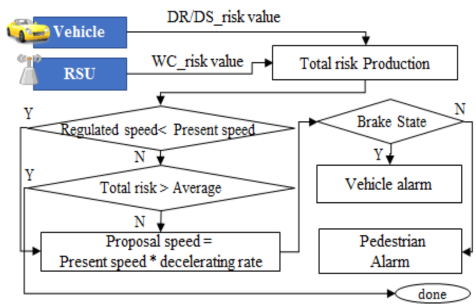
The scope of final risk is computed with the 216 Fuzzy rules generated by the total fuzzy rules and the final risk is computed by applying the average value to the Total Fuzzy Set Graph. Table 3 shows the sample of Total Fuzzy Rules and the risk is classified into VS(Very safety), SF(Safety), AV(Average), LD(Little Danger), DG(Danger), and VD(Very Danger).

3.3 Speed Reduction Phase

The speed reduction phase proposed in this paper is shown in Figure 7. The Speed Reduction is decided based on the Total_risk generated in RRP. The process deciding the speed reduction is as follows.

First, based on the regulation speed of the current location of a driving vehicle, the speed reduction phase is activated in case a current speed is higher than regulation speed. But even if a current speed does not exceeds regulation speed, the speed reduction phase is activated if Total_risk is higher than Average.

Second, Speed reduction is decided in proportion to Total_risk based on a current speed, and the speed reduction ratio is shown in Table 4.



(Figure 7) The total flowchart of a Speed Reduction Phase

(Table 4) Speed reduction ratio based on Total_risk

Total_risk	Decelerating rate
Very Safety	0%
Safety	5%
Average	10%
Little Danger	15%
Danger	20%
Very Danger	30%

Third, The speed reduction to inform a driver of is gotten by multiplying a current speed by a speed reduction ratio as follows.

Speed Reduction= $Current\,speed \times decelerating\,rate$

If the speed reduction ratio is decided, a risk notification phase is processed according to the driver's response that received the speed reduction ratio.

3.4 Risk Notification Phase

The Risk Notification Phase in this paper works in case vehicles exceeds regulation speed, that is, speed reduction is above 15% in speed reduction phase or in case the final risk exceeds Average. The process of the Risk Notification phase is as follows.

First, if the speed reduction ratio suggested to drivers is above 15% and they reduces speed with a brake, the Risk Notification phase transfers a notification message to rear vehicles to prevent collision caused by abrupt stop. At this time, its data consists of a Speed Reduction Warning Message and a Speed Reduction Ratio.

Second, if the speed reduction ratio suggested to drivers is above 15% and they do not reduce speed within a given time, pedestrians is easily exposed to the threat of safety, contrary to vehicles. If speed is not reduced, the Risk Notification Phase transfers a collision message to pedestrians around according to a moving direction. At this time, the transferred data consists of a current pedestrians' location information, the possible collision area, and a Warning Message.

4. The Performance Analysis

The proposed risk reasoning driving strategy based on fuzzy on VANET prevents vehicle collision between vehicles and between a vehicle and a pedestrian beforehand, achieves fuel and cost savings, and reduces the time loss.

This paper uses the current situation of a road in Figure 6 to analyze the performance of the Risk Reasoning Phase based on Fuzzy, But, in using a real Coordinate value, the change of digits is needed because the difference of the near distance between vehicles and between a vehicle and a pedestrian is nearly 0.0001°. All experiments is done on the basis of the number 2 vehicle in Figure 6. Because all vehicles are driving on the same road, the WC_risk that judges risk about weather and road condition is fixed as the VS(Very Safety) value that inserted Sun, Semi-Congest, False data in Fuzzy.

4.1. DR_risk Analysis

Because pedestrians have nothing to do with driving resistance, DR_risk is set as the LD(Little danger) considering autonomy. The DR_risk of a vehicle in this paper computes a risk by using an DR_risk algorithm.

(Table 5) The experimental environment and result data about the DR_risk

	1_Vehicle	2_Vehicle	3_Vehicle
W	1,380kg	1,600kg	2,300kg
Θ	4%	5%	6%
g	$9.8_{m/s^2}$	$9.8_{m/s^2}$	$9.8_{m/s^2}$
V_{res}	$60_{km/h} = 16.7_{m/s}$	$65_{km/h} = 18.05_{m/s}$	$60_{km/h} = 16.7_{m/s}$
A	1.89	2.50	3.50
p	$1,202_{kg/m^3}$	$1,202_{kg/m^3}$	$1,202_{kg/m^3}$
Target speed	$10_{km/h}$	$10_{km/h}$	$20_{km/h}$
Travel time	3s	4s	5s
Acceleration	0.93	0.69	1.11
Road	Dry_asphalt =μ_R: 0.015	Dry_asphalt =μ_R: 0.015	Dry_asphalt =μ_R: 0.015
Sharpe	Half_sphere =μ_{Air}: 0.42	Half_sphere =μ_{Air}: 0.42	Half_sphere =μ_{Air}: 0.42
F_R	202.86	235.2	338.1
F_{Air}	133.05	205.59	287.84
F_{Ar}	201.61	173.48	401.19
F_θ	270.48	392.0	676.2
InterimF_d	20.2	25.16	42.58
Express way_F_d	21.2	26.3	44.65
National highway_F_d	21.62	27.04	45.62

Considering an experimental environment, the number 1 vehicle is gradually accelerated by driving at an average speed with low weight and low slope. Compared to the number 1 vehicle, the slope of the number 2 vehicle was increased, its weight and speed were gained and its acceleration was lost. The number 3 vehicle gained weight and acceleration, slope was increased, and its speed is the same as the number 1 vehicle. As the result, the values of vehicles is shown as follows in case of rolling resistance, air resistance, and slope resistance.

number 1 <number2 <number3

Acceleration resistance is shown as follows.

number2<number1<number3

In case of the DR_risk in the highway of, a weight value is given by air and acceleration resistance and In case of the DR_risk in the national road, a weight value is given by rolling and slope resistance. As the result, in the highway the number 1 vehicle has 21.2 resistance value and in the national road it has 21.62 resistance value, the number 2 vehicle has 26.3, 27.04 each and the number 3 vehicle has 44.65 and 45.62 each.

In this paper, because vehicles can reduce speed well according as driving resistance gets higher, the DR_risk gets higher according as resistance gets lower. When this paper applies the computed driving resistance value before to DR_risk Fuzzy Rule, the following result is computed.

First, in case the number 1 vehicle is driving in the highway, the result is 16.8 and in the national road 16.38. Therefore, because the DR_risk of the vehicle belongs to the SF(Safety) interval, speed can be reduced rapidly if a risk is detected.

Second, in case the number 2 vehicle is driving in the highway, the result is 11.7 and in the national road 10.96. The number 3 vehicle belongs to 0.0 in both the highway and the national road. Because DR_risk of the number 2, 3 vehicle belongs to the VS(Very Safety) interval, speed can be reduced rapidly.

(Table 6) The analysis result of DS_risk about each vehicle and pedestrian

ID \ Result	Distance Data	Speed Data	DS_risk
1	0.1 Low 0.2 Medium	0.7:LD 0.3:DG	SF/AV:8.14
3	0.5 L_High	0.7:LD 0.5:DG	LD:13.5
4	0.0 Low	0.7:LD 0.5:DG	SF/AV:7.5
A	0.0 Low	0.3 AV	SF:4.0

The DS_risk is computed by using the direction, distance, and speed in Figure 6. Table 6 shows the result of the DS_risk. Considering the distance data as a result applied to the Fuzzy rule of the DS_risk, the distance data of the number 4 vehicle and pedestrian A on the basis of the number 2 vehicle has a low risk as 0.0 Low interval. Applying 2.5 distance data to the number 1 vehicle, it has 0.1 Low interval and 0.2 Medium interval. The number 3 vehicle has the most dangerous location because it belongs to 0.5 Little High interval by applying 7 distance data to the number 3 vehicle.

Considering the speed data applied to the DS_risk Fuzzy Rule, Pedestrian A has 0.3, Average interval on the basis of the number 2 vehicle. The number 1 vehicle has 0.7, Little Danger and 0.3 Danger interval. The number 3 and 4 vehicle belongs to 0.7 Little Danger and 0.5 Danger Interval. Applying the above result to the DS_risk Fuzzy Rule, the number 1 and 4 belongs to Safety and Average interval. Therefore, very safe distance and speed is not maintained. But in case of pedestrian A, he has a comparatively safe distance and speed as Safety. The distance data between the number 2 and the number 3 vehicle belongs to Little High and the Speed data between them belongs to Little Danger and Danger. Therefore, because the Final DS_risk of the number 3 vehicle belongs to Little Danger, collision risk is comparatively high.

(Table 7) The analysis result of Total_risk about each vehicle and pedestrian

ID	DS_risk	WC_risk	DR_risk	Total_risk
1	SF/AV	VS	SF	SF:52~56
3	LD		VS	SF/AV:59
4	SF/AV		VS	VS/SF:49~52
A	SF		LD	SF/AV:60

Table 7 shows the result of Total_risk using the DS_risk, WD_risk, and DR_risk computed in this way. Therefore, The vehicle which has the lowest collision risk on the basis of the number 2 vehicle is the number 4 vehicle. The analysis result of the number 4 vehicle is as follows. First, it has comparatively safe distance and speed. Second, it can reduce speed rapidly because of high driving resistance. Third, it has the interval of VS(Very Safety), and SF(Safety) because the scope of Total_risk is 49~52. On the other hand, The vehicle which has the highest collision risk on the basis of the number 2 vehicle is the number 3 vehicle. Because it has LD(Little Danger) about distance and speed data, its collision risk is comparatively high and the scope of Total_risk is 59.00~59.99. But, because the DR_risk value of the number 3 vehicle is high, Total_risk is a little lower, compared to the other vehicles with the same speed and distance. Therefore, the Total_risk proposed in this paper improves risk judgement considering speed, distance, and driving resistance.

5. Conclusion

This paper proposes An Fuzzy-based Risk Reasoning Driving Strategy on VANET to prevent vehicle collision beforehand. The characteristics of this paper are as follows.

First, the RRP(Risk Reasoning Phase) using a vehicle distance and speed can be utilized in not only the highway but also the unpaved road under a wireless environment.

Second, by preventing collision accident beforehand, the death rate, the cost and the various resources loss caused by traffic accident can be reduced

Third, according to a driver's response information about a speed reduction ratio, the risk that can happen to pedestrians and vehicles by transferring a risk notification message can be reasoned beforehand.

Therefore, this paper not only prevents collision accident beforehand by reasoning the risk happening to pedestrians and vehicles but also decreases the loss of various resources by reducing traffic jam caused by accident.

Reference

[1] S.I. Kim, H.K. Kahng, and S.W. Cheung, "Robust Route Establishment and Management for Vehicular Ad hoc Networks," Journal of KIISE, vol.40, no.1, pp.44-51, 2013.
http://www.dbpia.co.kr/Article/NODE02095048

[2] Y.H. Lee. S.T. Kim, and G.B. Kim, "Design and Evaluation of an Early Intelligent Alert Broadcasting Algorithm for VANETs," Journal of Korean Society for Internet Information, vol.13, no.4, pp95-102, 2012.
http://dx.doi.org/10.7472/jksii.2012.13.4.95

[3] Wenjia Li and Anupam Joshi, Security Issues in Mobile Ad Hoc Networks - A Survey,
http://www.csee.umbc.edu/~wenjia1/699_report.pdf

[4] M.S. Corson, J.P. Maker, J.H. Cernicione, "Internet-based Mobile Ad Hoc Networking," IEEE Internet Computing, July-August 1999, pp.63-70.
http://dx.doi.org/10.1109/4236.780962

[5] wikipeida dictionary,
http://en.wikipedia.org/wiki/Intelligent_transportation_system

[6] ETSI.org,
http://www.etsi.org/technologies-clusters/technologies/intelligent-transport

[7] Stephen Ezell, Intelligent Transportation Systems, ITIF, January 2010,
http://www.itif.org/files/2010-1-27-ITS_Leadership.pdf

[8] L. A. Zadeh, "Fuzzy Sets," INFORMATION AND CONTROL 8, pp.338-353, 1965.
http://www.cs.berkeley.edu/~zadeh/papers/Fuzzy%20Sets-Information%20and%20Control-1965.pdf

[9] Se Ryoung Kim and Huy Kang Kim, "Fuzzy Expert System for Detecting Anti-Forensic Activities," Journal of Korean Society for Internet Information, vol.12, no.5, pp.47-61, 2011.
http://www.jksii.or.kr/upload/1/872_1.pdf

[10] A Short Fuzzy Logic Tutorial,
http://cs.bilkent.edu.tr/~zeynep/files/short_fuzzy_logic_tutorial.pdf

[11] Mendel J, "Fuzzy logic systems for engineering: a tutorial," In proceedings of the IEEE, vol.83, no.3, pp.45-377, 1995.
http://dx.doi.org/10.1109/5.364485

[12] Thuc Kieu-Xuan and Insoo Koo, "A Cooperative Spectrum Sensing Scheme Using Fuzzy Logic for Cognitive Radio Networks", KSII TRANSACTIONS ON INTERNET AND INFORMATION SYSTEMS vol.4, no.3, pp.289-303, 2010.
http://dx.doi.org/10.3837/tiis.2010.06.006

[13] Fuzzy control programming, Technical report, International Electrotechnical Commission, 1997.
http://www.fuzzytech.com/binaries/ieccd1.pdf

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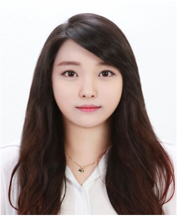

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