Implementation of Smart Traffic Safety Systems using Fuzzy Theory

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Abstract

Traffic accidents due to excessive speed frequently occur in places where traffic signal controllers are installed, places where sharp curves exist, or places where the traffic signal cycle does not match the current time. These traffic accidents cause economic loss due to the destruction of road facilities and structures, and cause a big problem of increasing the number of traffic accident deaths. When a traffic accident occurs, leaving a tire mark before or after a car crash, pre-collision speed of the car is calculated using the law of conservation of momentum or the skid mark formula. In the skip skid mark generated in ABS brake vehicles and the comb-shaped yaw mark generated by tire trace caused by lateral sliding, there is a difference of 30-40% in the reliability of the vehicle speed calculated by the smite mark. In this paper, we propose an algorithm that can improve the calculation reliability in vehicle speed by using skid marks in order to compensate for this problem. In addition, we present an intelligent speed calculation algorithm for traffic safety and a computer simulation in order to prevent traffic accidents by estimating the speed of a vehicle, using Skid marks, Yaw marks, and ABS brake characteristics and fuzzy rules.

Key Words: ABS Brake, Yaw Mark, Traffic Accident Prevention, Skid Mark, Fuzzy Logic

1. Introduction

Traffic accidents are generally triggered when the relationship between cars, people, and roads is not good; the causes of the accident include insufficient installation of traffic safety facilities, errors in road design and unstable psychological status of drivers. According to the traffic accident trend data by the Korea Road Traffic Authority in 2019, the number of domestic traffic accidents was 229,600, the number of deaths 3,349, and the number of injuries 341,712. The number of accidents occurred in the uphill road line was 2,709 and the number of deaths was 86. In the downhill road line, the number of accidents was 2,787 and the number of deaths was 141. The number of accidents occurred on the flatland was 8.914, the number of deaths was 279, and the number of injured people was 13,471. The causes of these problems may be a rapidly increasing number of cars, driver carelessness, a lack of traffic safety facilities, and poor plans for traffic safety. Traffic order and

culture have not yet been fully settled according to economic income, and the expansion of traffic safety facilities, which is urgent to prevent accidents, is insufficient. Traffic safety speed signs installed on the road shows only the usual speed limit without considering this situation. But only a text, "Beware of fog. Drive at reduced Speed" is posted on the traffic information board. In this paper we present an algorithm for calculating the intelligent traffic safety speed in order to solve these problems and prevent traffic accidents. The proposed signs are expected to be able to ensure the driver's safety and provide other useful information, by allowing the driver to recognize the speed of safety that changes with weather conditions in real time. The traffic accident prediction model can be used in order to predict traffic accidents in the future and in order to make important judgments for establishing traffic safety policies.

In this paper, we explain the theory of skid marks in Section 2, describe an algorithm for the speed calculation and simulation results based on Skid marks in Section 3, and present conclusion in Section 4. The traffic accident prediction model can be used not only to predict traffic accidents in the future, but also to obtain important data to judge for establishing traffic safety policies. In particular, it is possible to prevent large-scale traffic accidents that may occur on roads where ice sheets remain in winter season.

2. Theory of Skid Mark

When a driver of a car tries to stop the vehicle while driving, in the full braking that presses lightly the brake pedal with the slip rate of 20-30%, tire traces are not shown on the road surface. However, when you press the brake pedal suddenly and strongly a phenomenon in which tires, installed around the brake disc or drum, generate traces of tires on the road surface due to frictional heat generated between the road surfaces. This called a skid mark. Skid marks are a normal phenomenon on the roads that occur in the longitudinal direction of the vehicle. Skid marks are shown differently in appearance on the road surface depending on road gradient, tire wear, pressure distribution between brake shoes and drum, and weather conditions. In the flat state of the road surface, the skid mark shape occurs as much as the width of the tire tread, but the skid mark shape is different depending on the high and low pressures of tire. In the term skid mark, skid means slipping. The skid mark refers to various tire marks, such as yaw marks, that appears when a vehicle suddenly stops due to a sudden brake before direct collisions or after transverse turns. In other words, a skid mark is a phenomenon in which a mark is left on the road when the tire does not proceed in the longitudinal direction of the road but slides in the transverse direction. If there are no black box images, skid marks can be of great help to determine the cause of the traffic accident. In case the crash of vehicle occurred, skid mark is a means of analyzing the pre-collision trajectory by estimating the speed before the car crash and speed after the car crash.

Analysis of the skid mark can provide various data such as the speed and direction of the car before the collision, the speed and direction of the car after the collision, and the time of the brake pedal pressed. By analyzing the skid mark using the law of conservation of momentum and Newton's law, the vehicle speed before and after an accident can be calculated. If you analyze the skid mark, obtained from vehicle accident, according to the law of conservation of energy and the theory of velocity acceleration, the vehicle speed before the accident and the vehicle speed after the accident can be calculated. However, the starting point of the skid mark is formed by leaving a shadow mark that is difficult to identify with the naked eyes. Therefore, if you calculate only the tire traces identified by the naked eyes, the value of calculated speed is less than the actual speed. Therefore, about 20% of the traces of shadow mark shown should be added to the values of the calculated speed. At the lowest speed of a real car, the reliability is about 70%.

$$V = \sqrt{254 * (\mu \pm G) * d} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Data Source: http://blog.daum.net/speedace/23

where
V : velocity (km/h)
d : skid mark (m)
μ : Coefficient of friction between tire and road surface (dry 0.8. humid 0.4-0.6)
G : Road gradient , downhill (-), uphill (+)] (%)
When you suddenly hit the brakes of vehicle running on a flat road, the center of gravity of the vehicle moves from behind to the front, then the front of the vehicle body is bent forward. This phenomenon is called nose down. At the point where the front and rear wheels are touched to the road surface, friction forces of road are applied to the rear of the vehicle, and the center of mass is to move in the forward direction of the vehicle by inertia. Among the tire tracks appearing at the crash site on the road, the typical one is a skid-mark.

Skid means "to slide along" a surface It is the sliding friction that appears between the running tire and the road surface. If the driver suddenly applies the brake while driving, the wheel stops spinning suddenly to slide touched with the road surface. If the tread of a tire made of natural rubber slides on the road surface, skid-mark appears when the chemical component of rubber decomposed by friction heat is pressed onto the road surface. The situation changes depending on the speed and the braking time of vehicle.

A. Relationship between speed and actual braking time

B. Actual braking time on the Surface of dry asphalt and on the surface of wet asphalt

Since the coefficient of surface friction of the wet road is less than that of the dry road, the actual braking time of the car on the wet road is slightly longer. Since there is no significant difference between the surface friction coefficient of a worn road and the surface friction coefficient of a new road, there is little difference in actual braking time.

C. Instantaneous braking time on the surface of paved roads and unpaved roads

The instantaneous braking time on the paved road (surface of new asphalt road) and the instantaneous braking time on unpaved road (gravel road and dirt road) were compared. The reason for the short instantaneous braking time on the surface of the asphalt road compared to the surface of the unpaved road is that the friction coefficient of the paved road surface is small.
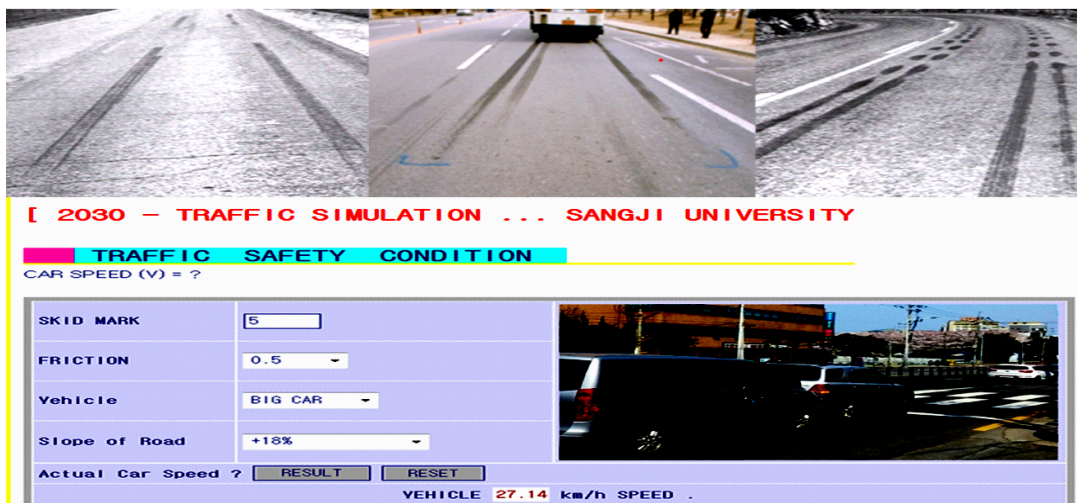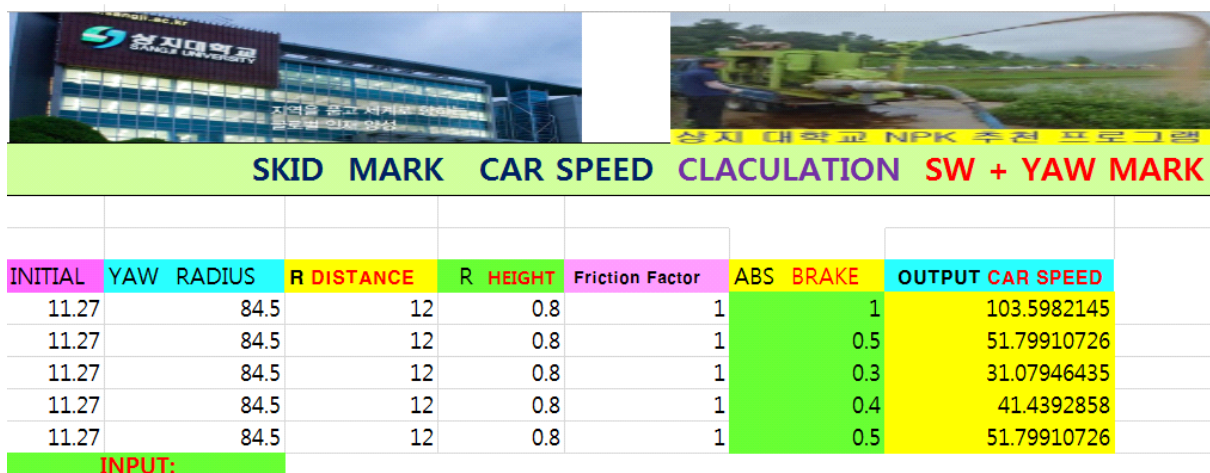

Figure 1. The simulation for skid mark

Figure 1 shows the simulation process for skid marks to prevent traffic accidents caused by sudden changes in weather.

Table 1. Safety speed based on road condition

Distance(m)	Speed (km/h)	Distance(m)	Speed (km/h)	Distance(m)	Speed (km/h)	Distance(m)	Speed (km/h)
1	14.25	12	49.38	23	68.36	34	83.11
2	20.15	13	51.39	24	69.83	35	84.33
3	24.69	14	53.33	25	71.27	36	85.52
4	28.50	15	55.20	26	72.68	37	86.70
5	31.87	16	57.01	27	74.07	38	87.87
6	34.91	17	58.77	28	75.42	39	89.02
7	37.71	18	60.47	29	76.76	40	90.15
8	40.31	19	62.13	30	78.07	41	91.27
9	42.76	20	63.74	31	79.36	42	92.38
10	45.07	21	65.32	32	80.63	43	93.47
11	47.27	22	66.86	33	81.88	44	94.55

Data Source: Transportation Safety Education Center (Korea Transportation Safety Authority)

Figure 2. Simulation for yaw mark, Data source : Gyeongnam Daily (http://www.gnnews.co.kr)

Figure 2 shows the simulation for the skid mark considering the characteristics of the Yaw mark and Anti brake system. The skip skid mark refers to the braking traces generated on the road surface by a vehicle equipped with an Anti-lock Brake system (ABS). The skid mark is a trace of vehicle tire braking generated on the surface of a road, it has been used domestically and internationally for a long time as a standard for estimating vehicle speed. As with the normal skid mark, the vehicle speed is calculated using the speed estimation formula by using the total length from the start of the mark to the end of the mark as the length of the braking trail. However, in the case of gap skid marks, the some of braking traces are missing. Therefore, the remaining part (excluding the deleted length from the total braking length) is used in the speed estimation formula. Compared to vehicles without ABS, vehicles equipped with ABS have excellent braking performance. Therefore, the length of skid mark of vehicles equipped with ABS is less than half the length of skid mark of vehicles without ABS

Even if a skid mark has occurred, the skid mark may fade over time and may look different depending on the position of the sun, so if we check the skid mark right after sunset, we can see for sure whether the tire traces occur. In this paper we present a simulation for Yaw mark considering the braking characteristics of the anti brake system. In the road environment where traffic accidents occurred

$$V= \sqrt{127 * (\mu' \pm G) * R} \quad \text{...} \quad (2)$$

Data Source: http://blog.daum.net/speedace/23

  Where,
V : velocity (km/h)
: friction coefficient between tire and road surface (dry 0.8. wet 0.4-0.6)
G : Gradient of road [downhill(-), uphill(+)] (%)
R : radius of curvature(m)
C : arc length (m)
M : longitudinal distance in middle (m)

The above equation explains the calculation process; in the yaw mark if R is 84.5 m, C is 24 m, M is 0.98 m, and the coefficient of friction on the road is 0.8, the minimum speed of the vehicle without the anti brake system is 103 km/h, but the minimum speed of the vehicle with the anti brake system is 61km/h.

   Rule : IF A is t1 THEN C is B2 : (Fu : 0.95)
   fact : A is t1' : (Fr :0.80)
   conclusion : C is (FC :0.6)   : (FC : => MIN (0.95,0.80) * 0.6 => 0.8 *0.6=) => 0.48
   A : friction coefficient
   C : inference results
   Fu : fuzzy number representing the uncertainty of rule
   Fr : fuzzy number representing the uncertainty of fact
   FC : fuzzy number representing the uncertainty of conclusion
   V1, V2, V1', V2' : values

   IF C_SPEED = Med And
   SLOE = High And
   SNOW_RAIN = High And
   Then
   SENSORY INDEX = AREA CNF 70

When AND is used as shown above, we calculate the certainty factor of the final conclusion, by multiplying the certainty factors rule and the lowest (Min) certainty factor from the antecedent of the fuzzy rules. For example, if 50, 75, and 60, under the above four conditions, are determined as the certainty factors of SPEED, SLOPE, and RAIN, respectively, the SAFETY INDEX = $0.50 \times 0.70 = 0.35$, will have the certainty factor of the conclusion for the safety speed index of vehicle,

If the existing method is used instead of the fuzzy rules, the speed limit value, the slope of the road, and the snow conditions are not considered, so the safety speed index values calculate the speed indicated on the road traffic signs. Therefore, it is not possible to calculate an accurate safe speed considering weather conditions

and slope conditions. The problem with the safety speed calculation algorithm that existed in the past was that it did not take into account weather conditions and road conditions; so it always maintained the safety speed of the car at 60 km for 365 days, regardless of the situations such as rain, sunrise, snow, or road freezing. Therefore, we propose the optimal traffic safety speed algorithm and computer simulation results inn order to minimize the traffic accidents caused by car drivers by considering that the weather conditions and road conditions provided by GPS and GIS of the Meteorological Agency database are used in real time.
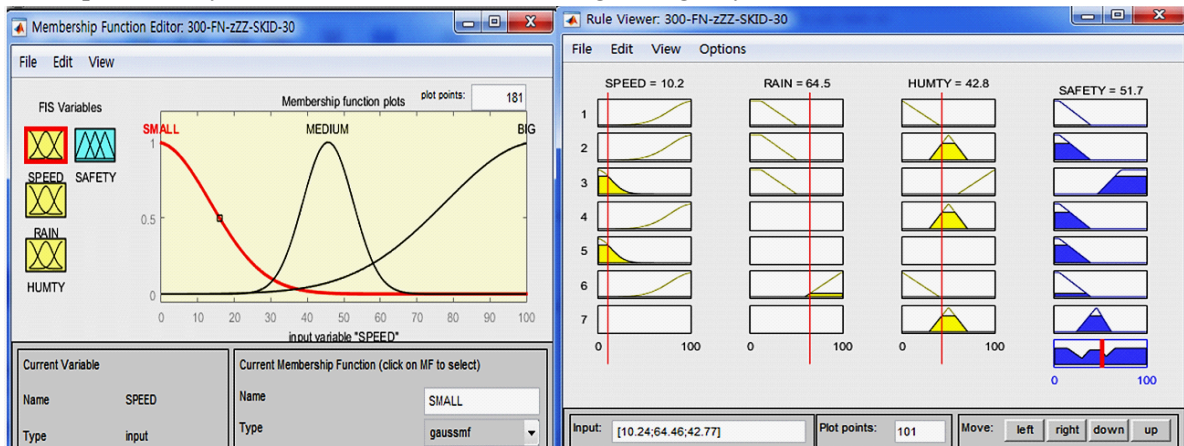

Figure 3. Fuzzy membership function

Figure 3 describes the membership function of measuring fine dust using fuzzy rules. Here, the three input conditions are temperature, humidity, and wind while the output conditions are traffic speed and safety index. These days, research on driverless vehicles is nearing the commercialization stage. If the driverless car recognizes the road traffic speed sign car speed of 60 km / hour, and does not take into account weather conditions or the shape of an intersection, and unconditionally maintains the car speed at the car speed of 60 km / hour on the road, the traffic accident rate is It will increase a lot. This is because the conditions on the road and vehicle speed signs do not take into account weather conditions or intersection types, so they display 60 km / hour unconditionally 365 days a year. Therefore, in this paper, to solve this problem, we solved this problem by using MATLAB FUZZY INFERENCE SYSTEM TOOL.
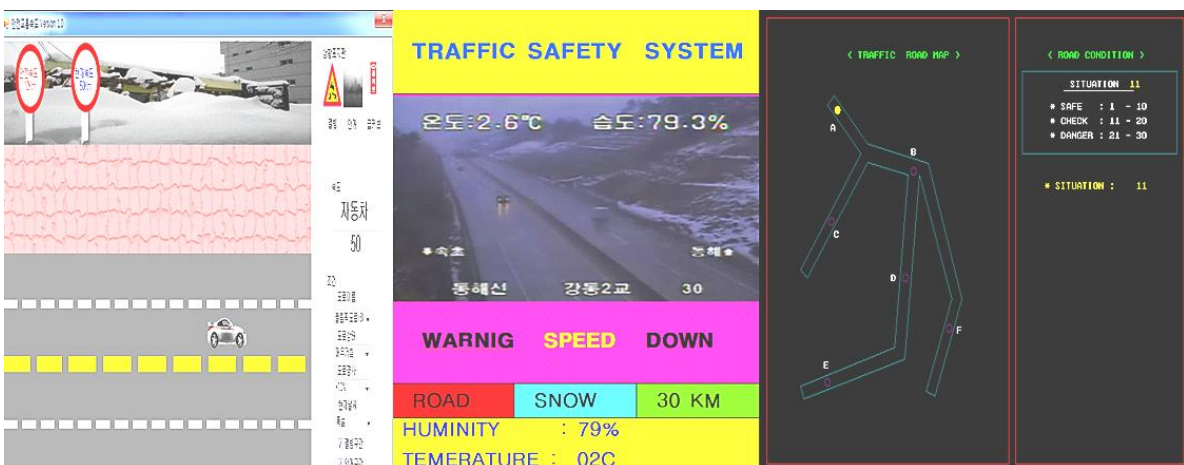

Figure 4. Simulation result of traffic speed 1

Figure 4 illustrations the results of simulation for the traffic safety speed with the road conditions taken into account. Especially, Figure 4 explains the simulation results of an automatic warning broadcast that can slow down 200 meters before the danger zone of a traffic accident when there is a sudden fog or heavy snowfall on the road, an ice section occurs.
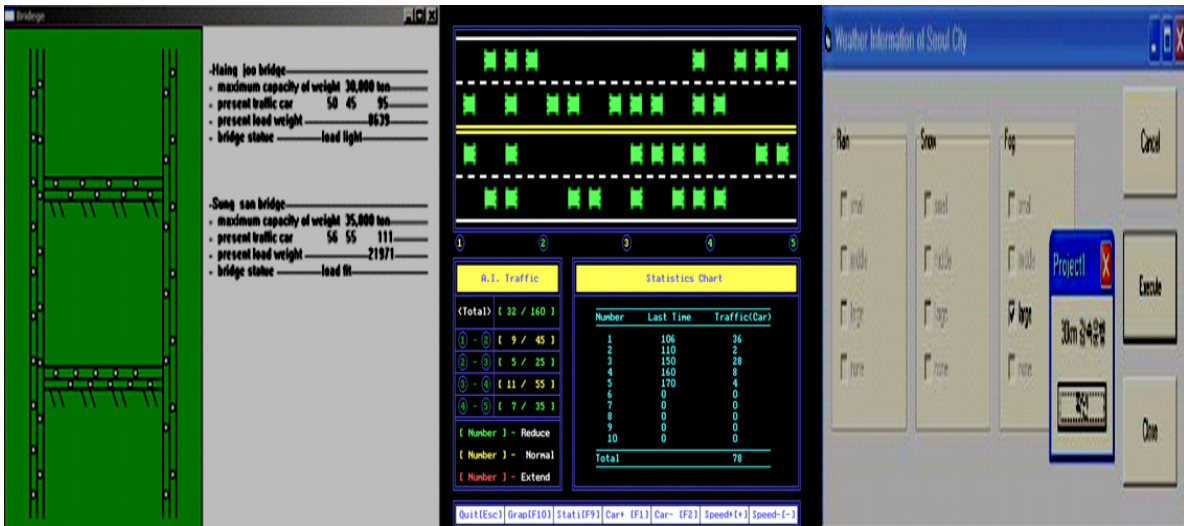

Figure 5. Simulation result of traffic safety speed 2

Figure 5 illustrations the results of simulation for the traffic safety speed with the weather conditions taken into account. Moreover, In Figure 5, in order to prevent traffic accidents, the simulation results in which the safe traffic speed should be reduced by 50% in consideration of weather and road conditions are explained.

Table 2. Optimal vehicle safety speed based on weather conditions

Intersection areas	Intersection situation	Weather conditions	Speed Comparison on Traffic Signs km / hour	
Road shapes	Intersection shape	Weather situation	Intelligent traffic signs	conventional traffic signs
Six-lane	Flat	Normal	100	100
Six-lane	Uphill	Normal	92	100
Four-lane	Downhill	Weak rain	58	80
Eight-lane	Uphill	Heavy rain	85	100
Four-lane	Downhill	Heavy rain	45	80
Six-lane	Flat	Fog	39	80
Two-lane	Flat	Weak rain	45	60
Two-lane	Uphill	Heavy rain	33	60

Table 2 shows the process of calculating the optimal safety speed with conditions and intersection conditions. taken into account. In this paper, we present the calculation of optimal safe speed by assuming that the safe speed on a four-lane road is 80 km/hour, and by considering the intersection type (uphill, downhill), number of lanes (2 lanes, 4 lanes, 6 lanes, 8 lanes) and weather conditions.

As a result of computer simulation, we automatically detect road conditions using a humidity sensor and a temperature sensor, and show that the safety speed decreases by more than 20% in case of rain or snow. In addition, even with the same rain falls, we show the process of recognizing that 56 km/hour is a safe speed, decelerated by 30% when the rain falls weakly.

The previous safety speed signs indicated a speed of 80 km/hour, in the conditions of rain or snow. In this paper, however, we present the results of simulations to calculate optimal safety speed by recognizing weather conditions using humidity sensor and temperature sensor by automatically detecting the road conditions.

4. Conclusion

The causes of increased occurrence of automobile accidents include negligence of safety, insufficient facilities for traffic safety, and enhancement of vehicle performance. If an accident actually occurs, the scale often gets bigger. In order to identify the cause of the traffic accident, it is necessary to know the direction of progress before the collision, the speed of car just before the collision. It is also necessary to know whether or not the brake pedal has been pressed at the danger of the opponent vehicle′s approaching. When an accident occurs, it is difficult to determine the cause of the accident without witnesses. We calculated the optimal speed of vehicle using a fuzzy rule that accepts the length of the skid mark as an input value. We were able to make more accurate predictions by about 20 to 30 percent as a result of performing a computer simulation program, compared to the previous method of speed calculation.

In this paper, we propose an algorithm that can improve the calculation reliability in vehicle speed by using skid marks in order to compensate for this problem. In addition, we present an intelligent speed calculation algorithm for traffic safety and a computer simulation in order to prevent traffic accidents by estimating the speed of a vehicle, using Skid marks, Yaw marks, and ABS brake characteristics and fuzzy rules. The problem with calculation algorithm for the safety speed that existed before was that there was a risk of frequent traffic accidents since it was difficult for the driver to drive a car according to the characteristics of the road because the vehicle safety speed was always maintained at 60km regardless of the weather conditions such as rain or sunrise. In order to solve this problem, we simulated an algorithm in order to calculate the optimal safe speed in real time so that the vehicle can move safely by maintaining the speed limit.

```
this.RoadName.FormattingEnabled = true;
this.RoadName.Items.AddRange(new object[] {
this.RoadName.Location = new System.Drawing.Point(26, 37);
this.RoadName.Name = "RoadName";
this.RoadName.Size = new System.Drawing.Size(97, 20);
this.RoadName.TabIndex = 1;
this.RoadName.SelectedIndexChanged += new System.EventHandler(this.RoadName_SelectedIndexChanged);
this.CarSpeedP.Location = new System.Drawing.Point(10, 53);
this.CarSpeedP.Multiline = true;
this.CarSpeedP.Name = "CarSpeedP";
```

```
this.CarSpeedP.Size = new System.Drawing.Size(123, 38);

this.CarSpeedP.TabIndex = 6;

this.CarSpeedP.TextAlign = System.Windows.Forms.HorizontalAlignment.Center;

Type='mamdani'

Version=2.0

NumInputs=3

NumOutputs=1

NumRules=7

AndMethod='min'

OrMethod='max'

ImpMethod='min'

AggMethod='max'

DefuzzMethod='centroid'

[Input1]

Name='WIND'

Range=[0 100]

NumMFs=3

MF1='SMALL':'gaussmf',[14.71 -1.319]f

MF2='MEDIUM':'gaussmf',[6.913 33.25]

MF3='BIG':'gaussmf',[25.32 94.47]

[Input2]

Name='RAIN'

Range=[0 100]

NumMFs=2

MF1='LOW':'trapmf',[-11.3 -10.9 22.1 60.7142857142857]

MF2='HIGH':'trapmf',[35.3174603174603 74.8 105 128]

[Input3]

Name='HUMTY'

Range=[0 100]

NumMFs=3

MF1='SMALL':'trimf',[-40 0 40]

MF2='MEDIUM':'trimf',[29 50 70.7671957671957]

MF3='BIG':'trimf',[60 100 140]

[Output1]

Name='SAFETY'

Range=[0 100]

NumMFs=3

MF1='SAFE':'trimf',[-21.3063492063492 0.553650793650791 43.5185185185185]

MF2='Average':'trimf',[29.2 51.1 71.031746031746]

MF3='DANGER':'trimf',[54.3650793650794 102 102]

switch (RoadName.SelectedIndex)

case 0:

RoadName2.Text = "seoul expressroad"; break;
```

```
case 1:

RoadName2.Text = "A ROAD"; break;

case 2:

RoadName2.Text = "B ROAD"; break;

case 3:

RoadName2.Text = "C ROAD"; break;

case 4:

RoadName2.Text = "D ROAD"; break;

float temp = (float)Convert.ToDouble(CarSpeedP.Text);

nowspeed = Convert.ToInt32(CarSpeedP.Text);

CarSpeed = temp;

temp = temp + ((CarSpeed / 100) * Datanum[2]);

temp = temp + ((CarSpeed / 100) * Rule_Base[RatioPostion, RoadStatePosition]);

//temp = temp + ((CarSpeed / 100) * Datanum[0]);

temp = Check_Road(temp);

safespeed = (int)temp;

timer1.Interval = Select_Speed((int)temp);

private int Select_Speed(int Speed)

int TimeSpeed = 0;

if (Speed > 10) { TimeSpeed = 1000; }

if (Speed > 15) { TimeSpeed = 950; }

if (Speed > 20) { TimeSpeed = 900; }

if (Speed > 25) { TimeSpeed = 850; }

if (Speed > 30) { TimeSpeed = 800; }

if (Speed > 35) { TimeSpeed = 750; }

if (Speed > 40) { TimeSpeed = 700; }

if (Speed > 45) { TimeSpeed = 650; }

if (Speed > 50) { TimeSpeed = 600; }

if (Speed > 55) { TimeSpeed = 550; }

if (Speed > 60) { TimeSpeed = 500; }

if (Speed > 65) { TimeSpeed = 450; }

if (Speed > 70) { TimeSpeed = 400; }

if (Speed > 75) { TimeSpeed = 350; }

if (Speed > 80) { TimeSpeed = 300; }

if (Speed > 85) { TimeSpeed = 250; }

if (Speed > 90) { TimeSpeed = 200; }

if (Speed > 100) { TimeSpeed = 150; }

if (Speed > 110) { TimeSpeed = 100; }

if (Speed > 130) { TimeSpeed = 50; }

if (Speed > 160) { TimeSpeed = 25; }

return TimeSpeed;
```

```
private float Check_Road(float Speed)

{

if (freezing.Checked == true) { Speed = Speed - (Speed / 10); SafeBoard.Image = (Image)Properties.Resources.slip; }

else { SafeBoard.Image = (Image)Properties.Resources.; }

if (fog.Checked == true) { Speed = Speed - (Speed / 10); SafeBoard2.Image = (Image)Properties.Resources.FOG; }

else { SafeBoard2.Image = (Image)Properties.Resources.; }

if (sharpcurve.Checked == true) { Speed = Speed - (Speed / 10); SafeBoard3.Image = (Image)Properties.Resources.sharp curv; }

else { SafeBoard3.Image = (Image)Properties.Resources.; }

if (LINE2.Checked == true) { Speed = Speed - (Speed / 5); line = 2; }

if (LINE4_6.Checked == true) { Speed = Speed - ((Speed / 6) * 2); line = 4; }

if (LINE4_8.Checked == true) { Speed = Speed - ((Speed / 5) * 1); line = 8; }

return Speed;

RoadState.Items.Add("slip");

break;

case 1:

RoadState.Items.Clear();

RoadState.Items.Add("VERY  HARD");

RoadState.Items.Add("HARD");

RoadState.Items.Add("NORMAL");

RoadState.Items.Add("SOFT");

break;

case 2:

RoadState.Items.Clear();

RoadState.Items.Add("VERY  HARD");

RoadState.Items.Add("HARD");

RoadState.Items.Add("NORMAL");

RoadState.Items.Add("SOFT");

break;

case 3:

RoadState.Items.Clear();

RoadState.Items.Add("VERY  HARD");

RoadState.Items.Add("HARD");

RoadState.Items.Add("NORMAL");

RoadState.Items.Add("SOFT");

break;

private void RoadState_SelectedIndexChanged(object sender, EventArgs e)

//Add values based on road conditions. It's a % value.

switch (RoadState.SelectedItem.ToString())

case "VERY HARD":

RoadStatePosition = 0;

break;

case "HARD":

RoadStatePosition = 1;
```

```
break;
case "NORMAL":
RoadStatePosition = 2;
break;
case "SOFT":
RoadStatePosition = 3;
break;
private void RoadRatio_SelectedIndexChanged(object sender, EventArgs e)
switch (RoadRatio.SelectedItem.ToString())
case "-10%":
RatioPostion = 4;
break;
case "-%05":
RatioPostion = 3;
break;
case "+00%":
RatioPostion = 2;
break;
case "+05%":
RatioPostion = 1;
break;
case "+10%":
RatioPostion = 0;
break;
```

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