Research on High-Risk Road Sections Identification and Driving Early Warning System in Mountainous Areas Based on Edge-Cloud Integration Technology

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Abstract—The operation of mountainous highways is of high risks and the emergency rescue after an accident is of great difficulty. Affected by the mountains, river densities and other topographic features, highways in mountainous areas are characterized by linear complexity, long span bridge and tunnel group, frequent transitions among subgrade-bridge-tunnel, steep slopes, complex setup of interchange, changeable climate and easy occurrence of secondary accident, etc. In the 5G Internet era, the artificial intelligence theories and methods continue to deepen. To fully integrate emerging information technologies such as computer vision and Edge-cloud Integration to establish a high-risk road sections identification and driving early warning system in mountainous areas will help drivers to drive, promote the intellectualization of mountainous highways, and improve the safety of traffic operation management. In this paper, the Edge-cloud Integration technology and the navigation map data, combined with vehicle vision, are used to establish an early traffic warning system. This system collects and shares data through vehicle-mounted terminal and navigation map, uses Matter-element Model to identify and measure risk in cloud, and feeds back the results to vehicle-mounted terminal. If the identification result shows that it is the high-risk sections, combined with the navigation map, there will be a voice warning to ensure driving safety.

1. Introduction
The mountainous area of our country accounts for about 2/3 of the country's land area, and it is widely distributed in the southwest, central, northwest, and southern China. The mountainous area highway characteristic is most obvious in the Southwest Yunnan, Guizhou Sichuan, Chongqing area. Due to the large altitude differences of terrain, and crisscroses of rivers and valleys, there are lots of sharp curves and steep slopes, long downgrades, cliffs adjacent to the water, poor sight distance, icing and fogging, roadside interference, complex emergencies and other high-risk road sections which are not conducive to driving safety in national and provincial trunk highways. So traffic accidents often occur owing to drivers' failure to obtain road information and the road conditions ahead in time. In order to alleviate...
the frequent occurrence of traffic accidents in mountainous areas, it is necessary to use the emerging information technology to analyze the driving risks, and combine with the navigation map, give a voice warning to prompt drivers, so as to ensure the driving safety and improve the safety level of road network operation.

There have been many studies on risk identification of high-risk sections of mountainous highways at home and abroad, which is also an important content of domestic and foreign experts and scholars. John Milton studied the impact of accidents from road alignment, traffic volume, speed and other indicators. Using the data of some trunk road networks in Washington state, John Milton analyzed the contribution value of each factor to the accident, and determined the important factors affecting the traffic accident[1]; Ibrahim conducted research on highway sections with small horizontal curve radius and limited sight distance. And the results showed that the occurrence of unfavorable combination of alignment will increase the incidence of traffic accidents, and the unfavorable combination of horizontal and vertical curves with small radius has the greatest impact[2]. Yetis Sazi Murat selected the road geometric alignment, accident attributes, traffic environment, accident type and other indicators, and used Shannon Entropy Method to determine the traffic risk level of the road section under the interaction of various indicators[3]. Yu et al. established Poisson distribution model and random effects models based on Bayesian theory by presupposing different driving states of mountainous expressway to study the traffic accident risk of it[4]. By analyzing the mechanism of traffic accidents, Liu Xingwang put forward the state-factor analysis method, and used the Analytic Hierarchy Process (AHP) to obtain the proportion of each factor, and then the possible state of the accident happening[5]. Li Tingting used Matter-element Model to evaluate the accident risk of mountainous highways, which overcame the deficiency of using experience to score indicators in Fuzzy Theory, and grasped the safety status and potential risk of mountainous highways comprehensively and accurately[6].

There are a lot of researches on mountainous highways driving early warning at home and abroad. Mobileye, an Israeli company, is committed to the research of driving safety technology centered on machine vision. It uses high dynamic range (HDR) CMOS image sensor to collect the information of the road ahead, and uses the image processor EyeQ to calculate with complex and reliable image processing algorithm to provide visual and voice early warning[7]. Iteris, an American company, has developed a Lane Departure Warning System for Mercedes Benz commercial vehicles, and Infiniti, a Japanese car company, has also designed a Safety Barrier System (which is a combination of a series of active safety technologies), etc[8]. Domestic well-known universities, Tsinghua University, Shanghai Jiaotong University, National University of Defense Technology, Xi'an Jiaotong University have all carried out relevant researches on smart cars and driving early warning.

The existing results have contributed to the risk identification and early warning technology of mountainous highways, but there is a lack of an integrated system for risk identification and early warning of the roads, and there is no combination of emerging information technologies. So the drivers cannot obtain road information ahead effectively, accurately, and timely and a complete and accurate early warning system for driving safety on high-risk sections in mountainous areas is not built. Then the problem of traffic accidents in mountainous areas cannot be improved effectively. In the context of telematics, and in view of uncertain risk indicators, new information technology can be utilized to establish a Matter-element Model and the drivers can be warned by the intelligent voice.

2. Edge-cloud Integration Technology

Edge-cloud Integration technology[9] is a new development direction of cloud computing. Its core idea is: the edge is close to the data source, the nearby end service is provided, and the cloud provides high-value data; and cloud provides persistence data storage for the edge end, and provides computing resources for complex computing applications. Its main advantages are: reducing network operation and service delivery delays, and protecting data security; reducing the burden on edge computing units, and meeting the needs of edge backup data; The two sides are complementary and synergistic.

In 2005, the cloud computing model was proposed and widely used. In the cloud computing model,
the source data is transmitted to the cloud center and calculation is performed in the cloud. However, due to some problems such as the data source may involve privacy issues before transmission; the transmission will be affected by network delays; the cloud computing pressure will increase when it reaches the cloud and the source data sender is unwilling to share the data, the utility of data is reduced to a certain extent. The edge is often the main source of data. So by increasing the ability of data calculation and storage near or at the edge can not only reduce the amount of cloud data processing, but also accelerate the speed of edge users to obtain the required information. Different edge ends of different data sources are similar to the point-to-point connection mode, which can provide the possibility of integrative sharing of different edge data sources [10].

The risk identification and early warning system for high-risk sections of mountainous highways based on Edge-cloud Integration technology uses the advantages of its computing to realize the data sharing among intelligent vehicle-mounted terminals, navigation maps and clouds. And then distinguish the road conditions ahead effectively, timely and accurately, determine the risk level, and alert the driver with intelligent voice. In this system, the intelligent vehicle-mounted terminal and navigation map belong to the edge end. The intelligent vehicle-mounted terminal provides real-time data such as fog concentration, crosswind, road integrity and emergency events by using vehicle recorder and machine vision, and provides the position information by using the navigation map. In this way, data on traffic structures, road alignments, and historical traffic accidents on the road ahead are obtained. combined with the data at the two edge ends, packaged and sent to the cloud, and the data is analyzed using the matter element extension model to determine the risk level. By Combining the data at the two edge ends, packaging it and sending it to the cloud, and using the Matter-element Model to conduct risk analysis on the data, and then the risk level can be determined. That is to say, the cloud computing feeds back information to the edge, and the edge takes corresponding measures based on the results, and give intelligent warns to the driver, then the goal of driving safety is achieved.

3. Identification and Risk Measurement of High-risk Road Sections in Mountainous Areas

3.1. Construction of Indicator System

Mountainous highway system is a comprehensive system composed of multiple factors, and its driving safety is affected by single, multiple and combined factors. Through analysis, the road sections with frequent traffic accidents, emergencies, road conditions, external environment and traffic structures are the main factors which affect drivers' driving safety.

The accident-prone areas are one aspect of evaluating the risk level. The road sections are in the accident-prone areas, posing a potential threat to safe driving. The severity of emergencies also directly affects the driving of vehicles, generally referring to various accidents in the field of road traffic, road construction and various bad weather affecting road traffic. Poor road alignment: the radius of horizontal and vertical curve is large; stopping sight distance is too short. Unfavorable linear combination: the combination of long straight line and steep slope or horizontal (vertical) curves with small radius; a horizontal curve contains multiple vertical curves; horizontal curve with small radius or multiple horizontal curves are added into the vertical curve; the connection of horizontal curve with small radius and the top (bottom) of convex (concave) vertical curve; the coincidence of the top (bottom) of the convex (concave) vertical curve and the inflection point of the reverse horizontal curve; the starting and ending points of the vertical curve are set on the straight line segment or circular curve segment of a horizontal curve ; The length of the straight line between the same (reverse) horizontal curves is less than 6 (2) times of the design speed; the connection of the tunnel and the bridge; the connection of a tunnel and a long downhill or steep downhill; the combination of a long downhill or steep downhill and curves; continuous curves; continuous long downhill. The external environment that is unfavorable for driving mainly includes fog, crosswind, rain and snow weather, etc, which has great influence on the visibility of drivers and the stability of vehicles. In addition to the above factors, traffic structures such as bridges, tunnels, interchanges and their unfavorable combinations all threaten
driving safety. The unfavorable combinations including: bridge-bridge, tunnel-tunnel, bridge-tunnel, bridge-interchange, tunnel-interchange, bridge-tunnel-interchange.

After analyzing the factors affecting driving safety in mountainous highways comprehensively, and according to the membership degree of each indicator, the safety risk evaluation system of high-risk road sections in mountainous areas is constructed, as shown in Figure 1:

![Safety Risk Evaluation System of High-risk Road Sections in Mountainous Areas](image)

Figure 1: Safety Risk Evaluation System of High-risk Road Sections in Mountainous Areas

### 3.2 Indicator Gradation and Classification

According to the relevant specifications and standards such as Design Specification for Highway Alignment (JTG D20-2017) and Contingency Plan for Highway Traffic Emergencies, etc, the driving safety of high-risk sections in mountainous areas is divided into four grades for evaluation, and each indicator is divided into specific grades according to the actual design parameters and grade classification standards of the evaluated highways[11]. And the division results can be obtained in the Table 1.

| Indicator                 | Sub-indicator                      | Risk Grades          |
|---------------------------|------------------------------------|----------------------|
|                           |                                     | **Safe**             |
| Road Condition $c_i$      | Radius of Horizontal Curve $c_{1i}$ | >4000                |
|                           | Convex Curve $c_{2i}$               | (700,4000]           |
|                           | Concave Curve $c_{3i}$              | (400,700]            |
| Longitudinal Slope $c_{4i}$| Slope Length $c_{5i}$              | ≤400                 |

|                           |                                     | **Relative Safe**    |
|                           |                                     | (400,700]            |
|                           |                                     | (6500,10000]         |
|                           |                                     | ≤6500                |
|                           |                                     | (3000,4500]          |
|                           |                                     | ≤3000                |

Table 1. Risk Assessment Indicator Gradation and Classification
| Traffic Accident $C_1$ | Slop% (Slop Length m) | Stopping Sight Distance $C_{15}$ (m) | Unfavorable Combination (s) $C_{14}$ | Road Condition $C_{16}$ | Year of Open to Traffic $C_2$ | Visibility $C_{31}$ (m) | Surface Skid-resisting Capability $C_{32}$ | Crosswind $C_{33}$ | Emergencies $C_{4}$ | Traffic structure $s C_5$ |
|------------------------|----------------------|-------------------------------------|---------------------------------|-----------------------|-----------------------------|---------------------|---------------------------------|------------------|------------------------|------------------|
| (Sloped%) (Sloped Length m) | [0.2, 0.3] | [0.3, 0.4] | [0.4, 0.5] | [0.5, 0.6] | [0.6, 0.7] | [0.7, 0.8] | [0.8, 0.9] | [0.9, 1.0] | [1.0, 1.5] | [1.5, 2.0] |
| (Sloped Length m) | [400, 600] | [600, 800] | [800, 1000] | [1000, 1200] | [1200, 1400] | [1400, 1600] | [1600, 1800] | [1800, 2000] | [2000, 2500] | [2500, 3000] |
| Slop Length m | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥1000 | [3, 4] | [4, 5] | [5, 6] | [6, 7] | [7, 8] | [8, 9] | [9, 10] | [10, 11] | [11, 15] | [15, 20] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥100 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| 0 | [0, 1] | [1, 2] | [2, 3] | [3, 4] | [4, 5] | [5, 6] | [6, 7] | [7, 8] | [8, 9] | [9, 10] |
| ≥5 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥300 | [200, 300] | [180, 200] | [160, 180] | [140, 160] | [120, 140] | [100, 120] | [80, 100] | [60, 80] | [40, 60] | [20, 40] |
| ≥180 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥100 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥50 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥100 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
| ≥250 | [0.3] | [0.4] | [0.5] | [0.6] | [0.7] | [0.8] | [0.9] | [1.0] | [1.5] | [2.0] |
The interval values of each standard risk indicator can be obtained in Table 2:

| Indicator | Sub-indicator | Safe       | Relative safe | Low Risk | High Risk |
|-----------|---------------|------------|---------------|----------|-----------|
| $c_i$     | $c_{i1}$      | [0,2)      | [2,6)         | [6,8)    | [8,10]    |
|           | $c_{i2}$      | [0,2.5)    | [2.5,7.5)     | (7.5,9.9) | (9.9,10]  |
|           | $c_{i3}$      | [0,2)      | [2,6)         | [6,8)    | [8,10]    |
|           | $c_{i4}$      | [0,2)      | [2,4)         | [4,8)    | [8,10]    |
|           | $c_{i5}$      | [0,2)      | [2,5)         | [5,9)    | [9,10]    |
|           | $c_{i6}$      | [0,0.1)    | [0,1.5)       | [5,7]    | [7,10]    |
| $c_i$     | $c_{i7}$      | [0,2.5)    | [2.5,7.5)     | [5.7,5)  | [7.5,10]  |
|           | $c_{i8}$      | [0,2)      | [2,4)         | [4,7)    | [7,10]    |
|           | $c_{i9}$      | [0,0.1)    | [0,1.3]       | [3,7]    | [7,10]    |
|           | $c_{i10}$     | [0,0.1)    | [0,1.5)       | [5,7]    | [7,10]    |

3.3. Determination of Risk Levels by Matter-element Model
The Matter-element Model is a discipline founded by Cai Wen in 1983. It is used to describe the variability of things. It transforms the qualitative description of right and wrong into quantitative description, and establishes a multiple indicator evaluation model to evaluate things completely which provides a new way to solve the evaluation of things. A model is constructed according to the Matter-element Analysis Method, and combined with the AHP and the Entropy Weight Method, the weight of each indicator can be determined, which can effectively evaluate the driving safety risk level of high-risk highway sections in mountainous areas.

3.3.1. Construction of Matter Element Matrix of Mountainous Highway Risk Level
The matter element of driving safety risk evaluation on high-risk highway sections in mountainous
areas is composed of mountain road risk $N$, road risk characteristics $C$ and their corresponding quantities. Among them: assuming that there are $n$ eigenvectors in the evaluation object $N$, then eigenvector $c = (c_1, c_2, \ldots, c_n)$, the each corresponding eigenvalue $x = (x_1, x_2, \ldots, x_n)$. Then the matter element of mountainous highway risk can be expressed as formula (1):

$$R = \begin{bmatrix} N & C_1 & X_1 \\ C_2 & X_2 \\ \vdots & \vdots \\ C_n & X_n \end{bmatrix}$$

(1)

There are $n$ risk evaluation indicators of high risk road section in mountainous areas, their classical field $R_i$ can be expresses as formula (2):

$$R_i = \begin{bmatrix} N_i & C_1 & X_{i1} \\ C_2 & X_{i2} \\ \vdots & \vdots \\ C_n & X_{in} \end{bmatrix}$$

(2)

In this formula, $N_i$ means $i$ evaluation levels; $C_1, C_2, \ldots, C_n$ means the evaluation indicator; $X_{i1}, X_{i2}, \ldots, X_{in}$ means the value range of the evaluation indicator for the $i$ evaluation level.

The basic characteristics and corresponding values of the problem are expressed in the form of a matrix, which is expressed as a segment field matter-element matrix, and marked as $R_p$ in the formula (3):

$$R_p = \begin{bmatrix} P & C_1 & X_{p1} \\ C_2 & X_{p2} \\ \vdots & \vdots \\ C_n & X_{pn} \end{bmatrix}$$

(3)

In the formula, $P$ means all the evaluation levels; $X_{p1}, X_{p2}, \ldots, X_{pn}$ means the value ranges of the evaluation indicators for all evaluation levels, that is to say, the segment field.

Combined with the value of each risk indicator of high-risk highway sections in mountainous area, the segment field matrix of matter element to be evaluated is obtained as formula (4):

$$R = \begin{bmatrix} \[0,10] \\ \[0,10] \\ \[0,10] \\ \[0,10] \\ \[0,10] \\ \[0,10] \\ \[0,10] \\ \[0,10] \\ \[0,10] \end{bmatrix}$$

(4)

According to each factor that corresponding to the evaluation indicator, the characteristic value is expressed in the form of matrix to form the matter-element matrix to be evaluated, which is shown in formula (5):

$$R_p = \begin{bmatrix} P & C_1 & X_1 \\ C_2 & X_2 \\ \vdots & \vdots \\ C_n & X_n \end{bmatrix}$$

(5)
In the formula, \( P_0 \) is the matter-element to be evaluated; \( X_1, X_2, \ldots, X_n \) is the specific value of the specific evaluation indicator.

### 3.3.2. Calculation of the Correlation Function value of Matter-element to be Evaluated

The correlation function is used to indicate the extent to which the value of the matter element meets the value range of a certain level. According to the model calculation of the interval, the model calculation of \( [a_i-b_i] \) is shown in formula (6):

\[
d = |X_0| = |b_i - a_i|
\]

Then, the distance from a certain point \( X_i \) to the interval \( X_i \) is calculated as formula (7):

\[
\rho (X_i, X_0) = \left| X_i \cdot \frac{a_i + b_i}{2} - \frac{(b_i - a_i)}{2} \right|
\]

Then, the distance from the point \( X_i \) to the interval \( X_i \) is calculated as below:

\[
\rho (X_i, X_p) = \left| X_i \cdot \frac{a_p + b_p}{2} - \frac{(b_p - a_p)}{2} \right|
\]

According to the previous formula, the correlation function of the indicator to be evaluated is shown in formula (9):

\[
K(X_i) = \begin{cases} 
\frac{\rho (X_i, X_n)}{\rho (X_i, X_n) - \rho (X_i, X_n - 1)} & \text{if } X_i \in X_n \\
\rho (X_i, X_n) & \text{if } X_i \not\in X_n \land \rho (X_i, X_n) \neq 0 \\
\rho (X_i, X_n - 1) & \text{if } X_i \not\in X_n \land \rho (X_i, X_n) = 0
\end{cases}
\]

### 3.3.3. Determination of the Indicator Weight

There are lots of methods to determine the indicator weight, such as AHP, Grey Relation Analysis (GRA) and Entropy Method, etc. For the objectivity and accuracy of risk evaluation, this article combines AHP and entropy method to determine the weight of each evaluation indicator.

#### 3.3.3.1. Determination of indicator weight \( \omega_i \) by Entropy Method

Entropy is a measure of the degree of disorder in the system. Entropy weight reflects the amount of useful information carried and transmitted by various indicators. The more useful information is carried and transmitted, the greater the entropy weight, and vice versa. The steps for determining the entropy weight are as follows:

- The object to be evaluated is divided into \( m \) levels, and there are \( n \) evaluation indicators, and the matrix \( R = (r_{ij})_{mn} \) is obtained after normalization.
- Determine the entropy \( H_i \) of evaluation indicator:

\[
H_i = \frac{-1}{\ln m} \sum_{j=1}^{m} f_{\mu j} \ln f_{\mu j}
\]

\[
f_{\mu j} = \frac{r_{\mu j}}{\sum_{j=1}^{m} r_{\mu j}}
\]

In this formula,
Calculate the weight $\omega_i$ of each indicator

$$\omega_i = \frac{1 - H_i}{n - \sum_{i=1}^{n} H_i} \quad (11)$$

### 3.3.3.2. Determination of indicator weight $\omega_2$ by AHP

#### Construct the Judgement Matrix

By comparing the relative importance of every two elements in the evaluation indicator system, a judgment matrix is constructed. According to the actual situation and expert scores, a pairwise judgment matrix is established for each factor. The second hierarchy judgment matrix of the rule hierarchy is:

$$R_0 = \begin{bmatrix}
1 & C_2 & C_3 & C_4 & C_5 \\
C_1 & 1 & 1/2 & 4 & 7 & 3 \\
C_2 & 2 & 1 & 3 & 5 & 2 \\
C_3 & 1/4 & 1/3 & 1 & 2 & 1 \\
C_4 & 1/7 & 1/5 & 1/2 & 1 & 1/3 \\
C_5 & 1/3 & 1/2 & 1 & 3 & 1
\end{bmatrix} \quad (12)$$

Construct a judgment matrix for the third layer of the rule hierarchy in sequence, that is, construct a judgment matrix for road conditions, external environment, and traffic structures, as shown below:

$$R_1 = \begin{bmatrix}
C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\
C_{11} & 1 & 5 & 3 & 1/2 & 1/3 & 4 \\
C_{12} & 1/5 & 1 & 14 & 1/9 & 1/7 & 1/3 \\
C_{13} & 1/3 & 4 & 1 & 1/5 & 1/4 & 3 \\
C_{14} & 4 & 9 & 5 & 1 & 3 & 7 \\
C_{15} & 3 & 7 & 4 & 1/3 & 1 & 5 \\
C_{16} & 1/4 & 3 & 1/3 & 1/7 & 1/5 & 1
\end{bmatrix} \quad (13)$$

$$R_2 = \begin{bmatrix}
C_{31} & C_{32} & C_{33} \\
C_{31} & 1 & 3 & 5 \\
C_{32} & 1/3 & 1 & 3 \\
C_{33} & 1/5 & 1/3 & 1
\end{bmatrix} \quad (14)$$

$$R_3 = \begin{bmatrix}
C_{51} & C_{52} & C_{53} & C_{54} \\
C_{51} & 1 & 1/3 & 1/2 & 1/7 \\
C_{52} & 3 & 1 & 2 & 1/5 \\
C_{53} & 2 & 1/2 & 1 & 1/6 \\
C_{54} & 7 & 5 & 6 & 1
\end{bmatrix} \quad (15)$$

#### Hierarchy weight calculation and consistency check

Through calculation, the weight value of each indicator is obtained, as shown in Table 3:
Table 3. Calculation of the weight value by AHP

| Indicator | Sub-indicator | Weight |
|-----------|---------------|--------|
| $c_1$     | $c_{11}$      | 0.0557 |
|           | $c_{12}$      | 0.0096 |
|           | $c_{13}$      | 0.0291 |
|           | $c_{14}$      | 0.1352 |
|           | $c_{15}$      | 0.0891 |
|           | $c_{16}$      | 0.0167 |
| $c_2$     |               |        |
|           | $c_{21}$      | 0.3683 |
| $c_3$     | $c_{31}$      | 0.0687 |
|           | $c_{32}$      | 0.0279 |
|           | $c_{33}$      | 0.0113 |
| $c_4$     |               |        |
|           | $c_{41}$      | 0.0531 |
| $c_5$     | $c_{51}$      | 0.0090 |
|           | $c_{52}$      | 0.0240 |
|           | $c_{53}$      | 0.0145 |
|           | $c_{54}$      | 0.0879 |

3.3.3.3. Comprehensive Weight $\omega$

The weights obtained by entropy weight method and AHP have their own advantages and disadvantages. In this paper, we use the advantages of the two methods to give the weight of 0.5 respectively to get the risk indicator weight of the final model. So, the results obtained are more reliable, as shown in the formula:

$$\omega = 0.5\omega_1 + 0.5\omega_2 \quad (16)$$

3.4. Evaluation Level of Driving Risk

Combined with the calculation results of correlation function and the weight of each indicator, the risk evaluation level can be obtained. The cloud will feed back the early warning information to the edge based on the evaluation result, and give corresponding voice warnings for different risk indicators. The evaluation results are shown in Table 4:

Table 4. Risk Evaluation Level

| Evaluation Level | Risk division results and measurements |
|------------------|----------------------------------------|
| $k_{j,(\lambda_0)} > 1$ | The evaluation object exceeds the upper limit of the standard, the larger the safer. No warning is required |
| $0 \leq k_{j,(\lambda_0)} \leq 1$ | The evaluation object meets the standard requirements, the driving meets the basic safety requirements. No warning is required |
| $1 - k_{j,(\lambda_0)} < 0$ | The evaluation object does not meet the standard requirements, and there is a certain risk in driving. Voice warning is given and feedback to the edge. |
| $k_{j,(\lambda_0)} < -1$ | The evaluation object does not meet the requirements of the standard, and there is a relative large risk in driving. Early warning and intelligent guidance are given to the driver, and feedback to the edge. |
4. The Construction of Driving Early Warning System Based on Edge-cloud Integration Technology

The schematic diagram of the warning system for high-risk road sections in mountainous areas based on Edge-cloud Integration technology is shown in Figure 2.

![Figure 2: Schematic Diagram of the driving early warning System](image)

4.1. Collection of Risk Indicator Data

The construction of a driving early warning system requires data services at the edge. The collection of risk indicator data mainly realizes the collection of driving data such as driving video taken by the driving recorder and vehicle geographic location. Among them, the vehicle-mounted terminal collects the road and environmental conditions ahead through the driving video taken by the driving recorder, obtains the vehicle position coordinate information through GPS, collects the historical traffic accident data, road design parameters and traffic structure conditions, and transmits the comprehensive risk indicator data to the cloud.

4.1.1. Data Collection by Vehicle-mounted Terminal

The vehicle terminal uses the vehicle recorder to access the real-time driving video and image. The driving video is mainly collected by camera API of mobile device in vehicle-mounted Android system, and according to the complexity of driving environment and the condition of network transmission, the image resolution is selected. This system mainly takes the corresponding algorithm to extract the road surface and environment in the video and image.

4.1.2. GPS Data Sharing

Satellite maps are an important source of data for this system. Commonly used satellite maps include Baidu Map, Amap, and QQ Map. GPS can obtain geographic coordinates of vehicles effectively, and get the alignment, structures and traffic accidents of the road ahead accurately. And then package the data and send it to the cloud. For an excessively large amount of map data, the edge computing data processing mode can be introduced to reduce the delay of data transmission. And allowing the arbitrary computing resources and network resources between the path of data source and cloud computing center data to prepossess the map data.

4.2. Edge-cloud Data Integration

4.2.1. Data Transmission

The system includes two processes of uplink and downlink transmission. The data uplink process is to transmit the driving video image and position coordinate information taken by the driving recorder of
the vehicle-mounted terminal to the cloud server, and use the cloud computing resources to analyze and process the edge data. The data downlink process is that the cloud uses the risk forecast model to process the image and position coordinate information and feed back to the vehicle-mounted terminal, so as to realize the early warning of the driving risk of mountainous highway.

In the system initialization of the uplink process, in the Connect Thread, an object of the Socket class is created by the vehicle-mounted terminal. Then, enters the cloud-specified IP address and port number, and sends a connection request to the cloud. After the connection is successful, the IMEI number and JSON data format of the vehicle-mounted terminal are sent to the cloud, and then the driving video and the current GPS position data are packaged into the JSON and written into the mOutstream. All JSON data are integrated and sent to the cloud, and the connect thread line is closed. In the receiving thread, the cloud first declares the transmission port number and receives the IMEI number of the connected vehicle-mounted terminal, and then receives, processes and stores the driving video and GPS data uploaded by the vehicle-mounted terminal in sequence.

In the downlink process, the cloud integrates the road surface, environment monitoring results and GPS location information in the driving video into the information in JSON format, and the Matter-element Model is used to identify the risk and feed back to the vehicle-mounted terminal. The vehicle-mounted terminal creates a new Socket object, establishes a connection line, accepts the risk identification result through the getInputStream() method of Socket, and issues early warning information.

4.2.2. Image Processing
Driving video image transmission to the cloud will increase most of the delay of the system. So this system is designed to realize the function of monitoring the road bumps, wetness, visibility and other conditions in the image at the vehicle-mounted terminal. However, the computing and storage resources on the vehicle-mounted terminal are limited. So the system calls the C++ interface of the OpenCV image processing library to use Computer Vision Methods such as Gray Level Transformation, Threshold Processing, and Perspective Transformation to achieve the extraction of risk indicators in the image. The functions realized by C++ language are transplanted to the vehicle-mounted terminal equipped with Android system through Java local interface.

4.2.3. Risk Identification
The vehicle-mounted terminal image is uploaded to the cloud, and the image risk features are extracted by Multi-scale Convolutional Neural Network and stored in the database. Then, using cloud computing resources, and combined with matter-element risk evaluation model, the risk indicators extracted from images and GPS are identified. For the evaluation level of $k_{j,(n)0} > 1$ or $0 \leq k_{j,(n)0} \leq 1$, there is no need to feed back to the vehicle-mounted terminal. And for the evaluation level of $-1 \leq k_{j,(n)0} \leq 0$ or $k_{j,(n)0} < -1$, it needs to feed back to the edge and give voice warning to the driver.

4.3. Edge-cloud integration Warning
The goal of the system is to provide early warning on high-risk road sections, reduce traffic accidents in mountainous areas, improve driving safety, and realize the early-warning function of Edge-cloud Integration by combining the visual perception of edge cloud and vehicle-mounted terminal.

According to different risk indicators and risk levels, different voice warnings need to be given. Combined with psychology of driving, the content of voice warnings in different situations is shown in Table 5 below:

| Risk Evaluation Level of Cloud | Risk Indicator | Voice Warnings of Vehicle-mounted Terminal |
|-------------------------------|----------------|-----------------------------------------|
|                               |                |                                         |

Table 5. Voice Warning
|                      |                                                      |
|----------------------|------------------------------------------------------|
| **Road Condition**   | Bad curve/longitudinal slope/poor sight distance/ unfavorable combination ahead, driving is risky, please slow down and pay attention to the traffic |
| **Traffic Accident** | Accident-prone section ahead, driving is risky, please slow down and drive carefully. |
| **External Environment** | Fog/Rain/Snow/Crosswind ahead, driving is risky, please turn on the fog lights, reduce the speed, and drive cautiously. |
|                      | Emergency happened ahead, driving is risky, please pay attention to the surrounding environment and drive cautiously. |
| **Traffic Structure** | Bridge/ Tunnel/ Interchange/ Bridge-tunnel group ahead, driving is risky. Pay attention to the visual brightness changes caused by tunnels/bridges and tunnels groups, please turn on the lights in advance. Please pay attention to the diverging and converging of the interchange, reduce the speed, and drive cautiously. |

-1 \leq k_{j_{(N)}} < 0

|                      |                                                      |
|----------------------|------------------------------------------------------|
| **Road Condition**   | Bad curve/longitudinal slope/poor sight distance/ unfavorable combination ahead, driving is of relative high risk, please slow down and strictly abide by traffic rules. |
| **Traffic Accident** | Accident-prone section ahead, driving is of relative high risk, please slow down and abide by traffic rules strictly. |
| **External Environment** | Heavy fog/rain/snow/crosswind ahead, driving is of relative high risk, Please turn on the front and rear headlights, fog lights, and warning lights, reduce the speed and drive cautiously. |
| **Traffic Structure** | Long bridge/ Tunnel/ Interchange/ Bridge-tunnel group ahead, driving is of relative high risk. Pay attention to the visual brightness changes caused by tunnels/bridges and tunnels groups, please turn on the lights in advance. Please pay attention to the diverging and converging of the interchange, reduce the speed, and drive cautiously. |

**5. Conclusion**

In this paper, the Edge-cloud Integration technology, combined with Matter-element Model, is used to conduct the risk evaluation high-risk sections of mountainous highway, and through the early warning of Edge-cloud Integration to give the driver voice indication. It can reduce the amount of traffic accidents effectively and improve driving safety. The main conclusions are as follows:

- The system adopts the emerging information technology: the Edge-cloud Integration technology, which reduces the load of the vehicle-mounted terminal greatly, and uses the computing power and resources of the cloud effectively. It improves the efficiency in data transmission, storage, image processing, extraction of GPS position information, risk indicator evaluation, early warning information feedback and other aspects, thus the real-time and accuracy of the whole system is improved.
- The risk evaluation model of this system adopts the Matter-element Model, selects AHP and entropy weight method to determine the weight of risk indicator. The whole system, combining subjective and objective methods, and qualitative and quantitative indicators, ensures the practicability and accuracy of the model, and effectively provides drivers with driving information on the road ahead.
- The risk evaluation and early warning system of high-risk road section in mountainous area
provides a certain method for driver’s driving safety, and provides a certain theoretical support for traffic safety in mountainous area in the future.

ACKNOWLEDGEMENT
Thanks to Chongqing Science and Technology Bureau Foundation and Frontier Project (cstc2019jcyj-msxmX0695); Chongqing Education Commission Youth Science and Technology Project (KJQN201900722) and Chongqing Education Commission Middle and Primary School Innovation Talent Training Project (CY200704); Graduate Science and Technology Innovation Project of Chongqing Jiaotong University (2020S0034).

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