

Study on rainy Weather Situation of Highway Based on Historical Rainfall Classification

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Abstract: The traffic system consists of people, vehicles and roads, as well as the environment around the road during driving. Weather has always been an important factor that cannot be ignored along with the highway. Good weather will bring good vision conditions and psychological conditions to drivers, while bad weather conditions will directly or indirectly affect the driver's operation or vehicle power performance. As one of the most common weather, many people neglect the harm of rainy days to highway driving safety. When the rain reaches a certain level, it will lead to water on the road surface and reduce the friction coefficient of the road surface. If the driver drives too fast at this time, it will be more prone to deviation. When it reaches extremely bad conditions, it can even destroy the subgrade and pavement, which directly causes immeasurable safety hazards. Based on the rainfall data corresponding to the rainfall events in the traffic environment in the past few years, this paper proposes a research method for the characteristics of rainy days, which uses the fuzzy recognition method to classify the rainfall types of rainy days, to study the development trend of rainy days. After obtaining the development trend function of the historical type of rainy days, we can determine the type of the rainy day event and the specific time period of the type by comparing the closeness of the function of the current observation value with time and the historical function, so as to achieve the purpose of forecasting the development trend of the current weather event. Taking the change rate of rainfall change as the characteristic function, we can further quantify the change range of rainfall, the key indicator representing the intensity of rainy days. This strategy model is applied to expressway speed management, which can provide a good reference for traffic managers to make speed limit decisions, and can clearly decide when to cancel the speed limit strategy or upgrade to the road closure strategy.

Keywords: Highway, Rainy weather forecast, Fuzzy recognition.

1. Introduction

Since the 21st century, with the rapid economic development of countries around the world, the construction of expressways has also been rapidly constructed. The coverage of expressways in some countries has already reached half of the national territory. The increase of expressway mileage means that the whole road network system will also span more areas. For some countries with large territory, such a state will inevitably lead to the expressway being covered by a variety of meteorological environments. As one of the most common weather phenomena, rainy days will not affect the traffic of expressway when the intensity is light. If it reaches a certain intensity, it will lead to a sharp increase in the probability of traffic accidents. Especially for China, China has a vast territory and a large terrain span. Although it is a country, highways in different places face different types of meteorological disaster risks. In addition, China's construction capacity has become more and more powerful with the development of social economy in recent years, and the total mileage of expressways across the country has continued to rise, reaching 169100 kilometers by 2021.

How to reduce the impact of rain on highway traffic safety is a long-term research content in the field of transportation. From a macro perspective, some scholars analyzed and explored people's willingness to travel, choice of travel mode, expected speed of drivers, and probability of compliance with traffic speed limit measures under different weather conditions. Some scholars have also carried out the safety research of expressway in rainy days from the micro-perspective of the reduction of friction factors on the

pavement of expressway in rainy days and the reduction of reaction ability caused by the obstruction of driver's vision. Aguilar et al. [1] used the collision data of interstate highways to explore the factors affecting the collision frequency, with the focus on the impact of weather (precipitation, wind, etc.). The negative binomial model with random parameters is used to check the influence of the above variables on the accident frequency. Joshua et al. [2] showed that rainfall intensity has a great impact on the traffic capacity of the bottleneck section of the expressway. Soyung et al. [3] verified the impact of rainy weather conditions on traffic operation, accident frequency and accident severity through microscopic simulation modeling. Oluyemi et al. [4] studied the traffic and rainfall data collected in four different places in Nigeria for eight weeks, and the results showed that the travel speed changed significantly between dry and rainy night conditions. The average driving speed of light rain, moderate rain and heavy rain at night decreased by 3.4%, 6.8% and 10.2% respectively.

Although these studies are carried out on rainy days, they rarely serve the safety construction of expressway from the perspective of rainy day prediction. This paper will propose a method to analyze the rainy weather situation of expressway from the perspective of rainfall classification based on the rainfall data of historical rainy weather events, mainly using the fuzzy recognition method.

2. Classification of Historical Rainfall Events Based on Fuzzy Recognition

The weather in a region is changeable every day and seems irregular. But in fact, it can be seen from the meteorological

factors such as temperature, pressure and humidity that their generation, development and dissipation are regular. The weather conditions of a region for many years will also present certain regularity, which is reflected in the local climate to some extent. It must take many years to summarize the laws of climate. Therefore, for the research content of this paper, it is necessary to analyze the characteristics of rainfall data in the process of historical rainy events for many years.

The method used here is called fuzzy recognition method. Fuzzy recognition refers to the identification of useful parts in a large number of complex information, that is, to recognize the relevance of the received information and past memory and experience, and to eliminate irrelevant information. It mainly follows two principles, one is the principle of maximum subordination, the other is the principle of proximity. If any element within the scope of study has a number corresponding to it, the number is called the fuzzy set within the scope of study, and this relationship is called the membership of the element to the number. When the number can be changed at will, this will form a membership function, and the maximum membership is based on this theory. The proximity principle measures the proximity between two sets.

The principle of maximum membership is expressed by mathematical formula as follows:

$$A_i(u_0) = \bigvee_{j=1}^n A_j(u_0) \quad (1)$$

Where, u_0 represents the primary color and A_i represents the category.

The principle of proximity is expressed by mathematical formula as follows:

$$N(A_i, B) = \max_{1 \leq j \leq n} \{N(A_j, B)\} \quad (2)$$

Where, n represents the fuzzy set, B represents the object to be identified, and $N(A_j, B)$ represents the proximity. When set A and set B are closest to each other, A and B belong to the same class.

If you want to use python to implement the principle of maximum membership, the code example is as follows:

```
import math as m

def lsd(a, minx):
    b=[]
    c=[]
    for i in range(0, len(a)):
        b=a[i]
        for j in range(0, len(b)):
            if j!=2 and j!=1:
                if b[j]<minx[j]:
                    c.append(1)
                elif b[j]>minx[j]:
                    c.append(round(m.exp(-(b[j]-minx[j])**2), 4))
            elif j==2:
                if b[j]<minx[j]:
                    c.append(0)
                elif b[j]>minx[j]:
                    c.append(round(1-m.exp(-(b[j]-minx[j])**2), 4))
            else:
                if b[j]<0.09:
                    c.append(round(m.exp(-(b[j]-0.09)**2), 4))
                elif b[j]>0.09:
                    c.append(round(1-m.exp(-(b[j]-0.09)**2), 4))
                else:
                    c.append(1)
    return c

def main():
    s=[]
    t=[]
    miny=[]
    print(lsd(s, miny))
    print(lsd(t, miny))

if __name__ == "__main__":
    main()
```

Figure 1. The principle of maximum subordination python code example diagram

If you want to use python to implement the proximity principle, the code example is as follows:

```
import numpy as np

def minMaxDist(x, y):
    x = np.array(x, np.float16).reshape(-1)
    y = np.array(y, np.float16).reshape(-1)
    map_xy = np.vstack((x, y))
    return np.sum(np.min(map_xy, axis=0))/np.sum(np.max(map_xy, axis=0))

def main():
    s=[]
    t=[]
    miny=[]

    thd1=[]
    for i in range(0,3):
        p=lsd(t, miny)[0+i*4:4+i*4]
        for j in range(0,5):
            q=lsd(s, miny)[0+j*4:4+j*4]
            thd1.append(minMaxDist(p, q))
    for m in range(0,3):
        print(thd1[0+5*m:5+5*m])

if __name__ == "__main__":
    main()
```

Figure 2. Proximity principle python code example diagram

The idea of using the fuzzy recognition method to deal with the rainfall data of the historical rainy day event is to divide the actual rainfall process into multiple time periods, and establish the pattern matrix of the rainfall event according to the percentage of the rainfall in each time period in the total rainfall. Then the actual indicators of each rainfall process are compared with this matrix, and the general types of rainfall events can be classified according to the proximity principle. After the rainstorm for many years is divided into several categories according to this method, the function of related rainfall and time can be further fitted to represent each type of rainfall.

3. Matching Degree Between Current Monitoring Data and Historical Function

First of all, it is necessary to judge the position of the current detected rainfall index data in the historical function curve. First, divide the rainfall of the historical rainfall type function curve to which the current rainfall data belongs into m time segments. The difference of rainfall in each time segment compared with the previous time can be expressed as:

$$x_i = H_i - H_{i-1} \quad (i=1, 2, \dots, m) \quad (3)$$

Where, x_i represents the difference of rainfall in each time segment compared with the previous time; H_i refers to the rainfall in the i th segment of the predicted rainfall event; H_{i-1} refers to the rainfall in segment $i-1$ of the predicted rainfall event.

The change rate of rainfall difference in the two adjacent time periods in the history function can be further calculated to obtain a set of vector groups of rainfall difference change rate corresponding to the predicted value. The actual observation value is processed in the same way of time section division, and the vector group of rainfall difference change rate corresponding to the actual value at present is obtained by the same processing. The two can determine the actual trend and position of the rainfall time with the type by the progress calculation.

$$|X_{i+1}| = \left| \frac{\partial(x_{i+1}-x_i)}{\partial(t/m)} \right| \quad (i=1, 2, \dots, m-1) \quad (4)$$

Where, A represents the change rate of rainfall difference in the period B during the forecast rainfall event; C represents the total rainfall duration of the historical rainfall function. The change rate of rainfall difference of historical function and the change rate of rainfall difference of actual observation value are calculated according to the schedule:

$$\sigma_{i+1} = 1 - \sqrt{\frac{1}{m-1} \sum_{i=1}^{m-1} (|X'_{i+1}| - |X_{i+1}|)} \quad (i=1, 2, \dots, m-1) \quad (5)$$

Where, σ_{i+1} represents the closeness between the predicted precipitation difference change rate and the actual observed precipitation difference change rate in the period $i+1$, the closer to 1 means the closer, and the closer to 0 means the less close; X'_{i+1} represents the change rate of the difference of the actual observed rainfall in the $i+1$ period. Select X_{i+1} corresponding to the maximum closeness as the weight value a of the current weather trend. A positive value indicates that the rainfall trend will increase, and a negative value indicates that it will decrease with the trend. For other weather types, the corresponding weather situation weight factor can be obtained by the same method.

4. Establishment of Expressway Rainy Weather Situation Risk Model

Next, we start to establish the expressway rainy day risk model. It is worth noting that this model is only applicable to the situation where rainfall data is detected. Moreover, the longer the time of falling rain is, the more conducive it is to predict the rainfall trend, because this will, to a certain extent, avoid the accidental error caused by too little data from the current situation.

When the rainfall event reaches the local speed limit condition, this model starts to apply. The weight coefficient A obtained in the previous section can be used to express the fluctuation range of the following weather trend clearly and quantitatively.

Before the rainfall reaches the predicted peak value, it is necessary to compare and judge the speed limit value of the current highway. If the weather trend that the speed limit strategy has reached the highest level is still deteriorating, it

can be considered to take the temporary no-passing strategy for the current road instead of continuing to limit the speed. Because it is already in a particularly extreme state at this time, vehicles are vulnerable to rainstorm weather and safety accidents occur. Speed limit is meaningless.

After the rainfall reaches the predicted peak, it is necessary to compare and judge the speed limit value of the current expressway. If the speed limit strategy has been reduced to the lowest level and the weather trend continues to improve, it can be considered to further increase the speed limit threshold for rainfall events or cancel the speed limit provisions. Because it is close to normal weather at this time, it is difficult for the vehicle to receive the influence of rainy weather to have a safety accident or the rainy weather has dissipated, and the speed limit is no longer meaningful.

5. Conclusion

In this paper, a method of expressway rainy weather situation prediction based on fuzzy recognition and classification of historical rainy weather time rainfall data is proposed. Taking into account the fact that the regional climate is not easy to change greatly all the year round, this method first uses the fuzzy recognition method to analyze the historical rainfall data, and obtains the classification of historical rainfall types and their corresponding functions. Then, the closeness of the current monitoring data to the historical data function is calculated to determine the type of current rainfall. After determining the rainfall type, the next possible trend of current rainfall can be judged. This model can effectively serve the safety management of expressway in rainy days.

References

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