Division of Driver's Vision Plane Based on K-means Cluster Analysis

Bingkui Ji, Xueping Yao*, Yuzhuo Men and Mingda Li
Changchun Institute of Technology, Changchun, Jilin, China

*Corresponding author e-mail: jd_yxp@ccit.edu.cn

Abstract. The division of the driver's vision plane is the basis of study on the driver’s fixation objects and area of interest. This paper firstly collected the driver's eye movement data through a large number of real road tests. Then, considering the driver's areas of interest in driving, the K-means clustering was adopted to cluster plane coordinates of the drivers' the fixation points to divide the driver's vision plane. Through the comparison of the clustering results, the best clustering result was selected, and the driver's vision plane was divided into eight regions. Finally, this paper studied the distribution of the drivers’ fixation points in each region at parking, straight going, left turn and right turn. The results have verified the higher accuracy of the K-means clustering for the division of the driver's vision plane.

1. Introduction
Eyes are the most important channel for people to obtain external information. During the driving process, drivers get more than 90% of information from eye movements [1]. Insufficient information or important information missed by the driver will lead to driving misconducts and further traffic conflicts, or even traffic accidents. Therefore, it is essential to study the driver's eye movements. In recent years, extensive foreign researches have been made on the driver's visual behaviors, specifically including visual search mode of skilled drivers and unskilled drivers, comparison of search strategies, relationship between driver's visual behaviors and vehicle control and operations, the impact of workload on the driver's vision, and the connection between the driver's gaze area and the transportation facilities [2-3]. The research on eye movement behaviors is based on the division of the driver's vision plane, which is now mostly done by the experimental video [3], mechanical and unreliable. In this paper, the dynamic clustering of fixation point coordinates was adopted, together with the characteristics of the driver's eye movements and the area of interest [4], realizing the accurate division of the driver's vision plane.

At present, the common method of dividing the driver's vision plane is the mechanical division method and the one-by-one statistics of fixation targets [5]. The former is simple and easy, but with poor reliability. The latter, despite high reliability, carries heavy workload with tens of thousands of fixation points recorded in the experiment, which is unrealistic to analyze one by one. The dynamic clustering of the fixation point coordinates, based on the characteristics of the driver, is simple and easy in operations, and overcomes the shortcomings of the mechanical division method, namely the poor reliability. Therefore, the fixation point dynamic clustering method is used to divide the distribution area of fixation points.
2. Design of Road Experiment
A road test was conducted in Changchun City and the driver's visual indicator data and road traffic conditions were collected to study the division of the driver's vision plane based on k-means.

In order to obtain the driver's visual data under different traffic flow conditions, a two-day road test was conducted on July 2018 and November 2018, respectively, to collect the driver’s visual data at the morning peak, the morning flat, the afternoon flat and the evening peak. Also, the driver's visual characterization parameters were acquired by the Smart Eye eye tracker from Smart Eye, a Sweden company. To obtain real-time road conditions, a video recorder was placed in the cockpit to continuously record the road traffic environment information, as shown in Figure 1. Three drivers were selected for each experiment, including a professional driver aged 40-50 and driving for more than 20 years, a skilled driver aged between 30-40 and driving for more than 10 years, and an unskilled driver aged 20-30 and driving for less than 3 years. They were required to have adequate sleep and sound mental state on the day before the experiment. Alcohol, coffee or drugs were prohibited to avoid the impact on the driver’s visual indicators. Keep the cabin quiet along the way during the experiment every day, and the driver could take appropriate rest according to his own situation.

3. Dynamic Clustering of Visual Distribution Coordinates
Set $X = \{x_1, x_2, \ldots, x_i, \ldots, x_n\}$ as the data in $n$ $R^d$ spaces ($n$ refers to the number of $R^d$). Specify $k$ as the number of initial clusters before the clustering starts. $k$ can be selected in several ways, such as random selection or selection according to the number of samples. The basic steps of the means algorithm are as follows [6-7]:

During the division of the driver's vision plane by dynamic clustering [7], the number of clusters equals the number of the divided visual fields. Therefore, the number of clusters determines the number of divisions of the visual field, and the selection of the appropriate number of clusters is the basis and key of the follow-up research. With the excessive number of divided regions, it is difficult to define the correspondence between the distribution of the fixation points and the fixation objects in the region; while the insufficient number of regions cannot demonstrate the characteristics of the objects in the distribution region of the fixation points and the features of the information acquisition process.

Combined with the driver’s visual search characteristics in driving, this paper conducted a clustering analysis of the fixation point coordinates by the 6-cluster, 7-cluster, and 8-cluster k-means clustering method, and compared the advantages and disadvantages of the three clustering results to choose the proper way to divide the driver's vision plane. Through the k-means clustering of SPSS software, the number of clusters was selected as $k=6$, $k=7$ and $k=8$, with the clustering results shown in Table 1:
### Table 1. Every clustering center and the number of cases.

#### Clustering result if K=6

| Category | Initial Cluster Center | Final Cluster Center | Number of Cases |
|----------|------------------------|----------------------|-----------------|
| 1        | (0.35 0.29 -0.89)      | (-0.02 0.01 -1.00)   | 13166           |
| 2        | (-0.63 -0.63 -0.45)    | (-0.11 -0.08 -0.99)  | 5998            |
| 3        | (0.34 -0.60 -0.72)     | (0.21 -0.04 -0.96)   | 4468            |
| 4        | (0.94 -0.02 -0.35)     | (0.59 0 -0.77)       | 1802            |
| 5        | (-0.98 0.17 0.11)      | (-0.70 -0.04 -0.70)  | 1272            |
| 6        | (-0.52 0.27 0.81)      | (-0.42 0 -0.89)      | 588             |

#### Clustering result if K=7

| Category | Initial Cluster Center | Final Cluster Center | Number of Cases |
|----------|------------------------|----------------------|-----------------|
| 1        | (0.04 -0.08 -0.10)     | (-0.03 0 -1.00)      | 13290           |
| 2        | (-0.36 -0.71 -0.61)    | (-0.13 -0.08 -0.98)  | 5468            |
| 3        | (0.44 -0.67 -0.60)     | (0.18 0.04 -0.97)    | 3742            |
| 4        | (0.93 -0.12 -0.34)     | (-0.30 -0.19 -0.92)  | 1774            |
| 5        | (0.57 0.45 -0.69)      | (0.64 0.05 -0.73)    | 1293            |
| 6        | (-0.98 0.17 -0.11)     | (-0.72 -0.05 -0.68)  | 1056            |
| 7        | (-0.59 0.36 -0.72)     | (-0.51 0 -0.85)      | 671             |

#### Clustering result if K=8

| Category | Initial Cluster Center | Final Cluster Center | Number of Cases |
|----------|------------------------|----------------------|-----------------|
| 1        | (0.09 -0.50 -0.86)     | (-0.02 0.01 -1.00)   | 12880           |
| 2        | (0.01 0.14 -0.99)      | (-0.12 -0.07 -0.99)  | 5827            |
| 3        | (0.57 0.45 -0.69)      | (0.22 0.05 -0.97)    | 3095            |
| 4        | (-0.63 -0.63 -0.45)    | (0.13 -0.20 -0.96)   | 1693            |
| 5        | (0.58 -0.66 -0.48)     | (0.48 -0.12 -0.85)   | 1289            |
| 6        | (-0.98 0.17 -0.11)     | (-0.70 -0.04 -0.70)  | 1256            |
| 7        | (0.94 -0.02 -0.35)     | (0.72 0.15 -0.65)    | 683             |
| 8        | (-0.59 0.29 -0.75)     | (-0.44 0.00 -0.89)   | 571             |

The fixation points collected in the experiment are spatial points. In the interest of dividing the distribution region of the fixation points, the points after dynamic clustering were projected onto a plane perpendicular to the driving dimension. The distribution of the fixation points after clustering is shown in Fig. 1:

Based on the comparison and analysis of the clustering figures with k=7, 8, and 9, it was found that the clustering result most fit the actual situation when k=8 considering the area of interest and fixation shift characteristics of the driver during driving practice. Therefore, the distribution region of the driver's fixation points was divided into 8 areas, specifically as shown in Figure 2: 1 front lane, 2 left lane, 3 right lane, 4 in-vehicle dashboard, 5 right rearview mirror, 6 left rearview mirror, 7 outside the left lane, and 8 outside the right lane.
4. Analysis of the Distribution of the Driver’s Fixation Points

In line with the above division of the driver's vision plane, the distribution of the fixation points in various areas during parking, straight going, left turn and right turn was analyzed, as shown in Figure 3.
Figure 3. Distribution of driver’s fixation point in the vision plane.

The data analysis software of the eye tracker was utilized to record the distribution of the driver’s fixation points in each area during the parking, straight going, left turn and right turn in the experiment, as shown in Table 2.

| Area                          | Parking | Left turn | Right turn | Straight going |
|-------------------------------|---------|-----------|------------|----------------|
| 1 front lane                  | 58.2%   | 31.5%     | 47.1%      | 33.4%          |
| 2 left lane                   | 41.8%   | 26.4%     | 3.4%       | 30.1%          |
| 3 right lane                  | 0       | 14.2%     | 37.9%      | 31.3%          |
| 4 in-car dashboard            | 0       | 1.2%      | 1.2%       | 0.8%           |
| 5 right rear view mirror      | 0       | 0.8%      | 10.4%      | 1.1%           |
| 6 left rear view mirror       | 0       | 18.2%     | 0          | 1.4%           |
| 7 outside the left lane       | 0       | 8.1%      | 0          | 1.2%           |
| 8 outside the right lane      | 0       | 0.6%      | 0          | 0.7%           |

It can be seen from the above analysis that the driver's fixation points are the most concentrated at parking, mainly distributed in the area of 1 and 2, namely the area near the front lane, because the driver is most concerned about the traffic light when parking and then mainly gaze at the front. The driver's fixation points are mainly distributed in the front lane when going straight, because the driver obtains information mainly from the front lane when going straight, and occasionally checks other areas to achieve safe driving. When turning right, the driver's fixation points are mainly distributed in the 1 area and the 5 area, namely the front lane and the right rear view mirror. The reason is that the driver pays more attention to the front of the lane and the right side of the vehicle when turning right. In the case of turning left, the fixation points are mainly in the 1 area, namely the front lane. Also, the driver pays attention to the 2 and 3 areas, namely the left and right lanes. This is mainly because the
left turn is more dangerous than the other three driving states and requires comprehensive information to proceed.

5. Conclusion
1) Considering the large number and wide distribution of the driver's fixation points, k-means clustering is selected to divide the driver's vision plane compared with the existing division methods.

2) K-means clustering is used to carry out the dynamic clustering of the driver’s fixation point coordinates collected during the experiment when k=6, k=7, and k=8. By comparison, it is found that the clustering effect achieves the best when k=8. Therefore, 8 clusters are selected and the driver's vision plane is divided into 8 regions.

3) The distribution rules of the driver’s fixation points during parking, straight going, left turn and right turn are quantified. It is concluded that the distribution law of the driver's fixation points is closely related to the driving direction control.

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