Construction of Driving State Prediction Model Based On the Adjustment Variables of the Layout Elements

Huawei Xie*
Fujian Police College, Fuzhou 350007, China
*Corresponding author: xiehuawei@fjpsc.edu.cn

Abstract. This paper studies and analyzes the influence of cab layout elements such as vehicle seat, steering wheel, mirror and other adjustment variables on driving posture. The prediction model of adjustment variables of each arrangement element and key elements of driving posture is also established. Based on the multivariate factor regression analysis of the experimental data, the variables were adjusted according to the layout elements of the vehicle cab, and the corresponding driver's posture and human physical characteristics were predicted. At the same time, this paper collects new experimenter data, evaluates and verifies the prediction effect of the model, and analyzes the shortcomings and limitations of the prediction model.

1. Introduction
With the rapid development of economy and society and the development and progress of science and technology, facing the complicated law enforcement environment and arduous work tasks, the realistic and urgent problem facing the public security department is how to restore the truth, safeguard the dignity of the law and safeguard the legitimate rights and interests of the parties. When police deal with traffic accidents such as hit-and-run, report cases after the accident, and difficult cases, sometimes they will encounter some cases of inconsistent or doubtful statements about who is the "driver". In addition, some illegal drivers use others as a scapegoat to escape legal punishment, which makes it difficult for the traffic police to identify the drivers who cause accidents. If there is no clear driver, accidents often can not be handled in accordance with normal legal procedures and may even cause wrongful convictions, while the real murderer is "free from punishment". Whether the driver can judge correctly is not only related to the fair and standard handling of traffic accidents, but also related to social stability and harmony.

2. Analysis theory of driver's personal characteristics based on ergonomics
In the car cockpit, the seat is the equipment to maintain the driver's driving state, and also the equipment to support the driver's driving posture. The relatively simple man-machine operation environment determines the basic driving state of the driver. The driver sits back in the seat, hands hold the steering wheel, feet on the pedals, facing the front, the right hand can easily operate other controls, such as the shift lever, etc. Therefore, drivers with different personal characteristics will form their own car layout element adjustment habits based on comfort. According to human characteristics, the driver adjusts the seat height, distance and tilt Angle of the seat back, creating a comfortable and safe working environment. What needs to be paid attention to is the height of the seat back, tilt Angle and other data, in addition to considering the figure data, but also consider the direction of the human skeletal muscle and driving force.
The rearview mirror is an important equipment for drivers to observe the surrounding driving environment and other driving vehicles. In the process of vehicle driving, the driver's grasp of these information is related to the safety and economy of the car [1]. There is a certain connection between the rear view mirror and the driver's sitting height and visual distance and Angle of view. Based on long-term adaptation of the safe and reliable driving environment, no matter what shape of the driver, if you adjust the Angle of the rearview mirror, seat height, front and rear distance, then you can achieve a good field of vision.

3. Preparation for the experiment

3.1. The Experimenter
The experiment included 100 subjects, including 76 males and 24 females, who had been driving for more than a year. Young drivers are the representative types, ranging in age from 20 to 30 years old. The average height of the subjects is 168.55cm. The height distribution of the subjects basically conforms to the normal distribution. The table lists the specific situation of the subjects in the height range, as shown in Table 1.

| Grouping objects | Height range(cm) | Number of persons (persons) |
|------------------|------------------|-----------------------------|
| 1                | 160-165          | 10                          |
| 2                | 165-170          | 15                          |
| 3                | 170-175          | 15                          |
| 4                | 175-180          | 10                          |

3.2. The Experimental Car
In this experiment, the SUV which is more common in today's society and applicable to a wide range of people is selected as the fixed experimental model. Among them, compact SUV can be regarded as the sales force of SUV market because its positioning is more in line with the preferred requirements of buying economical vehicles. Therefore, Geely SX7 was finally selected as the experimental vehicle. In this study, the driver's seat, the Angle of the mirror and the steering wheel are composed of multiple factors, and other layout elements are taken as constraint conditions to conduct the experiment. From these mutual relations, the information related to the driver's personal characteristics can be obtained.

Figure 1 is the side view of the vehicle driving platform, in which the intersection point of the front end of the pedal and the floor of the cab (BOF) is defined as the origin of coordinates. In the coordinate system, X axis is forward backward from the origin along the driving direction, Y axis is perpendicular to X axis and toward the right side of the driver, and Z axis is vertical upward along the origin. The pedal inclination is 87°, the steering wheel height is 74cm, the horizontal distance from the steering wheel to the origin BOF is 40cm, the steering wheel Angle is 24°, and the seat Angle is 13°.
4. The experimental process

4.1. The Experiment Design
A simplified chain-like connection model is adopted to simulate driving posture [2]. The driving posture diagram is shown in Figure 2.

![Figure 1](image1.png)

**Fig 1.** Side view of driving platform

![Figure 2](image2.png)

**Fig 2.** Schematic diagram of driving posture

The predictive variables are taken as the input parameters of the driving state prediction model, which mainly refers to the data that drivers make corresponding adjustments to the internal layout elements of
the cab according to their driving habits and driving comfort states. At the same time, the seat back Angle, the horizontal distance from the rightmost side of the seat to the BOF, the straight line distance from the center of the steering wheel to the rightmost side of the seat, and the inclination Angle of the left and right mirrors are taken as input variables. The interior layout elements such as seats, steering wheel and pedals of each vehicle are relatively different, so the fixed interior layout elements of its cab are taken as the constraint conditions of the model. The output variables are the driver's physical characteristic parameters: height and height-weight ratio. Considering the correlation between height and weight, the ratio of height to weight is used as the conversion variable to replace weight, as shown in Table 2.

Table 2. Input variables of prediction model

| Predictor variable                          | Constraint variables for kinematics |
|--------------------------------------------|-------------------------------------|
| Seat back corner                           | Steering wheel center, height, Angle, diameter |
| The horizontal distance from the far right of the seat to the BOF | The Angle of the seat cushion |
| The straight-line distance from the center of the steering wheel to the far right of the seat | Pedal Angle |
| Angle of left and right mirror             | Horizontal distance from center of steering wheel to BOF |

4.2. Simplification of Computational Models

In order to reduce the complexity of building the model, the driver's posture state is reasonably assumed here. a: If the steering wheel is divided into 12 equal parts, it is assumed that the driver's hands are held at the 2 and 10 points of the steering wheel, which is in line with the driving habits of most drivers. b: Assuming that the relative position of the foot is fixed during driving, the position of the foot is simply marked by the pedal BOF point. c: Assuming that the left and right sides of the driver's posture is relative, the left side of the driver's driving posture is measured to further simulate the driving state of the whole body in the cockpit.

4.3. Predictive Model of Driving State

The input parameters are mainly divided into two parts: the predictor variable and the constraint parameters of the cockpit layout. Relevant values were input into the linear regression equation obtained from the experiment to calculate the positions of feet, hand grip points and HIP points respectively, and then the positions and postures of eyes, body leaders, upper and lower limbs were predicted to further simulate the driving state of the whole body[3], and finally the personal characteristics of the corresponding drivers were obtained, as shown in Figure 3.
Next, the solving steps of the prediction model are expounded.

4.3.1. Foot Position. According to the simplification of the human body model and the coordinate setting of the car, the position of the foot can be simulated and simplified as the coordinate of the position of the pedal.

4.3.2. Hand Position. The center position of the steering wheel of the experimental vehicle is fixed. The Angle and diameter of the steering wheel can locate the grip position of the hand. Set the coordinate of the center point of the steering wheel as (Sx, Sy, Sz), α represents the Angle between the hand position and the horizontal plane of the center of the steering wheel in the plane of the steering wheel, and β represents the Angle between the plane of the steering wheel and the vertical plane, as shown in Figure 4. If the coordinate of the grasping point is (Hx, Hy, Hz), then $Hx = Sx + \cos\beta$, $Hy = Sy + d/2\sin\beta \cos\alpha$, $Hz = Sz + d/2\sin\beta \sin\alpha$.

![Flow chart of driving state prediction model](image)

Fig 3. Flow chart of driving state prediction model

![Schematic diagram of holding points](image)

Fig 4. Schematic diagram of holding points
4.3.3. The Position of the Hip Point. Regression analysis of the seat Angle, the horizontal distance from the rightmost side of the seat to the BOF and HIP can be used to obtain the X and Z axis positions of HIP.

Male:
\[ \text{HipZ} = 199.2177 + 4.6383 \times \text{Backrest angle}, R^2 = 0.808016388. \]
\[ \text{HipX} = -19.4012 + 0.9283 \times \text{Far-right horizontal distance of seat}, R^2 = 0.929821658. \]

Female:
\[ \text{HipZ} = 219.3499 + 3.5419 \times \text{Backrest angle}, R^2 = 0.881558458. \]
\[ \text{HipX} = -8.2699 + 0.1132 \times \text{Far-right horizontal distance of seat}, R^2 = 0.957811985. \]

4.3.4. Eye Position. The relative position of the driver’s eyes in the cab can be obtained by the regression equation. What is predicted here is the position of the center of the eyes (the center of both eyes), whose Y coordinates are assumed to be consistent with the center of the body.

The position relationship of the eye relative to the mirror can also be obtained by the regression equation. Here, the Y and Z coordinates of the eye point are predicted, which can be used to verify the position of the eye point.

Male:
\[ \text{eyespotsY} = 231.8 + 0.0374 \times \text{The rightmost distance of the seat} - 0.4217 \times \text{HipZ}, R^2 = 0.756527346. \]
\[ \text{eyespotsZ} = 1041.283 - 5.1288 \times \text{Trunk thighs} + 2.3683 \times \text{Left rearview mirror} + 4.2097 \times \text{Right rearview mirror}, R^2 = 0.819866696. \]

Female:
\[ \text{eyespotsY} = 217.8 + 0.0354 \times \text{Rightmost horizontal distance} - 0.4225 \times \text{HipZ}, R^2 = 0.744315814. \]
\[ \text{eyespotsZ} = 721.5182 - 4.346 \times \text{Trunk thighs} + 4.3401 \times \text{Left rearview mirror} + 5.228 \times \text{Right rearview mirror}, R^2 = 0.804034076. \]

4.3.5. Position of Trunk Junctions. Data analysis shows that the position size of the seat in the cockpit has an important but small effect on the trunk. There is a slight correlation between the change in steering position and the Angle of the trunk. This is mainly because the flexion and extension movement of the human spine adjusts the changes caused by the trunk, but at the same time, the influence of the seat and steering wheel on the trunk Angle can be analyzed in reverse.

Here, the trunk segment is simplified, and the trunk thigh Angle is obtained by using the correlation analysis equation of the comfortable Angle between the trunk thigh Angle, HIPZ, the back Angle and the knee Angle.

Male:
\[ \text{Trunk thighs} = 91.6445 - 0.1093 \times \text{HipZ} + 1.1768 \times \text{Backrest angle} + 0.1137 \times \text{Left knee Angle}, R^2 = 0.826967776. \]

Female:
\[ \text{Trunk thighs} = 81.2379 - 0.044 \times \text{HipZ} + 1.1046 + 0.0788 \times \text{Left knee Angle}, R = 0.868765165. \]

4.3.6. Height and Weight. As shown in Table 2, the eye height of the driver outside the car can be predicted according to the relevant information of eye points inside the car and lower limb posture. Combined with the size standard of each body part of normal Chinese people and the position of the eye points, the relationship between the height of the eyes inside the car and the height of the eyes outside the car was obtained, so as to predict the height of the driver. At the same time, the ratio of height and weight could be obtained from the regression equation, and finally the weight of the driver could be obtained.

Male:
\[ \text{Height-weight ratio} = 36.0317 + 0.1712 \times \text{Elbow Angle} - 1.4505 \times \text{Backrest angle} - 0.2602 \times \text{eyespotsY} + 0.1767 \times \text{Left knee Angle} - 0.2648 \times \text{height} + 0.1817 \times \text{HipZ}, R^2 = 0.831464181. \]

Female:
Height-weight ratio≈28.5317+0.182*Elbow Angle-1.4805*Backrest angle-0.2602*eyespotsY+0.1767*Left knee Angle-0.0248*height+0.1877*HipZ,R²=0.822803916.

4.4 Model Validation
In order to verify the validity of the model, the data of 5 subjects were selected for error analysis (their data were not included in regression statistics). Data comparison conditions are shown in Table 3.

| Variable                  | Maximum difference | Minimum difference | Average difference |
|---------------------------|--------------------|--------------------|-------------------|
| HipZ(mm)                  | 7.26               | 0.44               | 3.43              |
| HipX(mm)                  | 16.40              | 1.78               | 10.29             |
| Trunk thighs(°)           | 1.00               | 0.18               | 0.70              |
| Knee Angle(°)             | 2.40               | 0.40               | 1.10              |
| Lower limb length(mm)     | 30.61              | 10.83              | 19.65             |
| eyespotsZ(mm)             | 17.54(20.04)       | 1.43(2.90)         | 5.42(9.86)        |
| eyespotsY(mm)             | 4.00               | 0.55               | 2.37              |
| Sitting shoulder high(mm) | 17.84(21.10)       | 6.48(2.27)         | 9.13(10.95)       |
| Elbow Angle(°)            | 8.60               | 0.50               | 4.36              |
| height of eye(mm)         | 30.68              | 7.56               | 20.80             |
| height(mm)                | 14.62              | 0.490              | 6.42              |
| weight(kg)                | 4.20               | 2.120              | 3.59              |

4.5 Error cause analysis

4.5.1 Uncertainty of Postural Selection Behavior. The same person in the same driving environment may choose different seat positions or different body tilt Angle and other driving posture state, and when in an unfamiliar driving environment, the driving state of the driver may be different. These can lead to changes in the position of the eyes and individual joints, which in turn influence predictions of height and weight.

4.5.2 Experimental Data Errors. One is the experimental error caused by data measurement in the experimental process. The other is that the car was in a static state during the experiment, lacking the dynamic and real road conditions, resulting in the arbitrariness of the driver's posture choice. At the same time, the driver's clothing state, shoes are likely to affect the driver's posture state.
4.5.3. Individual Differences in Body Size. There are certain differences in the joint parts of each person's body, and the height ratio is different among people of the same height and people of different heights, and the body length of each person is not at the same percentile [4]. For example, a person whose height is in the 90th percentile has arm length in the 50th percentile.

5. Conclusion

5.1. Advantages and Value
The model can be used to effectively predict the postural state of drivers aged between 20 and 30 in the process of vehicle driving, and predict the personal characteristics of drivers according to the relevant debugging data. The model is applicable to the driving operating environment where the seat can move back and forth, the seat height is fixed and the Angle of the backrest Angle can be adjusted. It does not consider the driving situation where the driver uses additional seat cushion to increase the seat height. It can be effectively applied to the driving environment where the road condition is good and stable and the driving state changes are not significant. Compared with the traditional method of defining the size of human body by percentile model, it can effectively predict the posture state and personal characteristics of specific drivers. The prediction method and idea of the model have important reference value for the compact SUV similar to the experimental vehicle.

5.2. Weaknesses and Deficiencies
The model constructed in this study mainly focuses on the influence of adjustment variables of layout elements, such as seats and rearview mirrors, on driving state. Due to limited experimental equipment and conditions, other factors that may affect driving conditions, such as safety belts and overhead space height, were not considered. Relying on the statistical characteristics of the target driving group in statistics, only the young people between 20 and 30 years old are studied at present, and there is no corresponding research on other groups of different ages. Therefore, it is not suitable for people whose statistical characteristics differ greatly from that of the target driving group. Although this study has simulated and verified five experimenters, more experimental data are needed to support the numerical simulation of drivers' personal characteristics. At the same time, there are still some limitations in the practical application of this model, such as the motion state of drivers in normal driving, which needs further study. This model is only applicable to the static driving posture under the driving comfort state, but driving is an extremely complex state of motion. In the actual operation process, the convenience and comfort of the dynamic process such as shifting operation should be considered, and a large number of experiments should be verified and verified for specific use. In addition, the prediction effect of the experimental model needs to be further improved and evaluated. Considering whether there are other uncertain factors not taken into account, such as experimental errors caused by shoes and clothes, more attempts should be made to use this software to simulate the physical characteristics of drivers in traffic accidents on site.

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