# Passenger Car' Sitting Posture Prediction Research

Lipeng Qin(✉), Peiwen Zuo, and Hui Lv

China Auto Information Technology Co., Ltd., Tianjin, China
632410058@qq.com

**Abstract.** Sitting posture as the input of the design of Automobile seat face, makes a huge effect on the overall seat comfort. The current software for sitting posture calculation is based on the SAE manikin and European driving habits for sitting, which is much different from the Chinese one. This paper firstly analyzes the key factors that affect the driving posture, and defines the input of the prediction model, and then predict the position of eye points and H point in different vehicles for different drivers, with the step-wise regression method. A inverse kinematic method is applied to solve the posture of torso, upper limbs and lower limbs to obtain the overall sitting posture. Finally, the accuracy of the model is verified by a comparison between the measured data and the predicted one.

**Keywords:** Sitting posture · Influencing factors · Stepwise regression · Inverse kinematics · Model optimization

## 1 Introduction

Driving posture definition is the key for automotive seat design. After the interior layout is finished, the digital human model is used to define the driving angles, based on which, the supporting forces of the seat cushion and back are designed, and the seat foam then can be designed. Therefore, the accurate posture definition is crucial to the overall seat comfort.

The sitting posture is not only influenced by the anthropometry, but also is directly related with the driving habits in different countries [1]. A significant difference between the Chinese anthropometry and the European and American ones exists, which leads to a big discrepancy also, therefore, it is necessary to establish the driving posture prediction model based on the Chinese anthropometry.

This paper builds the sitting posture prediction model based the Chinese anthropometry, using stepwise regression and inverse kinematics methods [2–4], and realizes the purpose that predict sitting postures of different drivers in different seats, which also could provide automobile engineers the posture defining and checking tools.


S. Long and B. S. Dhillon (Eds.): MMESE 2022, LNEE 941, pp. 67–72, 2023.
https://doi.org/10.1007/978-981-19-4786-5_10

## 2 Experimental Scheme

The stratified sampling is used to recruit 1800 drivers from 6 cities of China, in which female subjects are 1/3 of the male ones, and their ages are in uniform distribution among 20–60.

There are 3 passenger cars for measuring, which are coded as A, B and C. Every subject's sitting postures in 3 cars are measured respectively, in order to research on the posture difference among drivers in different cars, as Fig. 1(a) shows [5].

(a) Posture scanning cameras (b) Body markers distribution

**Fig. 1.** Posture scanning facility and body markers

The subjects enter the car's driving position after their bodies are marked with reflective makers, just as Fig. 2(b) shows. They are guided to adjust seat to the most comfortable status in their mind, after that, subjects' sitting postures are measured and recorded, as Table 1 shows.

**Table 1.** Sitting posture angles list

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
|---|---|---|---|---|---|---|---|---|
| Torso angle | Hip angle | Knee angle | Ankle angle | Upper arm angle | Elbow angle | Wrist angle | Heel angle | Thigh angle |

## 3 Posture Influencing Factors

This paper explores impact from gender and vehicle to sitting postures using repeated measures ANOVA. The Bonferroni correction is adopted to make multiple comparisons among different factors to investigate the simple main effect if interaction effect exists between the two factors. Effects are considered as "significant" when $p < 0.05$.

The stepwise regression model is used to explore the relationships between the postural data and the age and anthropometric measurements. Define the entry and removal of using probability of F as 0.05 and 0.1 respectively. The analysis finds that gender and vehicle both have a significant effect on the posture [5].

The stepwise regression analysis between the posture angles and anthropometry and gender needs to standardize all three types data, and results are demonstrated as Table 2.

**Table 2.** Stepwise regression results

| Vehicle | Factors | Postural angles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
| A | AGE | 0 | −0.082 | 0.072 | 0 | 0 | 0 | 0 | 0 | 0.043 |
| | Stature | 0 | −0.535 | 0 | −0.133 | 0 | 0 | 0 | 0 | 0.614 |
| | WEI | −0.205 | −0.116 | 0 | 0.105 | 0.134 | 0 | −0.085 | 0.023 | 0 |
| | SH | 0.065 | 0.133 | 0.063 | 0 | 0.127 | 0.26 | −0.117 | 0 | −0.213 |
| | TRH | 0 | 0 | −0.252 | 0 | 0 | −0.06 | 0.104 | 0 | 0 |
| | SAH | 0 | 0.086 | 0 | 0 | 0 | 0.102 | −0.132 | 0 | 0 |
| | ATO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | AGE | 0 | 0 | 0 | 0.055 | 0 | 0 | −0.054 | 0 | 0 |
| | Stature | 0.287 | −0.259 | 0 | 0 | 0 | 0.211 | 0 | 0 | 0.543 |
| | WEI | −0.296 | −0.142 | 0.097 | 0 | 0.147 | 0 | −0.107 | 0 | −0.07 |
| | SH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | TRH | −0.139 | −0.117 | −0.256 | 0 | 0 | −0.149 | 0 | 0 | 0 |
| | SAH | 0 | 0.089 | 0.066 | 0 | 0.088 | 0.242 | −0.13 | 0.105 | −0.112 |
| | ATO | 0 | 0 | 0 | 0 | 0 | −0.08 | 0 | 0 | 0.075 |
| C | AGE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.105 | 0 |
| | Stature | −0.019 | −0.401 | 0 | −0.221 | 0 | 0 | 0 | 0 | 0.539 |
| | WEI | −0.284 | −0.134 | 0.075 | 0 | 0.167 | 0 | −0.071 | −0.148 | −0.07 |
| | SH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | TRH | 0 | 0 | −0.114 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SAH | 0 | 0.109 | 0 | 0.114 | 0.071 | 0.142 | −0.113 | 0 | −0.133 |
| | ATO | 0 | 0 | −0.097 | 0 | 0 | 0 | 0 | 0 | 0 |

The anthropometric measurements include: stature, weight (WEI), sitting height (SST), trochanter height (TRH), sitting acromion height (SAH), acromion to olecranon length (ATO).

Table 2 tells that Stature, WEI, SH, SAH and also vehicle are the main factors influencing postural angles, which are selected as the inputs to the prediction model.

## 4 Posture Prediction Model

Driver's anthropometry, seat parameters and vehicle layout make effects on the postures, which are taken as input to the model, as Fig. 2 shows.

Simplification is done to the prediction model to reduce the calculation complexity. The three-dimensional human model is simplified as the two-dimensional one, considering that sitting posture mainly indicates the joint angles. Also, it is deemed that normal driving posture is sagittally symmetric, and hands are assumed to be continuous with the forearms, and foot posture is neglected. The coordinate is simplified as x-z plane without y axis, as only the two-dimensional driving posture is concerned.

The eye and H point location regression equations are as Table 3 shows.

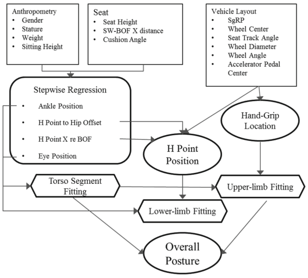


**Fig. 2.** Posture prediction model schematic diagram [1]

**Table 3.** Posture regression equation

| Variables | Stature | Sitting height | H30 | SW-BOFX | Cushion angle | Adjusted $R^2$ | RMSE |
|---|---|---|---|---|---|---|---|
| Hip X re BOF | 0.4701 | −429.8 | −0.173 | 0.4511 | −1.04 | 0.67 | 36.3 |
| Hip-to-eye angle | 0.00638 | | 115.73 | 0.0188 | 0.11 | 0.21 | 4.4 |
| Eye X re BOF | 0.5758 | 913.4 | −0.1514 | 0.5847 | | 0.71 | 51.1 |
| Eye Z re AHP | 0.3134 | 615.7 | 1.04 | 0.0288 | | 0.79 | 22.3 |
| Eye X re hip | 0.1177 | 1350.2 | | 0.155 | 1.22 | 0.31 | 37.9 |
| Eye Z re hip | 0.3324 | 665.4 | | −0.0221 | | 0.57 | 25.7 |
| Ankle X re BOF | 0.06 | 458.1 | 0.175 | 0.147 | 1.5 | 0.28 | 20.3 |
| Ankle Y re A pedal | −0.047 | | | | | 0.11 | 25.4 |
| Ankle Z re AHP | 0.0341 | | 0.1312 | | 0.47 | 0.21 | 18.4 |
| Knee angle | −0.0066 | 57.3 | −0.0341 | 0.0785 | −0.61 | 0.34 | 10.2 |
| Head angle | 0.00922 | 141.5 | | | | 0.04 | 12.3 |
| Neck angle | −0.01214 | | 0.0114 | | | 0.05 | 11.2 |
| Thorax angle | 0.01214 | 46.1 | | 0.00998 | | 0.04 | 8.2 |
| Abdomen angle | 0.011 | 190.5 | | 0.0314 | | 0.11 | 8.5 |
| Pelvis angle | 0.0112 | 101.2 | | 0.0181 | 0.41 | 0.05 | 11.4 |

The upper extremity and lower limb fitting are calculated using inverse kinematic method after the hip and eye locations are obtained. This paper solve the inverse kinematic with MATLAB Robotics toolbox.

The postural data of a female subject and a male subject are collected respectively to verify the model accuracy. The measured and predicted results are shown in Table 4.

**Table 4.** Comparison of measured and predicted results

| Posture | Subject | | | | | |
|---|---|---|---|---|---|---|
| | Male | | | Female | | |
| | Measured | Predicted | Error | Measured | Predicted | Error |
| Torso angle | 23.755 | 22.566 | 5.01% | 18.8326 | 19.411 | 3.07% |
| Hip angle | 101.254 | 106.78 | 5.46% | 95.6201 | 104.36 | 9.14% |
| Knee angle | 113.33 | 112.554 | 0.68% | 109.09 | 110.22 | 1.04% |
| Forearm angle | 19.4491 | 22.563 | 16.01% | 56.4071 | 61.47 | 8.98% |
| Elbow angle | 108.362 | 112.45 | 3.77% | 143.651 | 147.225 | 2.49% |
| Thigh angle | 12.2552 | 13.41 | 9.42% | 11.0793 | 12.177 | 9.91% |

The comparison results show that all the posture prediction error are all below 10% except for the male forearm posture.

## 5 Conclusion

It is found that driver's characteristics, vehicle design make a significant effect on the sitting posture. Take the identified effect factors as inputs to the model to predict eye, hip location, upper and lower limb fitting.

A comparison concludes that the model could predict Chinese driver's sitting postures well except the male forearm's error exceeds 10%.

The study was approved by the Logistics Department for Civilian Ethics Committee of China.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

**Compliance with Ethical Standards.** The study was approved by the Logistics Department for Civilian Ethics Committee of China Auto Information Technology Co., Ltd.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

## References


1. Reed, M.P., et al.: Comparison of methods for predicting automobile driver posture. In: Digital Human Modeling for Design and Engineering Conference and Exposition, Dearborn, Michigan (2000)
2. Beck, D.J., Chaffin, D.B.: Evaluation of inverse kinematic models for posture prediction. In: Proceedings of the International Conference on Computer Aided Ergonomics and Safety - CAES 1992, May 18–20, pp. 329 (1992)
3. Zhang, X., Chaffin, D.B.: Task effects on three-dimensional dynamic postures during seated reaching movements: an analysis method and illustration. In: Proceedings of the 1996 40th AnnuaI Meeting of the Human Factors and Ergonomics Society, PhiladeIphia, PA, Part1, vol. 1, pp. 594–598 (1996)
4. Faraway, J.J., Zhang, X.D., Chaffin, D.B.: Rectifying postures reconstructed from joint angles to meet constraints. J. Biomech. **32**, 733–736 (1999)
5. You, J., Qin, L., Zuo, P., Wang, X., Zhang, C.: Chinese drivers' preferred posture for sedans' seat ergonomic design. In: Long, S., Dhillon, B.S. (eds.) MMESE 2020. LNEE, vol. 645, pp. 23–32. Springer, Singapore (2020). https://doi.org/10.1007/978-981-15-6978-4_3