The Research on Layout and Simulation of Human-Machine Interface in Vehicle

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Abstract. In this paper, we analyzed the connotation of hip point, related ergonomics theories and industrial standard. Based on these analysis and hip point, this research outlined of man-machine relationships of operating device layout design in vehicle cab for improving safety, efficiency and comfort of the driver's operation. Moreover, we designed a simulation environment to analyze vehicle interface. With the development of the automobile industry and the maturity of the related technologies, the popularity of the automobile is more and more extensive. It is necessary to start designing from the perspective of "people oriented".

Keywords: Ergonomics · Hip point · Layout design · JACK simulation

1 Introduction

Ergonomics is a science that studies the interaction of human beings with other components of the system. Through its theories, principles and methods, we can optimize system efficiency, meet human's physiological and psychological characteristics. At the same time, it is necessary to study the relationship between human and the environment, so ergonomics is the basis of humanized design (Table 1).

Among these principles, we regard human safety and health as our primary goals. In general, there is exchange and interaction of information, material and energy between people and machines [1]. In the man-machine system, the man-machine interface plays a role of connecting the machine and the human which is the hub of information exchange. The relationship between the two can be seen from Fig. 1.

The layout of the cab is a key step in the process of car design, which directly affects the safety and comfort of the car. However, there are still methodological and technical difficulties in cab layout. With the improvement of automobile electrical degree, the car cab integrated LCD instrument, head-up display, central control screen and seat entertainment system, it enhances the driving experience. Therefore, the layout design play a very important role in the car design. At present, enterprises attach great importance to the application of ergonomics in the process of automobile development. Under the environment of intelligent manufacturing and people oriented, ergonomics promote the intelligent development of automobile interaction.

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Table 1. The design principles of ergonomics

Happiness	System effectiveness
Safety	Effectiveness
Healthy	Efficiency
Comfort	Reliability
User experience	

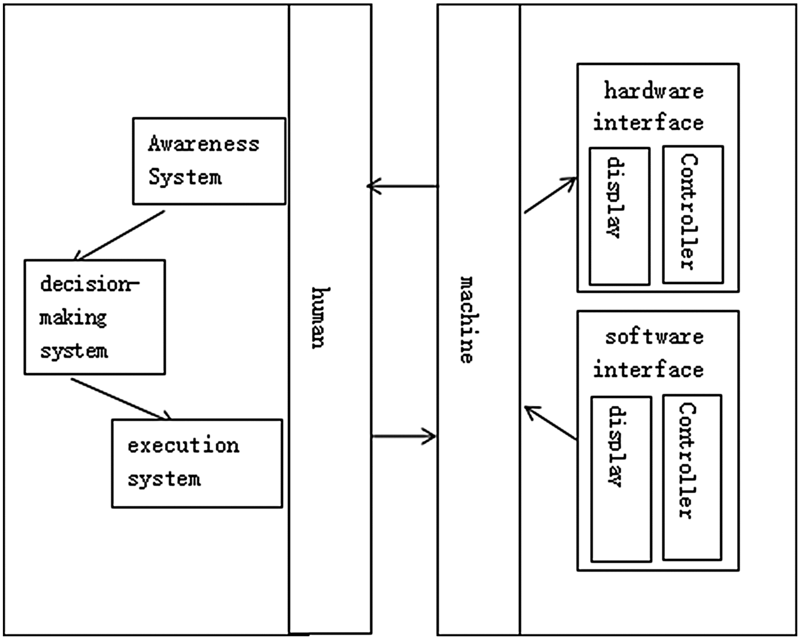

Fig. 1. The relationship between man-machine interface and human

The layout of the car cab should follow the following principles:

Based on above principles, considering the factors such as ride comfort, operation safety and SAE standard, it can be used to complete cab layout design combined with the digital simulation software (Table 2).

Table 2. The principle of cab layout

Ride comfort
Maneuverability
Vision
Convenience and safety
Relevant laws

JACK is an efficient software tool for crew simulation and automotive engineering design. 3D parametric human provided by the software [2] can be used in vehicle layout design and simulate the behavior of the driver. In order to avoid repeated changes in the design of the later stage, we can use it to do many ergonomics analysis in the early stage.

Based on the application of ergonomics in the layout of the car cab, this paper discussed the layout method for the car cab combining with the theory of ergonomics and tools of layout analysis, and provided a practical engineering case by JACK software [3].

2 Method

The Software simulation is based on the hip point and three ergonomics analysis tools [4], in which include visibility, accessibility and comfort analysis. The order of use of these tools is as shown (Fig. 2).

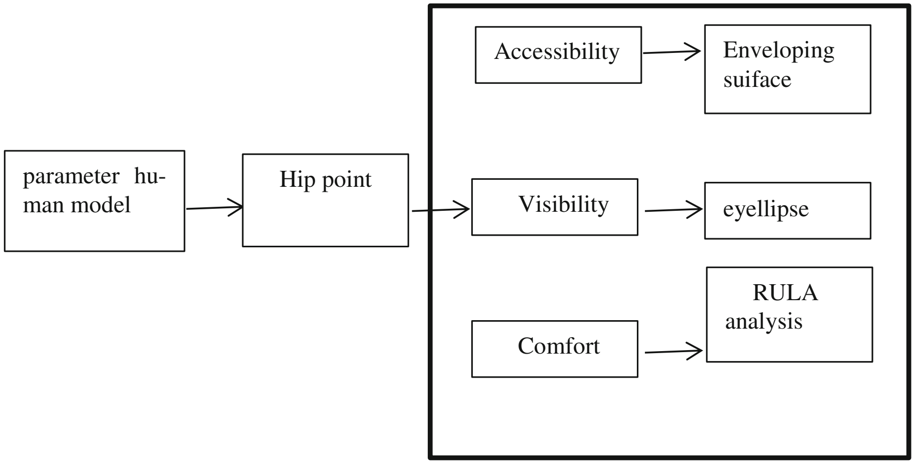

Fig. 2. Structure of ergonomics

2.1 Ergonomics Tools

Parameter Human Model

Parameter human model is an effective tool to describe human morphological and mechanical characteristics [5]. In the human-machine system, it is an necessary carrier for research, analysis and evaluation.

In this paper, we built 3D parameter human model through JACK software to check the ride comfort, the rationality of the layout of the pedal, the steering wheel, the seat and so on. Moreover, we made the motion simulation by driving the joints of the model (Fig. 3).

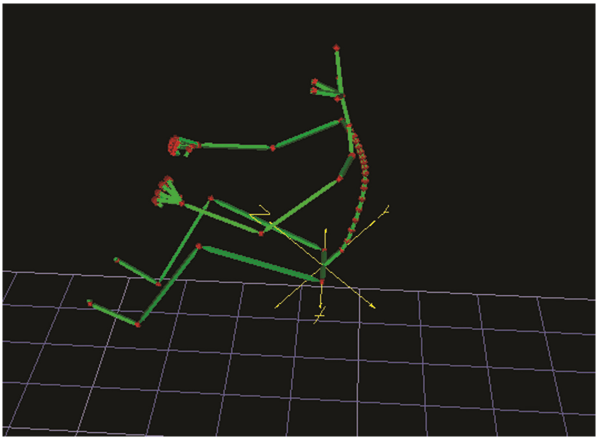

Fig. 3. The skeleton of 3D parameter human model

Hip Point

The hip-point is the theoretical, relative location of an occupant's hip: specifically the pivot point between the torso and upper leg portions of the body-as used in the cab layout design and vehicle regulation [6]. Hip point is the reference for evaluation of the car cab layout. The expression of hip points depends on the application, which mainly includes the actual-hip-points and the design-hip-points [7].

The H-point can be measured relative to other features, e.g. hip point to vehicle floor (H30) or hip point to pavement (H5). In other words, a vehicle said to have an hip point that is "high" relative to the vehicle floor, or road surface (Fig. 4). This method is called SAE Fit Line [8].

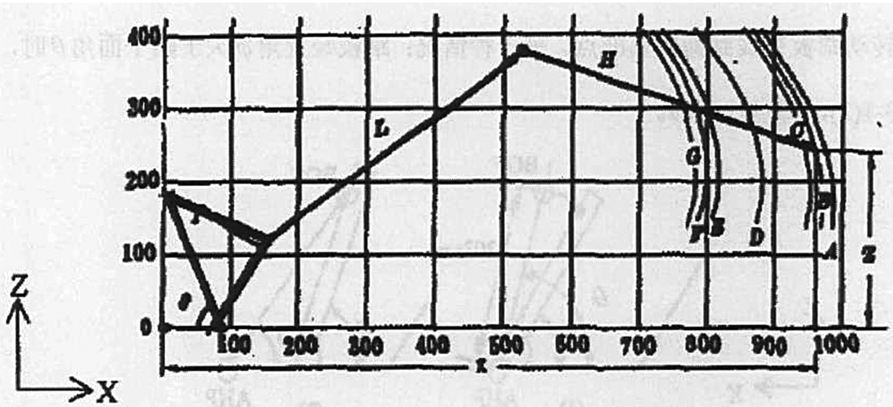

Fig. 4. Hip point position curve

There are 7 curves drawn by different percentile drivers in their respective driving position from a group of 2.5 percentile body to 97.5 percentile body.

$$X_{97.5} = 936.6 + 0.613879Z - 0.00186247Z^2$$
$$X_{95.} = 913.7 + 0.672316Z - 0.00195530Z^2$$
$$X_{90} = 885.0 + 0.735374Z - 0.00201650Z^2$$
$$X_{50} = 793.7 + 0.903387Z - 0.00225518Z^2$$
$$X_{10} = 715.9 + 0.968793Z - 0.00228674Z^2$$
$$X_5 = 692.6 + 0.981427Z - 0.00226230Z^2$$
$$X_{2.5} = 687.1 + 0.895336Z - 0.00210494Z^2$$

Eyellipse

Due to the input of visual information is more than 80% when driving, it should be ensured that the visual field is good. Eye ellipse is an elliptical distribution of the probability statistics of the coordinates of the position of the eye which takes elliptical distribution [9]. It is the main tool for visibility analysis that describe the position of the eye relative to the vehicle's interior reference point in field of cab layout (Fig. 5).

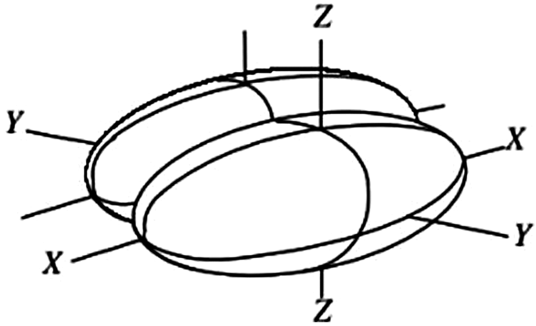

Fig. 5. Example of eyellipse

SAE standard gives two kinds of eyellipse size correspond to ninety-fifth and ninety-ninth percentile human body. One is when the horizontal adjustment stroke (L23) is in the range of 100–133 mm, one is when L23 is larger than 133 mm (Table 3).

Table 3. SAE eye ellipse size

Unit (mm)		95 percentile human body		99 percentile human body	
		100 < L23 < 133	L23 > 133	100 < L23 < 133	L23 > 133
Long axis		173	198	241	267
Short axis	Over head	105	105	149	149
	Side view	86	86	122	122

Enveloping Surface

The design of the car's indoor driving space is to be completed after ensuring ride comfort, visibility and accessibility, reasonable interior design makes driving experience safer and more comfortable. The main contents of the design of automotive interior space include hand space, head space before and after, knee space, abdomen space and leg space [10]. The main tools for the cab layout based on the human body parametric model include: human feature points, head envelope surface, around the lap envelope and abdomen envelope surface. Human body feature points are the locus of human joints and organs related to body layout, such as the head, eyes, abdomen, knee, hip feature points. The location of these feature points on the body in the car interior coordinate system can be determined by the driver's actual position after seating according to his wishes which are measured by photographic method. The connection of all the points in space has formed the human body characteristics distribution graph of different percentile men and women which is shown in Fig. 6.

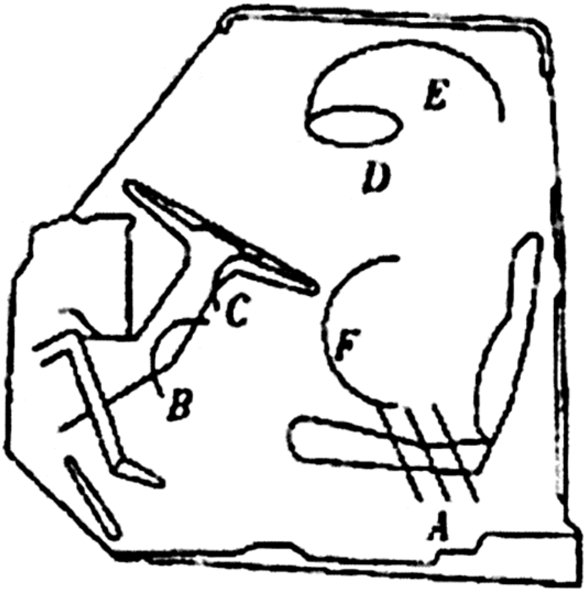

Fig. 6. Example of eyellipse

Notes A is the position line of hip point.
B, C is the knee envelope of left and right
D is the eye ellipse of driver
E is the head envelope
F is the abdomen envelope

Cab space design also includes all spatial layout design of components that may create constraints on the body's activities, such as space between arm and door guard, crew foot activity space design etc.

3 Discussion

3.1 Stage 1: Modeling and Positioning

First, we completed the modeling of the human body and the cab, which was the premise of visibility, accessibility and comfort analysis. During the process of modeling by JACK, we chose the database of Chinese to create the Chinese human body model and constructed the human body through 26 variables. As shown in the table, these variables could define a human body model (Table 4).

Table 4. 26 types of human body parameters in JACK

Stature	Hand length
Abdominal depth	Head breadth
Ankle height	Head height
Acromion height	Head length
Arm length	Hip breadth
Biacromial breadth	Interpupil distance
Bideltoid breadth	Shoulder elbow length
Buttock knee length	Sitting acromial height
Elbow rest height	Sitting eye height
Elbow-fingertip	Seated height
Foot breadth	Sitting knee height
Foot length	Length thigh clearance
Hand breadth	Thumbtip reach

After defining the size of the human model, we worked on creating and locating the driving attitude through driving the movement of each joint. In order to call directly, we saved the driving attitude to the database. At last, we imported the car CAD and bound it to the human model. As shown in the Fig. 7, we finished the modeling of the car cab and the driver.

3.2 Stage 2: Accessibility Check

When it came to accessibility check, we used the packaging guidelines (Automobile Design Guide) function provided by JACK software to verify the following aspects: push button max reach zone; three finger max reach zone; grasp max reach zone; wiper; shift area and thumb reach. The standard of inspection was the 5% female and 95% male human body model could meet the accessibility conditions.

Firstly, we ensured that the key components are within three reachable domains, which were the grasp maximum area, push button max reach zone; three finger max reach zone; grasp max reach zone; The radio and air conditioning knobs on the car must be controlled in this area. For example: Click Next > [Grasp Max Reach Zone] (the largest grab area), and the generated area was displayed on the screen in the form of curved boundary. As shown in Fig. 8, we could see the boundary surfaces.

Upon examination, we found that all buttons at the center console were in the push button max reach zone, hand brake, steering wheel, door handle and lever were in the grasp max reach zone.

Recently, with the increase of automobile functions, many functions such as driving mode switch buttons, shift paddles are integrated around the steering wheel to reduce the fatigue caused by frequent operation. Since JACK software doesn't give the accessibility criteria around the steering wheel, we reached a satisfactory solution.

Fig. 7. 3D driving model

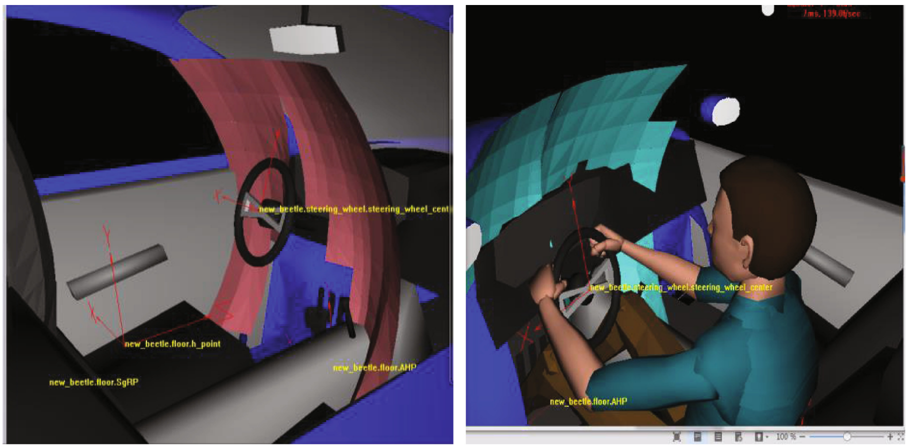

Fig. 8. Push button max reach zone and grasp maximum area

We simulated the position of our hands on the steering wheel by clicking the human control and manipulate function. and then, we generated reach zones including thumb domain and finger domain to check accessibility (Fig. 9).

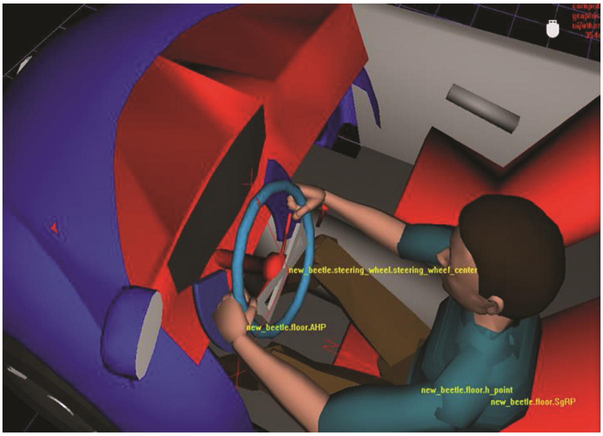

Fig. 9. Reach zones around steering wheel

3.3 Stage 3: Visibility Check

Visibility check is divided into two aspects

(1) Front view check

The front view includes the signal view, the view of the body barrier area, the bottom 30° view, and the wiper view.

(2) Rear view check

The rear view includes the inner mirror view and the side mirror view [11].

JACK's visibility field analysis tool was developed based on SAE eyellipse standard. Therefore, it can be directly applied to simulation without establishing visual simulation model.

In this paper, we used three functions including obscuration zones, reflection zones and packaging guidelines to calculate the scope of the vision field and finally the visibility check completed. As shown in the picture, there were results of visibility check about different checking item (Fig. 10).

3.4 Stage 4: Comfort Check

According to the driving conditions of the vehicle, driving comfort should include the following contents:

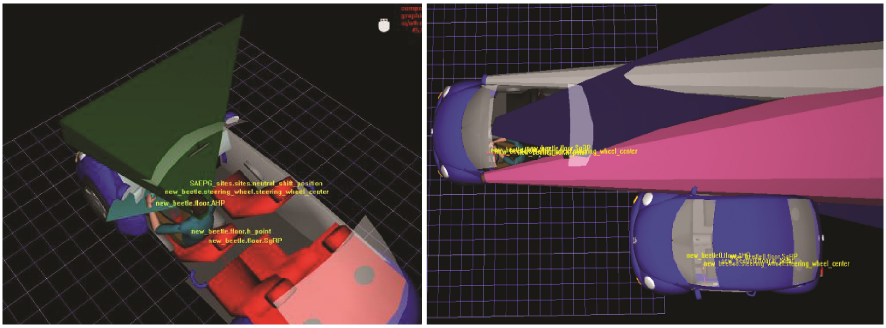

Fig. 10. Front view check and rear view check

(1) Static comfort: it refers to the influence of the seat on comfort related to the fit between the seat back and the human body when not considering the internal environment and the road condition of the vehicle.
(2) Dynamic comfort: it refers to the feeling of the driver when operating parts and interface interaction on comfort [12].

This was the process of comfort assessment:

Firstly, based on the data optimization algorithm, the most comfortable driving posture was quickly calculated by posture prediction module.

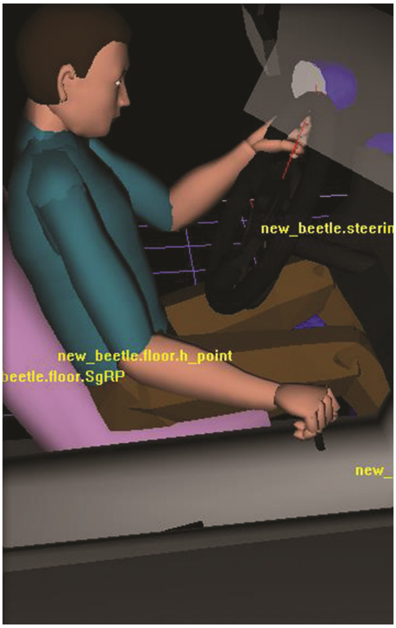

Fig. 11. Shift gesture

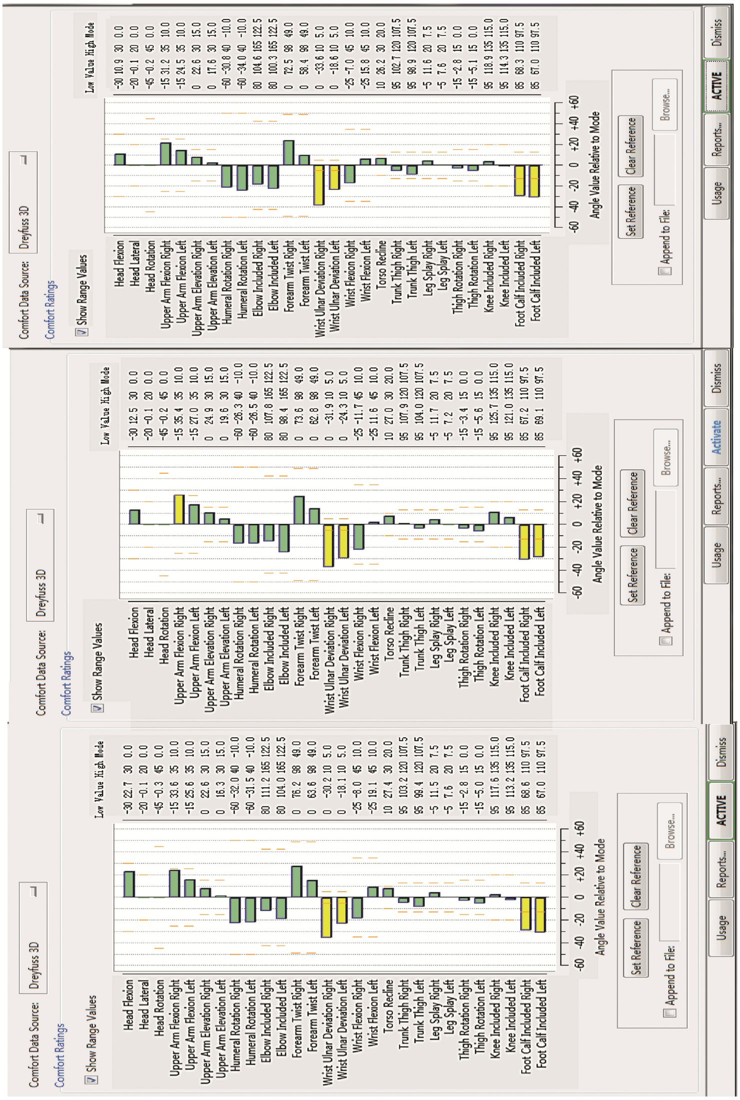

Fig. 12. Comfort evaluation results

Second stage, we established the driving operation gestures, including shifting, adjusting knobs, buttons, twisting and so on. For example, this picture showed shift gesture (Fig. 11).

Third stage, we achieved a comprehensive evaluation of comfort with comfort assessment module.

Finally, we got the comfort evaluation results (Fig. 12).

4 Conclusion

The main purpose of this paper is to study the layout of the cab based on ergonomics theory and JACK software. This paper is also the foundation for the future research of layout design in different kinds of vehicles.

In summary, the layout based on JACK could be a practical way to research the application of ergonomics theory in actual engineering. The main contents of this paper are as follows.

(1) According to ergonomics theory, we introduced three tools for accessibility check, visibility check and comfort check.
(2) Based on JACK software, we achieved cab layout analysis.

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