

Development of Driving Position CAD System Using Digital Human Model

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ABSTRACT

The design of automobile packages should generate products that accommodate the diverse body types of vehicle users. The use of digital human model (DHM) technology, which enables designers to more easily reproduce different body types on a computer, has recently become more widespread as a means of enabling this. Honda also employs DHM, but has attempted to produce more customer-oriented designs by analyzing driving position in terms of angles of joints and using the results of these analyses as the basis for evaluation of the operation of the driving position. As a result, the position of the DHM can be evaluated in terms of the angles of the joints, providing the foundation of a system in which the development of a package appropriate for a variety of body types can proceed simultaneously with design.

1. Introduction

Advances in body size measurement technology and computer technology have enabled the form and motion of the human body to be more accurately reproduced on a computer. Human factor analysis, which once required test subjects, can now be performed simply, quickly and objectively through simulations employing DHM.

A variety of approaches can be taken when using DHM technology, differing according to the purpose for which the technology is employed.

Experimental approach: The posture and motion of test subjects are measured, and the data obtained are used to construct a database. This approach enables posture and surface morphology to be more accurately reproduced.

Robotics engineering approach: The major methods employed in this approach are inverse kinematics and inverse dynamics. This approach enables dynamic motion to be reproduced on the basis of a limited amount of data.

Biomechanics approach: This approach enables simulation of the internal organs and muscles. The increased accuracy obtained through modeling the internal parts of the body makes this approach the one with the most promise for the future. The research described in this paper focused on

posture, and therefore employed a methodology drawn from the experimental approach. A number of software applications have been developed for DHM; this research uses RAMSIS, developed by the German manufacturer Human Solutions, GmbH.

A variety of different studies are required in the actual development process to determine driving position. Of these, examples of the application of RAMSIS have been selected for discussion in this paper. Figure 1 shows an example involving evaluation of the area around the knees and elbows. Here DHM of different body types are employed to

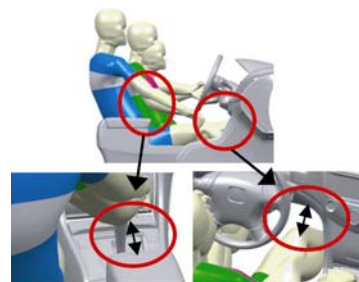


Fig. 1 Driving position evaluation

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measure the clearance between the knees and the lower cover and the elbows and the armrests in order to determine whether there is sufficient clearance to allow comfortable driving operations.

This makes it possible to evaluate whether there is enough clearance to shift gears and operate the pedals; however, it is currently not possible to evaluate ease of operation on the basis of the posture of the RAMSIS DHM. It was therefore necessary to focus on the formulation of indices to enable the quantitative evaluation of posture, and develop a technique employing RAMSIS to enable evaluation based on customer satisfaction.

2. Research Goals

The goal of this research was to use the results of analyses of driving postures and joint angles to formulate a quantitative evaluation system employing RAMSIS.

To commence the research, the factors regarding the driving position were abstracted, as shown in Fig. 2. The research focus was restricted to operation, with operation of the steering wheel and pedals becoming the major area of study.

3. Test Method

Figure 3 shows an outline of the test method. First, vehicle tests were conducted with test subjects to determine

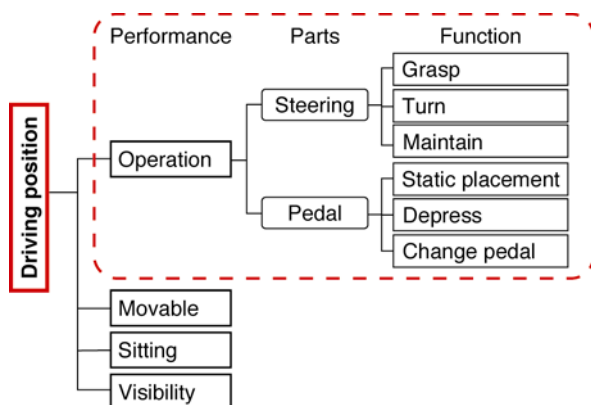


Fig. 2 Factor analysis of driving position

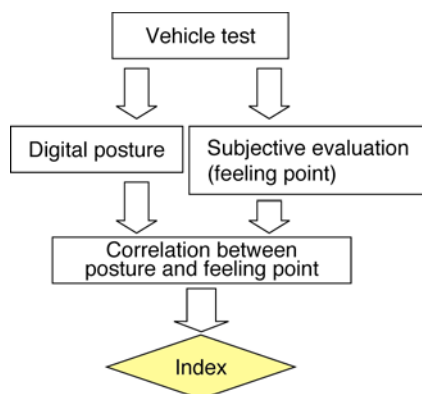


Fig. 3 Test flowchart

Table 1 Definition of 3 style posture

Posture	Definition
Comfort position	Each subject can freely establish driving posture
Forward position	Each subject moves to forward position which represents limit for driving
Rearward position	Each subject moves to rearward position which represents limit for driving

Table 2 Subjective evaluation

Rating	Evaluation
5	Excellent (Extremely comfortable)
4	Good
3	Acceptable
2	Barely acceptable
1	Not acceptable

posture and obtain subjective evaluations of the ease of operating the steering wheel and the pedals. Next, the sitting postures of the test subjects in the vehicles were reproduced on a test bench, and the angle of each joint of their bodies was measured using a technique enabling quantification of posture. Finally, indices were formulated by correlating subjective evaluation data with measurements of joint angles.

3.1. Vehicle Test Conditions

(1) Test subjects

24 males, mainly in their 30s, ranging from 160 to 190 cm in height

(2) Test vehicle

4-door sedan (AT)

(3) Postures for evaluation

Vehicle tests were conducted using each of three postures shown in Table 1.

(4) Test course

A course in the research facility representing an urban area was selected to enable normal driving postures to be reproduced.

3.2. Method of Subjective Evaluation

Subjective evaluation of ease of operation of the steering wheel and pedals in each of the three postures shown in Table 1 was based on the scale shown in Table 2. Test subjects were also interviewed to determine the posture which placed the maximum burden on their bodies during operation of the steering wheel and pedals.

3.3. Quantification of Posture

The sitting postures obtained from the driving tests were reproduced using a DP simulator, and the resulting joint angles were measured. Two cameras were employed to record each subject's driving posture from the front and the side, and the posture of each subject was quantified from the image data using specialized software⁽¹⁾. This data was imported into a CAD program, enabling the dimensions of each body, including joint angles (elbows, knees, ankles), to be measured. Figure 4 shows the flow of the quantification process from a photograph taken from the side.

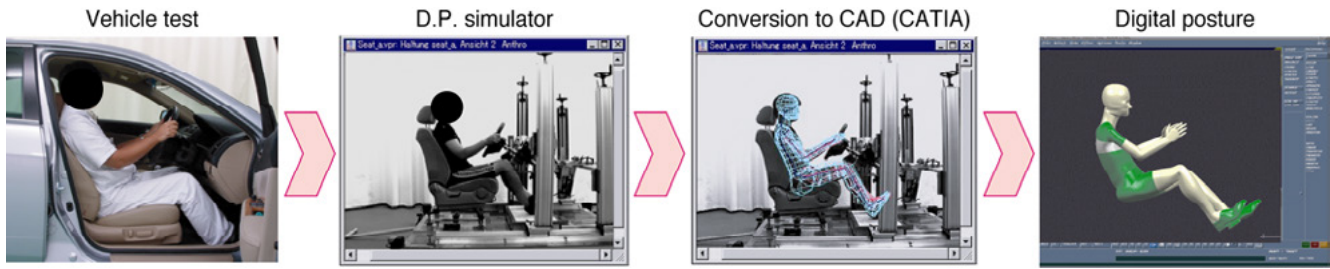


Fig. 4 Flowchart of digital posture simulation

4. Determining Areas of Focus

Subjective evaluations of the parts of the body which experienced the maximum burden during vehicle operation were used to abstract the parts of the body with the greatest effect on driving comfort in each of the driving positions employed. The results shown in Figs. 5 and 6 were obtained.

- (1) When operating the steering wheel, the angle of the elbows has the greatest effect.
- (2) When operating the pedals, the angle of the ankles has the greatest effect.

Analyses were therefore conducted focusing on the elbows and ankles.

5. Results of Analyses

The relation between height and elbow angle for each subject in the three driving positions was graphed using a regression line, with the results shown in Fig. 7. The relation between height and elbow angle was shown to be

proportional, with the angle decreasing with decreasing subject height. The reason for this is thought to be that shorter test subjects generally possess less muscular strength than taller subjects. It can be predicted that a smaller test subject will slide the seat forward to enable them to exert muscular strength more easily, and this reduces the distance between the steering wheel and their shoulders. As a result, when they grip the steering wheel, the angle of their elbows is therefore smaller than it would be for a taller driver.

The relation between ankle angle and height was graphed in the same way, producing the results shown in Fig. 8. Here, there is a slight inverse relationship between ankle angle and height in the rearward and forward positions, but the relation in the comfort position is basically constant. Ankle angle was therefore judged to be largely unrelated to height, and essentially constant.

This is thought to be because the movements made by the ankle in operating the pedals are small, and produce only a small muscular burden. Because this has no relation to relative muscular strength or weakness, the angle of the ankle

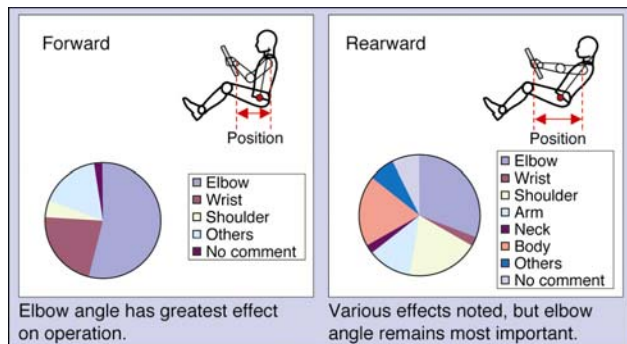


Fig. 5 Steering operation

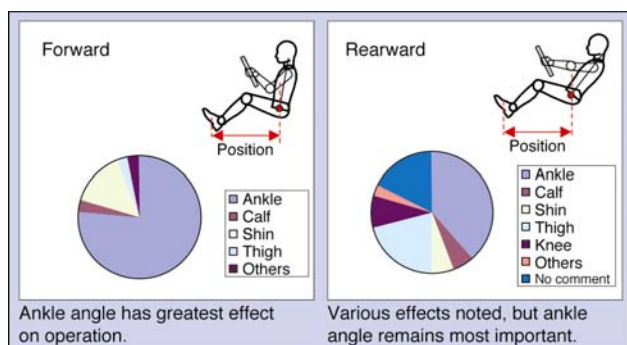


Fig. 6 Accelerator pedal operation

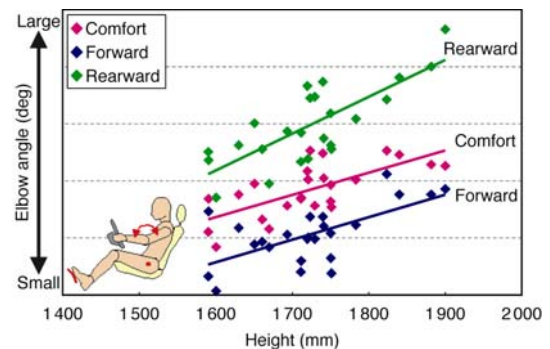


Fig. 7 Relation between elbow angle and height

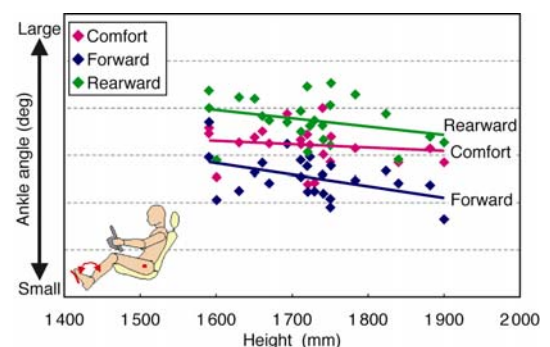


Fig. 8 Relation between right ankle angle and height

at which operation of the pedal is easiest is the same for drivers of different height. It is therefore constant no matter what physical type the driver can be classified as.

At the beginning of the study, it was predicted that subjective evaluations of the ease of operating the steering wheel and the pedals in the forward and rearward postures would cluster around the three-point rating (acceptable) level, but some test subjects recorded two- and one-point ratings (barely/not acceptable). The results from these test subjects were not usable to create indices as the data was originally compiled, and the study therefore continued as described in the next section.

6. Establishing Indices

6.1. Estimating Joint Angle (Acceptable Point)

Indices enabling evaluation of the ease of operating the steering wheel and the pedals were established on the basis of measurements of joint angles and subjective evaluations of ease of operation. Three-point rating evaluations were considered the acceptable point for indices, and data for test subjects recording one- and two-point evaluations were therefore corrected. A graph of the subjective evaluations of each test subject in each of the three test positions and the angle of their joints in each position was formulated to enable this correction. The subjects' joint angles at the three-point level (acceptable point) for forward and rearward postures were estimated from this graph. Figure 9 shows the method used to estimate the three-point level elbow angle for forward posture for one test subject.

6.2. Verification of Appropriateness of Estimated Joint Angle

A test of the appropriateness of the estimates of elbow and ankle angles was conducted with six of the test subjects. The D.P. simulator mentioned above was used to determine the three-point level joint angles for the test subjects, and they were asked to subjectively evaluate the ease of operation of the steering wheel and pedals in that position. Almost all the test subjects evaluated ease of operation at the estimated joint angles at the three-point level.

6.3. Indices of Operation

Figures 10 and 11 show, respectively, the indices of operation of the steering wheel and pedals formulated by obtaining joint angles at the three-point level, as described above.

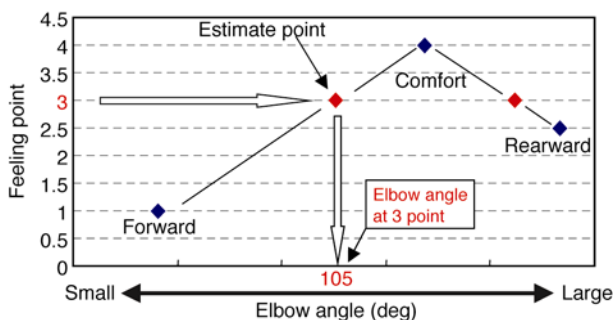


Fig. 9 Relation between elbow angle and feeling point

The following explanation will focus on Fig. 10, the index of steering wheel operation. The straight lines for "rearward" (green) and "forward" (blue) driving positions show three-point subjective evaluations of steering wheel operation for each posture.

The yellow area between these lines represents the recommended area for elbow angles enabling comfortable operation of the steering wheel. The ideal comfort angle is shown by the red line running approximately through the center of the yellow area. Driving posture should be as close as possible to this line. A RAMSIS simulation was conducted using data obtained from two mass-production vehicles, and elbow angles were plotted. The results showed that JM50 percentile and 95 percentile fell within the recommended area. These results are appropriate in consideration of marketplace evaluations.

The indices developed in this study were compared to another set of indices⁽²⁾ as a reference, and demonstrated the following characteristics:

- (1) The restriction of the evaluation zone against the other indices enabled more accurate evaluation of steering wheel operation.
- (2) Rigorous and wider range of evaluation was enabled by the fact that the newly developed indices make possible evaluation of comfort for individual body types.

The indices developed in this study can be used in the same way to enable the evaluation of the operation of the pedals.

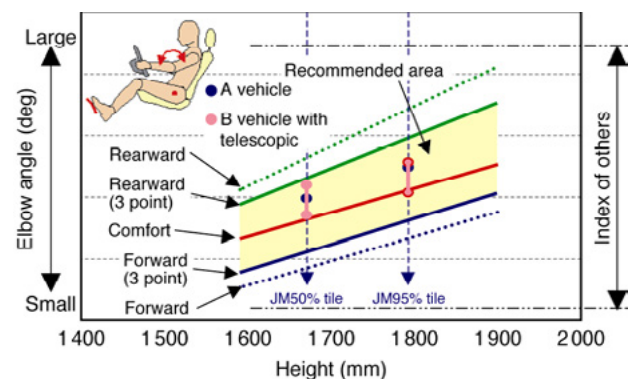


Fig. 10 Index of steering operation

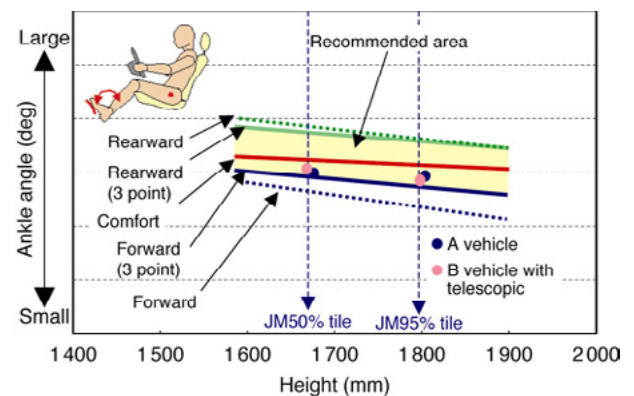


Fig. 11 Index of pedal operation

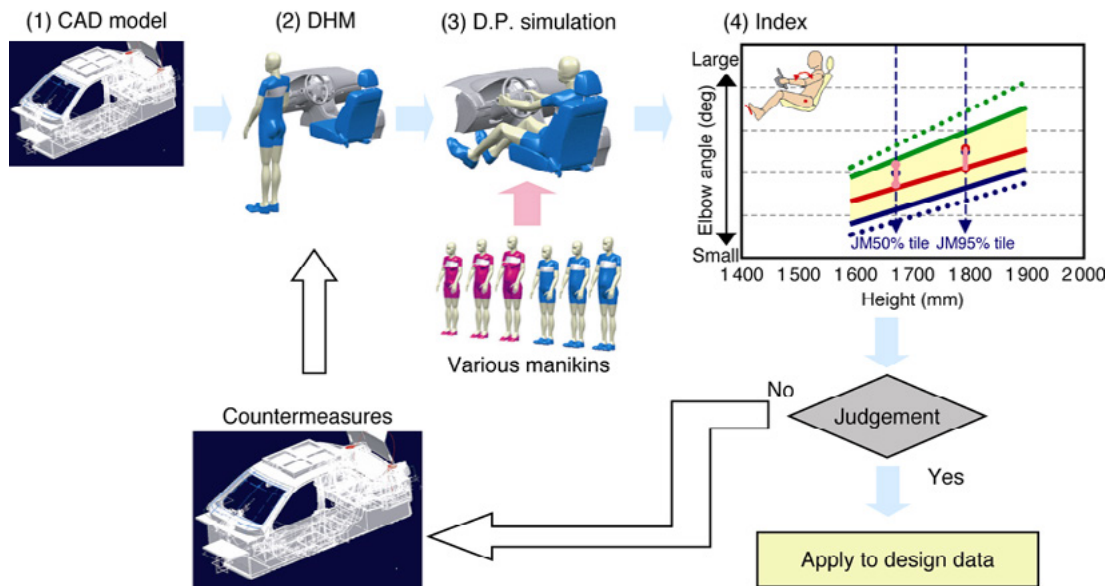


Fig. 12 D.P. evaluation system

7. Newly Developed System

Figure 12 shows the newly developed system employing RAMSIS.

- (1) The CAD model required for the simulation is formulated.
- (2) The parameters (height, seated height, etc.) necessary for selecting a body type from RAMSIS are input.
- (3) The RAMSIS model constructed in (2) is seated in the predetermined position.
- (4) Posture is evaluated using the newly developed indices.

Following the steps outlined above, the new system enables a human factor analysis to be conducted using CAD.

8. Conclusion

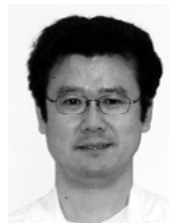
The research described in this paper developed indices to act as a foundation in the evaluation of driving position based on customer satisfaction. The newly developed system can be used as part of CAD from the earliest stages of development, enabling human factor analysis to proceed simultaneously with the production of designs.

The indices developed in this study were produced using Japanese males as test subjects. Future research will be required to determine the applicability of these indices to Japanese women and to men and women of different ethnicities.

References

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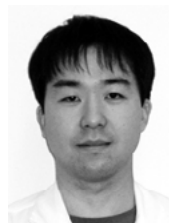
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