AN EXPERIMENTAL SETUP TO PARAMETERIZE AND SIMULATE UPHOLSTERED SEATS

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The increasing number of 3D-CAD-systems integrating computer based man models make it possible to evaluate the design of the man machine interface in an early state. The interaction of human and seat is not simulated in a satisfying way yet due to the extreme complexity of the task. At the Lehrstuhl für Ergonomie, Technische Universität München an experimental setup has been developed to investigate this interaction systematically. With the help of this setup upholstered seats can be parameterized by their spring characteristics and geometry to be simulated as physical representation of the seat with the same setup. Pressure distributions and deflection profiles can be measured with integrated sensors. The simulated seat also provides the possibility to vary the seat characteristics systematically. The experimental setup consists of two cushion units, adjustable in size and angle. Each unit consists of 9 by 9 adjustable positioning units, technically realized as programmable springs. Tests with selected positioning units have shown that the accuracy of positioning, as well as the accuracy of the measured and simulated spring characteristics is sufficient. Existing seat cushions have been simulated. Based on mathematical indices the similarity of measured pressure distributions on the simulated cushions and the corresponding seats were compared. Based on this results it can be stated that the characteristics of real seats can be simulated with sufficient accuracy. So it is possible to use the experimental setup as a tool to gain the necessary data to model the interaction between the human body and upholstered seats. Further research is going to be performed on the modeling according to the physical parameters geometry and spring characteristics of the seat as well as the pressure distribution and deflection profiles caused by the subjects interacting with the seat.

PREFACE

In contrast to nature human designed for dynamic activities became more and more a ‚homo sedens', the sitting human. Due to the growing part of activities performed in seated posture during working and spare time a large variety of illnesses results.
Therefore, the ergonomic design of seated workplaces has become a more and more important issue in the field of ergonomics. For these purposes an increasing number of computer based human models are used in seated workplace design. The major drawback of these models is that the most important part of the simulation, the interaction between human and seat, is realized by rudiment algorithms or interactive procedures for positioning by the user.
At the Lehrstuhl für Ergonomie the man model RAMSIS has been developed for ergonomic evaluations, mainly in car interiors. The positioning in relation to the driver seat is realized by a defined offset vector between the SAE-Reference point of the seat and the H-Point of RAMSIS determined in special experiments with test subjects for each seat. This positioning procedure for getting the driving posture neither has regard to surface geometry nor to the physical properties of the upholstery. Also questions regarding the influence of different angles of the cushions to each other could not be answered.

A MODEL DESCRIBING THE INTERACTION BETWEEN HUMAN AND SEAT

Major goal of research is a model to describe the interaction between human and seat for the man-model RAMSIS. Due to the fact that a holistic view of this interaction is an extreme complex system with a great number of parameters influencing each other, a reasonable abstraction has to take place.
In this simplification the main parameters for the model are the physical parameters geometry and spring characteristics of the seat as well as the resulting pressure distributions and deflection profiles caused by humans on seats (Figure 1). To measure the necessary data system-consistent a special research chair (Figure 2) has been developed at the Lehrstuhl für Ergonomie.
A test stand was built with an experimental chair as the main component. This experimental chair makes it possible to vary systematically the affecting parameters of the seating behavior. To adjust the geometry and the spring characteristics of the test seat in such a way that it is rated by subjects like a genuine cushion a seat measuring system is assigned to characterize upholstered seats. So it is possible to realize this parameters (e. g. spring constants, main dimensions) at the test stand and use them later as an input for a prognosis model.

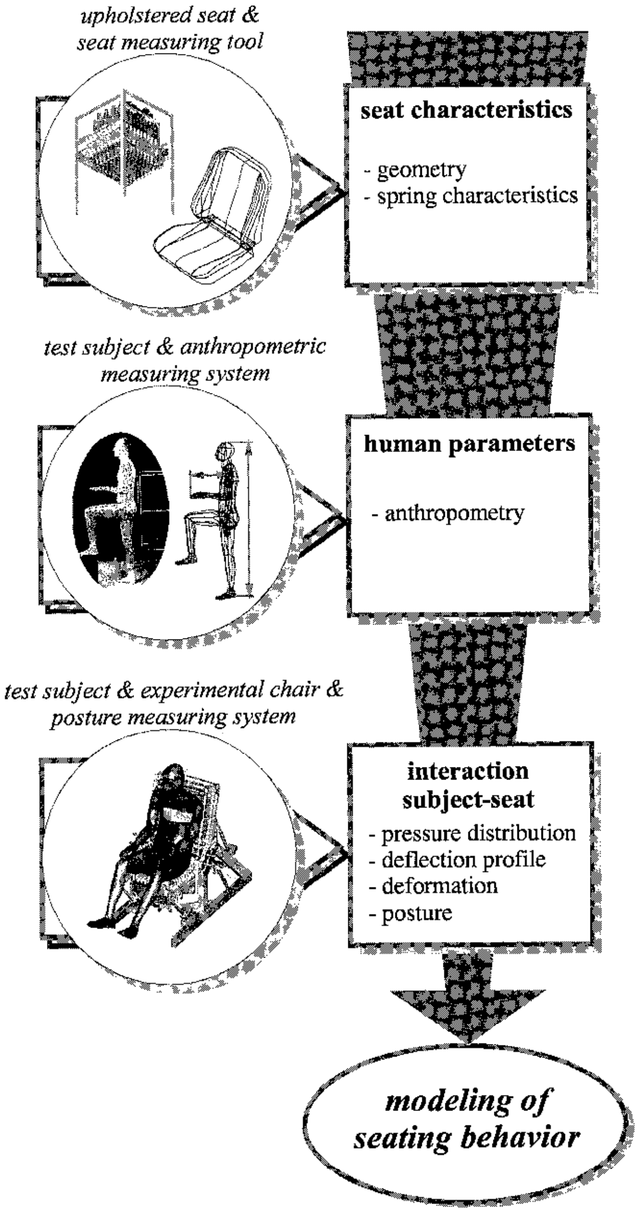

Figure 1: Concept of research

EXPERIMENTAL SETUP

The modules of the experimental chair consist of the components frame, two cushion units, controlling and measuring electronics, and controlling software. The measures and range of positioning were selected based on the anthropometric measures of the 5 percentile woman and an estimated maximum cushion size of 550 x 550 mm for the seat and 550 x 650 mm for the backrest. The aim is to simulate a cushion surface with a maximum level difference of 60 mm without load, respectively to measure such a cushion.

Mechanical components

Basic mechanical elements of the research chair are two cushion units fixed at a frame, which provides the possibility to adjust the angle between the cushion units from 70 to 130 degree using electric motors. The angle of seat cushion can be altered 5 degrees down and 20 degrees up from horizontal. The backrest cushion can be lowered 45 degrees back from vertical. (Figure 2)

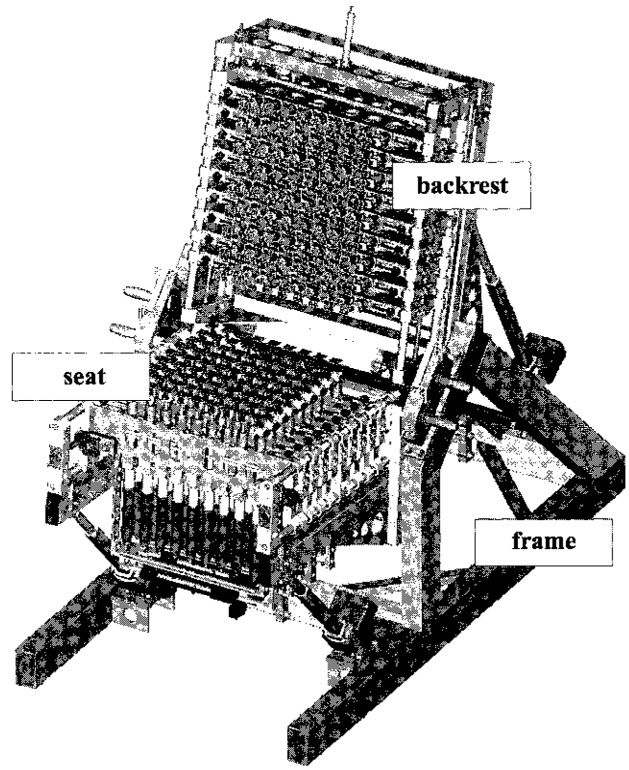

Figure 2: Basic mechanical elements of the research chair

Each of the cushion units consists of nine portals with respectively nine positioning units. The distance between the portals and the positioning units is adjustable to cover a wide range of different sized measuring areas. Each positioning unit has a contact plate installed on a universal joint with a maximum deflection of 35 degrees to ensure that the plate huddles against the body of the test subject. Additionally, the plates on the positioning units at the outer left and right side of the cushion units are adjustable in angle to ensure that even seats of a extreme contour can be simulated (Figure 3). Theoretically, each positioning unit can take a position between 0 and 120 mm to simulate or measure the seat surface geometry. But the range is quite smaller, due to the necessary range to simulate a spring characteristic.

Electrical components

Each positioning unit completes with four silicon based pressure sensors and a resistive position measuring device. Using automated positioning control pressure and position are linked by the definition of spring characteristics deposited in a control computer. So each positioning unit is realized as a spring with programmable characteristics. The frequency of one control loop from pressure measurement to position control is 24 Hz. (Figure 4)

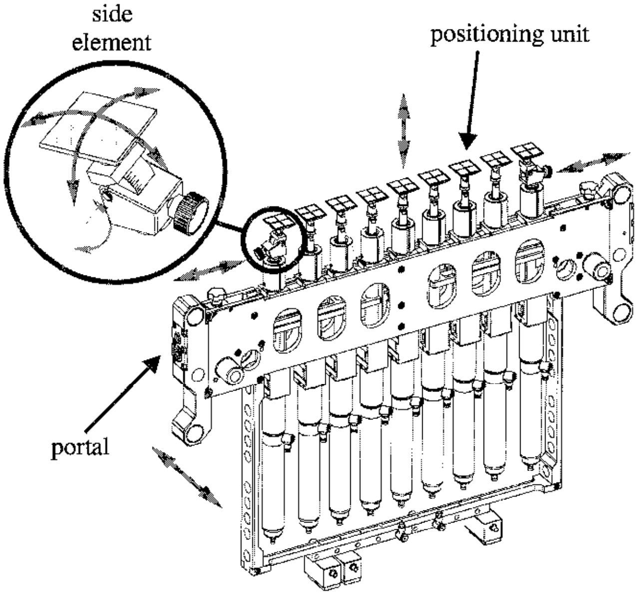

Figure 3: Detailed view of one portal

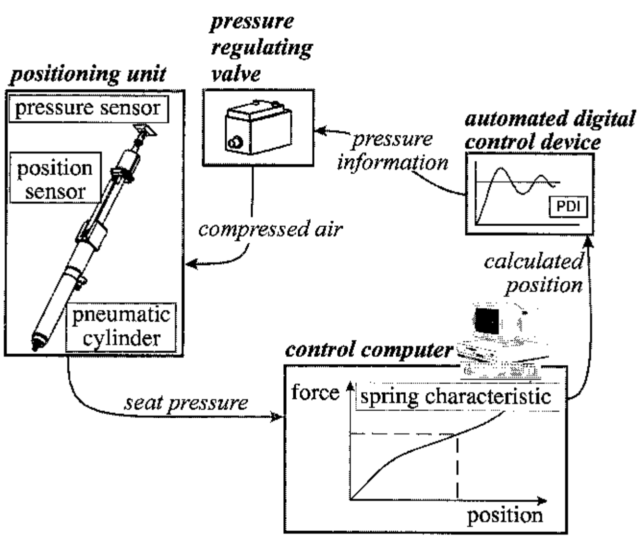

Figure 4: Control loop

SEAT PARAMETERIZATION AND SIMULATION

The experimental setup described above makes it possible both to measure the characteristics a of seats regarding geometry and spring constants and to simulate it based on the measured data.

Seat parameterization

A cushion unit is turned over and then lowered on the surface of the upholstery to parameterize a seat. The distance between the portals and positioning units have to be adjusted to the size of the cushions of the seat to measure.

To measure the spring constants and the geometry of the cushion a specially elaborated measuring procedure based on a mean load distribution is used. The mean of the load distributions of respectively 11 women and men performing a driving task in a driving simulator have been determined with a capacitive pressure mat. The used mockup is based on the measures of a higher middle class car. The subjects have been selected by the corpulence represented by the waist circumference. The gained data matrix was made symmetric and transformed from the 16 x 16 sensor matrix of the pressure mat to the 9 x 9 matrix of the experimental chair by a special elaborated procedure having regard to the distance between the positioning units. (Figure 5)

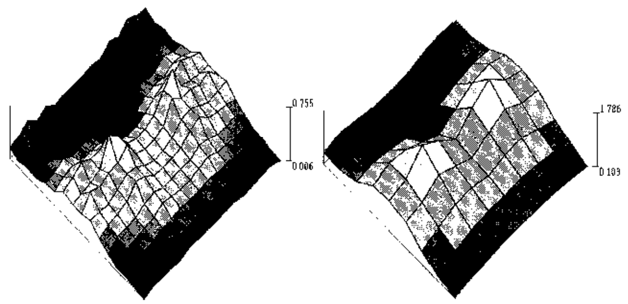

Figure 5: Mean relative load distribution: pressure mat 16 x 16 elements (l.), transformed to 9 x 9 matrix (r.)

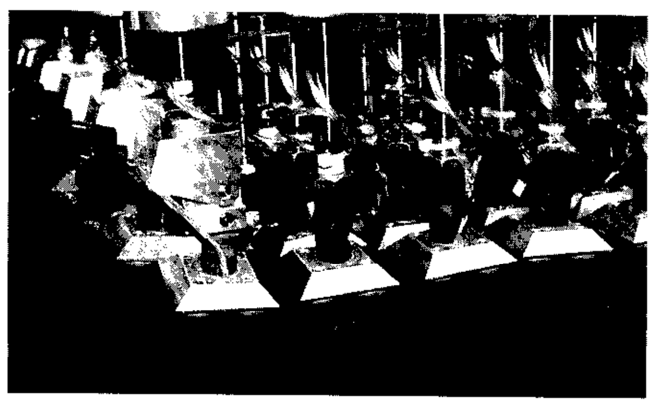

Figure 6: Measuring a seat

During the measuring procedure the positioning units are brought in contact with the cushion (Figure 6). Then the percentage of load using the determined mean load distribution is increased in defined steps. A measured point of the spring characteristic is declared as valid when the deviation of pressure is within a defined range. This procedure can be done from 1 to 255 times to get more or less detailed spring characteristics.

Seat simulation

To simulate a seat the data measured is used. The measured geometry is inverted and the positioning units are driven to the calculated height. So the surface of the upholstered seat is simulated. As mentioned above each positioning unit can be used as programmable spring. Using the previously measured spring characteristics the simulation is completed. Test subjects can sit down in the simulated seat and then the characteristics of the seat can be varied systematically by the test leader or test subject. Pressure distribution and deflection profile are measured with the integrated sensors. Naturally, it is possible to create synthetical data sets for geometry and spring characteristics and to simulate them on the experimental setup.

EVALUATION OF THE EXPERIMENTAL SETUP

Accuracy

To determine the accuracy of measurements and simulations with the experimental chair a variety of tests were made.

Positioning. The mean relative and absolute error in positioning was determined for selected positioning units in the positions 5 mm, 60 mm and 115 mm. Mean relative error was determined between 0.3 and 11.2 % depending on the position of the positioning unit, absolute error between 0.3 and 0.6 mm.

Pressure measurement. The mean relative and absolute error in pressure measuring was determined with different loads of 100 N, 200 N, 400 N, 800 N placed on the seat. Mean relative error was determined between 4.9 and 8.7 % depending on load, absolute error between 8.4 to 55.3 N.

Spring characteristics. Using error calculation the relative error in simulating spring characteristics results to 4.9 to 12.2 %, depending on position of the positioning device and load.

Reproducibility

To determine the reproducibility of measurements with the experimental chair a real seat was measured four times.

Geometry. The maximum absolute deviation in measuring the surface geometry of a cushion was determined between 1.6 and 5.5 mm.

Spring characteristics. The mean relative deviation of position resulting of the different measured spring characteristics over all positioning units was determined to 14.5 % with a standard deviation of 8.8 %.

Comparison between real and simulated seat

An investigation was done to evaluate the experimental setup concerning the realism of simulated seats. The resulting pressure distributions on a real and simulated seat (Figure 7) were compared.

Experiments. Four subjects had to sit down on the real and the simulated seats. The surfaces of the cushions were aligned horizontal. The subjects were told to take a relaxed posture with a distinct kyphosis and no contact to the backrest to ensure a reproducible posture and prevent influences resulting of different load distributions on seat and backrest.

Analysis. Mathematical indices, the Gaussian Distance and the Simple Matching Coefficient SMC, were used to determine the degree of likeliness of pressure distributions. Experiments took place to evaluate the mathematical indices concerning the influence of other parameters like backrest angle, intraindividual deviations between two postures or muscle contraction.

Results. The experiments and analysis indicated that the experimental setup makes it possible to simulate sufficiently real seats by using pressure distribution as criteria of comparison. The nine by nine resolution of the simulated cushion is sufficient, due to the fact that the distance between the tactile sensors of the body areas which are in contact with the seat is approx. 70 mm.
Therefore, it is postulated that seat comfort subject to pressure distribution can be investigated.

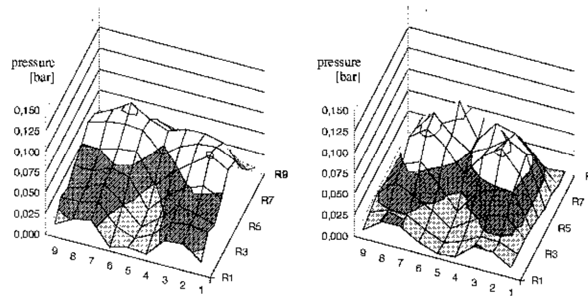

Figure 7: Pressure distribution on a real seat (left) and on the experimental chair (right)

PERSPECTIVES

Additional investigation has to be made to confirm the validity of the simulation of seats. Anthropometry, posture, deformation of soft parts, and subjective ratings of test subjects should be measured consistently in model and system to gain a holistic model of the interaction between human and seat.
Based on this data a model to predict pressure distributions and deflection profile using either FEM or statistic methods should be determined. Moreover, a model for predicting discomfort is going to be elaborated having regard to pressure distributions and posture resulting of different seat characteristics.
The implementation in a computer based human model can be realized in connection with a force based posture prediction model.

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