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Development of a Seating Buck for Ergonomic Vehicle Evaluation in VR Environment

Alexander Mueller, Simon Buck, Fabian Schmiel, and Temidayo Amosu

Esslingen University, Faculty of Mobility and Technology, Kanalstraße 33, 73728 Esslingen, Germany

ABSTRACT

The development of a seating buck for ergonomic vehicle evaluation in VR environment is discussed in detail, highlighting development, design and manufacturing aspects. A grid model is used as a basis, in which the position of the standardized heel point (AHP), that of the standardized hip point (SgRP) and that of the steering wheel centre (SWC) are described relative to each other and with standardized dimensions. In a next step, ranges could be identified for these dimensions that can be used to represent a wide field of vehicles available on the market. The development of adaptable modules for the steering wheel, the seat as well as the pedals is discussed and it is also explained how the drive for the adjustability of these modules was controlled, implemented and integrated into an overall design. The CAD model was digitally validated with respect to clash potential using the digital human model RAMSIS®. Finally, it is explained how exactly the vehicle dimensions can be controlled in the real model.

Keywords: Seating buck, Vehicle ergonomics, User-centred vehicle design, Digital human modeling, Virtual reality

INTRODUCTION

Current Situation and Problem

For the real and ergonomic validation of vehicle concepts, seating bucks and vehicle mock-ups are used in industry and research. The adaptability of these mock-ups with regard to standardized vehicle dimensions has proven to be very complicated in the past, so that seating bucks that can only be adapted to a very limited extent are still generally used in industrial applications today. The validation of the extents represented in the seating bucks usually takes place in an environment that can be experienced to a limited extent.

The time required for the development and manufacturing of the seating buck is to be regarded as critical, since the development activities of the various disciplines continue on a steady basis. Due to the resulting time lag between the time of the definition of the seating buck display scope and the current development status, it cannot always be ensured that current data is tested in the seating buck. In addition, the limited representation of design-critical environmental scenarios (e.g. urban environment) leads to limited evaluation results.

Objective

The paper aims to show how a fast adaptable and variable seating buck for driver vehicle evaluation can be systematically designed, in which all tactilely and haptically perceivable features are represented in a realistic position and orientation and, at the same time, the realistic visual and acoustic perception of the vehicle and its environment is ensured. Since a variety of seating positions of different vehicle types and degrees of automation should be representable, the main physical human-vehicle interfaces (especially steering wheel and seat) are interchangeable. The visual and acoustic perception of the vehicle or the environment is performed in a VR environment and is not the subject of this paper.

METHODS

For the development of the variable seating buck, the variable adjustment parameters as well as their dimensional ranges for the mapping of different vehicle types have to be determined first. In the next step, a parametric associative CAD grid model is built, which is then extended to include the supporting structure, the adjustment actuators and the assemblies of the physical human-machine interface as well as those for the VR application (force feedback elements). Finally, the seat box is being measured and calibrated.

Selection of Variable Setting Parameters

The conception of the vehicle dimensional layout takes place in the early phase of vehicle development and is based on vehicle dimensions that are standardized nationally, internationally and also across manufacturers in the form of a special exchange list (DIN 70020-1; SAE J1100; GCIE exchange list). Different vehicle concepts can be represented as a function of these dimensions. The following dimensions in particular are decisive for the representation of the driver's workplace:

A18 Steering Wheel Angle, Y-Plane
A47 Accelerator Angle
H17 Accelerator Heel Pont (AHP) to Steering Wheel Centre (SWC, Z-dimension)
H30-1 AHP to Seating Reference Point (SgRP) – Front (Z-dimension)
L11 AHP to Steering Wheel Centre (SWC, X-dimension)
L53-1 AHP to SgRP (X-dimension)
W8 AHP Y-Coordinate
W20-1 SgRP Y-Coordinate

Definition of the Design Framework

In order to determine the adjustment ranges of the vehicle dimensions listed above, data of current vehicle concepts is analysed (autograph dimensions, A2MAC1). The main objective is to use the seating buck to represent vehicle concepts with different seating heights. On the one hand, vehicles with low seating heights, i.e. sports vehicles, should be representable; on the other hand, vehicle concepts with high seating heights (SUVs and Vans) should be made experienceable. The dimensional ranges of the above-mentioned vehicle dimensions that enable the depiction of these different vehicle concepts are listed in Table 1.

Development of a Parametric Associative CAD Grid Model

The basis of the design is a parametric associative CAD grid model, which can be used to adapt the accelerator heel point (AHP), seating reference point (SgRP) as well as the steering wheel centre (SWC) depending on the previously defined dimensions in the dimensional ranges shown in Table 1 (cp. Figure 1).

Development and Integration of Structure and Assemblies of the Physical Man-Machine Interface

Based on a grid model, the first step is to design a supporting structure that holds the assemblies of the physical man-machine interface. A proven and standardized building kit with a large number of structural elements and linear guideways is used to design the structure. In the first step, the assemblies of the physical man-machine interface are taken from vehicles currently

Table 1. Adjustment ranges of the variable seating buck.

Dimension	Minimum	Maximum
A18	14°	40°
A47	42°	55°
H17	578 mm	744 mm
H30-1	180 mm	404 mm
L11	289 mm	517 mm
L53-1	761 mm	923 mm
W8	187 mm	226 mm
W20-1	321 mm	401 mm

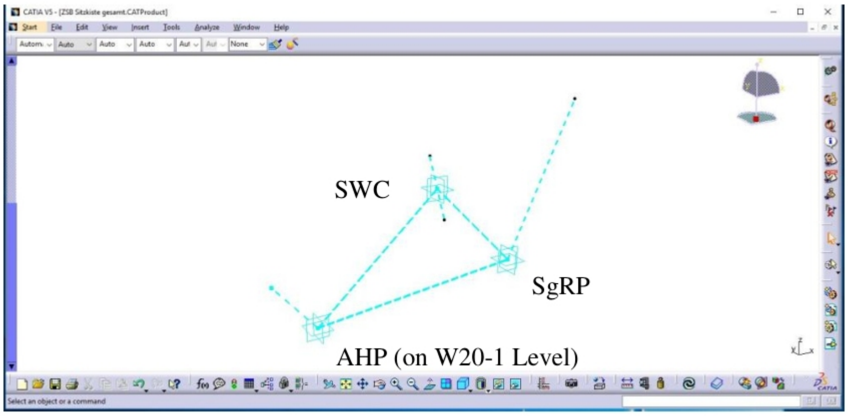

Figure 1: Parametric associative CAD grid model.

available on the market. In doing so, it is important that these assemblies are as vehicle concept-neutral as possible. The interface to these assemblies is designed in a manner that these assemblies can be exchanged with little effort if necessary. For the Z adjustment of the seat, the angle adjustment of the steering wheel and that of the pedals, the modular system mentioned above cannot be used due to a lack of supply. The Z adjustment of the seat is realized by means of a lifting table available on the market, which is integrated into the supporting structure. A ring segment guide is used for the angle adjustment of the steering wheel, so that the steering wheel angle can be adjusted around the centre of the steering wheel. The adjustment of the hanging pedal set is implemented with a lever mechanism. Force feedback elements are installed to connect the variable seating buck to the VR environment (cp. Sensodrive). On the one hand, a force feedback element for the steering wheel is installed, on the other hand, a pedal set with accelerator pedal and brake pedal. Figure 2 shows the supporting structure, the guidance and force feedback elements and the assemblies of the physical human-machine interface, as well as the validation of threshold setting values with respect to the collision potential with the digital human model RAMSIS® (cp Human Solutions). A simple driver collective with proven spread of anthropometric data is chosen for this purpose (5th percentile woman - 95th percentile man, cp. Bubb, et. al., 2015).

Development and Integration of Actuators

The seating buck is adjusted on a 12 V basis. An Arduino microcontroller (Arduino) is used to control the actuators. For the linear adjustments, standardized electric cylinders are used, which have proven themselves in building automation and in which displacement sensors are already integrated. Adjustment of the steering wheel angle is performed with a windshield wiper motor and a spur gear. The control is done with a potentiometer integrated in the gearbox (cp Figure 3). An additional potentiometer is installed to control the lift table.

Figure 2: CAD modell of the variable seating buck.

Figure 3: Steering wheel adjustment module and seating buck.

Measurements and Calibration

After the seating buck has been assembled, it is measured and calibrated. An H-point measuring machine standardized according to SAE 826 (SAE 826) is used for this purpose. The measurement is performed with a FARO measuring arm. Calibration is performed by first displaying threshold vehicle dimensions with the seating buck before measuring them. Figure 3 shows the assembled and variable VR seating buck.

RESULTS

By varying the above-mentioned vehicle dimensions, the seating buck can be used to represent the driver's workplace of different vehicle concepts. Table 2 shows how precisely the vehicle dimensions can be adjusted with the seating buck.

Table 2. Deviations of the measured values from the target values.

Dimension	Min. Target Value / Deviation	Max. Target Value / Deviation
A18	14° / +0.1°	40° / + 0.2°
A47	42° / −2°	55° / −5°
H17	578 mm / +0.7 mm	744 mm / +0.5 mm
H30-1	180 mm / +5.6 mm	404 mm / + 6.7 mm
L11	289 mm / +3.7 mm	517 mm / −0.5 mm
L53-1	761 mm / −12.3 mm	923 mm / +0.1 mm
W20-1 – W8	170 mm / + 5.4 mm	134.6 mm / −2.1 mm

DISCUSSION

The dimensional accuracy of the adjustable steering wheel position and steering wheel angle is very good. The steering wheel height and the distance of the steering wheel centre from the AHP can be approached with small and tolerable deviations, and the steering wheel angle is displayed with virtually no deviation. The position of the SgRP relative to the AHP is acceptable in terms of height, but can be further improved to a good value after further calibration. The X position of the seat relative to the AHP currently shows too large an error due to the accuracy of the displacement encoder built into the electric cylinder. It is planned to install an external position encoder, which has already proven its worth in positioning the seat in the Z direction. The position of the pedal set can be approached with good accuracy, the pedal angles are also to be recalibrated so that they can be set with good accuracy. Conceptually, the adjustment of the pedal set is subject to error, since in reality it does not rotate around the AHP. When designing the kinematics, the invariant distance between the Ball of Foot and the AHP must be taken into account.

CONCLUSION

The results show that the procedure outlined is generally target-oriented, and the seating buck can be adapted with sufficient accuracy.

Simplifications were also accepted deliberately in the definition of the adjustment parameters. For example, the pedal angles cannot be adjusted independently, nor can the Y coordinate of the steering wheel (SWC) be manipulated independently of that of the seat (SgRP). The seat also currently cannot be rotated about the Z-axis. Future concept evaluations using the seating buck will show whether the assumptions that led to these simplifications can be confirmed. However, the modular design of the seating buck accommodates a possible modification of the adjustment parameters and/or their adjustment ranges at a later time.

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