Investigation of methods for quantifying sitting postures in cars
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A study focused on pelvic orientation for improved safety assessment

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When performing safety assessments in the car industry, crash dummies are often used. These are simplified versions of the human body and only includes a limited number of body types. In reality people can look very different and further more choose to sit differently. Thus, a method is needed to be able to capture how people actually sit during a car drive. The measuring method investigated and recommended after this study is called Xsens MVN, which is a motion capture system.

Background

Today most crash tests in the car industry are being carried out on crash dummies which are full scale dolls constructed to interact with the restraint system during a crash in a similar way that the human body does. The crash dummies are used in controlled environments in standardized positions and following strict protocols. The testings are mostly done with the crash dummies sitting in a position according to the protocol which among other things means that the backrest will be in an upright position.

In reality however, passengers can choose a range of different sitting positions. There is no sitting posture that is ergonomically satisfactory over a longer period of time. Facing a population with many different body types and preferences it is particularly challenging to find out how passengers choose to sit. It has shown to be particularly important to measure the interaction between the lap-belt and the pelvis. This is a central interaction from a safety perspective as the pelvis is suppose to be the load-bearing structure where forces are applied during an accident. If passengers choose to recline back rest of the seat or to sit in a position where there is slack in seat belt system, the risk or submarining increases. Submarining is a phenomena which can lead to severe injuries as the pelvis is rotated backwards and the larger forces are applied on the soft tissues of the stomach instead of the hard structures of the pelvic bone.

As a consequence, being able to understand and to quantify passengers' sitting postures in cars has become a central asset to increase passenger safety in future cars. The data is also needed to improve the accuracy of virtual crash simulations. Moreover, with the development of autonomous cars, it is even more important to be able to quantify how passengers choose to sit as new behaviors may emerge when there is no longer a responsible driver in the car.

The aim of this master thesis was to find a measuring method that measures the posture of a passenger in a car seat, with focus on the orientation of the pelvis.

Approach of the study

The approach for the study is explained below:

- A prestudy was conducted to see how safety assessment is done today and what limitations are present with the current methods.
- To understand the ergonomic aspects and to find suitable technologies for capturing body movements, a literature study was made.
- A concept development was carried out including different activities with the objective to find a suitable concept for the measuring method wanted. A concept could be some equipment or a way of working. The most important activities were *Identifying user needs*, *Concept generation* and *Concept selection*.
- A concept testing with three experiments was performed where the most suitable concepts were tested. Experiment 1 was focused on verification of the measuring method. Experiment 2 focused on determining the orientation of a test person's pelvis when knowing the position of the shoulder and the knee. It also focused on evaluating how passengers choose to sit. During Experiment 3, the test persons were taken on a drive to test the equipment dynamically.
- An analysis of the collected data was conducted. For Experiment 1, the angles and segments from the verification

were analyzed. The settings for the equipment's software were examined. The pelvic angles were obtained from the equipment and compared with the results from the verification. For Experiment 2, the relevant angles were calculated and compared with the pelvic angle values from the equipment, as well as different movements of body parts. For Experiment 3, the data collection was reviewed and compared with notes.

Results and recommendations

The system that was considered the most suitable for quantifying passengers' sitting postures in cars was a motion capture system developed by Xsens. It consists of a hardware of 17 sensors which are placed on the test person's body on specific spots, see Figure 1. The sensors capture the motions of the test person and recreates a virtual manikin which can be seen in the software of the Xsens MVN system. The data collection can be followed live and the recorded sequences can also be visualized later. The equipment gives precise values for joint and body segments' orientations and also position, velocity etc. can be reviewed.

Figure 1: Xsens MVN
(https://www.xsens.com/products/xsens-mvn-analyze/)

The results from Experiment 1 showed that the Xsens MVN equipment gave accurate values when comparing the results to another well known static measuring method. In Experiment 2, Xsens MVN was used to test the possibility of determining the orientation of a passenger's pelvis when knowing the position of the shoulder and the knee. Such a connection would have facilitated the quantification of sitting postures but could not be found. Results from this experiment also showed that most of the passengers reclined their seat when they got to choose their preferred position in the car seat. In Experiment 3, the Xsens MVN equipment was tested during a car drive and results showed that it performed well in this environment. However, a compensation for the movement of the car is needed.

To conclude, Xsens MVN is an effective and reliable system to measure the posture of a passenger in a car seat during a drive. It is precise if calibration is done correctly and sensors stay in place.

The future in a broader perspective, will probably contain more technologies that capture body movement.