Towards an Intelligent Driver Seat for Safe Autonomy Level Transitions in Autonomous Cars*

Jan Peters[1], Bani Anvari[1] and Helge A. Wurdemann[2]

***Abstract*— Self driving autonomous cars are one of the biggest transforming technologies in the next decades. However, before having fully autonomous vehicles, that are able to complete end-to-end journeys, there will be the need to give back control to the human driver in certain situations. These autonomy transitions lead to safety risks. Here, we present a concept for a soft robotic driving seat, that serves as an assist to translate the driving control safely back to the driver in an automated vehicle. Instead of using visual or auditory signals, the haptic seat is able to give a more intuitive and less distracting feedback about the actual driving situation leading to safer human-robot handovers in a shared autonomy system.**

I. INTRODUCTION

According to the most optimistic predictions, the first commercially available fully-autonomous cars are expected in 2040 offering the consumer a full end-to-end journey. These self-driving vehicles will be equipped with technology allowing autonomy Level 5 in which there is no interference required by the human. In the race towards the first fully-autonomous car, the majority of cars will be equipped with technology that allows Level 3 or 4 autonomy over the next two decades. These semi-autonomous cars might be able to transport the driver autonomously on sections of a journey. However, the driver is required to take control occasionally between different levels of autonomy when required to complete an end-to-end journey. These handovers between the car and the driver cause safety concerns, as the driver might not be fully aware of the surrounding situation and the enabled autonomy features instantly. This project proposes a new interface design for semi-autonomous cars called iSeat (Figure 1). This system is fundamentally different compared to current systems using visual or auditory indications which might be mentally overloading and distracting. iSeat is an intelligent driver seat acting as a co-pilot measuring the current mental and physical engagement of the driver and allowing safe and coordinated autonomy level transitions. Of particular significance is the driver seat made of robotic structures serving the feedback purpose as well as providing monitoring capabilities through direct contact with the human. iSeat sensing information will be fused with multi-modal sensing data from electrical activity produced by skeletal muscles (Electromyography (EMG)) and in the driver's brain (Electroencephalography (EEG)), and input from vision cameras regarding the driver's posture and the point of gaze. This real-time knowledge will be classified through machine learning in terms of the drivers' awareness. Personalized feedback will be provided (i.e. tactile sensation, stiffness feedback, change of the driver seat ergonomics/comfort) to support the driver so that safe, timely, effective and intuitive transitions between different levels of autonomy can be completed.

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[1]J. Peters and B. Anvari are with the Department of Civil, Environmental and Geomatic Engineering, University College London, UK.

[2]H. A. Wurdemann is with the Department of Mechanical Engineering, University College London, UK. h.wurdemann@ucl.ac.uk

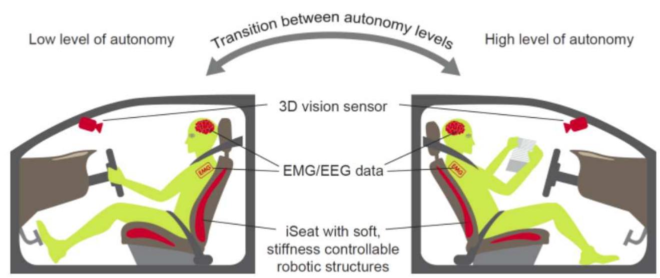

Fig. 1. Proposed iSeat with integrated soft, stiffness controllable robotic structures. Pressure data will be fused with EMG/EEG and vision information to define personalised haptic feedback using iSeat to allow safe transitions between different levels of autonomy.

II. THE SOFT ROBOTIC MANIPULATORS AND ACTUATION SYSTEM

Our proposed concept as shown in Figure 2 is based on a Landrover Discovery Sport SE driver seat. It includes two actuation areas with different actuators arranged in signal patterns for complex signal transmission to the driver during the handover process. Four soft, silicone-based actuators in each of the side bolsters give haptic feedback to the sides of the drivers legs. Each actuator is controlled independently by proportional pressure regulators. The actuators shown in Figure 3 are fabricated from Ecoflex 00-30 silicone and are reinforced with a 2-way stretchable fabric woven from 100 % Nylon to restrict the outward expansion of the actuators but allow elongation only. Pressurizing leads to an elongation of up to 25 mm producing a force at the tip of more than 50 N. Polylactic (PLA) rigid plates are used to reduce the bulge effect on the upper and lower surfaces of the actuators during operation. The second actuation area, located in the front bottom part of the iSeat, comprises four flat actuators which are placed under the seat cover. This second type of soft robotic actuator, manufactured with Ecoflex 00-50, has a triangular shaped chamber, leading to a dynamic haptic

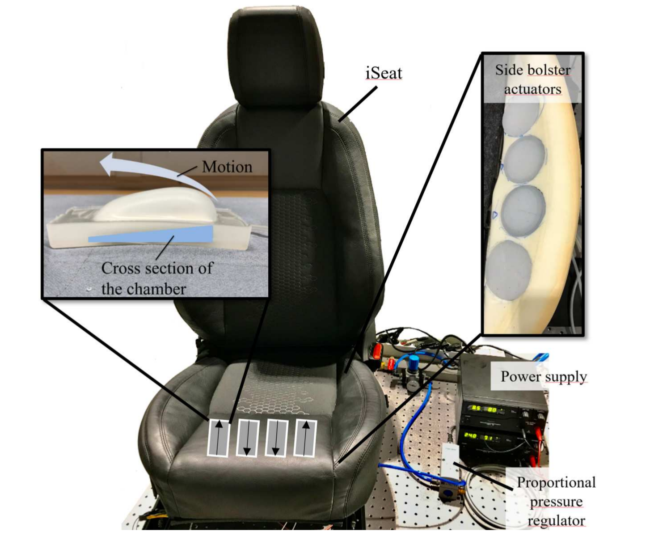

Fig. 2. Each side bolster is equipped with four actuators. The front bottom part of the iSeat comprises four flat actuators with a triangular shaped chamber, leading to a dynamic motion under the seat cover when pressurized. Each actuator can be controlled individually by proportional pressure regulators, allowing complex haptic signal patterns to be generated.

signal when mounted under the seat cover and pressurized. There are two actuators for each leg, one for a forward and one for a backward motion, so that different road scenarios can be displayed to the driver.

III. Modeling and Experimental Results

The used actuators have to provide a certain actuation force to give a reliable haptic signal. To model the elongation and stiffening capabilities of the round actuator, an analytical model was derived. The stress resulting from the pressurization can be calculated as $\sigma = p \cdot \frac{A_1}{A_2}$, where A_1 is the area of the cylindrical base and A_2 is the cross sectional area of the silicone which is stretched during pressurization. This stress is equal to the stress s_1 inside the silicone material, which is described in detail in [1]. With $\varepsilon = \frac{\Delta l}{l_0}$ follows

$$p = \frac{A_2}{A_1} \cdot 2 \cdot C_1 \cdot \left(1 + \frac{\Delta l}{l_0} - \frac{1}{(1+\frac{\Delta l}{l_0})^3}\right) \tag{1}$$

which describes the relationship between the input pressure p and the elongation Δl of the actuator regarding the length l_0 in the unpressurized state. Using the ideal gas law, the resistance force of the actuator can be calculated as

$$F = \frac{m_0 \cdot R_s \cdot T_0}{l_0 + \Delta l - x} - p_{atm} \cdot A_1 - p(x) \cdot A_1 \tag{2}$$

with the deflection x of the actutator tip and the elongation Δl resulting from pressurization. For initial results a simplified version of the actuator with fiber reinforcement instead of the 2-way stretch textil was pressurized while the elongation was recorded. The results, presented in Figure 4 (a), show a good match between the modeled elongation with Equation 1 and the measured elongation. For the second experiment, the tip of the actuator was deflected by a Zwick/Roell Z0.5 TH by 8 mm. Recording the force during the displacement explores the stiffness of the actuator, presented in Figure 4 (b).

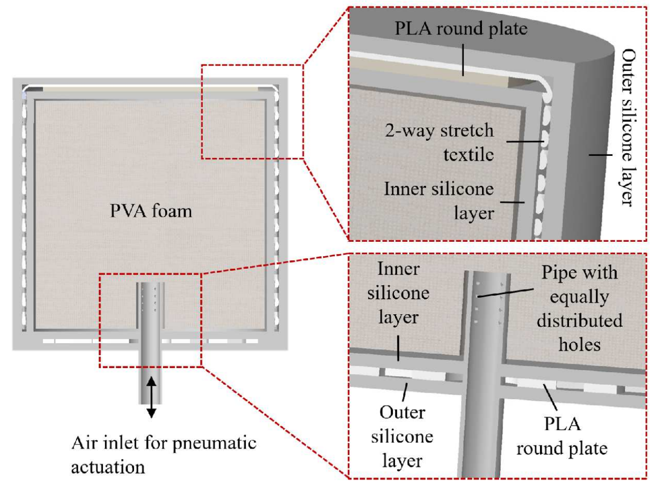

Fig. 3. The silicone-based soft actuator for the side bolsters has a cylindrical shape with a diameter of 58 mm and height of 70 mm. 2-way stretch textile is embedded between silicone layers in the wall. The top and bottom of the manipulator have enclosed Polylactic plates. The inner lumen of the actuator is filled with pre-compressed Polyvinyl Alcohol foam.

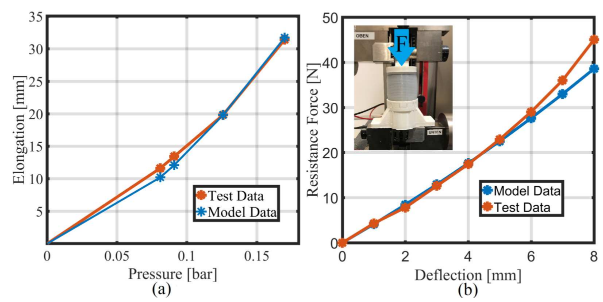

Fig. 4. Experimental results showing the relation between the input pressure and the resulting elongation (a) and the resistance force of the actuator for a certain deflection (b)

IV. Conclusions and Future Work

The iSeat system builds upon a complete re-think of the manner in which humans interact with autonomous cars. The smart combination of sensor systems, machine learning, haptics and robotics will result in a bi-directional human-machine cooperation that is safe, intuitive and effective. We used two kinds of soft actuators to form actuation areas in a seat, that can provide the driver with haptic feedback for a safe driving control transition from the autonomous car to the driver. Initial experimental results show the capabilities of the invented actuator for its' designated task in the proposed iSeat. The next steps in our project include the integration of more actuators, the combination of the sensor data (i.e. EEG and EMG) with machine learning and finally experiments in a driving simulator with test persons to proof the overall concept of the iSeat to serve as a co-pilot.

References

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