Benchmarking Soft Actuators for Human-Robot Interactions

This is part of a paper submitted to IROS 2017

Vincent Wall[1], Raphael Deimel[1], Espen Knoop[2], Moritz Bächer[2], Paul Beardsley[2] and Oliver Brock[1]

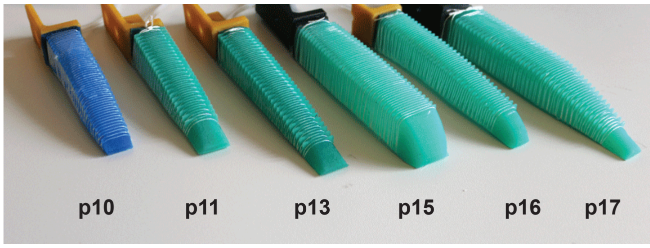

Fig. 1. Six PneuFlex actuator designs with different design parameters

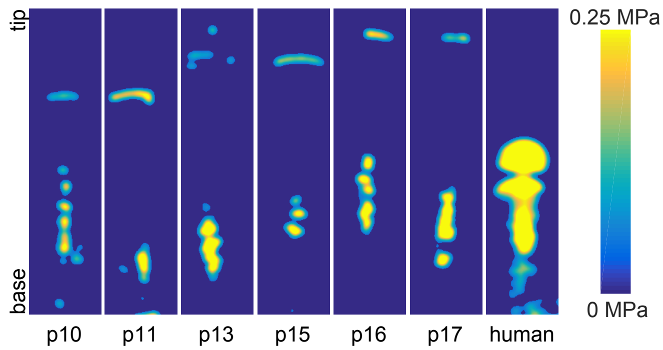

Fig. 2. The measured contact pressure distributions of the PneuFlex prototypes and a human finger for comparison

***Abstract*— Soft robotic actuators use compliance to passively adapt their shape to objects and the environment. The specific choices of design parameters decide the behavior of the actuator during these interactions. By analyzing human-human hand interactions we observed that the distribution of contact pressure is a relevant benchmarking metric to judge "humanness" and comfort of the interaction. In order to understand how the choice of design parameters of soft actuators influences the benchmarking results, we created a set of prototypes with different design parameters. By measuring and comparing the contact pressure distributions we can reason about which design properties are most relevant for more human-like interactions.**

I. Exploring the Design Space of Soft Actuators

We explore the design space of PneuFlex pneumatic actuators [1] as used in the RBO Hand 2. We evaluate the ability of different fingers to wrap around palm-shaped object, as would be required in a handshaking interaction.

The PneuFlex is a pneumatic continuum actuator, where the cross section along the length of the finger determines the compliance and actuation behavior. Fingers with different functionality can be creating by varying design parameters, and we chose to vary the following properties:

- The **stiffness profile** determines the relative rotational stiffness along the actuator.
- The **actuation ratio profile** describes for each point along the actuator its relative curvature caused by a certain amount of actuation pressure.
- The **nominal stiffness** is the absolute actuator stiffness.
- The **finger length** from base to tip.

We built six prototypes that varied these four parameters of the design (Fig. 1).

We gratefully acknowledge financial support by the European Commission (SOMA, H2020-ICT-645599).

[1]VW, RD and OB are with Robotics and Biology Laboratory, Technische Universität Berlin, Germany. vincent.wall@tu-berlin.de

[2]EK, MB and PB are with Disney Research, Stampfenbachstrasse 48, 8006 Zurich, Switzerland

We evaluate each finger design by measuring the distribution of contact pressure when performing a grasp of a palm-shaped object. Contact pressure is measured by wrapping the surface of the object with a pressure-sensitive film (Prescale, Fujifilm Corp.), which changes color with applied pressure.

Fig. 2 shows the resulting pressure distributions of the six design space samples, along with a human finger for comparison. It is obvious that the human finger has a much larger contact surface than the soft actuators. However, we observe notable differences between the PneuFlex fingers. Some fingers (e.g. P10 and P16) have a more uniform pressure distribution along the surface than others. The contact surface of fingers P13 and P17 is more planar than, e.g., that of P15. On the other hand, fingers P11 and P16 have highly localized pressure points at the fingertip, which would likely cause discomfort in a human interaction.

These differences show that changes in the actuator design influence the contact area and therefore also the resulting perceived sensation. Ongoing work is looking at explaining these differences from the finger design and exploring this design space further, with the ultimate goal of optimizing hands for handshaking and other interactions. It can be seen that the benchmarking approach taken here allows us to focus on specific aspects of robot hand designs before creating full hand prototypes.

References

[1] R. Deimel and O. Brock, "A novel type of compliant and underactuated robotic hand for dexterous grasping," *The International Journal of Robotics Research*, vol. 35, no. 1-3, pp. 161–185, 2016.