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Bio-mimetic pneumatic soft prosthetic hand

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ABSTRACT

Traditional prosthetic hand devices are rigid, heavy and expensive. In order to satisfy demanding manipulation tasks they require either sophisticated controlling strategies or complex mechanics. In this work we present a soft pneumatic prosthetic hand, which is not only very cheap in production, but also very simple to control due to its mechanical compliance. It can be very easily reshaped and resized in order to fit a particular patient needs. The aim of this research is to provide children patients with a device that can be frequently exchanged whenever a bigger size is needed or the device is broken. Due to its softness and compliance the device is mechanically safe even for very small children.

I. INTRODUCTION AND OBJECTIVE

As traditional rigid prosthetic hands have a number of draw- backs, soft robotics renders itself as a potential improvement of amputee people manipulation capabilities. Most important is that soft prosthetics can be significantly cheaper than a traditional one as it does not require neither sophisticated mechanical structure nor small and expensive electrical motors.

Thanks to that soft prosthetic can be especially suitable for young patients as their growth makes frequent prosthetic change a must. Other advantage is a soft prosthetic can be very easily controlled due to its compliance and adaptation capabilities. Even one degree of actuation may be sufficient for many grasping tasks.

Figure 1: Soft prosthetic hand

A number of soft hands have been presented so far and they were also considered to be used as prosthetics [1–3]. They offer a similar morphology to a real human hand, however, their shape and appearance differ a lot from actual human limb. For that reason we propose a new soft prosthetic hand design that provides 6 possible degrees of freedom including a motion corresponding with the base joint of the thumb, the carpometacarpal joint. Such a joint is designed to allow the thumb to work in both apposition and opposition modes, see Figure 1.

II. DESIGN

Hand

The hand design is based on a 3D scan of a real human hand in order to make it as bio-mimic as possible. It consists of 6 fluidic actuators, one per finger and two for the thumb, see Figure 2. The actuators are a hollow chambers with circular cross section that tend to elongate when pressurized. They are constrained by an exoskeleton made of stiff silicone, so the translational expansion is transferred into bending motion of the fingers, see Figure 4. Unlike the real human hand in the presented device the bending motion of the fingers is distributed along their length as they are made of soft material and there are no discrete joints inside.

We shown in previous research that it is possible to achieve finite rotary joints using only soft materials [4], but we found such solution not applicable in that case due to excessive joint size and the need of using separate actuator for each joint. Using such actuators would make the design and the manufacturing unnecessarily too complex.

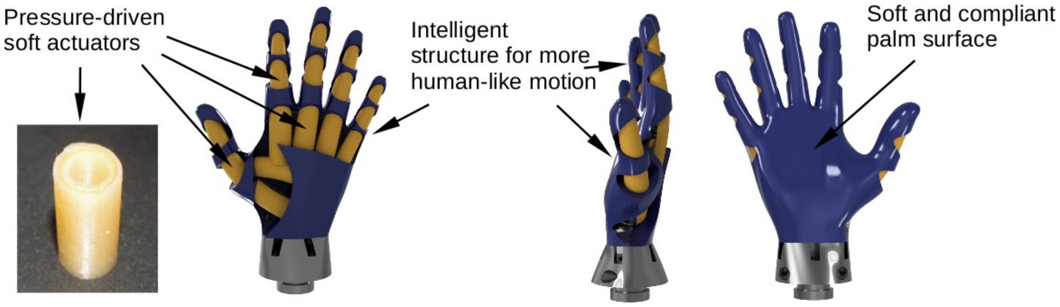

Figure 2: Structure of the hand

Actuator

As mentioned above, the actuators are pneumatic conical chambers that tend to elongate when pressurized. The diameter of each actuator varies depending on its length in order to fit the finger geometry and maximize the torque generated in the base finger joint. In order to constrain the radial expansion of the fingers a helical reinforcement made of a polyester thread is used. Such an actuation strategy has been already successfully embedded for manipulation, locomotion and grasping [4–6]. The bending of fingers in the desired direction has been achieved by combining the longitudinal expansion of the actuators with less flexible material on the internal side of the fingers and the palm surface. Each of the actuators can be controlled independently but due to their flexibility and compliance they can also efficiently work in groups. Such a property makes the dexterous manipulation less control-complex and allows the hand structure to take over part of the controller's effort.

Manufacturing

The manufacturing process is very much similar to the process described in [4–6]. It involves several sil- icone moulding steps and utilizes a set of 3D printed moulds. The materials used are two silicones of different stiffnesses and polyester thread used for the reinforcement. The process starts with preparing the thread to be embedded

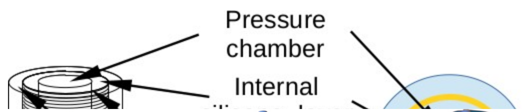

Figure 3: Structure of the actuator

into the fingers structure. The thread is winded tightly onto long conical cores. When wrapped the cores are enclosed within the mould and cast with soft silicone. The mould keeps them centred and creates a thin and uniform layer of silicone that bounds the reinforcing thread.

Figure 4: From the left, actuators, exoskeleton, parts of the hand in the main mould

As the rods diameter decrease with its length, the silicone layer with the thread inside can be easily removed from the rods towards the wider end, Figure 5

In the next stage a thin layer of silicone is added inside the actuators by filling them with silicone and inserting thinner rods.

Such layer protects the rein- forcing thread from detaching the initial structure when pressurized. The pre-prepared actuators and some auxiliary structures made of soft silicone are then arranged in a final mould that shapes the hand.

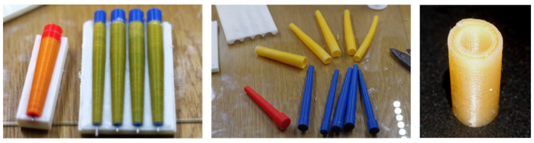

Figure 5: Actuators manufacturing: reinforcement, external layer, cross-section - reinforcement and internal layer visible.

The auxiliary structures help to provide more flexibility into the hand where required (e.g. in between the base - metacarpophalangeal - joint of each finger and the palm surface). When all the above is done, the mold is closed and the stiff silicone is injected into it that as the last manufacturing step.

III. CONCLUSIONS

Presented soft hand is an early prototype and has not been extensively tested yet. Nevertheless it shows high potential in terms of grasping capabilities and receives very positive feedback regarding its appearance and features. As the very next step we aim to conduct experiments to determine how the hand performs in different grasping tasks and how much grasping force it can generate.

We also consider hydraulic and pneumatic actuation. The goal of this research is to create prosthetic, but we will need to solve several issues before, including small and mobile yet powerful pressure source and a proper controlling interface.

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