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A novel 3RRS wearable fingertip cutaneous device for virtual interaction

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1 Introduction

Wearable haptic devices are recently gaining great popularity among researchers. Such interfaces will indeed enable natural forms of communication between the wearer and the environment. Humans will be free to move and interact with the surrounding world while being provided with rich and unobtrusive haptic information.

In this respect, fingertip cutaneous technologies have shown promising results. Prattichizzo et al. [5] presented a wearable cable-driven 3-degrees-of-freedom (3-DoF) cutaneous device for the fingertip. It consists of two parts: one is located on the back of the fingertip, supporting three DC motors, and the other one is placed in contact with the volar surface of the fingertip. The two parts are connected by three cables, actuated by the motors. The mobile platform can press into the user's fingertip and re-angle to simulate contacts with slanted surfaces. Three force sensors placed on the platform measure the contact force at the fingertip. The maximum force applicable is 1.5 N and the device weights as little as 30 g.

More recently, Tsetserukou et al. [7] presented a 2-DoF wearable fingertip display composed of a five-bar linkage system. Two DC motors, placed on the back of the finger, actuate the linkage mechanism. When the two motors spin in the same direction, the linkage system applies shear stimuli at the finger pulp; when the two motors spin in different directions, the linkage system applies normal stimuli at the finger pulp.

2 3RRS wearable device

This paper presents a novel 3RRS wearable fingertip device. It is composed of a static upper body and a mobile end-effector. The upper body (F in Fig. 1) is located on the nail side of the finger, supporting three small servo motors (C), and the mobile end-effector (E) is in contact with the finger pulp. The two parts are connected by three articulated legs (A), actuated by the motors. The end-effector can move toward the user's fingertip and rotate it to simulate contacts with arbitrarily-oriented surfaces. A piezoresistive sensor (D) can also measure the force applied by the mobile platform to the fingertip. Finally, a clamp (B) enables the user to easily fasten the device on the finger. Each leg, connecting the end-effector to the upper body, is composed of two rigid links connected to each other, the body, and the end-effector, according to a RRS (Revolute-Revolute-Spherical) kinematic chain.

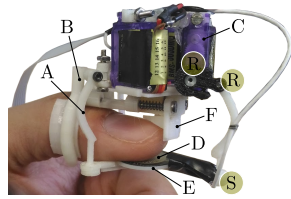


Fig. 1: The 3RRS thimble.

Controller	Atmega328
Power	4.8 to 6.0V
Roll range	$\pm 25^\circ$
Pitch range	$\pm 25^\circ$
Vertical displacement	15 mm
Normal force	up to 24 N

Table 1: 3RRS thimble features.

Specifically, three spherical (S) joints connect the distal links of the legs to the end-effector, one revolute (R) joint connects the distal and proximal links of each leg, and another revolute (R) joint connects the proximal link of each leg to the body. The three revolute joints between the proximal links and the body are actuated by the servo motors. In each leg, the axes of the two revolute joints are parallel, so that it constitutes a 2-DoF planar articulated mechanism, constraining the motion of the center of each spherical joint on a plane fixed w.r.t. the body. The mobile end-effector has therefore 3-DoF w.r.t. the body. The proposed device weights 25 g for $35 \times 50 \times 48$ mm dimensions. A preliminary version was presented in [1].

With respect to the cable-driven fingertip devices presented in [2,3,4,5,6], this device solves the indeterminacy due to the underactuation of the platform. This mechanical structure decouples position and force control problems, simplifying the control structure with respect to the solution proposed in [5].

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