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Compact Three-Degree-of-Freedom Fingertip Feedback Device with Large Range of Motion

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***Abstract*—This work presents a compact, three-degree-of-freedom haptic device with a large range of motion, delivering shear and rotational feedback. Using a truss structure with tendon-driven actuation, it achieves a wide range of motion and multiple degrees of freedom within a small form factor. Experimental results confirm high repeatability, with correctable position errors via feedforward compensation.**

***Index Terms*—Haptic devices, Shear and rotational haptic feedback**

I. Introduction

Haptic technology enhances task performance and user immersion through tactile feedback. However, creating compact multi-DoF devices remains challenging, as most fingertip devices provide limited degree of shear or rotational feedback, often with size and range trade-offs [1]. We present a compact, 3-DoF haptic device that delivers a large range of motion for both shear and rotational feedback by utilizing a truss structure and tendon-driven actuation.

II. Working Principle

The proposed truss structure (Fig. 1(a)) has two identical disc-shaped plates connected by four trusses and a spring. Each plate has sockets for the trusses' spherical ends. The spring maintains alignment and tendon tension. Both motions are analytically modeled (Fig. 1(b)). Four tendons are anchored symmetrically in pairs on the upper plate and routed to rear-mounted motors. This remote actuation enables a compact, multi-DoF structure.

The plates were fabricated using 3D printing (Formlabs 3, Clear resin) and piercings were utilized as trusses. The resulting device is highly compact, measuring 12 mm in diameter and 15 mm in height. Kinematic modeling predicts a range of motion of up to 130° for rotation and up to 6.8 mm in all directions of the xy-plane for shear motion.

III. Characterization

To evaluate range-of-motion, repeatability, and position error, the upper plate motion was tracked via a 4×4 ArUco marker from top view. Rotation was tested at 30°, 60°, 90° in both clockwise and counter-clockwise directions; shear at 2, 4, 6 mm in eight principal directions. Each test was repeated three times. The experimental results in Fig. 1(c) and (d) show that the device exhibits low standard deviations (<±0.5° for rotation and <±0.1 mm for shear), confirming the high repeatability of the device. Position errors reached up to 22% of the target displacement in both motions; however, rotational motion still achieved a notably wide range of 70°. In shear motion, directional error averaged 9°, but dropped to 3.8° in the four main directions. Error increases with displacement mainly due to tendon elongation, which feedforward control may compensate in future work.

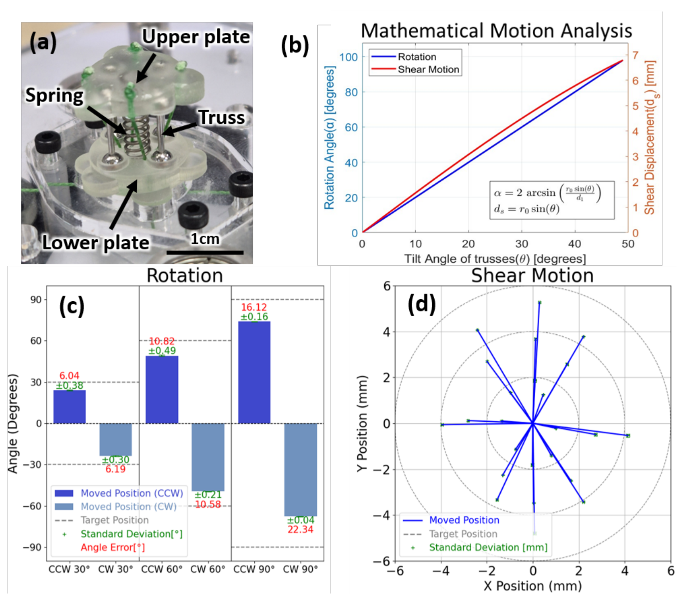

Fig. 1. (a) Truss structure, (b) Mathematical motion analysis, (c) Rotation analysis, (d)Shear motion analysis

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References

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