3-D Reconstruction of the Fingertip During Tactile Interactions

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I. Introduction

Tactile signals underlying our perception of touch originate from the mechanotransduction of skin deformation. Quantification of such deformation can provide new insights into the tactile information provided to the brain during interactions between the fingertips and objects . Measuring fingertip skin deformation without affecting its behavior is challenging, and studies have successfully used optical imaging and digital image correlation (DIC) to reconstruct planar deformations at the contact interface, using a transparent surface [1]–[3]. Moreover, recent work has shown the possibility to reconstruct 3-D surface deformation of the fingerpad resulting from interactions with von Frey hairs using a multiple-camera setup and stereovision [4]. Here, we aimed to extend this work and develop a method to reconstruct the 3-D deformation of the skin inside (planar) and outside (non-planar) the contact resulting from the normal and tangential loading of the fingertip over a flat transparent surface.

II. Methods

Using a robotic platform [5], the right index fingertip of participants is passively pressed against a flat surface. Then, while maintaining the normal force constant, the surface is slid over the fingertip at constant velocity (Fig. 1A). The fingerpad is imaged by pairs of high-res [2MP, 50fps] cameras, spaced by 30 degrees in the horizontal plane, placed on the ulnar side of the finger, both at an angle of 30 degrees below the horizontal. A speckles pattern is drawn on the fingerpad using black ink to create tractable features for the DIC (Fig. 1B). We used the Multi-DIC toolbox [6] to reconstruct the skin surface in 3-D and adapted it to account for large displacements (Fig. 1C).

III. Results and conclusion

The methods enabled us to track skin movement, as exemplified by the tracking of single landmarks in Fig. 1B. The 3-D reconstruction was validated in several ways. Among them, we verified that the tracked points did not penetrate the flat surface and were aligned on the same plane (Fig. 1D). We also reconstructed the surface deformation at the contact surface and verified that those matched quantitatively with measurements made according to previously validated methods. The results show great potential for reconstructing the entire 3-D deformation of the fingertip and will be used in future studies characterizing perceptual [2] or neurophysiological [7] output at the same time.

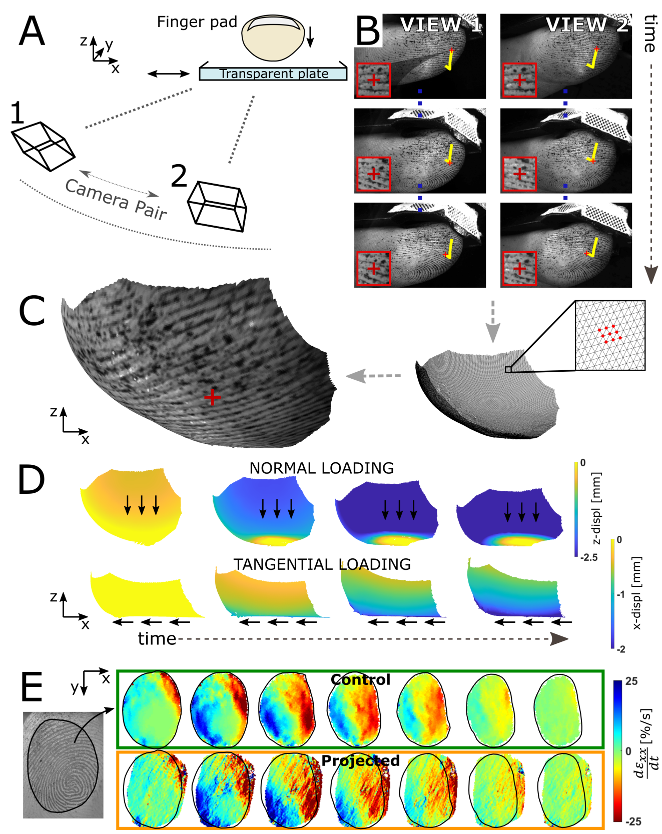

Fig. 1. (A) Overview of the experimental setup. (B) Raw pictures from two cameras at different times with a highlighted landmark (red) being tracked (yellow trajectory). (C) Reconstruction of the skin surface on a 3-D mesh. (D) Skin displacement field during normal and tangential loading. (E) Contact surface strain rate for control [1] and 3-D projected data.

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