A Study on Feature Analysis for Push and Stroke Manipulation of Elastic Objects

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***Abstract*— This paper introduces a preliminary study on feature analysis of push and stroke manipulations to elastic objects. We measured time-series fingertip position and strain data from 10 subjects touching nine types of elastic objects. The analysis results using support vector machine learning show that 2D features obtained from fingertip position and strain can stably recognize push and stroke manipulations to the elastic objects.**

I. INTRODUCTION

Analysis of dexterous hand manipulation has gained recent attention across the human and robotic domains [1, 2]. Specifically, tactile information generated between fingers and an object plays a major role in determining the appropriate finger operation, and is an important indicator for quantitatively understanding the finger operation mechanism [3]. Although some studies have attempted to directly measure finger operations to quantify tactile information [2, 3], few studies have focused on the fingertip-centric recognition of haptic interaction with real-world elastic objects.

This paper introduces a preliminary study to quantitatively examine finger manipulations to elastic objects. Push and stroke operation with one finger is a basic, essential skill for medical palpation procedures [4]. As a first step toward a fingertip-based recognition, this study focuses on binary classification of push and stroke operations with relatively detailed motion on a small region of an elastic object. Low-dimensional robust feature descriptors that are invariant to operator, finger position, and target object are explored.

II. METHODS

To analyze natural human finger operations, we focused on the simultaneous measurement of 3D position and fingertip strain, key factors that affect the sense of touch when the operator touches actual objects. Hence, a finger operation measurement system [5] that does not inhibit fingertip sensation is used for user experiments (Fig 1a). We hypothesized that human's push and stoke operation can be classified by low dimensional features of the fingerpad information. Four candidates of feature values: moving average $\boldsymbol{v}_a$ and standard deviation $\boldsymbol{v}_\sigma$ of fingertip velocity and moving average $\boldsymbol{\varepsilon}_a$ and standard deviation $\boldsymbol{\varepsilon}_\sigma$ of fingertip strain are selected. Regarding a time frame to evaluate time-series measured data, 0.9s is used based on preliminary analysis for discrimination of finger operation.

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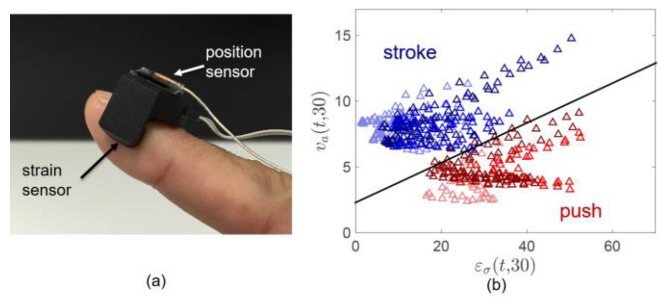

Fig. 1. Measurement system and , (b) 2D appearance of a deformed state and (c) estimation results and measured marker positions as ground truth.

III. EXPERIMENTS AND RESULTS

User experiments were conducted to obtain time-series fingertip position and strain from 10 participants touching nine types of elastic objects. When conducting the push and stroke operations, each operator was instructed to change the contact position, finger pressure, fingertip movement direction, and amount of fingertip movement on the surface of the elastic body. Each operator was also instructed to perform the actions that they considered to be "push" and "stoke" operations. The classification results were computed by binary classification using a support vector machine and 10-fold cross validation for each subject, that is, the decision boundary was computed from the nine training datasets, and then applied to another test dataset (Fig. 1b).

We confirmed the recognition rates for all fifteen combinations of feature sets defined by 4D features ($\boldsymbol{v}_a$, $\boldsymbol{v}_\sigma$, $\boldsymbol{\varepsilon}_a$, $\boldsymbol{\varepsilon}_\sigma$). The results show that the two-dimensional features obtained from fingertip position and strain within a 0.9-s time frame can stably recognize push and stroke operations on elastic bodies of different shapes, stiffnesses, and thicknesses at a higher recognition rate (> 90%).

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