Haptic Augmentation for Palpation Using Contact Centroid

Sunghoon Yim[1], Seokhee Jeon[2], and Seungmoon Choi[1]
[1]Department of Computer Science and Engineering, Pohang University of Science and Technology (POSTECH), Pohang, Republic of Korea
[2] Department of Computer Science and Engineering, Kyung Hee University, Pohang, Republic of Korea
E-mail: {algorab,choism}@postech.ac.kr, jeon@khu.ac.kr

Abstract—**This paper presents an approach to selectively augment visco-elastic and frictional forces in the palpation. The approach first decomposes the normal and tangential force components using the contact centroid technique that approximates the complex contact area as a representative point. Then, we selectively amplify or diminish normal and/or tangential force component. The approach can enhance the detectability of a nodule inside a medical tissue mock-up.**

Keywords—**Augmentation, Palpation, Contact centroid**.

I. INTRODUCTION

In haptic augmented reality (AR), real touch sensation is augmented by virtual stimuli, allowing us to alter the haptic properties of real objects [2]. In our earlier work, we introduced a haptic AR system that can alter the stiffness and friction of a physical object [2]. This can be used for breast palpation training by altering the haptic properties of a tissue mock-up [3]. However, these approaches require the preprocessing steps including contact dynamics modeling of the target object.

In this paper, we proposed an enhanced approach that does not need any preprocessing for augmentation. We utilized a concept of contact centroid, a single point that estimates the behavior of the whole contact area. We decompose reaction forces into the normal and tangential components using estimated contact centroid and selectively scale them for augmentation.

II. Force Decomposition and Augmentation

Our framework uses a rigid spherical probe tip instrumented with a 6 axis F/T sensor (NANO17, ATI Technologies).

The first step of our approach is the decomposition of the reaction force. The decomposition is based on the approximation of the traction distribution over a contact area. The contact area is approximated using a single representative contact point, i.e., contact centroid [1], a reaction force, and torque acting on the point.

A contact centroid is defined as a point on the probe tip surface and the moment at the contact centroid is parallel to the surface normal. The contact centroid can be easily estimated using an algorithm in [1].

The contact normal direction is assumed as the surface normal at the contact centroid on the probe tip surface. The reaction force vector is decomposed into normal force $\mathbf{f}_{normal}$ and tangential force $\mathbf{f}_{tangential}$.

For the scaling, we command augmentation force,

$$\mathbf{f}_{command} = (k-1)\mathbf{f}_{normal} + (j-1)\mathbf{f}_{tangential},$$

where k and j are scaling gains for normal and tangential augmentation, respectively.

III. Result

We tested the framework using a breast mock-up with harder nodules inside (see Fig 1). By amplifying normal force components only, our system could enhance the nodule detectability.

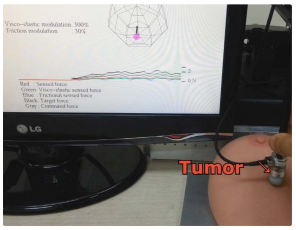

Fig. 1. Haptic augmentation framework with a breast mock-up.

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