Chapter 21
Artificial Tactile Sensing and Robotic Surgery Using Higher Order Neural Networks

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ABSTRACT
In this chapter, a new medical instrument, namely, the Tactile Tumor Detector (TTD) able to simulate the sense of touch in clinical and surgical applications is introduced. All theoretical and experimental attempts for its construction are presented. Theoretical analyses are mostly based on finite element method (FEM), artificial neural networks (ANN), and higher order neural networks (HONN). The TTD is used for detecting abnormal masses in biological tissue, specifically for breast examinations. We also present a research work on ANN and HONN done on the theoretical results of the TTD to reduce the subjectivity of estimation in diagnosing tumor characteristics. We used HONN as a stronger open box intelligent unit than traditional black box neural networks (NN) for estimating the characteristics of tumor and tissue. The results show that by having an HONN model of our nonlinear input-output mapping, there are many advantages compared with ANN model, including faster running for new data, lesser RMS error and better fitting properties.

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INTRODUCTION

Tactile sensing is the process of determining physical properties and events through contact with objects in the world, and a tactile sensor is a device or system that can measure a given property of an object or contact event by physical contact between the sensor and the object. These properties include shape, location, size, temperature, roughness, softness, and so on.

In addition to surgical usages of the tactile sensing, physical examinations performing by physicians on the patient’s body such as the detection of the presence of abnormal masses is the other application of tactile sensing. In this case, design and construction of a device mimicking the sense of touch and compensating the lack of skillfulness is necessary.

In this chapter, we introduce a medical instrument, namely, the TTD which can provide the surgeons with tactile information. All the theoretical analyses, mostly based on FEM, and experiments will be presented. Moreover, there is a specific work on ANN and HONN done on the theoretical results of the TTD. By performing this work, a consistent method employing systematic engineering approaches, such as FEM, ANN, and HONN, has been offered to reduce the subjectivity and individuality in clinical palpations.

BACKGROUND

Tactile sensors are utilized to sense a wide range of stimuli in various biomedical engineering and medical robotics applications, such as detection of the presence or absence of a grasped tissue/object or even mapping of a complete tactile image (Dargahi, 2001; Dargahi & Najarian, 2004a; Najarian et al, 2009). These sensors normally consist of an array of sensors (Fisch et al, 2003; Najarian et al, 2006).

In clinical practice, doctors routinely palpate the patients’ body with the fingers and palm, especially for those diseases where a palpable nodule or lump in tissue is the most common symptom. Even if the nodule is detected via palpation, there is a lack of any precise measuring devices, so all that can be documented is the general location of the tumor within the tissue (Barman & Guha, 2006). In some patients, this technique has preference over some imaging techniques (Zeng et al, 1997). In consequence, many new breast examination techniques have been proposed, most of which are based on the difference between tissue stiffness and tumor stiffness (Kane et al, 1996). Artificial tactile sensing is a new method for obtaining the characteristics of a tumor in the soft tissue (Dargahi & Najarian, 2004b; Dargahi & Najarian, 2005). This includes detecting the presence or absence of a tumor or even mapping a complete tactile image (Bar-Cohen et al, 2000; Dargahi, 2002; Singh et al, 2003). Artificial palpation is another important application of tactile sensing.

It is known that elastography is a merger of several related fields of study: tissue elastic constant (biomechanics), tissue contrast differences, tissue motion by using imaging systems (X-ray, ultrasound and magnetic resonance imaging), and vibrating targets by using coherent radiation (laser, sonar and ultrasound) (Gao et al, 1996). In recent years, atomic force microscopy (AFM) has been successfully applied to local elasticity measurements especially in biological fields (Vinckier & Semenza, 1998). In addition to aforementioned methods, tactile sensing technology is another approach with which the measurement of soft tissue elasticity is possible. This technology tries to imitate the sense of touch which is of crucial importance in the field of minimally invasive surgery (MIS) and robotic surgery (Lee, 2000) examined the state-of-the-art of tactile sensing in its mechatronic aspects. Following this, another research team reviewed the tactile sensing technology for minimal access surgery (Eltaib & Hewit, 2003).