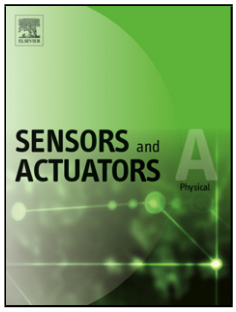

Title: A tactile sensor for measuring hardness of soft tissue with applications to minimally invasive surgery

Authors: Lei Zhang, Feng Ju, Yanfei Cao, Yaoyao Wang, Bai Chen

PII: S0924-4247(17)31074-9
DOI: http://dx.doi.org/10.1016/j.sna.2017.09.012
Reference: SNA 10320

To appear in: *Sensors and Actuators A*

Received date: 6-6-2017
Revised date: 8-9-2017
Accepted date: 8-9-2017

Please cite this article as: {http://dx.doi.org/

A tactile sensor for measuring hardness of soft tissue with applications to minimally invasive surgery

Lei Zhang, Feng Ju, Yanfei Cao, Yaoyao Wang, Bai Chen*

School of Mechanical and Electrical Engineering
Nanjing University of Aeronautics and Astronautics
No.29, Yudao Street, Nanjing, 210000, Jiangsu Province, China
chenbye@nuaa.edu.cn

Highlights

- Tactile sensor for measuring hardness of soft tissue with application to minimally invasive surgery.
- A spiral metal plate is designed to reduce the resonant frequency of the sensor which can restrict the impact brought by the effective mass of tissue.
- Only one piece of PZT ceramic is used as both actuator and sensing element, reducing the number of components of the sensor.
- Simple structure and small size (8mm×8mm×5mm) suitable for MIS.

***Abstract*—This paper presents a novel tactile sensor for measuring hardness of soft tissue in minimally invasive surgery (MIS). The proposed tactile sensor consists of a piezoelectric ceramic plate, a spiral metal plate and a probe. The resonant frequency of the sensor shifts when the sensor contact with a tissue. For restricting the impact brought by the effective mass of the tissue, the spiral metal plate is designed to reduce the resonant frequency of the sensor. Another feature of this sensor is that only one piece of lead zirconate titanate (PZT) is used as both actuator and sensing element. So the structure of the sensor is very simple which can be easily miniaturized and is suitable for MIS. The finite element analyses are carried out to verify the feasibility of the sensor and compare with the experimental results. Several silicone samples are used to test the performance of the sensor and the results show the ability of the sensor to measure hardness of soft tissue and detect lumps inside tissue.**

***Keywords*—Tactile sensor; Hardness measurement; Biological tissue; Resonant frequency shift; Minimally invasive surgery.**