Soft Multimodal Sensor With Adjustable Force Sensing Range For Soft Tissue Palpation

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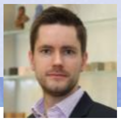

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Introduction

Motivation

- Surgical robots lack direct tactile feedback, resulting in decreased tumor edge detection [1].
- Current sensors are hard tipped, increasing tissue damage [2].
- Current sensors are not adaptable, decreasing usability [2].

Aims:

- To analyse the force sensing performance of a soft multimodal sensor.
- To demonstrate the sensor's force sensing range and sensitivity can be adjusted by changing its internal pressure.

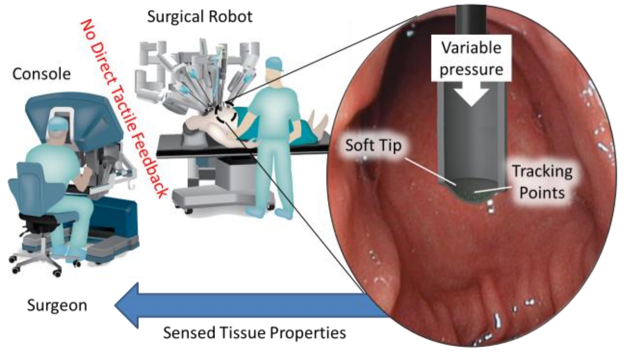

Figure 1 – Sensor application: Our sensor aims to feed tactile information to the Surgeon during robotic surgery [3].

Sensor construction and function

The pressure modulated optical tracking (PMOT) sensor functions through tracking a pressurized deformable membrane. The stiffness of the sensor can be increased by increasing the internal pressure [4]. By varying the stiffness of the membrane, the range and sensitivity of the sensor can be controlled.

The PMOT sensor (Fig. 2) consists of:

- A **stiff housing.**
- An **elastomer membrane with 1 mm diameter hemispherical tracking points** in two circles of different radii shown in Fig. 3b.
- **Pneumatic piping**, connected to a pressure regulator used to control the pressurisation of the membrane.
- A **camera** which captures the location of the tracking points. This is fed to a computer which calculates and records the position of the centre of each tracking point using a set of commands in the OpenCV library.

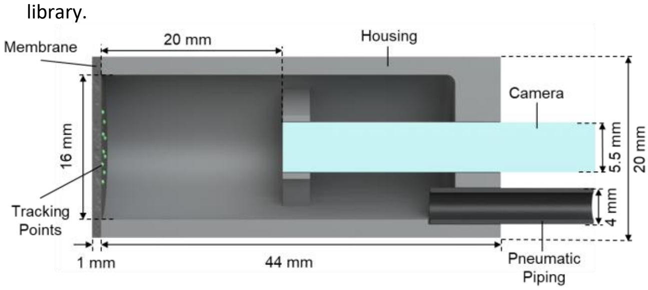

Figure 2 – Cross sectional view of the PMOT sensor with dimensions.

For a video giving more information on the PMOT sensor design and function, please follow this QR code.

Method

An F/T (Force/Torque) sensor, mounted opposite the PMOT sensor (Fig. 3a), was moved in steps towards the PMOT sensor and back, with the force and tracking point locations being sampled after each step.

This was repeated 6 times per pressure at internal pressures of 9, 13 & 17 kPa. Fig. 3b shows the identifiers that will be used to refer to the tacking points.

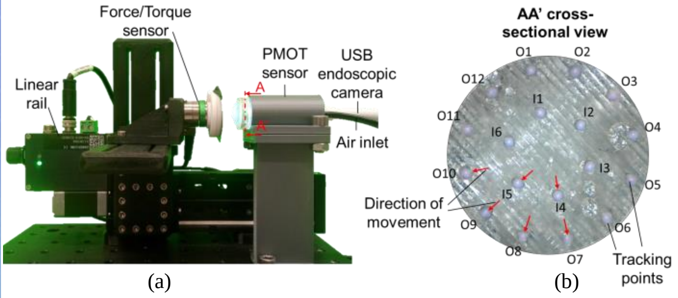

Figure 3 - (a) Experimental setup; (b) The projected locations of the tracking points are visually monitored.

Results

Variance between samples and experiments was found to be low. Point O2 had an average $\mathbf{R^2}$ of **0.956** and an **RMSE** of **0.13 N.**

A linear fit is used to find the sensitivity and range of the device at each tracking point at each pressure. The **sensitivity** is compared in Fig. 4.

The range at each **pressure** was: **9 kPa =1.56 N**, **13 kPa =2.25 N**, & **17 kPa >3.50 N.**

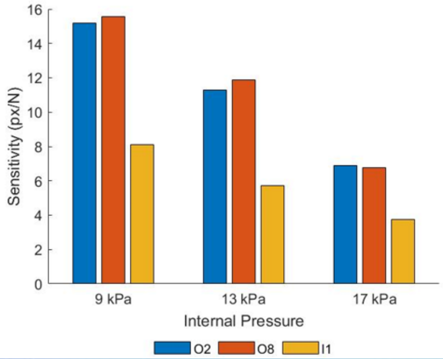

Figure 4 – Force sensing sensitivity at different internal pressures. As the internal pressure increases, the sensitivity decreases.

Discussion

Results show that:

- Point displacement can be reliably used to measure force.
- By increasing the pressure of the sensor, the range of the sensor is increased, and the sensitivity of the sensor is decreased.

In future work, we will:

- Develop an algorithm for in-line tuning depending on the internal pressure.
- Test the ability of this sensor to measure force when interacting with soft objects and at small angles.
- Analyse the PMOT sensors other sensing modalities.
- Miniaturize the sensor for use in robotic surgery.

References

[1] Williams, S. B. et al. (2010) Radical retropubic prostatectomy and robotic-assisted laparoscopic prostatectomy: likelihood of positive surgical margin(s). Urology. 76 (5), 1097–1101.
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[3] Adapted from images from https://ehealth.eletsonline.com/ and "Stomach Endoscope Okay" by timtak
[4] Ali, A. et al. (2019) Dynamic response characteristics in variable stiffness soft inflatable links. *Towards Autonomous Robotic Systems*. 160-170.

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