Research Journal of Applied Sciences 10 (11): 725-727, 2015
ISSN: 1815-932X

Research of Data Visualization Methods for Tactile Diagnostics Devices Based on Mems Pressure Transducers

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Abstract: Owing to rapidly developing methods of minimally invasive surgery a new class of devices appeared. These devices are known as tactile sensors for remote palpation. They give a possibility to the surgeon not to enter into direct contact with the internal organs of the patient and obtain tactile data. Although, production practice of tactile sensors is evolving, the issue of interpretation of tactile data remains open. The study describes the program for tactile feedback visualization for robotic manipulators and haptic diagnostics devices based on silicon crystals matrixes of piezoresistive pressure sensing elements. The characteristics of the series of tactile microsensor devices used in the experiment are presented. The program allows even an unprepared user to detect tumors in the depths of healthy tissue.

Key words: Visualization, Minimally Invasive Surgery (MIS), MEMS, tactile sensor, healthy

INTRODUCTION

Currently technologies of tactile perception are widely applied in medicine and robotics. MEMS devices are most suitable for use as tactile sensors as they are able to give competitive advantages due to the possibility of their mass production, small size and advanced features. In medicine there is an increasing trend towards the incorporation of MEMS devices in the composition of surgical instruments. MEMS technologies allow surgeons to obtain information about density and temperature of the tissue in real time. Additionally, MEMS technologies allow to use more efficient and faster methods of capturing, cutting and retrieving tissue, thus, improving the results of surgical treatment (Rebello, 2004).

In open surgery the surgeon has free access to organs and tissues and is able to manipulate them freely. However, in many cases the incision that allows accessing the desired area, injures the patient to a greater extent than the surgery itself.

Currently MIS Methods are rapidly evolving as they allow the operator (surgeon) not to enter into direct contact with the internal organs of the patient (Preusche *et al*., 2002). The value of MIS is difficult to overestimate because the surgical operations do not require large incisions, they are notable for reduced blood loss, shorter recovery period, decreased risk of infection and improved cosmetic results.

The surgeon uses the sense of touch to obtain basic information about the state of the examined tissue. For example, if the tumor is hidden in the depths of the healthy tissue, it is almost impossible to detect it visually. In this regard, for further development of the MIS it is necessary to create tools to obtain tactile information.

THEORETICAL PART

Dealing with manipulators, equipped with tactile mechanoreceptors, the operator need to obtain tactile information in a convenient form. The devices for haptic feedback perform this function in real time but do not allow the analysis of haptic data in future. In addition, tactile sensitivity is an individual characteristic (Dahiya *et al*., 2010) which means the need for constant calibration of the haptic feedback device.

Even with the creation of a device which is able to mechanically transmit tactile data at the tip of the human finger with high resolution, simultaneous spatial thresholds of tactile sensitivity of the fingertips simultaneously touching two points is on the order of 1-3 mm (Schmidt, 1981). From the point of view of resolution visualization of tactile data has a much greater potential.

Visualization of tactile information allows to record tactile data and to analyze it in future. For example, during MIS operations tactilediagnostics device and an endoscope with a built in camera can be used jointly. The video stream in combination with tactile data is of great value both for research and for training purposes. In addition, the operator (surgeon) is not required to use any outside equipment impeding his work.

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The main trend in the field of tactile sensors is playing back haptic properties of human skin. Tactile devices of matrix type match this requirement in the best way, since each cell of the matrix representing the microelectronic pressure sensorgives specific information and together form a holistic view of the form of the object. Attempts to use most types of sensors (capacitive, magnetic, optical, piezoelectric, etc.) as artificial receptors are known. Most of them have significant drawbacks which make it impossible to use them in practical applications or impose significant limitations (Sokhanvar *et al*., 2013).

Silicon piezoresistive pressure transducers are the most suitable to create tactile sensors. This statement reinforces the global experience (Dahiya *et al*., 2010) which shows that in case of creating arrays with a high density of sensing elements, the choice falls on silicon technology including MEMS devices. One of the key benefits of silicon MEMS devices is the ability to create sensitive elements on production lines for CMOS circuits. Silicon bulk micromachining technology is well studied and allows to produce crystals with high (>40 units/cm^2) density of sensitive elements. Silicon also has a strong piezoresistive effect, almost ideal elastic characteristic, high mechanical strength and stable electrical characteristics for a long time.

Due to the high linearity of response and low hysteresis value it is possible to achieve high accuracy of the output signal. At the same time the problem of temperature dependence can be solved by means of temperature compensation.

EXPERIMANTAL PART

In SPC “Technological center” several models of crystals with matrixes of pressure sensing elements were developed for use in tactile diagnostics devices for surgical applications. The matrix is a silicon crystal, there 7, 19 or 32 integrated pressure transducers (Table 1) with a membrane thickness of 18±3 μm. Each transducer is a piezoresistive bridge which is designed to operate in the pressure range 0÷40 kPa with sensitivity of 0.4÷0.7 mV/V/kPa. Manufacturing technology of crystals includes 10 photolithographic cycles. Using cycles of silicon bulk micromachining, it was managed to make the dimensions of matrixes suitable for use in endoscopes with standard diameters 10 or 20 mm (Fig. 1). The matrix is designed to convert local pressures into an electrical signal which is processed and presented in a convenient form.

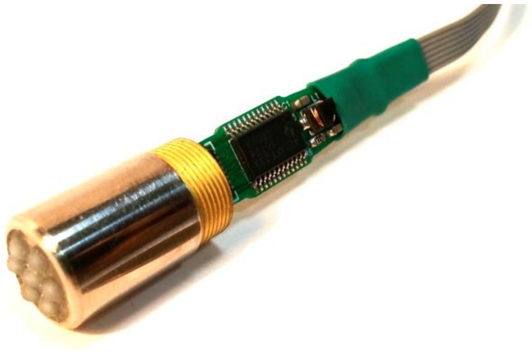

Fig. 1: TMSD (model MIPD-7)

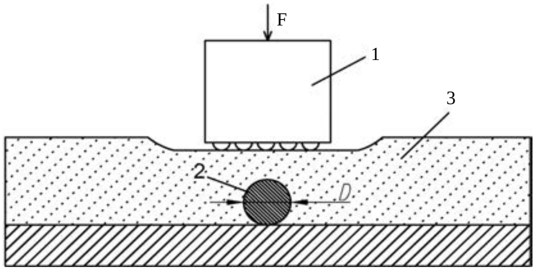

Fig. 2: Schematic representation of the experiment; 1: TMSD; 2: Iron ball (tumor) and 3: Silicone rubber layer (healthy tissue)

Table 1: TMSD models

TMSD (model)	Spacing (mm)	S (mm^2)	Number of sensing elements	Resolution D_{min} (mm)
MIPD-7	2.40	42.4	7	0.6
MIPD-19	2.71	167.1	19	0.6
MIPD-32	1.08	44.6	32	0.1

Figure 2 presents the conditions simulating the presence of the solid tissue (tumor) in the depths of the healthy tissue. At the time of contact of TMSD (Tactile Micro Sensor Device) and analyzed tissue tumor in the depths of the healthy tissue creates a force which transmits to the sensing elements. Size of the tumor, its stiffness, shape and depth will influence the output signal of the TMSD.

Specially, developed program for visualization of tactile information allows to display the tactile data in real time and record it for further analysis. When the probe (tactile sensor) contats with the studied surface, the program displays a color image (color-contour map) of the distribution of stiffness of the tissue. Figure 3 shows an example of data visualization using MIPD-19. Blue color represents the soft tissue, red-hard, i.e., the tumor. Figure 3a-c illustrate the amount of pressure applied to the TMSD during the examination of the tissue.

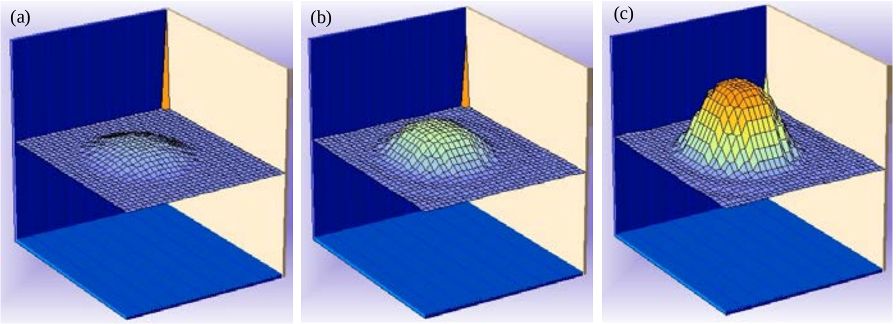

Fig. 3: Visualization of tactile data: a) beginning of contact (minimal pressure); b) average contact (nominal pressure) and c) strong contact (maximum pressure)

RESULTS

The experiment showed that nominal amount of applied pressure is optimum for detecting artificial tumors. With a little practice (15-30 min) even an unprepared user is able to detect artificial tumors using the developed program.

The program interface allows the user to change the view of color-contour maps (2D or 3D). Also, the program allows calibrating the sensor depending on the range of applied pressure and mechanical properties of the examined tissue. The function of setting thresholds changes the smoothness of the color-contour maps for readability.

CONCLUSION

The special program for visualization of tactile information of microsensor devices based on silicon matrixes of pressure transducers was developed. The program presents the tactile data as a color image of the density distribution of the investigated object and records the information for further analysis. The software is intended for use in MIS tools and various robotic manipulators.

ACKNOWLEDGEMENTS

The research was financially supported by the Ministry of Education and Science of the Russian Federation within state contract No. 14.577.21.0112 (unique identifier applied research RFMEFI57714X0112). The research was carried out using the equipment of CCU “Functional testing and diagnostics of micro and nanosystem technique” on the basis of SPC “Technological center”.

REFERENCES

Dahiya, R.S., G. Metta, M. Valle and G. Sandini, 2010. Tactile sensing from humans to humanoids. Robotics IEEE Trans., 26: 1-20.

Preusche, C., T. Ortmaier and G. Hirzinger, 2002. Teleoperation concepts in minimal invasive surgery. Control Eng. Pract., 10: 1245-1250.

Rebello, K.J., 2004. Applications of MEMS in surgery. Proc. IEEE., 92: 43-55.

Schmidt, R.F., 1981. Fundamentals of Sensory Physiology. Springer-Verlag, Heldberg Berlin, New York, Pages: 93-100.

Sokhanvar, S., J. Dargahi, S. Najarian, S. Arbatani, 2013. Tactile Sensing and Displays. John Wiley and Sons Ltd., New Jersey, USA., Pages: 23-34.