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Force Feedback Control System Dedicated for Robin Heart Surgical Robot

Zbigniew Nawrat[a]*, Kamil Rohr[a], Péter Fürjes[b], Lukasz Mucha[a], Krzysztof Lis[a], János Radó[b], Csaba Dücső[b], Peter Földesy[b], Wojciech Sadowski[a], Dariusz Krawczyk[a], Piotr Kroczek[a], Gábor Szebényi[c], Pál Soós[d], Zbigniew Małota[a]

[a]*Foundation of Cardiac Surgery Development, Biocybernetics Laboratory, 345a Wolności str., Zabrze, 41-800, Poland*
[b]*Inst. of Technical Physics and Materials Science, Centre for Energy Research, HAS, 29-33 Konkoly-Thege str, Budapest, 1121, Hungary;*
[c]*Budapest University of Technology and Economics, 3. Műegyetem rkp, Budapest, 1111, Hungary;*
[d]*Heart and Vascular Center, Semmelweis University, Budapest, 9 Gaál József str, Budapest, 1122, Hungary;*

Abstract

3D contact force sensors were developed and integrated in a demonstration system for testing the feasibility of their application in minimal invasive surgery (MIS). The final goal is to integrate the new subsystems in the Robin Heart surgery robot of FRK. [1] Three different functions are targeted: 1.***Micro-joystick actuator*** to be integrated in the hilt of the laparoscope to easily control robotic movement during operation. 2. ***Force sensor*** inside the laparoscopic jaw provide feedback to the surgeon by measuring the grasping strength and 3. ***3D force/tactile sensor*** which facilitates palpation for tissue diagnostics during operation. In this work we demonstrate the functional applicability of the silicon based piezoresistive 3D force sensors in MIS robotic systems to improve their flexibility and reliability by providing real-time force and tactile information during the operation.

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Keywords: MEMS, 3D force sensor, piezoresistive, minimal invasive surgery, ROBinHEART robot systems, real-time feedback

* Corresponding author. Tel.: +48-32-373-56-64;
E-mail address: nawrat@frk.pl

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1. Introduction

The lack of force feedback is one of the main barriers in the progress and widespread application of robotic surgery. [2, 3] The main tasks of the surgical robot control (Fig. 1) are the mapping and analysis the movements of the surgeon operator (position/velocity and possibly other physical parameters), as well as facilitate arm movement by providing control signals to the actuators. Additionally desirable to reverse transfer the force/touch information to the person handling the tools. These signals can help the operator to make immediate correcting actions during the operation: cutting, separation, handle and move tissues, to care vascular clamping, to tie a knot, to recognise the type of tissue (pathology, calcification), to manipulate between different elements of internal organs without the risk of harming neighboring tissue, and also to sense collision of arms/or tools by automatic recognition. Force sensors in ROBinHeart MIS robots

1.1. Micro-joystick actuator

Since the robot moves with 5 degrees of freedom (Fig.1 right), activating the complex movement is available by the use of clutch switching control object. By choosing the appropriate mode the sensor provides the ability to control all the functions of the spherical robot: to lean forward or sideways or alternatively to penetrate or withdraw and to rotate of the tool axis. The feasibility of appropriate control system equipped with this novel sensor was investigated and compared with the classic remote control methods.

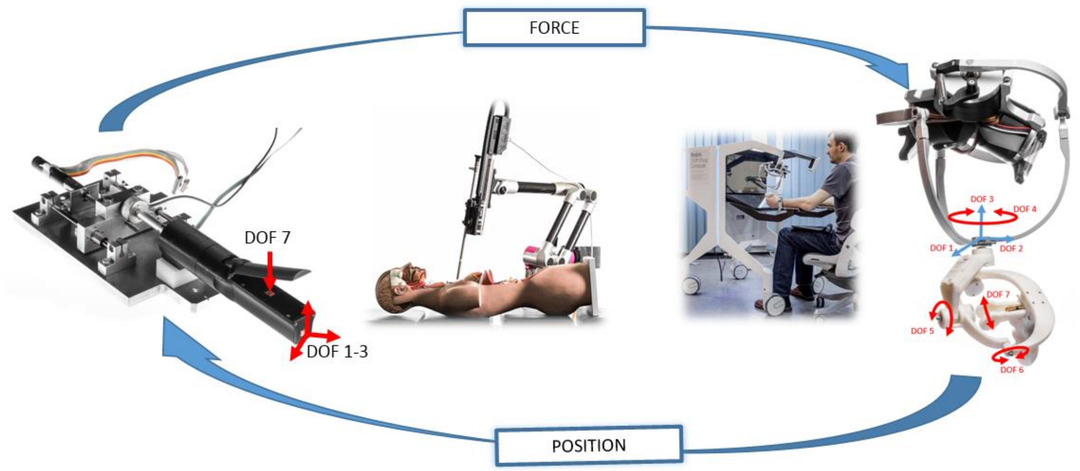

Fig. 1. Schematic representation of the master-slave systems with force-feedback and manipulation.

The force sensors were assembled on flexible PCB and their application for control controlling Robin Heart Vision camera was proved (Fig.2).

Fig. 2. Prototype mini-joystick integrated in a laparoscope (top left) to control robotic arm movement.

1.2. Force and tactile sensing in the laparoscope tool

Preliminary tests of laparoscope integrated force sensors were also accomplished to provide additional on-line information for the surgeon during operation. The model tools were equipped with two 3D force sensors of MFA: one mounted on a tip of grasper for creation tactile signal, whereas the other directly inside the tool for measure the grasping forces (Fig.3). The characteristics of each sensor were set to meet the special requirements of the given functions. An appropriate control systems and test beds has been developed at FRK.

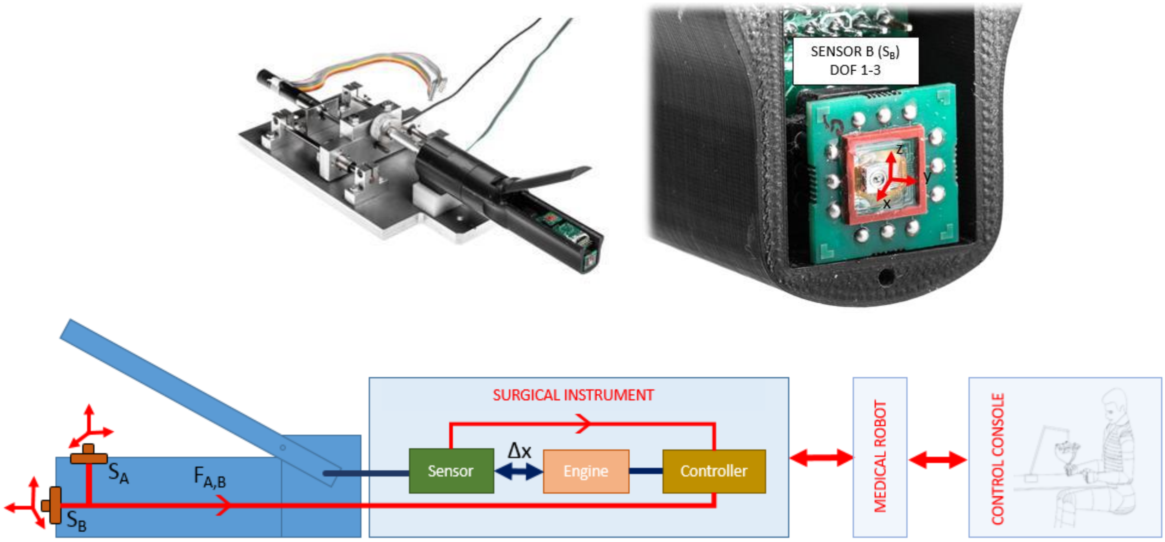

Fig. 3. Model of INCITE tools with tactile sensor on tip and grasping 3D force sensors inside.

Preliminary tests were accomplished to reveal the possible information the force/tactile sensors integrated in the laparoscope head can provide. Our work is also focused on the preliminary definition of the biomechanical effects present during surgical operations. Tactile measurements were also accomplished on artificial and real animal tissues to evaluate the applicability of the sensors for biomechanical screening during MIS surgery (Fig. 4).

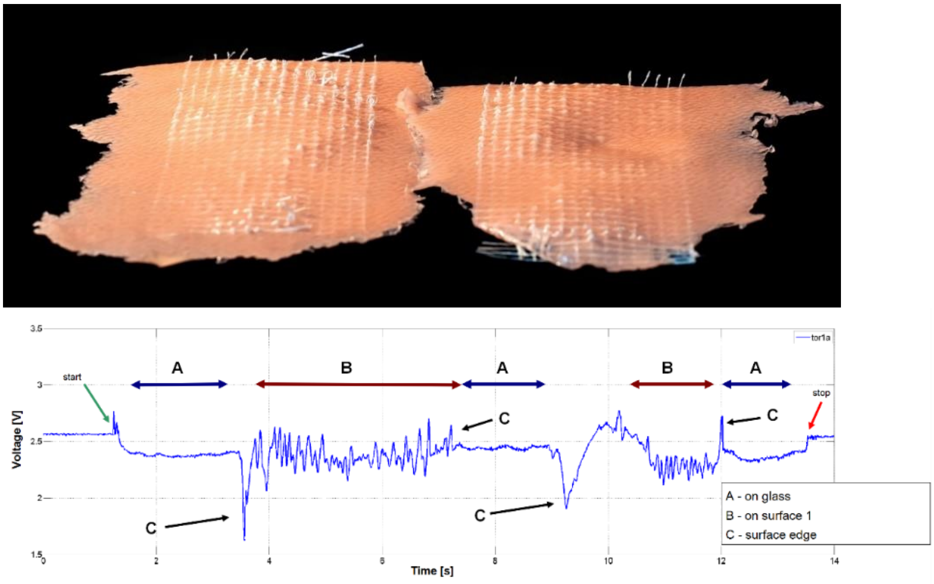

Fig. 4. Preliminary measurements for surface characterization by tip integrated tactile sensor.

3. Conclusions

A model of the robot controller using a prototype 3D sensor force, which has been successfully tested during the study of functional robot (robot control study during a workshop surgical = 200 people, students and doctors), have been performed. Pre-studies of prototype sensors have demonstrated their usefulness in robot force feedback system to assess the state of tissue (tactil sensor for tactic decission) and to assess the clamping force the grasper surgical system (acting force sensor for safety end precision working). Team work is continuing to reduce the size measuring system for typical surgical instruments and optimisation (ergonomy) the surgeon control haptic devices (system) [4]. Developed devices will be used in preparation for the implementation of models of robot Robin Heart.

Acknowledgements

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