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SMART SURGICAL INSTRUMENTS FOR ROBOTS

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Abstract: *Robotic and mechatronic systems already are making their way into the operating room The objective of this work is design of a compact , convenient ,simplified, with better possibilities and at suitable price intelligent instruments for robots with application in laparoscopic surgery thereby and the small hospitals to have accesses and patient benefit from it. The ultimate aim of the work is radical improvements to the quality and efficiency of our healthcare. In contrast to daVinchi by Intuitive Surgical Incorporation and Zeus by Computer Motion which instruments are designed for manipulation and video observation this paper describes novel instrument with wide possibilities including diagnostics and local therapy of carcinoma. The presented smart instruments for robot are an attempt to offer a solution that satisfies in some extent the complex requirements towards the computer-assisted microsurgery. Practical experiments have been conducted with different soft and elastic materials. The purpose of the carried out experiments is to verify the working capacity of the instruments*

Key words: *Smart surgical instrument, Mechatronic device, Laparoscopy, UHF therapy, Diagnostic device*

1. INTRODUCTION[1]

Robotic and mechatronic systems already are making their way into the operating room. The introduction of robots in minimally invasive surgery such as the *da Vinchi* - Intuitive Surgical® USA [1] and *Zeus* - Computer Motion Inc [2] will considerably enhance the surgeon skills.They are not intended as replacement for human doctors, but rather as smart surgical tools. By way the last decade, more than 1.5 million laparoscopic surgical procedures, including gynecologic, cardiac, urology, thoracic, and general surgery, have been performed worldwide by *daVinchi* robot system (Intuitive Surgical Incorporation) . Many research groups have aimed to improve the *daVinchi* system or to propose novel surgical robot systems. A surgical robot end-effectors with a new joint mechanisms for large force, accurate motion, and preventing joint hysteresis has been proposed. In contrast to *daVinchi* and *Zeus* which instruments are designed for manipulation and video observation this paper describes novel instruments with wide possibilities including diagnostics and local therapy of carcinoma. Designed smart tools for robots with application in laparoscopic surgery included four types of instruments - for diagnosis [3-4], manipulation [5], therapy and observation. By developing novel specialized instruments it has to be created more compact, simple, cheaper and easier robotic instruments than ever. It has to be developed novel smart instruments for robotic surgical systems and capability of irregular shape objects manipulation such as stones, organs, tissues etc.

Each instrument is divided into three sections:

- Control block (electronic interface board) ;
- Handle of the tools where is incorporated a block with embedded force sensors, a linear stepper motor and a position sensor;

Different designed end effectors which are fixed to the end of the tools. The design of an each instrument for the robot system consists of a force feedback sensor, a position sensor, a linear motor, and signals processing system. In handle of the mechatronics device a linear actuator works in combination with sensors providing positional feedback. Therefore an absolute encoder, is implemented which is coupled to the shaft of the actuator. As a result of the high measuring resolution of his output feedback signals the proper accuracy of the tip translational positioning is ensured. In construction of handle mechatronics device is also incorporated an axial bi-direction force sensor. The sensor is intended for use as intermediate link between the linear actuator and tool's jaws. This force sensor aids as the tactile sense, and the tactile information is sent to the surgeon's fingers via a tactile feedback device to provide him with a feeling of the shape, hardness, or size of tissues grasped with the instrument. The force interaction is very precise measured in the requisite operating range from 0 to 1500 grams and due to sensor linear - in its convenient conversion constant voltage. Another important function of this device is to fix

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the moment of contact of the jaw to organs/ tissues/ blood vessels respectively, the time was extended. Also it is very important to fix the moment of tissue –tool interaction for local therapy.

On the Fig.1 is shown an experimental module with the smart instrument with application in laparoscopic surgery.

Fig 1. An Experimental module

The presented smart instruments for robot are an attempt to offer a solution that satisfies in some extent the complex requirements towards the computer-assisted microsurgery.

2. SMART SENSITIVE INTERACTION INSTRUMENT FOR DIAGNOSTICS PROCEDURES

The designed instrument for diagnosis poses a wide range of force capabilities measuring (0-1500 grams) both in insertion and retraction of the instrument for implementing different types of end-effectors. It was recognized the presence of the tools –surface force interactions and the lack of these. The instrument is designed to provide the surgeon with a feeling of the shape, hardness, or size of tissues grasped with the instrument. .On the Fig 2 is shown smart sensitive interaction instrument for diagnostics procedures.

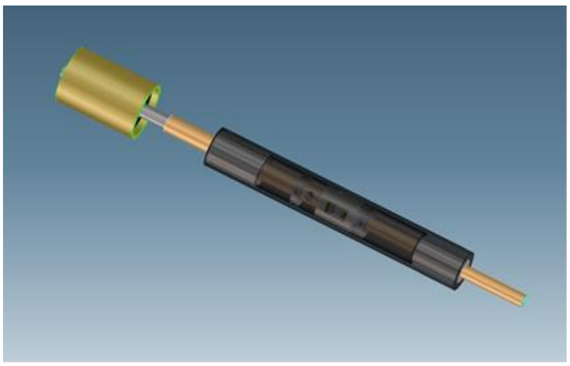


Fig 2. Smart Sensitive interaction instrument for diagnostics procedures

Principle of the work- When surgeon moves the handle of the device his movements are translated in digital signals and controller performs signal processing. The Controller determines control signals to the laparoscopic instrument for implementation of the necessary commands. For measuring purpose an original mechatronic construction where two force sensors situated opposite each other into the handle of tool was designed and produced, in contrast to the direct force measurement method, where the force sensors are incorporated into the jaws of the tools. The instrument can be dividing on a handle, shaft and modular jaws for grasping and manipulation of irregular objects in the process of laparoscopic surgery. The basic component of this instrument is the handle where are incorporated, a construction of an axial bi –directional force sensor. We applied two force sensors by Honeywell Company [6] which are situated opposite each other in an original mechanical construction which was designed and produced for that reason. Force sensors FSS1500NSB by Company Honeywell USA are very appropriate for medical application. FSS sensor allows to very precise measurement of gripping force in the requisite operating range from 0 to 1500 g and due to their linear characteristics - in its convenient conversion constant voltage. Another important function of this sensor is recognizing the moment of contact of the jaw to organs/ tissues/ blood vessels respectively, the time was extended. Size of this sensor is 4 x 4 x 10 mm

The force applied by the surgeon depends on the force of interaction tool-tissue (1). The difference between the force applied by the surgeon and force feedback received from the laparoscopic tool during the jaws –tissue interaction giving the required value adjustment of force (2).

$$F_{real} = f\left(F_{output}\right) \tag{1}$$

$$F_{input} - F_{feedback} = \Delta F_{input} \tag{2}$$

3. SMART INSTRUMENTS FOR THERAPEUTICS PROCEDURES

On the Fig. 3 is shown a smart instrument for therapy. We are applied the construction and principle of the work which was described at previous section. The main elements of the instrument are a step motor by PrimoPall [7] , incremental contactless encoder, a force sensors by Honeywell and therapeutics module mounted on the top of the slider.

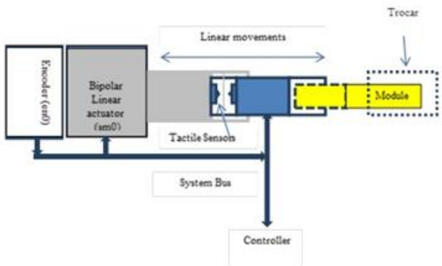
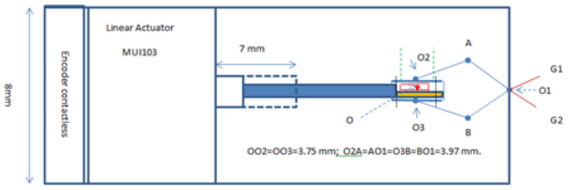


Fig. 3. Smart tool for therapeutics procedures in laparoscopic surgery

3.1. An instrument for mechanical therapeutics procedures.

An instrument for a therapy (On Fig.4) is a sophisticated module that incorporates engines, sensors for positioning and control of encoders and mechanical structures that perform manipulation on tissues (laparoscopic interventions). It is coupled on the top of the Basic platform slider, having three degrees of freedom: translation, rotation, and jabbing between the jaws and been controlled by Controller.



Linear Actuator Slider
Sensor FSS
Support
Jaws

Fig.4. An instrument for mechanical therapy.

3.2. An instrument for RF therapy.

This instrument is designed for programmable tissue exposure in the frequency range from 0 Hz to 500MHz or 40 MHz to 8 GHz . The irradiation is local. A programmed change in the intensity and frequency of the radio signal is a function of time. Main Idea is to transport the end of the tool where is embedded UFR emitter and therapy to be executed locally.

The instrument uses an UHF Generator that generates a programmed frequency, forms the required radio signal through the output stage, and outputs it to an emitter to perform radiotherapy via a wired channel. The linear displacement of the module and its positioning at a set point is provided by the main step motor , taking into account force sensors readings to confirm the contact with the object of the therapy.

The UHF Generator shown on the Fig. 5 is external device, controlled by Controller and generates the signal to the UFR emitter.

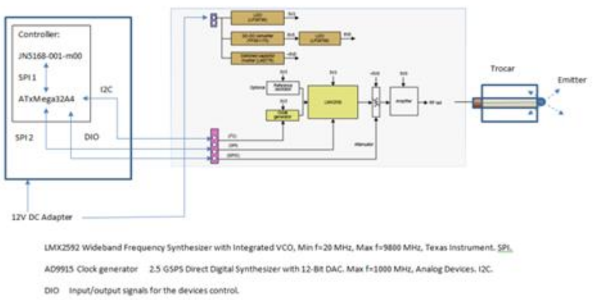


Fig 5. The UHF Generator und UFR control block.

4. INSTRUMENT FOR MANIPULATIONS

The basic construction of the instrument for manipulation is described in previous sections

On the Fig. 6 is shown an instrument for robot for manipulation.

Fig 6. Smart Instrument for robot

In the case when the tool is droved by symmetrical rollers and an wedge mechanism is shown of the Fig 7.

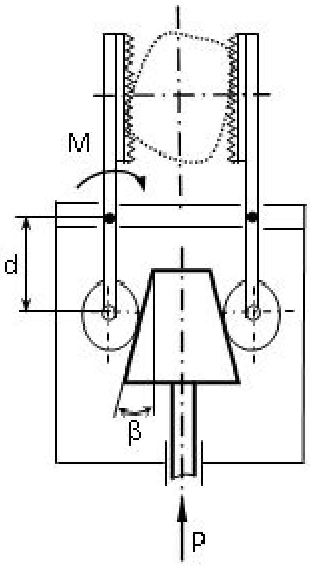


Fig 7. Scheme of an instrument which is droved by wedge mechanism.

Then the force P is computing by equation:

$$P\cdot\eta=\frac{1}{b}\cdot\sum_{j=1}^{n}M_j\cdot tg(\beta+\rho) \qquad (3)$$

Where ρ is the angle account for the strength of the axes of linkages, n is a number of the jaws, b is distance from the centre to the axis of jaws.

For grippers with symmetrical jaws where $M_1=M_2=M$ Driving force is obtained by:

$$P\cdot\eta=\frac{1}{b}\cdot 2\cdot M\cdot tg(\beta+\rho) \qquad (4)$$

When the jaws are droved by two symmetrical actuators, the force is obtained by:

$$P\cdot\eta=\frac{1}{b}\cdot M\cdot tg(\beta+\rho) \qquad (5)$$

According to the rule, the thickness of the end effectors is selected in reference to the constructional recommendations. For gripper with elastic cover-plates and elastic objects such as soft tissues, the point of the contact is realized with surface which size is corresponded to the size of the manipulated objects.

5. EXPERIMENT AND ANALYZES

We are used TCL-TC program for conducted experiments. The TCL-TK program demonstrates the operation of the smart tools by searching for contact, detecting the presence or the lack of the tool-surface interaction, measuring the interaction force of the instrument with a given surface. The results obtained are visualized in a graphical form and save in a database. The results are compared with other such results of the program results.

The following examples are made to illustrate the application of testing model. The experiments are conducted with a piece of Styrofoam and different end-effectors which was designed and produced.The same experiment was conducted with a piece of memory material. The tissues are viscoelastics therefore the use of the memory material is good a choice for their simulation. The aim of the conducted experiment was to demonstrate the precision and functionality of the experimental module with force capabilities.

At a distance of about 2 mm from the wall inwards, the dissection was made. The selected tool was inserted. The step of the motor was 1/2 (24 microns) and the indicial force was 140 grams. Firstly, the instrument searches the contact point with the surface, detecting the presence of the tool-surface interaction and measuring the force interaction of the tip tool with the given surface.

The result from the experiment is shown on the Fig 8, where the Force in grams is given on Y axes and the step of the motor is given on X axes. The stepper motor performs 300 steps and after each of them is doing a measurement of the force and recording of the result in a reference file.

Under the same conditions measurements were made with the piece of rubber inserted into the dissection and a result file was obtained (Fig. 9).

The step of the motor was 1/2 and the indicial force which the instrument has to search was 140 grams. The instrument searches the contact point with the surface, detecting the presence of the tool-surface interaction and measuring the force interaction of the tip tool with the given surface (including the piece of rubber).

On the Fig 10 are selected results from first and second conducted experiment (the pieces of Styrofoam and rubber respectively) where the Force in grams is given on the Y axes and the step of the motor is given on the X axes The same experiment was conducted with a piece of memory material. The results are similar. The results from these, as well as all conducted experiments, show the exceptionally high accuracy of the measuring process (5%) for Automat and Manual modes of operation of the designed experimental force module in a wide range of forces (0-1500 grams) both in insertion and retraction of the instrument and implementing different types of end-effectors for those experiments. It was recognized the presence of the tools –surface force interactions and the lack of these.

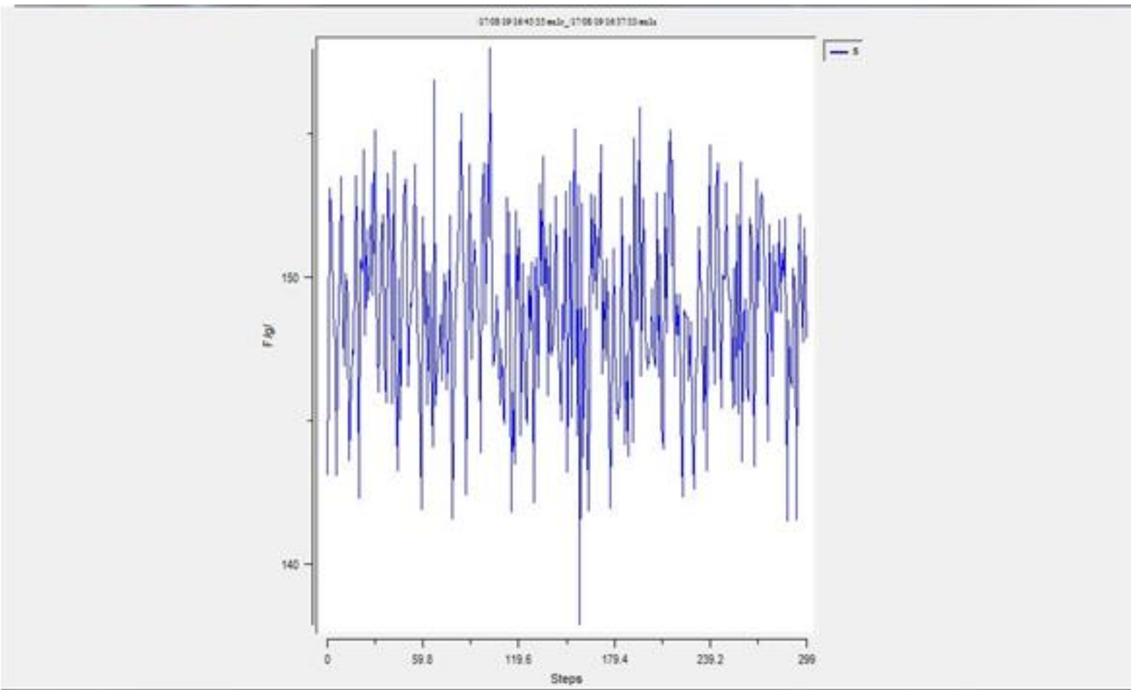


Fig. 8. Conducted Experiment with a piece of Styrofoam

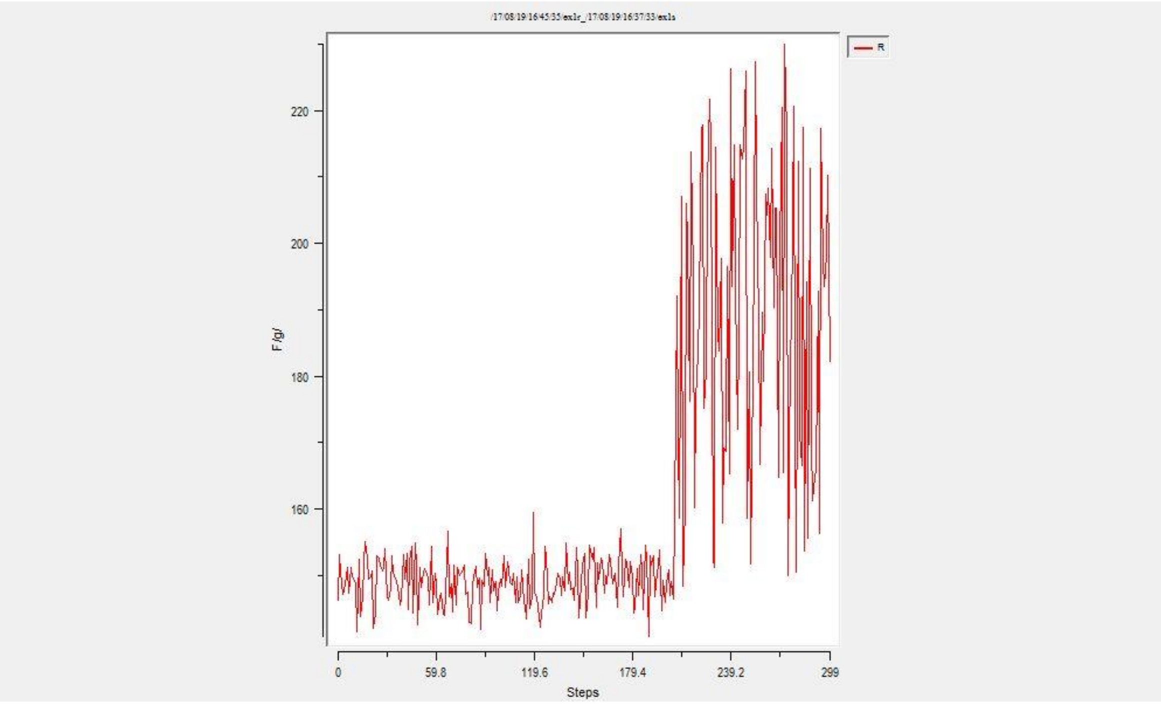


Fig. 9. Conducted Experiment with a piece of rubber

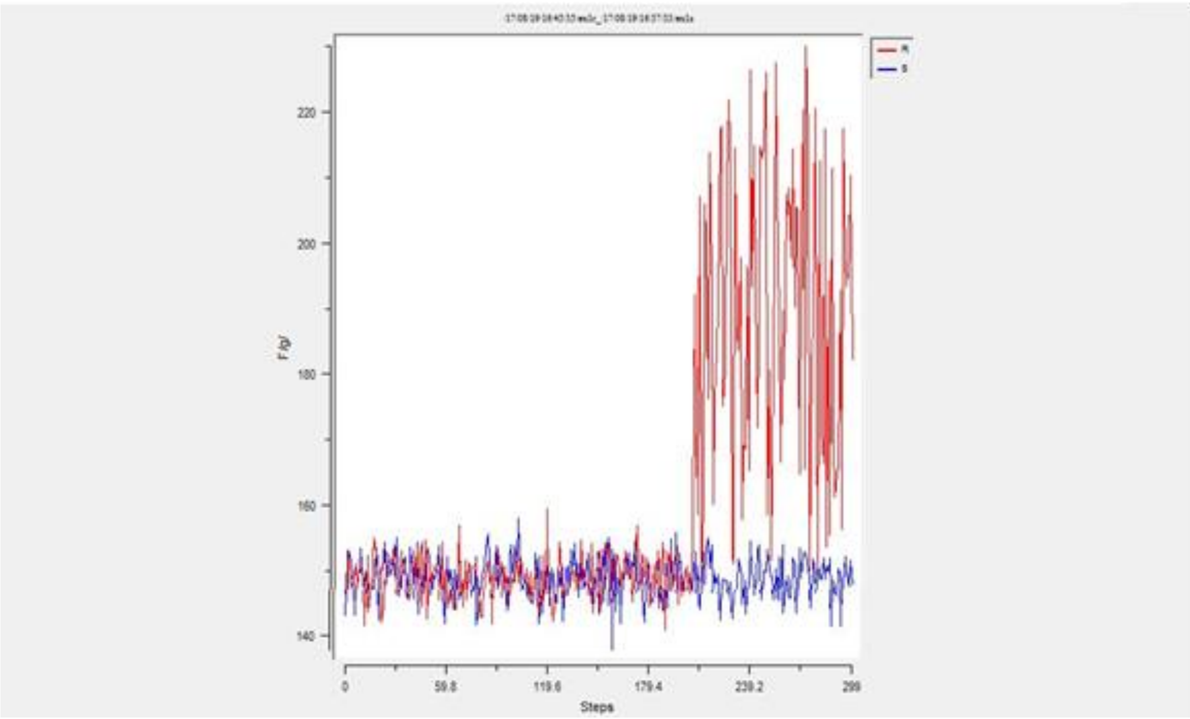


Fig. 10. Comparison of Conducted Experiment with a piece of Styrofoam and rubber

6. CONCLUSIONS

This paper described smart tools for robots with application in laparoscopic surgery. In contrast to *daVinchi* by Intuitive Surgical Incorporation and *Zeus* by Computer Motion which instruments are designed for manipulation and video observation we offer novel modular mechatronics device with additional functions-diagnosis, manipulation, observation and therapy. The target of the work is to bring radical improvements to the quality and efficiency of our healthcare. User-friendly software which to provide a graphical environment for designing, testing, editing and downloading control sequences is realized also. The experimental module of the was designed and produced. The same experiment was conducted. The aim of the conducted experiment was to demonstrate the precision and functionality of the experimental module of the smart instruments for robots.

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