DEVELOPING SENSORS FOR SURGERY SUPPORT ROBOTS

20328 Mona Kudo

1. INTRODUCTION

Today, many kinds of surgery support robots are used in medical procedures all over economically advanced countries such as the United States of America, the United Kingdom, Germany and Japan. Many surgery support robots have been developed. Between these nations, the number of robots are growing.

Surgery support robots will be able to perform surgeries single-handed in abdominal operations or laparoscopic surgical operations in the near future because they will be mass produced at low prices[1]. They might be made and used all over the world. However, there are some problems which have to be solved to make surgery support robots common and improve science and engineering.

This report discusses how to solve these issues from the viewpoint of technology. This report focuses on how to make the robots with sensors to provide tactile feedback. The technology that will help surgery in the future.

2. LITERATURE REVIEW

1)What are surgery support robots?

This means "endoscopic operation support robot systems". Originally, they were developed as telepresence robots which were used between war zones and medical facilities to treat soldiers injures[2]. As a result, Puma200, an industrial robot produced by Unimation in 1985 became a pioneer of surgery support robots and various robots had been produced since (see Table1)

Surgery support robots help surgeons with remote operations, they are not "automatic" surgery robots.

Three factors, are part of the robot: an endoscope, manipulator forceps and robot arm Most robots use a master slave system where surgeons can remote control them.

2) Common surgery support robots

Many surgery support robots have been developed and the "da Vinci Surgical System" is the most famous. It was developed as a surgery support robot by Intuitive Surgical in 1999 and used for the first time in 2000 at Keio University Hospital. As of the time of writing, more than 20 hospitals use it[3].

Da Vinci has many positives most notably the minimally invasive nature of the surgery. It can help surgery without leaving large scars[4].

---

[1] Norihito Kishi (2011). *Robots help Japan* Bungei Shunju

[2] HIRUDA Co. (2017/04/23 access). HELTH PRESS-Surgery support robots have evolved since da Vinci was born

[3] Fujita Health University Hospital (2017/04/23 access). da Vinci, the surgery support robot system URL: http://fujitahu.ac.jp/HOSPITAL1/advanced-medicine/da-Vinci/index.html

[4] Fujita Health University Hospital (2017/04/23 access). da Vinci, the surgery support robot system

Currently, Da Vinci is often used for urdogical surgery and some doctors believe that it will be used for gastroenterological surgery in the near future[5].

Three parts, the operation unit, the robot arms and a monitor for assistants make "da Vinci" (see Figure 1). The surgeon can see a clear picture from the endoscope, so the surgery is as safe as currently possible. Recently, the fifth generation of da Vinci has been developed[6].

3) Problems

"da Vinci" has many positives which can help surgeons, however, there is a big issue in that there is no tactile feedback.

In the case of surgery using "da Vinci", surgeons use forceps without touching the patient's body directly. This increases the risk of medical mistakes[7].

For example, if forceps damage part of a patient's body not shown on the monitor, the surgeon cannot see this happening and he may only notice it after the surgery is complete. This may lead to a serious accident.

The Japanese company, DENSO and Shinshu University developed "iArmS" which can remove the shaking of a surgeon's hands (see Figure 2). The system uses sensors to perceive the movement of the surgeon hands and it removes very minute shakes to improve the accuracy of surgery.

3. METHODOLOGY

1) Hypothesis

There are two possible steps to a solution to the problems of tactile feedback.

First, forceps can be sheathed in a silicone rubber that is like human skin (see Figure 3). This idea can answer one of my research questions, "how can forceps be used in bodies without damage?" There is a risk to the patient's body caused by touching hard metal forceps[8]. Therefore, if the surface of the forceps is soft it decreases the risk. Silicon rubber is often used in the part of medical science, for example, models of bodies, caps for syringes, and in some parts

URL: http://fujitahu.ac.jp/HOSPITAL1/advanced-medicine/da-Vinci/index.html

[5] Tokyo Medical University Hospital (2017/04/23 access). Completely analyze of da Vinci, the surgery support robot
URL: http://hospinfo.tokyomed.ac.jp/davinci/top/

[6] HIRUDA Co. (2017/04/23 access). HELTH PRESS-Surgery support robots have evolved since da Vinci was born URL: http://healthpress.jp/2015/03/2-3.html

[7], Cyril Fievet (2003). *The New Century of Robots* Hakusui Sha

[8] Cyril Fievet (2003). *The New Century of Robots* Hakusui Sha

of laparoscopic surgical operations. In addition, the thinner types are used in heart-lung machines[9].

Second, inserting sensors into the silicone rubber. This idea answers the question, "how can a skin for robots be made?" According to the example of "iArmS", it is possible to insert sensors into robot arms[10]. According to Dr Fumiya Ida, if the robot has some sensors in its silicone rubber it can provide tactile feedback. Inserting sensors into the silicone skin parallel to each other (see Figure 3) will allow pressure from the patient's body to be perceived.

The sensor used in the robot can perceive pressure and send a signal to the master unit. When the signal has been sent to the master unit, the surgeon can 'feel' the patient through the robot.

2) Data for sensor performance

According to Table 2, the sensor which has the highest numerical value of gauge factor (the ratio of reactive change in electrical resistance to the mechanical strain) is ZnO Nanowire Films. However, the maximum strain is not good for the robots[11]. On the other hand, CTPE doesn't have a high numerical gauge value but has a suitable minimum width and maximum strain to make a sensor for surgery robots[12].

CTPE can be used as a sensor with high performance and has a greater function than other sensors and materials.

According to Table 2, CTPE is very sensitive and the function is not lost even when very thin. So, it can be used for sensitive robots such as surgery support robots.

4. DISCUSSION

1) Research questions

Dr Fumiya Ida, answered the following research questions.

Q1. What is the most effective way to make the sensors smaller?

A1. It seems that MEMS, Micro Electro Mechanical Systems is the best. It has a micron level structure with some sensors and electronic circuit. The

[9] FUJIKURA COMPOSITES (2017/04/23 access) Medical silicone rubber URL: http://fujikuraindustrial.com/articles/index/168/category:0

[10] DENSO Japan (2017/4/24 access) DENSO developed the new surgery support robot, "iArmS" URL: http://www.denso.co.jp/ja/news/newsreleases/2015/150427-01.html

[11] Josie Hughes and Fumiya Iida *Localized differential sensing of soft deformable surfaces*, 2017

[12] Josie Hughes and Fumiya Iida *Localized differential sensing of soft deformable surfaces*, 2017

difference between this and others is whether it has a moving point or not. This is a device which is necessary to make robots smaller.

Q2. What way is the most effective to spread the excursion of sensors?
A2. I think using something soft is the best way, for example, silicone rubber. the reason why it is the best is that the soft and thin material can expand and spread its excursion like a balloon. In addition, to increase the number of joints is also effective. To increase the joints, we can find that robot arms can move more than two directions with one joint. If we increase joints, the robot can move all angles. I'm developing the new arms now. It refers to "octopus leg". Its shape has a lot of joints. When we try to increase joints until reaching the limit, the shape becomes like octopus legs. In addition, they have nerve fibers. If you want to add tactile feedback to robots, you should refer to them. Of course, we can also increase arms to spread the excursion.

Q3. What is the most effective way to make the robots move smoothly?
A3. I can tell you the same answer as before question. To increase joints is the best way, too. As you know, octopus legs can move smoothly because it has a lot of joints.

Q4. How can we increase the feedback of sensors?
A4. There are two ways. First, to increase sensors. If you do so, you can get a lot of feedback. This idea might be easy to understand. Second, to change the materials which is used for robots. I made a table that shows the materials and their feedback (Table2). I think you had better use the best material to create your idea. This time, if you don't think about selling the robots, you can use the expensive one which has the best performance.

2)The plan

First, this section outlines a solution of using CTPE for the sensors in silicone rubber of the surgery support robots.

There are the four steps to making sensors for a surgery support robot.

First, making "a skin". Silicone rubber has a high gas permeability, so it is often used in medical contexts for example, as a membrane for an artificial heart and lung device[13]. By using this technology, a thin skin for the robot can be made.

Second, inserting sensors into the silicone rubber. The sensor is made of

[13] FUJIKURA COMPOSITES (2017/04/23 access) Medical silicone rubber
URL: http://fujikuraindustrial.com/articles/index/168/category:0

CTPE and is very thin, the minimum width is 0.5mm. The length of the sensor is 10~33mm for the edge of forceps. They are very thin, so they are inserted as shown in Figure 4.

Third, connecting the sensors to the master unit. This provides the feedback when the forceps touch.

Finally, sheathing the forceps in a skin. At first, the edge of forceps is sheathed in the silicone rubber and CTPE sensors. Then, the shaft is sheathed, too. [Figure 5]

This methodology would introduce tactile feedback to surgery support robots.

5. CONCLUSION

From this research, CTPE sensors can be implemented for surgery support robots such "da Vinci". Currently, sensors are made from metal, but they may also be made from other materials, for example, carbon nanotubes. If the technology advances, it may become able to be implemented to solve this problem.

Today, surgery support robots are used in many advanced countries. However, in Japan, they have been used only in the few medical facilities. There are some reasons for this notably the accidents with the laparoscopic operation system which happened in Gunma in 2015. However, people are worried about using new technology such "da Vinci" in Japan. That is why safe models of surgery support robots must be made.

Figure 8: Dr. Fumiya Ida with me

6. ACKNOWLEDGEMENTS

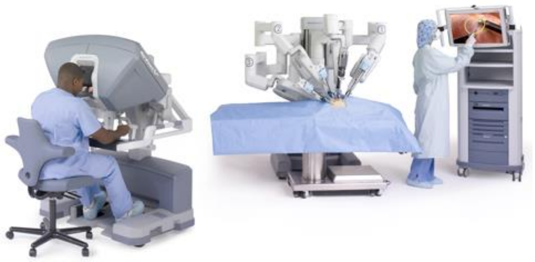
Thanks to Dr. Fumiya Ida (BIRL in Cambridge University), Prof. Masato Nagino (Nagoya University) and Dr. Toshikazu Sakai (Fujita Health University) for providing data and information.

Year	Name	How to use for
1985	Puma200	Neurosurgical biopsy
1986	ROBODOC	Total hip arthroplasty
1987	Cyber knife	Radiosurgery
1988	Puma560	Trans-urethral resection of the prostate
1997	Neuro Mate Stereotaxic System AESOP	Stereotaxic operation Minimally invasive surgery
1998	Zeus	Thoracic surgery
1999	da Vinci [I]	Thoracic endoscopic surgery
2008	neuro mate	Stereotaxic operation

Table1

Robots made for surgery

(Made from HIRUDA Co. (2017/04/23 access) HELTH PRESS-Surgery support robots have evolved since da Vinci was born.)



Sensor type	Gauge factor	Minimum width	Maximum strain
Strain gauge	1-2	~2mm	5%
Ionic liquid sensors	3-5	0.6mm	100%+
ZnO Nanowire Films	200	~2mm	50%
Graphene foam	15-29	3mm	75%
Silver nanocomposite	2-14	3mm	70%
CTPE	9-20	0.5mm	100%

Figure 1: da Vinci Surgical System
(https://www.ach.or.jp/about/daVinci/)

Figure 2: iArms
(http://www.denso.co.jp/ja/news/newsreleases/2015/150427-01.html)

Figure 3: Sensors in silicone rubber (Josie Hughes and Fumiya Iida *Localized differential sensing of soft deformable surfaces,* 2017)

Table2

"Comparison of gauge factor, minimum achievable diameters and the maximum strain that resistive based sensors can undergo"
[made by Dr. Fumiya Iida in 2017]

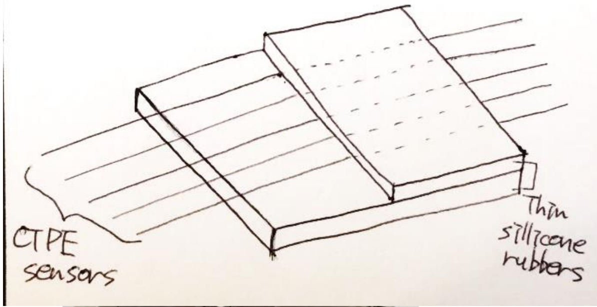
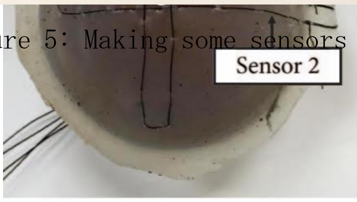


Figure 5: Making some sensors and inserting



them into the silicone rubber

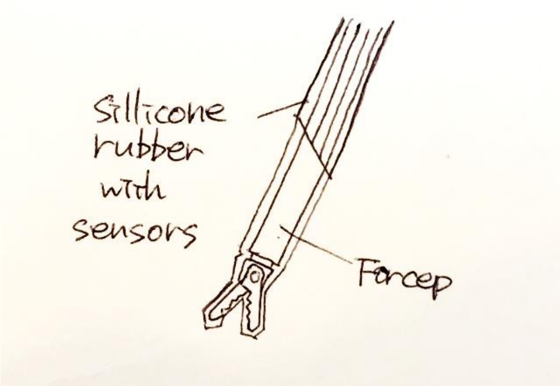


Figure 6: Sheathing forceps in "a skin"

Mona Kudo