Non-Contact Impedance Sensor

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Abstract— **This paper discusses the Non-Contact Impedance Sensor that can measure the mass, viscosity and stiffness on environment. The developed sensor is composed of a laser displacement sensor and air force supply nozzle. The application of the developed sensor are human internal organs, skin, foods, and industrial products. We show the design based on the patent (♯2002-329145) and explain the expected market.**

1. Introduction

There are various needs for measuring the mechanical impedance (mass, viscosity, stiffness) of environment, such as medical examination of a cancer tissue, medical examination of eye pressure, estimation of human skin age, judgment of the best time for eating fruits or meats, and evaluation of the degree of completeness of compliant material in industrial products. While various approaches have been proposed for answering these issues, most of them are based on the direct contact method [1][2], where the pushing force is actively given by a force probe. By the relationship between the applied force and the displacement, we can compute the impedance parameters. These approaches, however, cause several inherent issues due to the direct contact between the probe and the environment, for example, imparting damages to environment, receiving damage of the sensing probe itself, and sanitary issue especially for both foods and human beauty care. To cope with these issues, non-contact approaches have been proposed recently and their effectiveness has been reported [3][4]. Instead of a force probe, an air-jet is normally utilized for imparting an equivalent force to the environment. We also developed the Non-Contact Impedance Sensor as shown in Fig. 1[5]. As shown in Fig. 2, various application exists in this sensor. This paper explains the design of the developed sensor based on the patent (♯2002-329145) and shows the expected market.

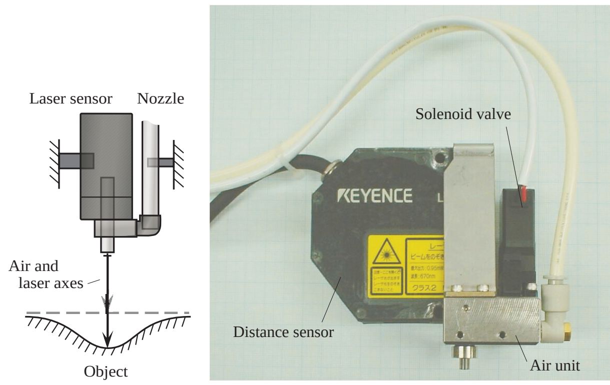


Fig. 1. An overview of the developed sensor

Fig. 2. Various application fields

2. Non-Contact Impedance Sensor

2.1 Basic Design of Non-Contact Impedance Sensor

Fig. 1 show the basic design of the developed sensor unit and its overview, respectively. The sensor unit is composed of a laser distance sensor and an air supply adaptor. The key idea is that the hole of air supply adaptor is so designed that the longitudinal axis perfectly coincides with the sensing axis of the laser sensor. To achieve this tuning up easily, we attach a sliding mechanism for the air supply adaptor, which helps us to change the position with observing the laser spot. The air supply system is equipped with a high speed solenoid valve which is the key element of the sensor toward a high speed sensing. The valve can operate with the maximum switching frequency of 500[Hz] under the supply pressure of 0.05[MPa] through 0.25[MPa]. Such a high response allows us to estimate the impedance parameters with high quality as well as high speed. Fig. 3 shows the overview of the whole system including the Non-Contact Impedance Sensor.

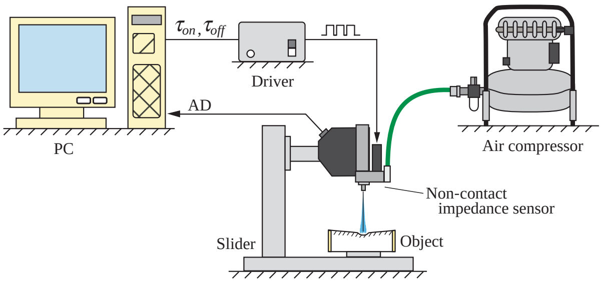
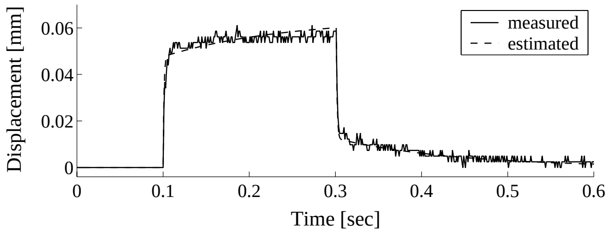


Fig. 3. Sensing system



$\hat{k}_1 = 3800$[N/m], $\hat{k}_2 = 11100$[N/m], $\hat{c}_1 = 3.68$[Ns/m], $\hat{c}_2 = 1550$[Ns/m]

Fig. 4. Application to pear

2.2 How to Estimate Impedance Parameters

Let us suppose that we apply a force for a linear four elements damper-spring model (Voigt model). We can describe the equation of motion for the model as follows:

$$b_2\ddot{x}(t) + b_1\dot{x}(t) + b_0x(t) = a_1\dot{f}(t) + f(t) \qquad (1)$$

$$\left(\begin{array}{ll} b_2 = \frac{c_1c_2}{k_1+k_2}, & b_1 = \frac{c_1k_2+c_2k_1}{k_1+k_2} \\ b_0 = \frac{k_1k_2}{k_1+k_2}, & a_1 = \frac{c_1+c_2}{k_1+k_2} \end{array}\right)$$

where c_i, k_i(i=1,2), $x(t)$, and $f(t)$ are damper, spring of the environment, the displacement the environment, and the applied force, respectively. Suppose that we obtain a set of displacement $\boldsymbol{x}(t) = [x_1, x_2, \cdots, x_n]^T$ for a given force set $\boldsymbol{f}(t) = [f_1, f_2, \cdots, f_n]^T$. By applying the least-square method, we can obtain the estimated impedance parameters $\hat{k}_1$, $\hat{k}_2$, $\hat{c}_1$, and $\hat{c}_2$[5].

3. Experiments

As an example of application, we applied this sensor for measuring the degree of ripeness for pear. Fig. 4 shows the experimental results, we apply stepwise air jet for 200[msec] for the surface of pear and measure the displacement of the surface. Although the displacement of a pear is only 50[μm], we can to measure such a tiny displacement. By using the four-elements model, we can estimate impedance parameters. The displacement reproduced by these parameters is expressed with the dashed line in Fig. 4. From Fig. 4, we can see a nice coincidence between the reconstructed data and experimental data. This means the estimation is nicely done.

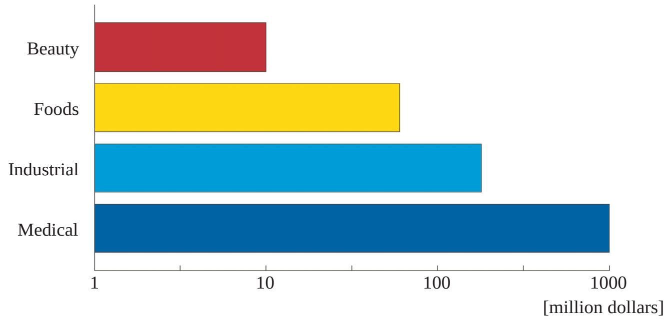


Fig. 5. Market scale of application fields

TABLE I
ITEMS OF THE MARKET SURVEY

Target	T-number	S-number	Unit price
Beauty clinic	10000	1	$1,000
Fruit market	5000	3	$4,000
Factory	1500	10	$4,000
Hospital	20000	1	$50,000

4. Market Survey

Fig. 5 shows the expected market in the world. From this figure, we can see that there is a big market, even with total $1,250,000,000. This survey is based on TABLE I, where T-number and S-number are the number of shops, markets or hospitals, and the number of sensors to be necessary, respectively. Due to the simple structure and fewer numbers of mechanical components, we can manufacture the sensor with less than half price of the conventional contact sensors.Since there are many fields where non-contact impedance sensing is definitely necessary, we believe that this sensor will bring a big market in various fields, such as beauty care, foods, medical and industry.

5. Conclusions

We discussed the developed Non-Contact Impedance Sensor capable of estimating the local impedance parameters exactly without any contact. We also showed the expected market.

References

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[3] H. Shinoda and H. Yamasaki: Noncontact sensing of surface hardness, *J. of SICE*, vol.27, no.7, pp. 749–754, 1991.
[4] NIDEK: Non-contact tonometer, *http://www.nidek.com.*
[5] M. Kaneko and T. Kawahara: Co-axis type non-contact impedance sensor, *In Proc. of the IEEE Int. Conf. on Robotics and Automation*, pp. 709–714, 2004.

Non-Contact Impedance Sensor

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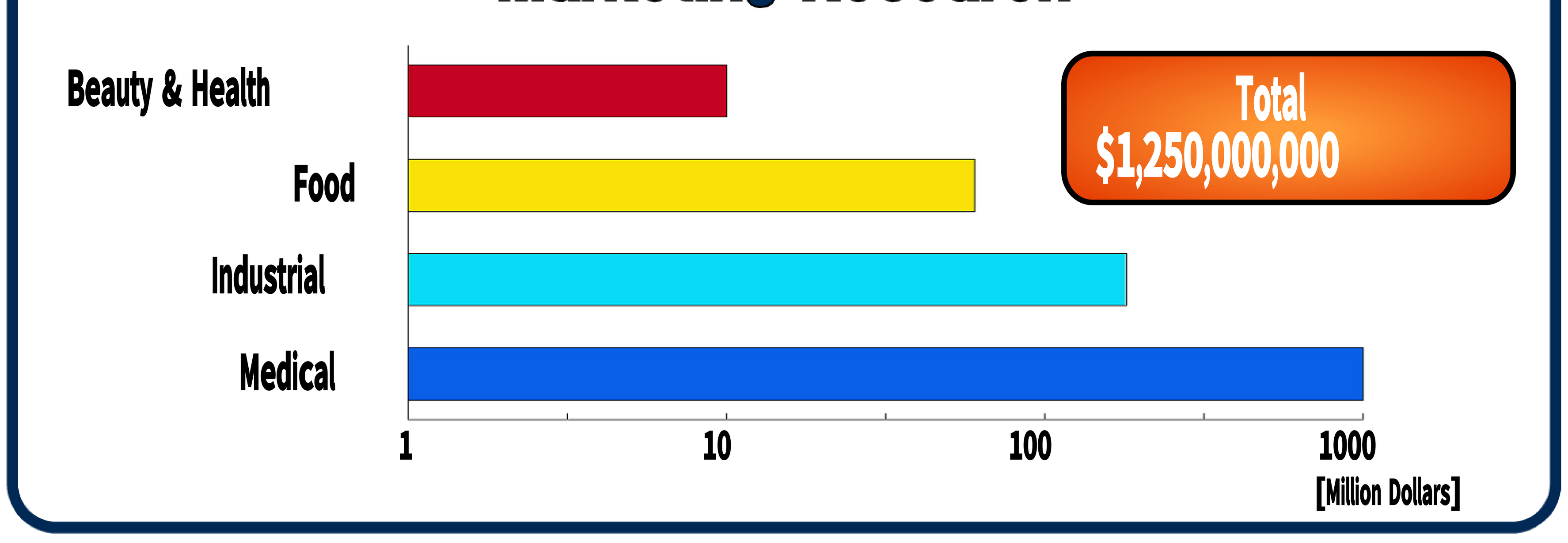
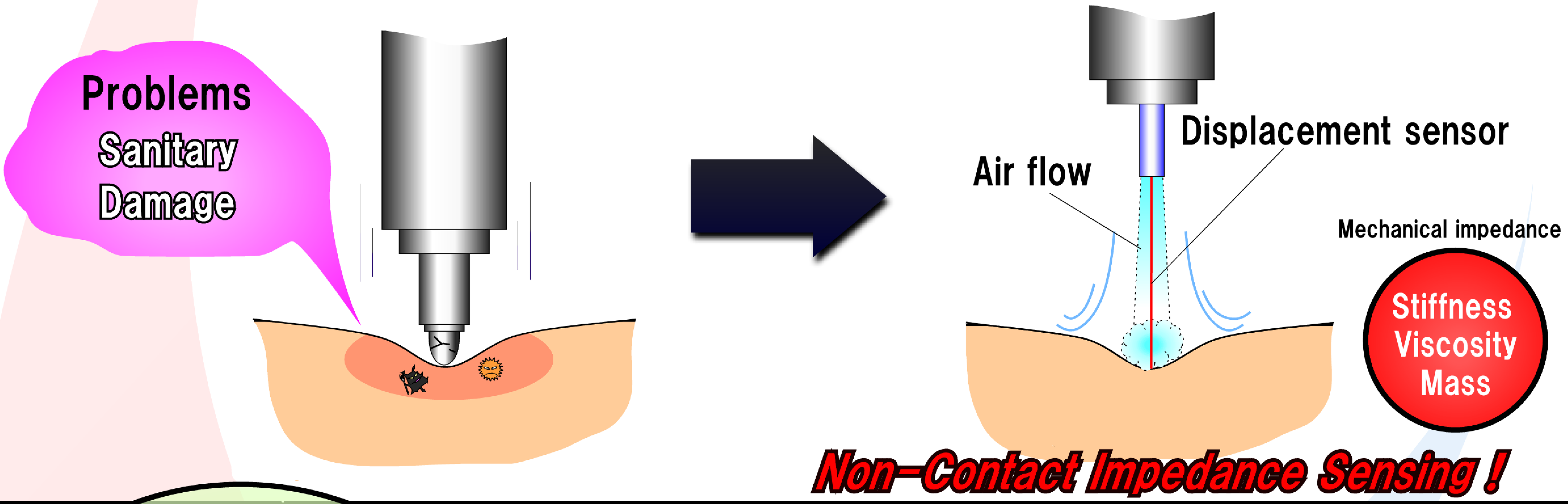
Marketing Research

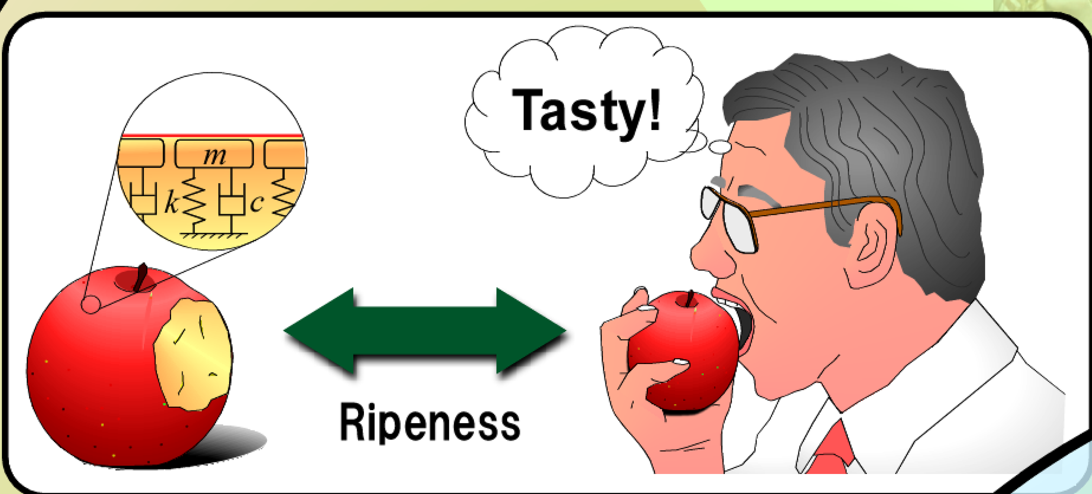


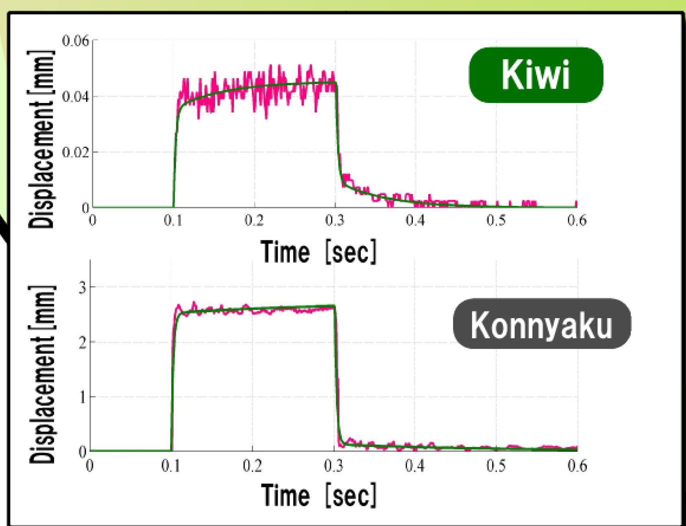
Contact Method

Non-Contact Method



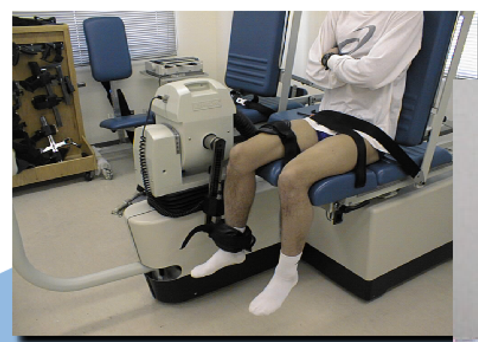
Food






Fruits

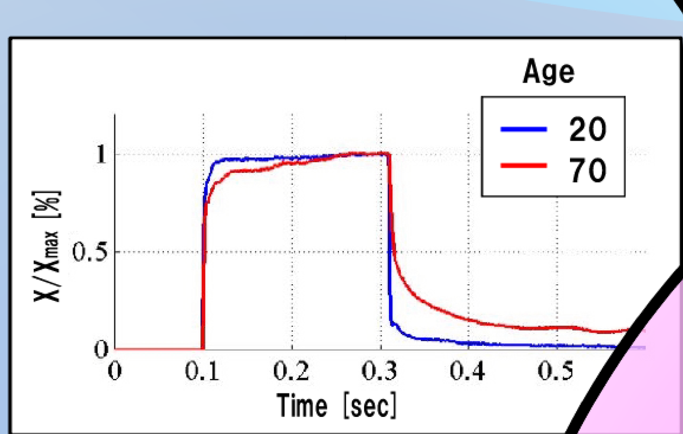

Bread


Massage

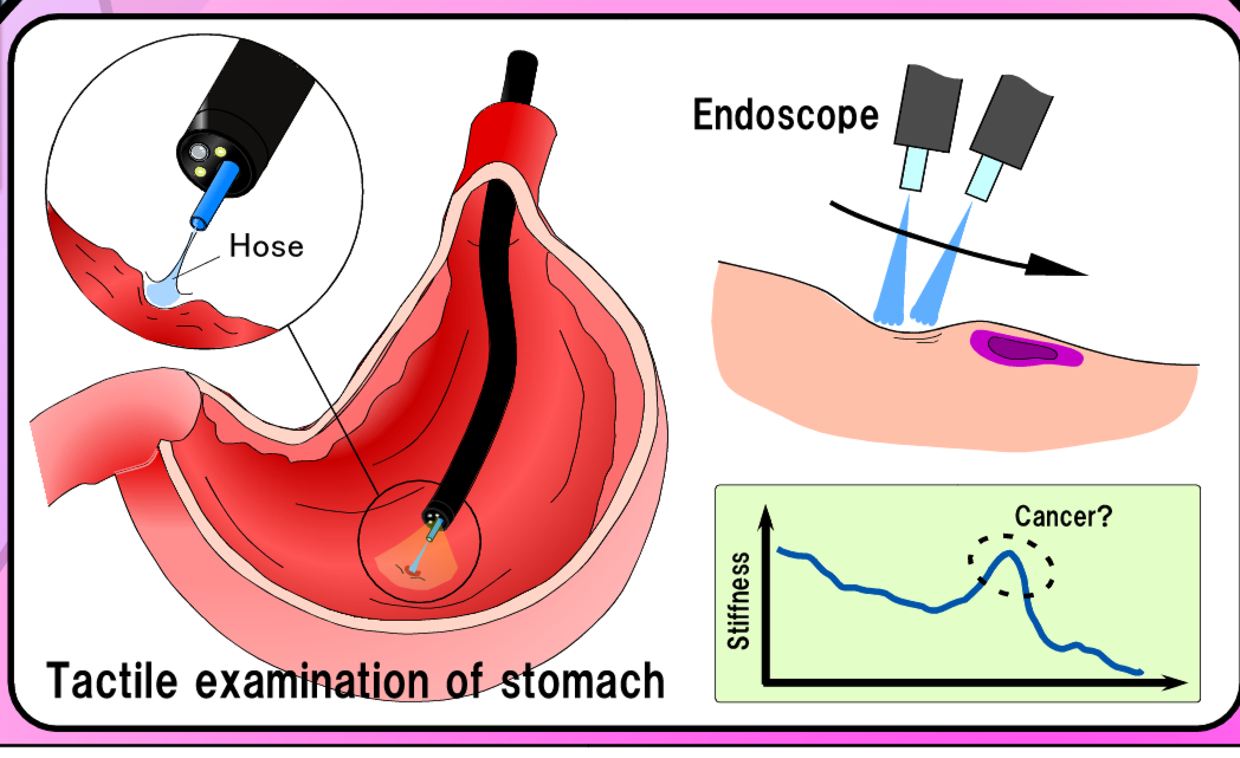

Beauty salon

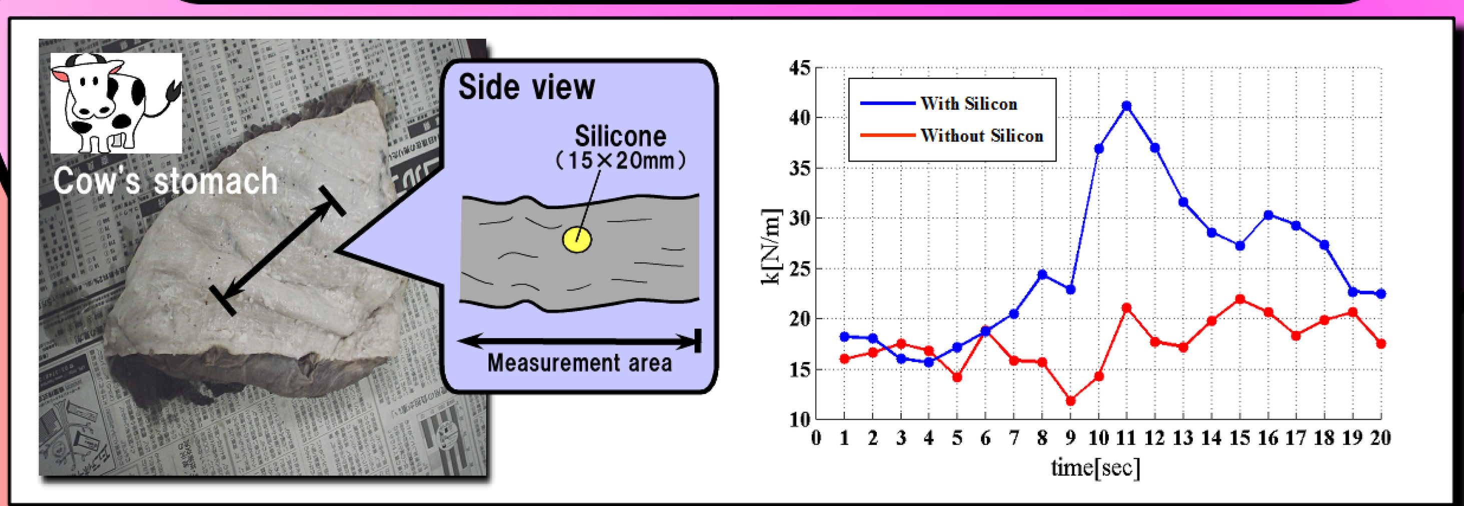

Endoscopic diagnosis

Beauty & Health

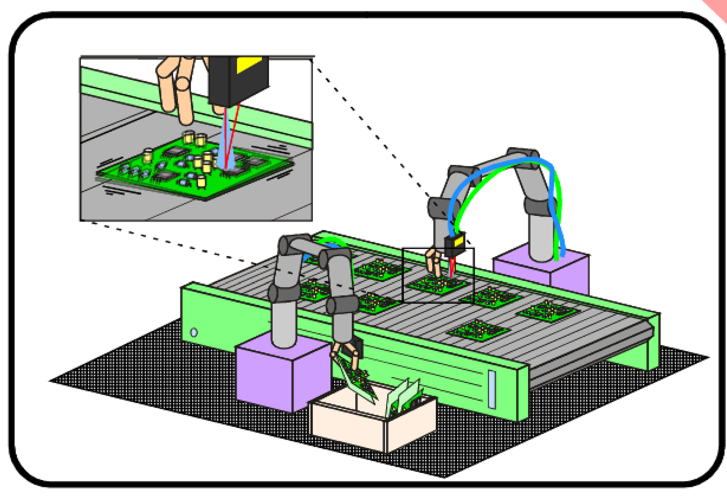


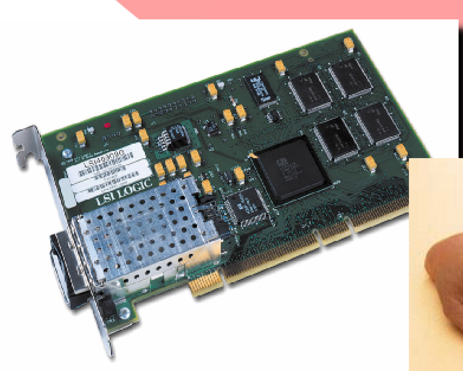
Medical





Industrial




Circuit board

Silicone implants