Wearable Tactile Action Sensor

HapLog®

(Haptic Skill Logger)

CONTENTS

1. Introduction

It is difficult to convey the nuance of human behavior in words. How much power is "Squeeze oneself to push" and "Touch lightly?" Although a human being uses verbal and visual information to acquire the skills for adjusting the power and behavior of touching with a fingertip or the skills for touching behavior composed of such actions, precise acquisition is impossible. In addition, also in the evaluation of usability, analysis is often performed through the subjective evaluation based on the results of a questionnaire and the moving images of actions. However, the status is that it is difficult to provide objectivity unfortunately.

Therefore, we thought that it was necessary to identify the power level (contact pressure) and the action of a fingertip in order to acquire the skills of tactile action. The haptic skill logger (HapLog) is a wearable device mounted on a fingertip to monitor the tactile pressure and the acceleration of a fingertip during tactile action, as well as the vibration transmitted to a finger that may relate to tactile sensations.

2. Philosophy of HapLog

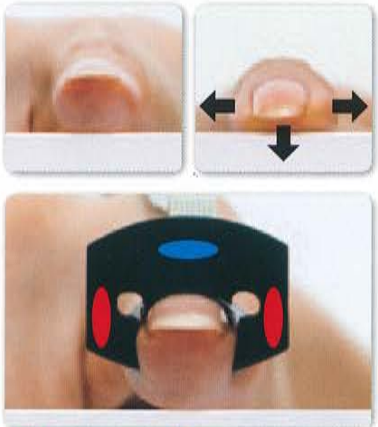
A large part of the sensations obtained from the tactile action of a fingertip is acquired through rather active but not passive action. Furthermore, the information perceived by the fingertip is fed back to the tactile action. Therefore, we consider it necessary that the natural tactile action is accompanied by the actual feeling of a fingertip.

Along with the progress of recent sensing technology, many techniques for precisely measuring tactile pressure are proposed. A large part of these techniques is one using a sensor built into the object to be subjected to tactile action or one mounted as a sensor on the fingerprint area of a finger. However, in these techniques, it is considered that, if the object is skin, a sensor cannot be built into or is difficult to use for multipurpose functions. In addition, since the fingerprint area covered by a sensor cannot sense tactile impressions obtained from the fingertip, the information is not fed back and natural tactile action cannot be realized. That is as if skin cream is applied with fingers wearing gloves.

We considered that it is necessary not to mount anything on the fingerprint area in order to objectively evaluate the natural tactile action.

3. Principle of measurement

We focused on the deformation of a finger caused by contact of the finger in order to measure tactile pressure while leaving the sensation of the fingerprint area as it is. The contact area of a fingertip that is laterally deformed even by light contact with an object increases. It is considered that this phenomenon contributes to the improvement in the grip when holding something.



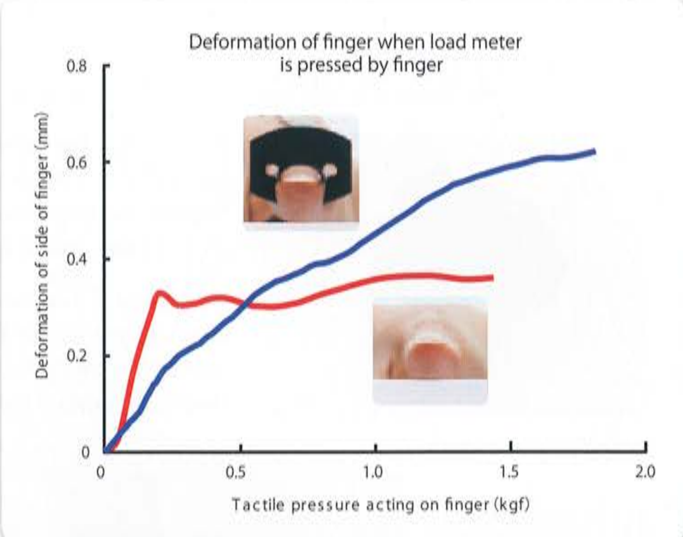
Strain gauge Acceleration sensor

HapLog catches a finger from the nail side, and measures the deformation of the finger caused by contact. Thus the measurement of tactile pressure is possible while leaving the sensation at the fingerprint area as it is. In addition, the arrangement of a strain gauge on the location of the side of the finger will detect the deformation of the finger with high sensitivity. Furthermore, an acceleration sensor is arranged on the top.

This will analyze the tactile pressure, the finger movement, and the vibration transmitted to the finger in a natural tactile action.

Characteristics of deformation of finger caused by contact

Now, our concern is how the finger is deformed. We investigated the relationship between the characteristics of finger deformation and the tactile pressure using a laser displacement gauge. A normal finger not mounted with anything is linearly deformed in the low load region and thereafter shows only a small change (red graphic line). This allows to estimate the tactile pressure only in the low load region. However, the finger mounted with HapLog that generates small tension in the finger is linearly deformed in the wide load range (blue graphic line).



4. Precautions for measurement

1 **Since this is a device to be mounted on a finger, measurement accuracy varies depending on the characteristics and location of the finger.**

It is not dependent on the performance of an acceleration sensor and a strain gauge installed.

2 **Be careful when the degree of deformation of a contact object is greater than that of a finger.**

When an object is deformed by finger contact, the measured value is indicated lower than the tactile pressure. Since the tactile pressure at the fingertip is sensed more significantly than the deformation of the finger, it is thought that the measured value of HapLog is not the power level added by the fingertip but the tactile pressure sensed by the fingertip.

3 **Tactile pressure generated by tapping with fingernail cannot be measured.**

Since HapLog adopts the system for estimating a tactile pressure from the deformation of finger caused by contact, tapping action with nail tip not accompanied by the deformation of finger disables accurate measurement.

4 **The sensor is not of complete waterproof construction.**

5. Starting measurement

Mounting on finger

We consider the preferable mounting position of the HapLog sensor is just on the middle of a finger (thick portion). If the mounting position is too shifted to the fingertip, the finger-catching section contacts an object. In addition, fix the sensor on a nail with double-sided tape if necessary.

The sensor is available for finger sizes of 11 mm, 12 mm, 14 mm, 16 mm, and 18 mm. Use the sensor that matches the finger size. If the most preferable size is unavailable, apply double-sided tape (two or three pieces of the tape) so that they reach both sides of the finger to make the sensor closely in contact with the finger.

Calibration

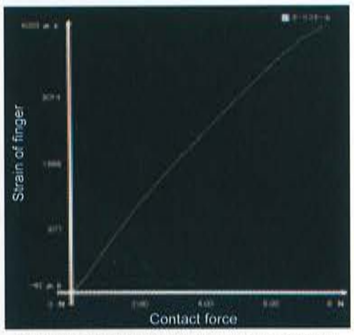
In the system that estimates tactile pressure from the deformation of a finger in the condition where it is mounted with the HapLog sensor, the difference in the deformation characteristics of a personal finger and that of the mounting position affect the output value.

Therefore, it is necessary to reveal the relationship between the deformation characteristics of a personal finger and the tactile pressure. Thus calibration work is performed after mounting on a finger.

This calibration work is performed in the condition where the finger is stationary on the top of the HapLog calibration unit, the finger is kept straight, and the cable has no tension. See the Operation Manual for details.

In addition, perform this calibration work from time to time not only when the mounted position of the finger has changed but also when the sensor was used for a long time.

HapLog calibration unit



Screen for finger pressure calibration

Measurement

After the calibration, perform zero-point correction again to enable actual measurement. The vertical axis can be changed before measurement. Investigate the maximum value to be measured to determine the vertical axis.

Standard sampling frequency is 1000 Hz. Output data is in the CSV format.

❶ Tactile pressure

Measurement range of tactile pressure

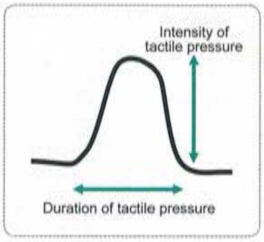
Contact causing the deformation of the finger enables measurement. Wide range of forces from soft contact to skin at tens of mN to strong force like typing of about 30–40 N can be measured.

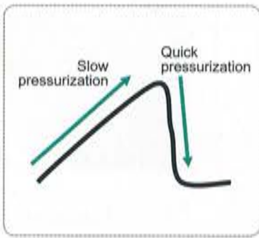
Tactile pressure waveform

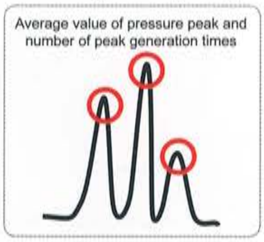
At present, we are not in the stage where the elements of tactile action can simply be explained by a parameter such as the friction coefficient. Therefore, it is necessary to interpret the waveform of tactile pressure to find the transition circumstances of force.

The information provided by the waveform is the intensity of tactile pressure, the time of duration, the speed of pressure increase and decrease, etc. The characteristics of tactile action should be found from these features. We recommend taking moving images and checking them.

In addition, it is effective to reveal the action based on the number of pressure peaks higher than the specified load, the average value, the duration of tactile pressure, etc. during the measurement work period.







Example of tactile pressure measurement

The sensor is already widely utilized in many fields.


Taking out tablet easily


Force for holding lipstick


Pressing pump handle easily


Applying eye drops easily


Opening refilling container easily


Holding PET bottle easily to pour


How to hold pen


Operating steering handle easily

For developmental analysis

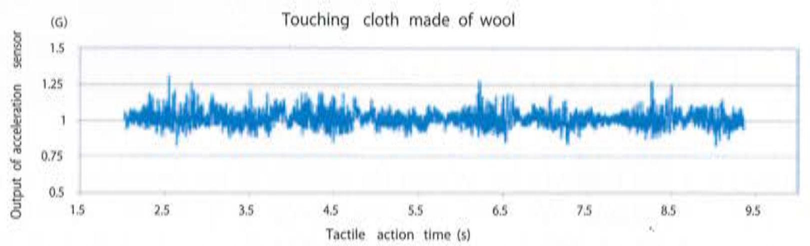
When analyzing the data of tactile pressure, it is effective to check the data in linkage with moving images of action. Various kinds of software for editing moving images and output data are available (Pixel Runner manufactured by Pixel Gate Ltd., etc.)

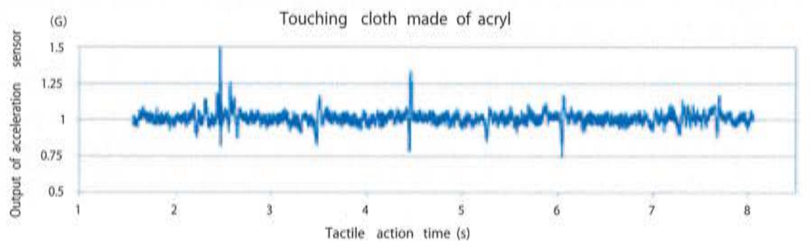
❷ Acceleration

Output of acceleration sensor

The data of the acceleration sensor are analyzed with two methods. One is to analyze the data for each axis (X, Y, and Z) and the other is to analyze the composite acceleration. (The above graph shows the composite acceleration.)

The above graph shows that tactile action varies depending on the type of cloth and that the cloth made of wool was more quickly touched.





Example of measurement by acceleration sensor

Output of the acceleration sensor represents the characteristics of the finger movement.

Applying cosmetics

Massage skill

Opening sealing cover of yogurt container

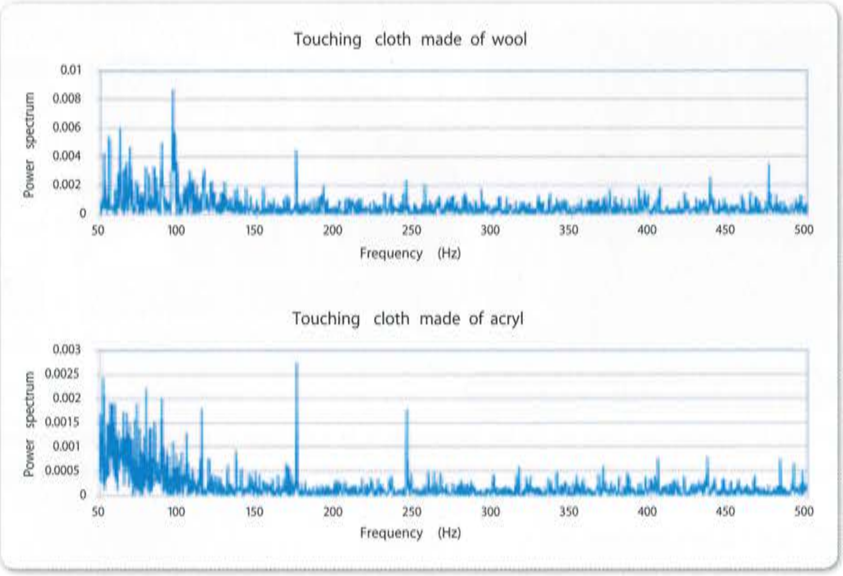
Rehabilitation and skill acquiring action

❸ Vibration

Example of vibration measurement

It is known that the sensory receptor of human beings responds in the specific frequency band, and it is effective to perform the frequency analysis of information on the vibration of the acceleration sensor to identify tactile sensation. HapLog can be set whether a frequency filter is installed or not. In order to detect micro-vibrations caused by friction, the frequency filter should be removed. In addition, the acquired data of the acceleration sensor contains the influence due to human action more than the information on micro-vibrations caused by friction. Therefore, it is necessary to analyze by removing the data in the low frequency band dependent on the influence of action. Thereafter the Fourier transformation is applied to the data of each of three axes and that of composite acceleration.

Although the quantification of tactile sensation is not yet established, the frequency analysis of vibration enables to detect the difference of objects.



6. Development

HapLog is a tool that can be utilized for studies of the visualization of tactile action skill and the quantification of tactile sensations. We think that the elements of tactile pressure, speed, and rhythm are important for the visualization of tactile action skills. Furthermore, we think that the deformation of the finger, friction of the finger, characteristics of vibration caused by friction, the regularity of vibration, etc., are important in the quantification of tactile sensations.

The close interpretation of these data can scientifically promote the development of various products, such as the judgment of texture (glossiness, smoothness, etc.) actually sensed by human being and the evaluation of usability which were so far unclear. In addition, since the tactile action skill possessed by human being as empirical values becomes transmittable, the application as new communication tool is expected.

7. Q&A

Q How much is the range of acceleration to be measured?

A The sensor can measure up to ±2 G, ±4 G, and ±8 G, which can be switched on the PC screen. Settings of ±2 G and ±8 G are recommended for the normal action of human being and the quick action like swing, respectively.

Q When synchronizing an external trigger with another device, do the software used by HapLog work well?

A Yes. The software of HapLog contains the function for use with an external trigger.

Q What is filter?

A Filter (frequency filter) removes noise existing in data. To turn OFF the filter, set the "Filter" cell on the channel information screen at "0."

Q What is the guideline for selecting sampling frequency?

A Sampling frequency means the number of data to be sampled for one second. The higher the set value is, the more in detail the data can be obtained. However, the number of data and the number of data processing times increase and the phenomenon of noise catching is generated as negative effects.

8. Literature

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