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journal or publication title	International journal of applied electromagnetics and mechanics
volume	59
number	3
page range	1111-1118
year	2019-03-21
URL	http://hdl.handle.net/10097/00126963

doi: 10.3233/JAE-171181

International Journal of Applied Electromagnetics and Mechanics 41 (2017) 1–6
IOS Press

Human scratching motion analysis method by using three-dimensional motion measurement system

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Abstract. Monitoring of scratching motion accompanied with itch is important for the medical treatment of skin diseases. Although there were some studies on monitoring scratching motion, the mechanical characteristics of scratching have not been researched enough. Therefore, in this paper, we developed an estimation method of human scratching motion characteristics, especially contact force. In experiment, we measured motions of scratching weakly and strongly against artificial skin placed on three-axis force sensor. Displacement of artificial skin and fingertip trajectory were analyzed by using three-dimensional motion measurement system and compared with contact force measured by the force sensor. In addition, an analysis of scratching motion against human skin by using the developed system was conducted too. From these results, we confirmed that measuring skin displacement of skin surface and fingertip trajectory are effective for the estimation of the mechanical characteristics of scratching.

Keywords: scratching,motion analysis, itch, skin damage, artificial skin

1. Introduction

Itch is defined as "an unpleasant sensation that provokes the desire to scratch," and it is a familiar symptom that accompanies various skin diseases[1].Although relief of itch can be obtained by suitable scratching and rubbing, strongly scratching caused by intense itch, may worsen a skin disease[2]. It leads to a vicious cycles referred to as "itch-scratch cycle". Therefore, the management of itch is important from the viewpoint of a patient's quality of life (QOL) as well as the medical treatment of a skin disease. Now, a medical interview and a diagnosis of the skin scar are carried out to evaluate itch[3]. However, since itch is subjective, these methods are not capable of evaluating itch objectively and quantitatively. Accordingly, measuring scratching behaviour as the alternative method of evaluating itch, wich is a reflex behaviour of itch, have attracted attention.

Observation of sleeping subjects with infrared camera revealed that frequency of scratching is related to the diagnostic score of skin disease[4]. This proves measurement of scratching behavior is effective for dermatological diagnosis. Another study used microphone sensor attached on the nail and proved the potential of scratching monitoring[5]. The study showed a method using wearable sensor is available for scrtaching monitoring. However, these studies has a problem that they only measures quantities of

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scratching behavior and ignores the mechanical characteristics of scratching which skin damage depends on. This may lead to an error for the evaluation of itch. Although study of the mechanical characteristics of scratching is required by previous reasons, the mechanical characteristics of scratching has not been studied yet since it cannot be measured directly.

Therefore, in this study, we developed a three-dimensional motion measurement system for measuring scratching motion. By using this system,we conduct a fundamental research for evaluating mechanical characteristics of scratching. We measure weakly and strongly scratching motions against artificial skin placed on three-axis force sensor and their own skin.

2. Scratching measurement system

We developed a scratching measurement system as shown in Fig.1. This system uses three-dimensional optical motion capture system (VICON GIGANET/M). This motion capture system can trace marker positions by using 4 infrared camera. In our system, we placed markers on the scratching target and the scratching hand. This enables this system to track the displacement of the target and the hand motion during scratching. The sampling frequency of this system is 100 Hz.

2.1. Fingertip trajectory

Although this system can trace the hand motion, we cannot record the trajectory of fingertip which is directly contacting the scratching target during scratching. This is because placing marker on the fingertip interrupts scratching. Therefore, we developed an estimation method of fingertip position. First, we placed markers on the hand as shown in (a) of Fig.2 and researched the relationship among markers.

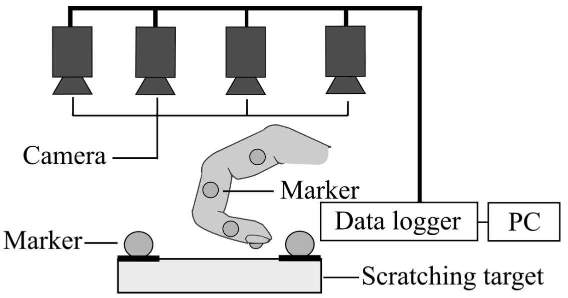
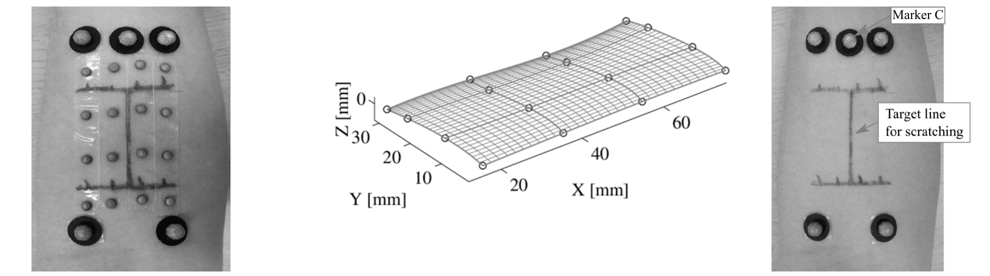


Fig. 1. Measurement system

(a) Obtaining the relationship

(b) During the experiment

Fig. 2. Marker positions of the hand



(a) Shape measurement

(b) Obtained skin surface shape

(c) During scratching

Fig. 3. Marker placement of forearm

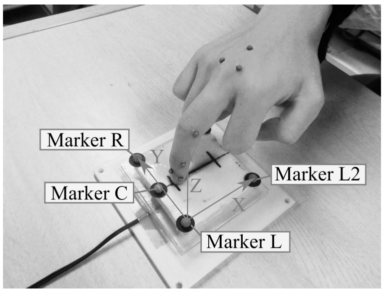


Fig. 4. Coordinates and marker placements of artificial skin

Table 1 Measurement condition

Subject	8 males(age 21∼ 29)
Sampling frequency	100 Hz (motion capture system) 10 kHz (Load cell)
Measurement time	5 s
Number of trial	3 times

During motion measurement, we replaced some markers like (b) in Fig.2. The fingertip marker position was estimated by using the previously researched relationship of markers. By this method, we succesfully measured the fingertip trajectory during scratching.

2.2. Skin surface shape measurement

The depth of contact is a parameter which can be related with the intense of scratching. By the estimation of fingertip trajectory, we can observe the depth of contact by caluculating the distance of the fingertip from the surface of scratching target. However, to calculated the depth of contact correctly, we need to measure the surface shape of scratching target since it can be round shaped like human skin. Therefore, we measured the skin surface shape using the developed system in advance. (a) of Fig.3 shows the marker placement we used for the shape measurement. The surface between the markers was estimated by spline interpolation. (b) in Fig.3 shows an example of the skin surface shape obtained by this method. During measurement, some markers was replaced so as not to interrupt scratching as like (c) in Fig.3.

3. Scratching measurement using artificial skin

We executed a scratching motion measurement examination using artificial skin and a three-dimensional force measurement system, Load cell to confirm the effectivity of the developed system. We analyzed the relationship of scratching motion and mechanical characteristics of scratching by using the developed system.

3.1. Experimental setup

We placed artificial skin (polyurethan sheet, 10*70*70 (mm)) on a Load cell to measure the force applied on the skin. Fig.4 shows the scenery and the orientation of the experiment. Table1 shows the measurement condition. Each subjects was asked scratching weakly and strongly for three times each in their sense. The measurement was held three times for each intensity. They scratched on the black line parallel to the X-axis as shown in Fig.4. In this experiment, we supposed the surface of artificial skin flat.

3.2. Result & discuttion

Fig. 5 shows the example of a Load cell output. We can observe that when scratching, contact force is mostly applied to the skin in X and Z dimension. We set a threshold for Z-axis output for identifying

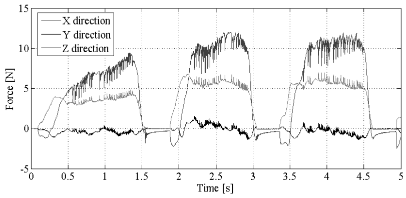


Fig. 5. Load cell output (SubjectA, strongly). Blue line for X direction, black line for Y direction, red line for Z direction.

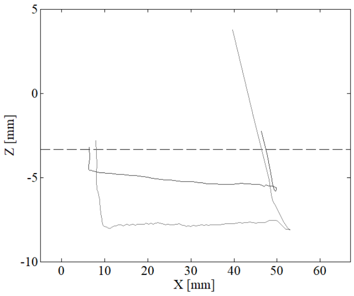


Fig. 6. Fingertip trajectory. Red line for strongly scratching, blue line for weakly scratching.

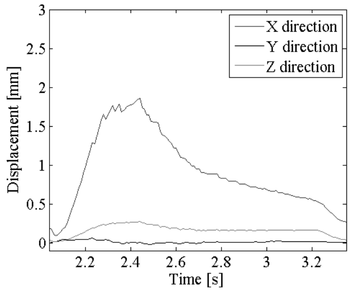
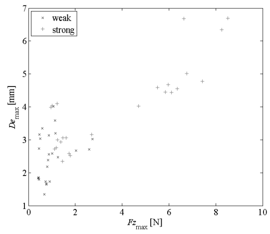


Fig. 7. Displacement of Marker C shown in Fig. 3 (c) for each axis

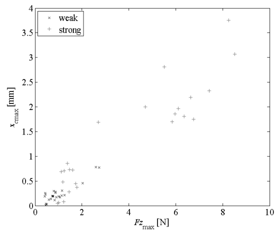
starting time of each scratching. We used the 2nd time scratching of each measurement for analysis so as to ignore the effectivity of the hand's position when starting and ending the scratching.

Fig.6 is an example of estimated trajectory in the presented method. The dot line shows the skin surface. We can see stronger scratching lead deeper fingertip contact. For comparison, we calculated the maximum depth as De_max. Fig.7 is the marker displacement of Marker C as shown in Fig.4. The X-axis is shown to be most moved during scratching. Therefore, we calculated the maximum X-axis displacement as x_{cmax}.

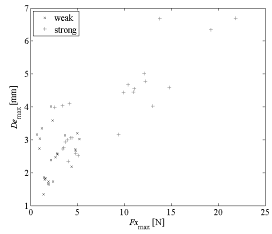
In Fig.8, we can observe all of the parameters we calculated, $Fx_{max}, Fz_{max}, De_{max}, x_{cmax}$ is highly related with each other. Also, they are all related with the strength of scratching. Now, it is suggested that for estimation of mechanical characteristics of scratching, we can use contact depth of fingertip and skin displacement.



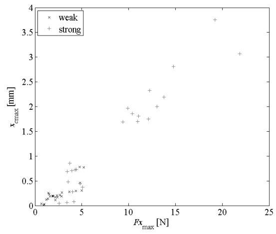
(a) Relationship between Fz_{max} & De_{max} (r=0.844)



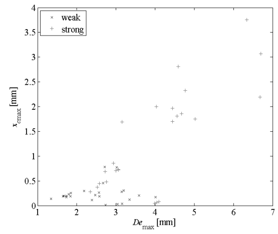
(b) Relationship between Fz_{max} & x_{cmax} (r=0.946)



(c) Relationship between Fx_{max} & De_{max} (r=0.839)

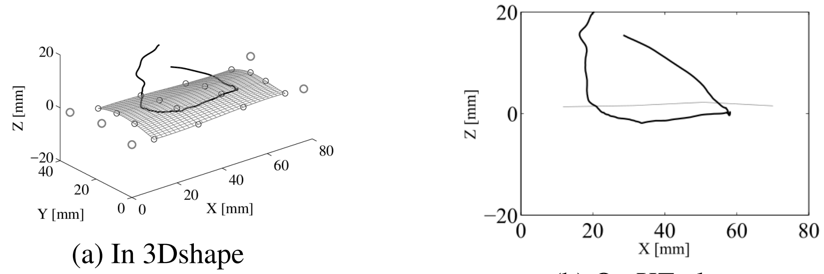


(d) Relationship between Fx_{max} & x_{cmax} (r=0.967)



(e) Relationship between De_{max} & x_{cmax} (r=0.795)

Fig. 8. Relationship between parameters



(a) In 3Dshape

(b) On XZ plane

Fig. 9. fingertip trajectory (SubjectB, weakly scratching)

4. Scratching measurement on human skin

In the previous section, we revealed that evaluation of mechanical characteristics are available by depth of contact and fingertip displacement. Next, we need to confirm that this is true on human skin too.

4.1. Experimental setup

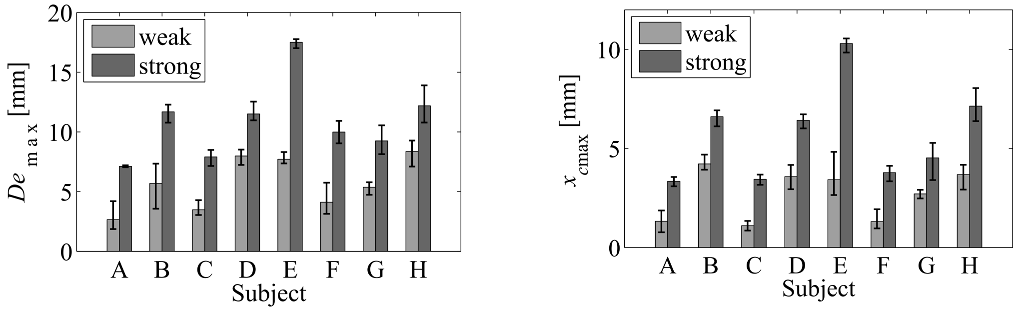
We used the same subjects with the experiment on artificial skin. Each subject was asked to scratch on the black line parallel to Y-axis as shown in (c) of Fig.3. The subject scratched on their own forearm three times weakly or strongly. Measurement was held three times for a intensity condition. The sampling frequency of the motion measurement system is 100 Hz. These conditions are the same with the previous section.

4.2. Result & discussion

(a) in Fig.9 shows an example of estimated skin surface and fingertip trajectory. Trajectory seen from XZ plane is plotted in (b). The blue mesh represents the skin surface and black line is fingertip trajectory. We can observe human skin's round shape and fingertip actually contacting deeply with the skin while scratching. We defined the time that fingertip and skin surface became closer than 2mm as the starting point of scratching. In the same reason with the previous section, we used the 2nd scratching of each measurement for analysis. Now, we can calculate De_{max}. x_{cmax} aslike previous section.

In (a) of Fig.10, which shows the average De_{max} and maximum and minimum of it as an error bar, we can observe strength of scratching is also related withDe_{max} on human skin. The same thing can be said on x_{cmax}, as shown in (b) of Fig.10 in the same way with (a). The result of significance test was both p<0.05, which means the differences of these parameters against the strength of scratching are meaningful.

In Fig. 11, we observed the relationship between textitDe_{max} and x_{cmax}. The correlation coefficient is *r*=0.930 and these two parameters were raveled to be highly related. In the previous section, we confirmed these two parameters are related to mechanical characteristics of scratching too. Therefore, it is suggested that by measuring either depth of contact or skin displacement, estimation of mechanical characteristics or strength of scratching are available.



(a) De_{max} (b) x_{cmax}

Fig. 10. The relationship between each parameters and intense of scratching

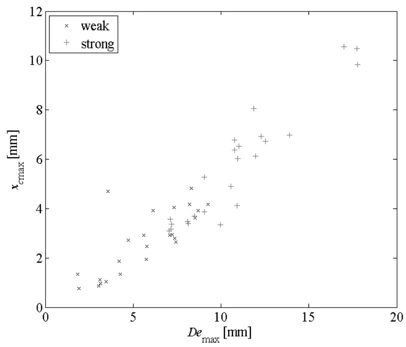


Fig. 11. Relationship between De_{max} & x_{cmax}

5. Conclusion

In this paper, we conducted a motion measurement while scratching artificial and human skin strongly and weakly. As a result, we revealed that mechanical characteristics of scratching, especially contact force is related with the strength of scratching which can be estimated by measuring scratching motion, especially depth of contact and skin displacement. By using the result we revealed in this study, we can develop a system which can more accurately evaluate itch by considering mechanical characteristics of scratching. Also, by investigating the relationship between mechanical characteristics of scratching and skin damage, this method may be able to estimate the skin damage caused by scratching at dermatological diagnosis.

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