Toward Prevention of Pressure Ulcer: Method of Automatic Wrinkle Removal by Friction-less Soft Robot-arm

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Abstract

In this study, we present a method of automatically removing wrinkles by the extension of Soft Robot-arm, focusing on the wrinkles of clothes that lead to pressure ulcers for bedridden elderlies. The proposed pneumatic driven Robot-arm is flexible in structure, capable of entering the gap between the human body and the bed surface without friction. As a result of the experiment, we confirmed that it was possible to remove wrinkles by 30% in one operation and almost 100% in three operations by extending Robot-arm in the direction to elongate wrinkles. Also, the effect of changing body pressure distribution was confirmed. Since this method can be realized with safe and simple operation, even if the caregiver is absent, it can be expected to be applied for prevention of pressure ulcers of the elderly.

Keywords: Prevention of pressure ulcer, Reduction of nursing burden, Nursing care robot

Introduction

Pressure sores are conditions in which the blood is not flowing to the skin and the skin is necrotized due to the constant compression of a certain part of the skin. It is prone to occur if an elderly person whose physical strength has declined remains in a bed-rest condition or sitting position for a long time (Landis E et al., 1930). Preventive measures are important because pressure ulcers are painful as well as concerns that infection spreads throughout the body when bacteria are infected in this tissue (Ryan P.Crenshaw et al., 1989).

As a preventive measure by external factors, body pressure dispersion and posture change have been considered until now. As measures against the former, mattresses that distribute body pressure devised materials and shapes have been introduces (Binayak Roy et al., 2005). As the latter, active deformable beds that can turn over support have been used in the nursing scene (Lin Tan et al., 2009). However, it is impossible to solve the skin's wrinkles and wrinkles of clothes by these measures alone. If you leave them for more than 2 hours for the elderly with weak skin, it will trigger the pressure ulcer (Adams, R. et al., 2010). In the case of elderly people who are difficult to turn over by themselves, it is necessary for carers to perform pressure depressurization work in order to remove them. Frequent such work is hard for caregivers. Especially in families where elderly people live alone, carers entering and leaving the home day or night are resistant to protecting their privacy. For these reasons, a means capable of conducting a decompression operation without human intervention is desired.

Then, in this research, we propose a device that automatically removes the clothing wrinkles that occur between the human body and the bed surface without involving the care giver. To do this, the following conditions are required for the device that comes in contact with the human body. i) a sufficiently flexible structure without concern of damaging the human body, ii) generation of driving force enabling to move even under a human load, iii) generation of motion that does not cause friction against the skin. To realize this, we introduce a Soft Robot-arm that extends a flexible chamber by pneumatic drive with tip growth operation. In this paper, we first introduce the configuration of the robot arm and propose an operation method to remove the wrinkles. Next, verification results of wrinkle removal are shown by human experiment, and the effectiveness of the proposed method is verified.

Material and Method

Configuration and Driving Principle of Soft Robot-arm

We propose a method of automatic removal of the wrinkles by actively extendable Robot-arm, attached to the side of the bed and can be inserted between the lying body and the bed surface. Such a Robot-arm is required not only to have structural flexibility without concern of damaging the human body, but also to generate sufficient output to move without causing friction to the skin, capable of moving even under a human body load.

Therefore, inspired by the growing process of the plant root, we introduce a friction-free Soft Robot-arm that can be expanded by the tip growth operation. The Robot-arm consists of a flexible airbag chamber, wire and motor. When the interior of the airbag chamber is pressurized by air pressure, the inside of the chamber extends while being extended outward. Also, while pulling the wire with a motor while keeping the air pressure low, the chamber is stored inside. In these extension and storage operations, friction does not occur on the outside of Robot-arm with respect to the human body or the bed surface.

A similar driving principle has been applied to robots for exploration of narrow areas in the past (D.Misshima et al., 2003) (H.Tsukagoshi et al., 2011) (Elliot W.Hawkes et al., 2017). However, they did not have the function of opening the gap and jacking-up the object. As show in Table 1, the Soft Robot-arm proposed in this study is durable enough to lift up a part of the human body and to enter between the human body and the bed surface without gaps. Specifically, the diameter of the flexible chamber is designed to be about half of the thickness of the chest of the human body, and as a property combining flexibility and durability, it has a configuration in which a urethane sheet is welded. As a result, we confirmed that the Robot-arm was capable of moving under middle of the back, waist, buttocks, and thigh of the adult.

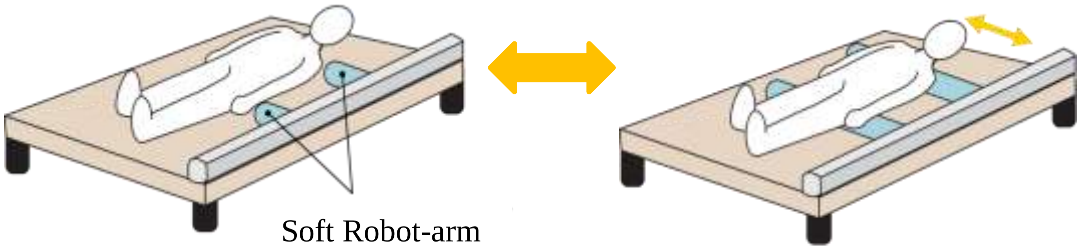


Figure 1. Image of automatic wrinkle removal by proposed soft robot-arm.

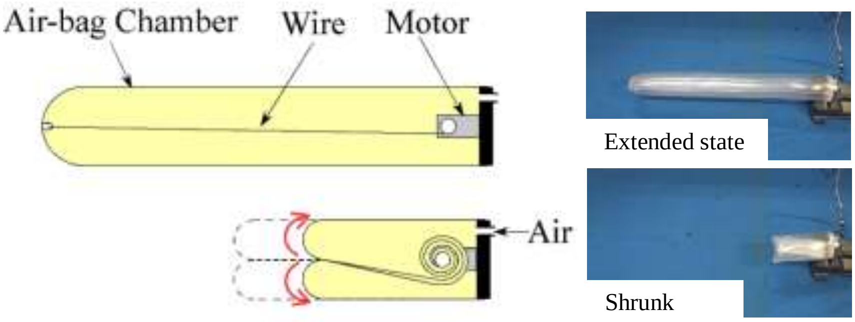


Figure 2. Configuration of Tip-growing type Pneumatic Soft Robot-arm. Driving principle on left and overall view of the developed prototype on right.

The principle of removing wrinkles in clothes by Robot-arm is shown in Figure 3. First, the tip of the robot arm extends until it contacts the side surface of the human body. Next, the projecting portion at the distal end slips into the lower part of the human body while shifting along the curved surface of the convex human body. Furthermore, when the moment due to the lifting force of the robot arm exceeds the moment due to the load of the human body, a rotating motion occurs in the human body. Then, while the tip moves under the load of the human body, it pushes the wrinkles of the clothes to the side opposite to the insertion. In the above operation, although the robot arm is non-sliding with the outside, it is possible to push the wrinkle at the tip by utilizing the state where the robot arm is pressed with the weight.

Table1. Specification of the developed Soft Robot-arm.

Size:	760 × 150 × 150 (mm)
Mass:	600 (g)
Outer diameter :	80 (mm)
Velocity :	Extending Motion: Max. 30 (mm/s)
	Shrinking Motion: Max. 2.5 (mm/s)
Extendable stroke :	500 (mm)

Pushing force at the tip :	Max. 200 (N)
Vertical supporting force :	Max. 180 (N)
Applied air pressure :	Shrinking Motion: 10(kPa) Extending Motion: 50(kPa)
Available body part to be inserted :	Middle of the back, Waist, Buttocks, Thigh

Figure 3. Overall view of the state where Soft Robot-arm is inserted on the center of the back.

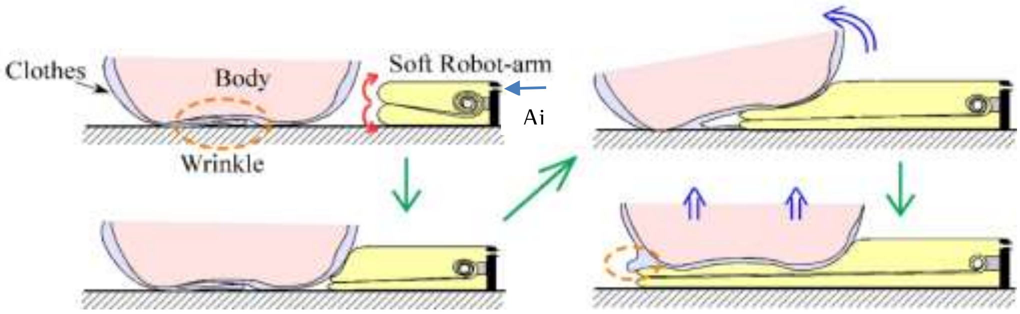


Figure 4. Sequence of automatic wrinkle removal by Soft Robot-arm.

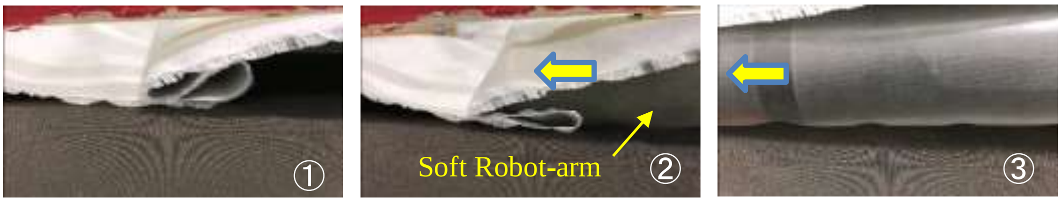


Figure 5. State where wrinkles of clothes are removed by Soft Robot-arm.

Experiments

Two experiments were conducted to verify the effectiveness of removal of wrinkles in clothes with Soft Robot-arm. One is to compare changes in the amount of wrinkles in clothes and another is to examine the effect of wrinkle changes on the human body.

As the former experiment, in order to evaluate the amount of wrinkles occurring in the clothes of the human body during bedtime, image analysis software (Image J) was used to measure by image processing. The subject was an adult male with a body weight of 64 kg and a height of 167 cm, lying on his back on the acrylic board with his pajamas wearing, changed his posture and caused wrinkles. From this state, the soft robot arm was inserted between the center part of the back and the acrylic board, and wrinkles of the pajamas were recorded from the bottom of the acrylic plate with video. Regarding the recorded image, after converting it to grayscale, the lower 30% pixel portion in the histogram of the white part (pixel value: 255) from the black part (pixel value: 0) of the image was regarded as wrinkle (see Figure 6 (a)).

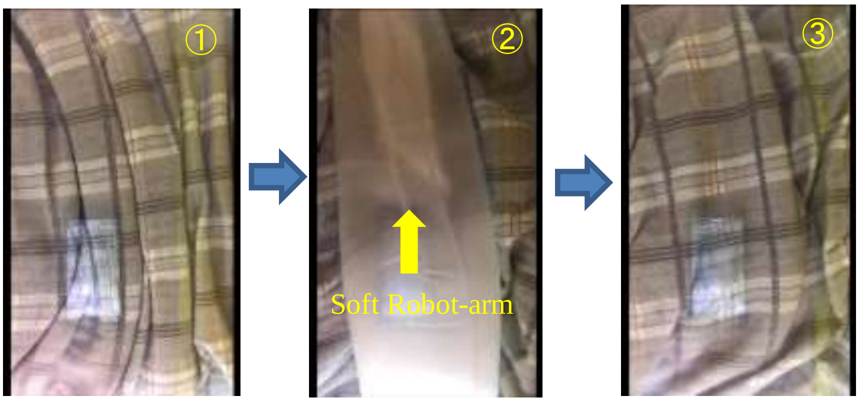
On the other hand, as the latter experiment, the pressure that the human body receives from wrinkles and bed surfaces of clothes was measured. Specifically, a pressure sensor sheet (BodiTrak FSA BT 1510) was set on the back and changes in pressure distribution before and after insertion of the soft robot arm were recorded.

Results

It was confirmed by analysis of image processing that wrinkles of clothes that occurred on the back of a bedded condition could be effectively reduced by insertion of Robot-arm. Specifically, the reduction effect depends on the movement of the body causing wrinkles. We compared the percentage of clothes wrinkles that could be removed for the wrinkles by four different types of actions. They are "Wrinkle 1" when the back was shifted in the right and left direction, "Wrinkle 2" when the back was shifted in the direction of the foot, "Wrinkle 2" when the back was rotated around the bed surface: "Wrinkle 3" when moving in the left-right direction and the foot direction: "Wrinkle 4", which are totally 4 patterns. As shown in Figure 7, 30% of Wrinkle 1 was removed by a single insertion of Robot-arm. In addition, wrinkles could be removed almost 100% by three insertions of Robot-arm. In Wrinkle 2, 20% was removed by one insertion (Figure 6 (b)), but after the third insertion, only the first 50% was removed. Wrinkle 3 increased by 20% with one insertion. It was then removed by 10% by three insertions. In Wrinkle 4, 15% was removed by one insertion, then 30% was removed by 3 insertions. Comparing these results, the most efficient removal was the pattern of Wrinkle 1, which is considered to be due to the direction in which Robot-arm extends and the direction extending the wrinkle coincide.

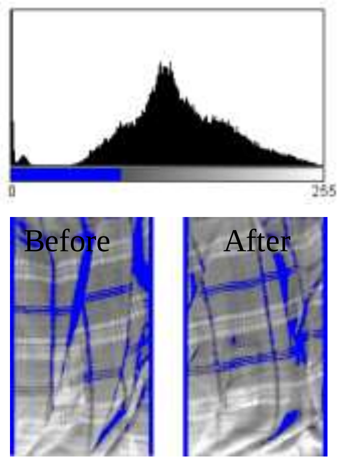
Next, when Wrinkle 1 in the center of the back, the change in body pressure distribution before and after inserting Robot-arm is as shown in Figure 8. As a result, it was confirmed that the concentration of the local body pressure due to the wrinkle which occurred before insertion could be effectively reduced by inserting Robot-arm. It was also investigated that the body pressure distribution around the shoulder blades varied before and after insertion. It seems that it was possible to change the tilt of the body by inserting Robot-arm and to change the body pressure distribution.

(a) Experimental setup

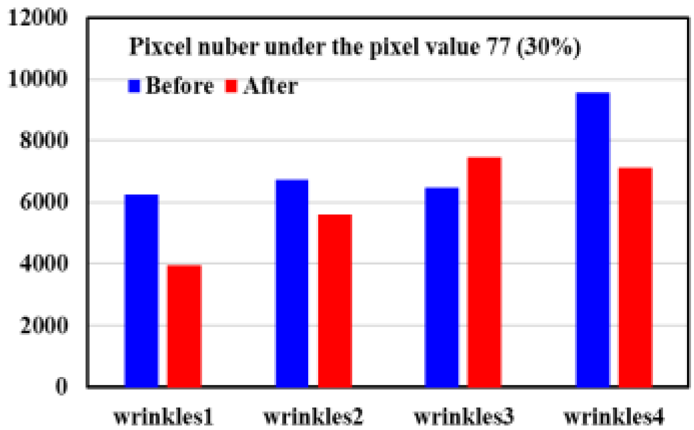


(b) State of change of wrinkles

Figure 6. Observation of the state of change of wrinkles on the back clothes.



(a) Histogram and area of wrinkles



(b) Pixcel number under 30 %

Figure 7. Change of wrinkles measured by image processing.

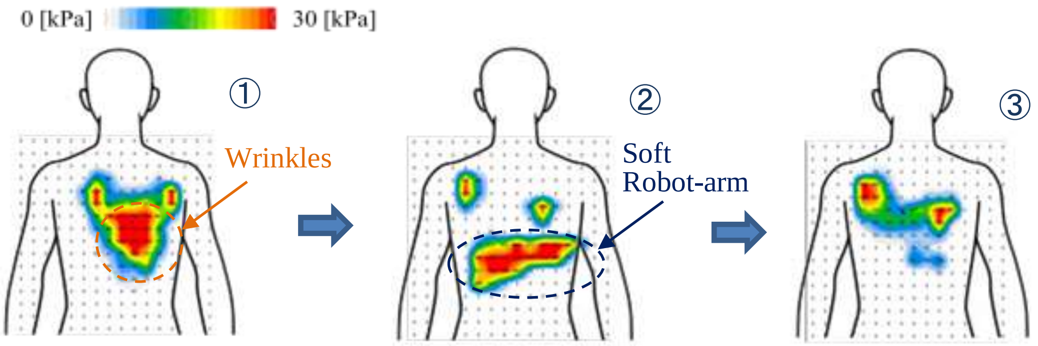


Figure 8. Transition of the body pressure distribution to investigate the effect of the wrinkle removal by Soft Robot-arm.

Discussion

We confirmed that the proposed friction-less Soft Robot-arm could automatically remove wrinkles caused under human load. On the other hand, it was also clarified that in order to effectively remove wrinkles, it is necessary to stretch the Robot-arm along the direction in which wrinkles are extended. When performing a jack-up action to raise the back of the bed, the wrinkles of the pajamas will have a wrinkle similar to the case where the body is shifted in the direction of the foot, that is, a pattern of Wrinkle 2 occurs. In this case, it is predicted that the action of stretching Robot-arm in the direction from the shoulder to the hip of the human body can eliminate wrinkles most efficiently. When assuming an actual nursing care site, it is convenient to install Robot-arm on the handrail of the bed as shown in Figure 9. In order to remove a pattern of Wrinkle 2, it is effective to attach Robot-arm diagonally to the handrail so that the component of the force elongating in the direction of the body axis is generated.

It is considered that decubitus occurs when a pressure of about 70-100 mmHg (10-14 kPa) lasts more than 2 hours. By inserting Robot-arm, not only the effect of removing wrinkles but also the effect of changing body pressure distribution was confirmed. If Robot-arm is driven at an appropriate timing based on information on body pressure distribution, it is expected that it will be able to demonstrate the effect of prevention of pressure ulcer efficiently.

Figure 9. Installation of Soft Robot-arm on the handrail of the bed.

Conclusions

In this study, we investigated the effect of automatic removal of wrinkles of clothes by extension action of pneumatic driven Soft Robot-arm. The proposed Robot-arm has a structure in which only the tip extends like the growth of the root of the plant, so there is no fear of rubbing with the skin. For this reason, it was possible to enter while lifting a human body without buckling between the human body and the bed surface while being flexible. As a result of experiments, it was confirmed that wrinkles could be efficiently removed by extending Soft Robot-arm in the direction to elongate wrinkles. Experiments, in this paper, were conducted assuming that it was inserted in the range from the center of the back to the thigh. In the future, we will develop an improved robot-arm that can be inserted into the shoulder blades and heels, and will conduct similar verification experiments.

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