Clothes Manipulation by Inchworm Robot Grippers

Khairul Salleh **Hiroaki Seki** **Yoshitsugu Kamiya** **Masatoshi Hikizu**

Department of Mechanical Systems Engineering
Kanazawa University, Kakuma-machi, Kanazawa, Ishikawa 920-1192 JAPAN
E-mail: hseki@t.kanazawa-u.ac.jp

Abstract

Deformable objects manipulation by robot is very challenging. We focused on clothes manipulation as an example and applied edge tracing method in order to search for corners of particular clothes. Tracing in this paper context involves tracing the towel's edge, with the robot arm movement based on feedback from sensors. Development of special tools for deformable object manipulation is also considered to be important as well and must consider the properties of the deformable objects. We designed inchworm type grippers for the purpose of clothes manipulation. This paper proposes a unique tracing method for towel spreading using the inchworm grippers. Experimental results have demonstrated the effectiveness of both the proposed method and the grippers.

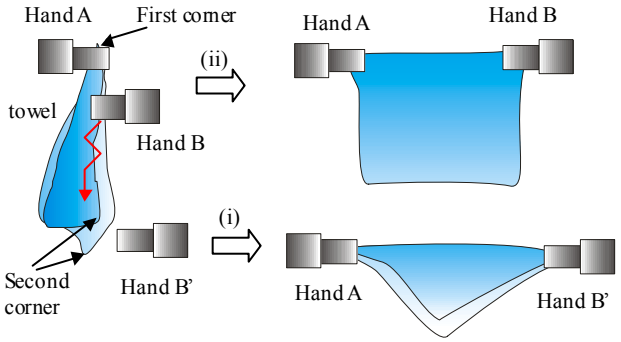
Keywords

Edge tracing, deformable object, robot gripper, inchworm, spreading of clothes, home service robot

1. Introduction

The world is full of deformable objects. Let's just look around us. Clothes, papers, cables, plastic bags; they are all deformable objects. Even in today's robotics, researches concerning deformable object manipulation are becoming more and more popular. The presence of these objects means that home service robots need to be dexterous in object handling [1]. In handling clothes, for example, the robot must first recognize the shape of clothes. Due to contact and gravity, clothes rarely show their original shape. In this case, edge tracing is important in object recognition [2]. We use it here to spread clothes, which is important in folding or hanging clothes out to dry. Much research has been done on deformable object manipulation [3,4,5,6,7,8] but very little on clothes manipulation. Even that on clothes manipulation is largely theoretical [9,10] rather than practical. We propose practical research on towel spreading as an example of clothes manipulation using sensor-based edge tracing.

Spreading clothes basically involves holding two corners of the clothes to spread or fold them [10]. The problem is finding the appropriate corners. Vision sensors help find corners [11], but corners are not necessarily visible or exposed to the camera, causing the robot to hold the clothes unsatisfactorily (Figure 1). Even when a camera detects a corner, the corner may not be appropriate. By using tracing manipulation to find the second corner, it is proven that the second corner found is that next to the initially found corner and not the one apposite it [12,13]. But there are also problems concerning tracing manipulation. One of the major problems is how to retrieve the fabric when it is in danger of slipping away from the gripper. The robot may be able to detect that the fabric is about to slip but it is hard to retrieve or prevent it. If the robot tries to regrasp the fabric, it would probably slip away. If the robot tries to retrieve the fabric without regrasping it, it would most probably drag the fabric along, flexing it instead of retrieving it. This is due to the fact that deformable objects are sensitive to contact forces. The robot can be programmed to retrace the fabric from the beginning but this will take time. The solution to this problem is to design a special tool that can trace the fabric and does not release it. This paper proposes tracing using inchworm type grippers as a solution.



(i) Example of an improper clothes spreading
(ii) Example of a proper clothes spreading

Figure 1 - Problems in clothes spreading

2. Clothes Manipulation System

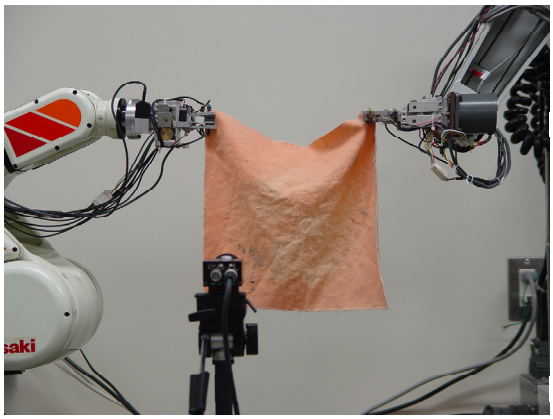


Figure 2 - Clothes spreading scene

Figure 2 shows a scene in towel spreading. In this research, we use two robot arms, Js2 (Kawasaki Heavy Industries) with 6 degrees of freedom (DOF) and RCH-40 (Yamaha) with 5 DOF. Both arms are equipped with grippers designed for clothes manipulation. A CCD camera that detects and confirms corners is located in front of the two robot arms. The images taken by the CCD camera are in 8-bit gray scale and 640x480 pixels in size. TRV-CPW5 image processing board (Fujitsu) speeds up image processing.

The robot grippers designed for fabric manipulation play important roles in clothes manipulation. Figure 3 shows the details of the inchworm grippers attached to the Js2's wrist. There are two pairs of gripper, one is a fixed gripper and the other one capable of sliding sideways using a Maxon motor with rotary encoder (18V, 3.0W, lift-torque 10.8mNm, max rpm 16000rpm) via 2 spur gears of the same diameter and a ball screw with a 1mm lead. The encoder's resolution is 100pulse/rotation. The maximum distance between the two pairs of grippers is 60mm.The grippers both have 3 pairs of infrared sensors to check whether or not the fabric is inside them. Infrared LED OP298B (Optek) and phototransistor TPS601A (Toshiba) is used. The grippers can also detect force being applied to the fabric via strain gauges attached to them. The thick part of the gripper just behind the thin part acts as a stopper to protect the thin part from breaking due to excessive force. The gap between the two fingers of a gripper (gripper gap) is controlled using an RC servomotor from Futaba.

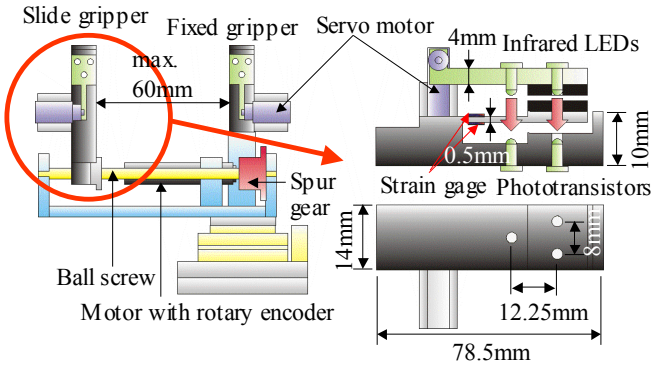


Figure 3 - Inchworm robot grippers

4. Finding a Corner using Edge Tracing Manipulation

Let's assume that the RCH-40 gripper is grasping the first corner. This can be achieved using the CCD camera [12]. After Js2 gripper is positioned at the edge of the towel just beneath the first corner, it will start tracing the edge of the towel by smartly using the feedbacks from the infrared sensors (Figure 4) with the fixed gripper positioned on top and the slide gripper below. This movement pattern is based on the feedbacks from Js2 gripper's infrared sensors and should enable Js2 to find a corner next to the one being held and not the one across it. Since the inchworm type robot grippers have two sets of grippers, at least one of the grippers can be made to grasp the towel while the other gripper traces the edge of the towel. The advantage of using the inchworm grippers is that Js2 will be grasping the fabric all the time, reducing the probability for the towel to slip away during tracing besides no precise force control is required during tracing. This is because the two grippers of the inchworm type grippers are near to each other and in case the tracing gripper accidentally releases the towel, it can regrasp and retrace the towel from under the other gripper without the Js2 having to trace the towel back from the start.

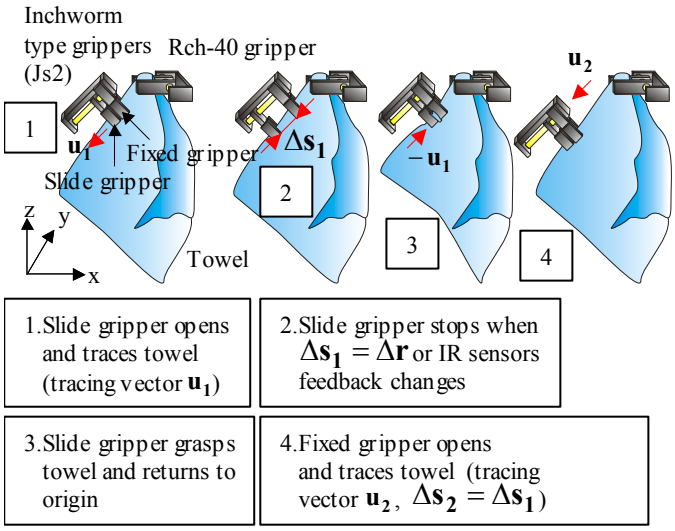


Figure 4 - Inchworm movement during tracing

The gripper movement during tracing is like the movement of an inchworm (Figure 5). The slide gripper will trace the towel until the slide gripper reaches the maximum sliding distance (maximum tracing distance $\Delta\mathbf{r}$) during infrared feedback patterns A and B or until the infrared sensors feedback changes while the fixed gripper maintain its firm hold of the towel. During this process, Js2 will remain static. The actual tracing distance is $\Delta\mathbf{s}_1$. The relation between $\Delta\mathbf{r}$ and $\Delta\mathbf{s}_1$ can be written as follows:

$$\Delta\mathbf{s}_1 \le \Delta\mathbf{r} \tag{1}$$

The tracing vector for the sliding gripper $\mathbf{u}_1$ is perpendicular with the orientation of the inchworm type grippers on the xz-plane. The tracing vectors $\mathbf{u}_1$ can be written as follows:

$$\mathbf{u}_1 = (-\sin\theta, -\cos\theta),\ |\mathbf{u}_1| = 1 \tag{2}$$

After either $\Delta\mathbf{s}_1 = \Delta\mathbf{r}$ or the infrared sensors feedback changes from pattern A to pattern B (Figure 4) or vice versa, the slide gripper will grasp the towel and then return to its origin. This means that during this process, both grippers are supposed to firmly hold the towel. The new tracing vector for the slide gripper during this process $\mathbf{u}_{1new}$ can be written as follows:

$$\mathbf{u}_{1new} = -\mathbf{u}_1 = (\sin\theta, \cos\theta) \tag{3}$$

The sliding distance is $\Delta\mathbf{s}_1'$ where:

$$\Delta\mathbf{s}_1' = \Delta\mathbf{s}_1 \tag{4}$$

After returning to its origin, the fixed gripper will open slightly and then the Js2 will move downwards. The fixed gripper will be tracing the towel's edge during this process

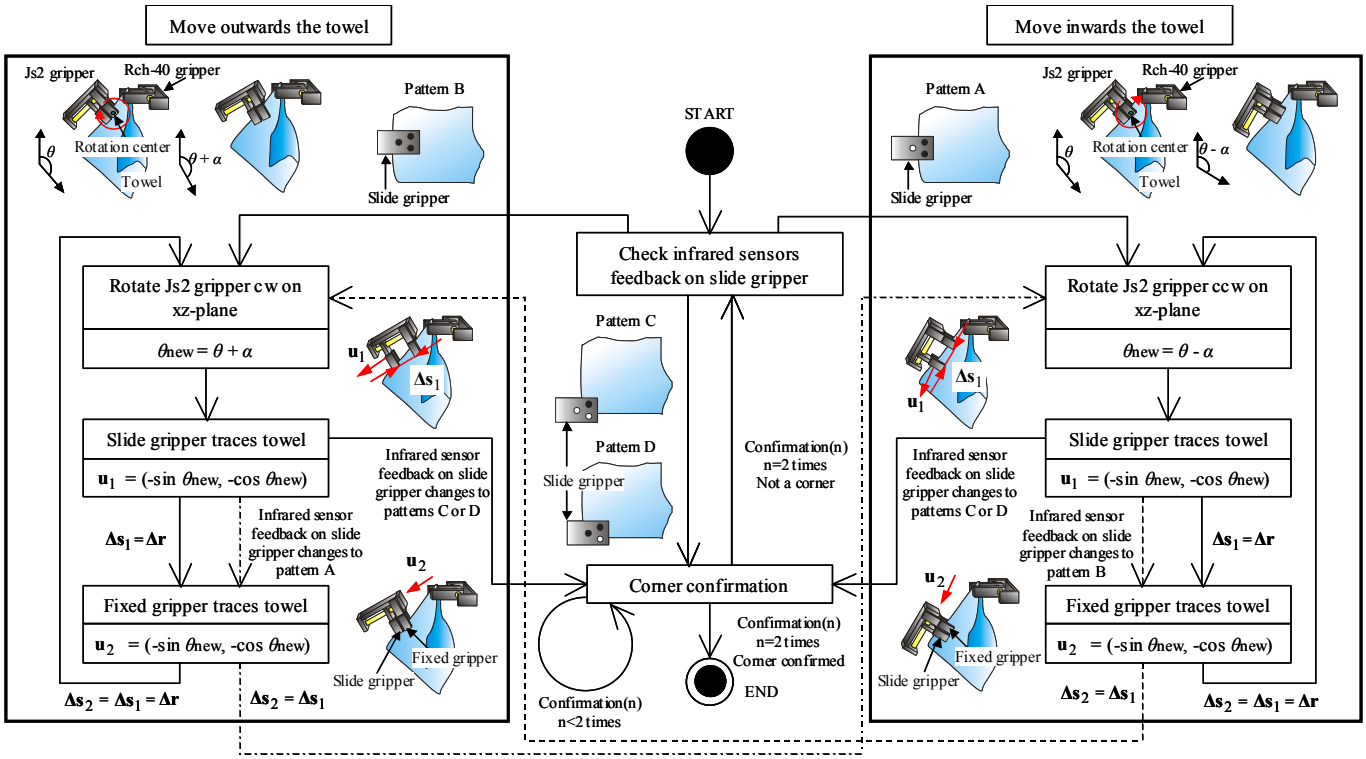


Figure 5 – Tracing algorithm using inchworm grippers

(tracing vector for the fixed gripper $\mathbf{u_2}$ and tracing distance $\Delta\mathbf{s_2}$). $\mathbf{u_2}$ and $\Delta\mathbf{s_2}$ can be written as follows:

$$\mathbf{u_2} = \mathbf{u_1} = (-\sin\theta, -\cos\theta)\,, \; |\,\mathbf{u_2}\,| = |\,\mathbf{u_1}\,| = 1 \qquad (5)$$

$$\Delta\mathbf{s_2} = \Delta\mathbf{s_1} \qquad (6)$$

Both grippers will then grasp the fabric firmly before Js2 changes the inchworm grippers' orientation θ based on the final infrared feedback pattern of the slide gripper when it first traced the towel. In case of pattern A, the robot will open the slide gripper slightly before Js2 rotates the inchworm grippers counter clockwise (rotating angle α) on the xz-plane so that the tracing direction will be facing deeper into the towel. In case of pattern B, the robot will open the fixed gripper slightly before Js2 rotates clockwise (rotating angle α) instead on the xz-plane so that the tracing direction will be facing away from the towel. The rotation center is the center of the fixed gripper's fingertip. The slide gripper will then again starts tracing the towel. The new tracing vector $\mathbf{u}_{1new}$ can be written as follows:

$$\mathbf{u}_{1new} = (-\sin(\theta - \alpha), -\cos(\theta - \alpha))\,, \qquad (7)$$

$$\mathbf{u}_{1new} = (-\sin(\theta + \alpha), -\cos(\theta + \alpha))\,, \qquad (8)$$

where eq.(7) represents the new tracing vector for pattern A and eq.(8) represents the new tracing vector for pattern B.

Js2 will trace the edge of the towel until the infrared sensors feedback on the sliding gripper turns to patterns C or D, indicating that Js2 is holding a possible corner, and corner confirmation process will take place. This is done by changing the orientation of the Js2 gripper θ and checking it the feedback stays at pattern C, D or not. The corner confirmation process is done two times. If the second corner is reached and confirmed, Js2 gripper will firmly grasp the corner and the towel is then spread.

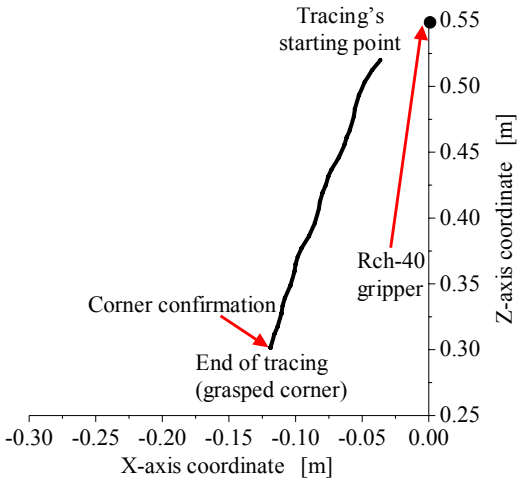
5. Experimental Results

Experiments were conducted 20 times to evaluate the proposed edge-tracing algorithm using a towel with the following properties: size 32cm x 32cm, thickness 2.28mm, mass per unit 0.037g/cm², coefficient of friction 0.615, and stretch rate 0.005cm/gf. All experiments were started with the Rch-40 gripper holding a corner of the towel. $\Delta\mathbf{r}$ and α are set at 5mm and 5deg respectively.

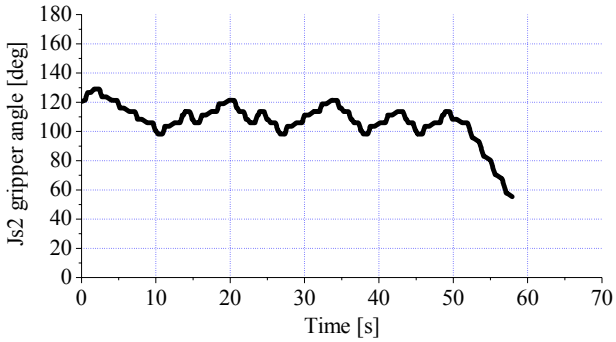
Figure 6 shows the data acquired during one of the tracing experiments. From Figure 6 (c), we can see that at the end of tracing, the infrared sensors feedback on the slide gripper turned to patterns C or D. This proves that the robot knows when it is approaching a corner. We can also see from Figure 6 (c) that corner confirmation process took place based on the number of times the feedback turned to patterns C or D at the end of tracing. Figure 6 (a) shows the trajectory for inchworm grippers. Figure 6 (b) shows the orientation of the inchworm grippers on the xz-plane. The percentage for Js2 finding a corner is 80%, proving that our proposed tracing manipulation method has been successful. The average time is approximately 58sec. Failures are mainly due to the Js2 gripper failing to trace along the edge of the towel. This happens when Js2 gripper does not hold the edge of the towel at the beginning of the tracing manipulation.

6. Conclusion

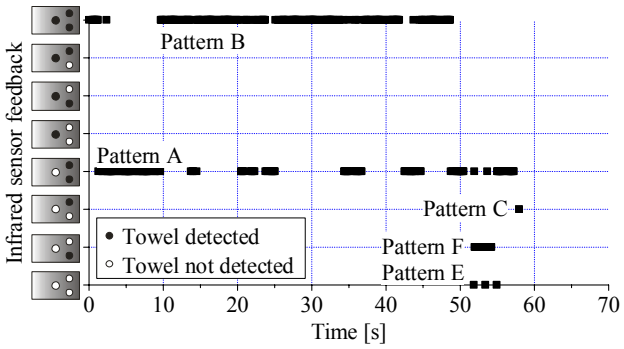
A method for finding a corner of a towel using a unique edge



(a) Js2 gripper trajectory



(b) Js2 gripper orientation θ on the xz-plane



(c) Infrared sensors feedback from slide gripper

Figure 6 - Experimental data obtained during edge tracing of towel by Js2 with inchworm type grippers

tracing method by inchworm grippers is presented. The gripper has enabled Js2 to trace the edge of the towel with more stability and also successfully even without the help of a vision sensor.

Projected plans include the improvement in both speed and reliability of the process. Collaboration with the existing vision sensor might solve this problem. Applying the current algorithm to other clothes such as shirts and skirts is also important to check the robustness of the method to other kinds of clothes as well.

References

[1] Hirai, S. 1998. Deformable object manipulation. Journal of the Robotics Society of Japan 16(2): 136-139.

[2] Arslan, A. and Turkoglu, I. 1999. An edge tracing method for object recognition. In Proceedings of International Conference in Central Europe on Computer Graphics, Visualization and Interactive Digital Media, Vol 3. Citing Internet sources URL http://wscg.zcu.cz/wscg99/papers/H53-final.pdf

[3] Wakamatsu, H. and Wada, T. 1998. Modeling of string objects for their manipulation. Journal of the Robotics Society of Japan 16(2): 145-148.

[4] Nakagaki, H. 1998. Insertion task of a flexible beam or a flexible wire. Journal of the Robotics Society of Japan 16(2): 159-162.

[5] Abegg, F., Henrich, D., and Worn, H. 1999. Manipulating deformable linear objects –Vision-based recognition of contact state transitions-. In Proceedings of the 9th International Conference on Advanced Robotics. Citing Internet sources URL http://wwwipr.ira.uka.de/de/Publikationen/detailed_publication.htm?id=976207040.

[6] Balkcom, D.J. and Mason, M.T. 2004. Introducing robotic origami folding. In Proceedings of IEEE International Conference on Robotics and Automation, 3245-3250.

[7] Kraus Jr., W. and McCarragher, B.J. 1997. Case studies in the manipulation of flexible parts using a hybrid position/force approach. In Proceedings of IEEE International Conference on Robotics and Automation, 367-372.

[8] Smith, P.W., Nandhakumar, N. and Tamadorai, A.K., 1996. Vision based manipulation of non rigid objects. In Proceedings of IEEE International Conference Automat, Vol.4, 3191-3196.

[9] Desbrun, M., Schroder, P. and Barr, A. 1999. Interactive animation of structured deformable objects. In Proceedings of the Graphics Interface Conference, 1-8.

[10] Hamajima, K. and Kakikura, M. 1998. Planning strategy for task of unfolding clothes. In Proceedings of the 16th Annual Conference of the Robotics Society of Japan, 389-390.

[11] Ono, E., Kita, N. and Sakane, S. 1997. Unfolding a folded using information of outline with vision and touch sensor. Journal of the Robotics Society of Japan 15(2): 113-121.

[12] Salleh, K., Seki, H., Kamiya, Y. and Hikizu, M. 2004. Spreading of clothes by robot arms using tracing method. In Proceedings of the 5th International Conference on Machine Automation, 63-68.

[13] Salleh, K., Seki, H., Kamiya, Y. and Hikizu, M. 2006. Tracing manipulation by robot grippers equipped with gear tips. In Proceedings of IEEE International Conference on Robotics, Automation & Mechatronics, 278-283.