,

Motion selection for 3D robotic snap assembly

Peihao Shi, Kensuke Harada, Weiwei Wan, Ixchel G. Ramirez
Department of Systems Innovation, Osaka University, 1-3 Machikaneyama-cho
Toyonaka, Osaka, Japan.

Juan Rojas
School of Mechanical and Electrical Engineering, GDUT, 100 Waihuanxi Lu, Gongxue 2, 105
Guangdong University of Technology, Guanzhou, Guandong, China

Hiromu Onda
AIST, 1-1-1Umezono
Tsukuba, Ibaraki, Japan

Abstract

In this paper, we aim to provide an assembly method for a snap joints assembly task. We create a 3D cellphone model and use ADAMS simulation environment to analyze the relative motion between screen and backer part. We focus on two points in this research. 1) Two kinds of relative motion between the screen and backer parts, i.e., the rotation-based and the translation-based methods, are compared, and 2) difference between assembly and disassembly is analyzed. By using the maximum elastic energy in an assembly process, we show that 1) the rotation-based assembly motion has better robustness than the translation-based assembly motion in cellphone assembly tasks when we set the same initial position error, and 2) The rotation-based assembly method is more effective for snap joint disassembly.

Keywords: Robotic Assembly, Snap joints, Strain Energy.

1. Introduction

Snap joints connection is one of the typical examples of plastic parts assemblage. As the widely application and mass-production of plastic parts, snap joints assembly is becoming more and more popular in assemble method of Industrial products. In snap joint assembly, the connection between two parts is built by elastic deformation of snap joints. [1] Fig.1 shows an example of the snap assembly task. Because of the elastic deformation of the snap joints, it becomes relatively hard for an industry robot to finish snap joints assembly task. As for the research on robotic snap joints assembly. Rojas et al. have proposed a force control method [5] and identification of assembly state [6-8] for the snap assembly problem.

In this paper we aim to provide a better assembly method for a cellphone snap joints assembly task. We create a 3D model of a cellphone, and use ADAMS simulation environment to analyze the assembly process of the cellphone. Using the Maximum Elastic Energy (MEE) as an index for evaluating the quality of a snap joints assembly tasks, we compare two kinds of assembly methods, i.e., rotation-based and translation-based methods. We also compare the difference of MEE in assembly and disassembly when we choose different assembly method. By using the maximum elastic energy in an assembly process, we show that 1) the rotation-based assembly motion has better robustness than the translation-based assembly motion in cellphone assembly tasks when we set the same initial position error, and 2) the rotation-based assembly method is more effective for disassembly tasks.

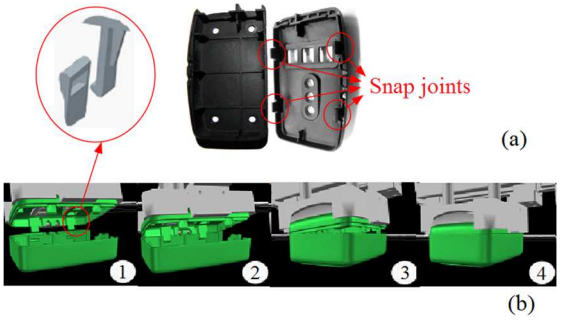

Fig.1 Snap assembly task

2. Approach and Definitions

We create a 3D model of a cellphone used in a physics simulation environment where the screen part contains four snap joints as shown in Fig. 2. We simulate the assembly process by using the predefined relative motion between two parts. Throughout a physics simulation of a snap joint assembly, we consider obtaining the function curve of strain energy and obtaining the MEE from the strain energy curve.

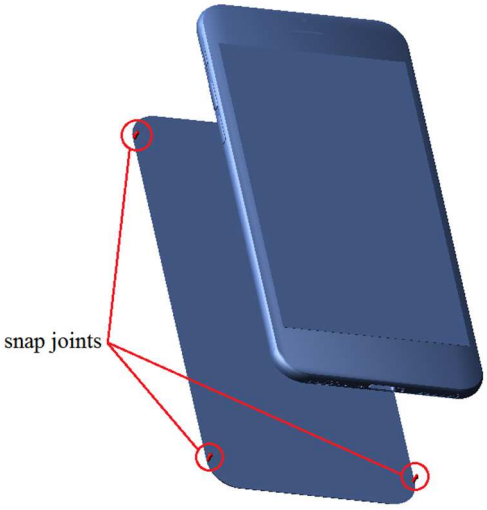

Fig.2 3D cellphone model.

We consider Ei(s) as the total elastic energy in the assembly process. Let *s* be the functions of a scalar, 0≤s≤1, and s changes from 0 to 1 as the part is being assembled. The maximum elastic energy (MEE) *Ui* is being defined for snap assembly/disassembly task of Part *i*. [9]

$$U_i = \max_{0 \le s \le 1} E_i \qquad (1)$$

By compare the MEE of different assembly methods, we can choose the better assembly method which the MEE is smaller.

3. Experiment and Analysis.

In this section, we set two kinds of relative motions where one is translational assembly and the other is rotational assembly. These two motions are representative human assembly motion. The rotation based relative motion is shown in Fig. 3 where the snap on~~in~~ one side of the screen part first contact the backer part, then the screen part is rotated until the snap joints on an~~of~~ other side comes into contact with the backer part, finally the screen part translates until it completely fits into the backer part. On the other hand, translation based relative motion is shown in Fig. 4 where the screen part simply translates to fit into the backer part. We compute and compare the MEE of rotation-based/translation-based relative motion. And the better assembly method is be defined as the one bring smaller MEE in assembly process.

3.1 Initial Position Errors.

In robotic assembly tasks. Influence of initial positon errors can be used as a criterion of robustness of assembly. In our experiment, we set the initial position errors of screen part to 0mm, 1mm, 2mm to compare the rotation-based and translation-based assembly motion.

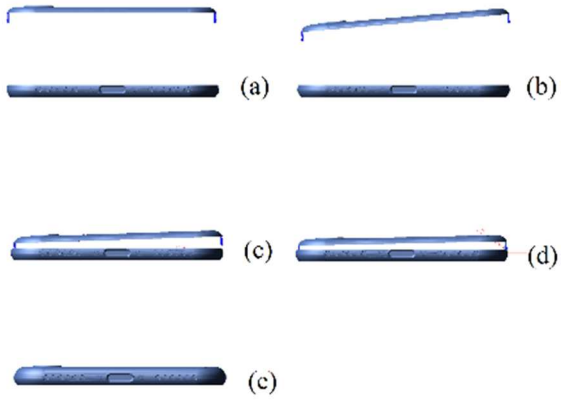

Fig.3 Rotation-based relative motion.

Fig. 5 and Fig 6 shows the simulation results when we set the initial position errors to 0mm. The result shown the MEE of translation based-motion (1.19J) is

bigger than the MEE of the rotation-based motion (0.94J).

Fig. 7 and Fig. 8 shows the simulation result when we set the initial position errors to 1mm. The result shown the strain energy of translation based-motion (2.17J) is bigger than the rotation-based motion (1.12J).

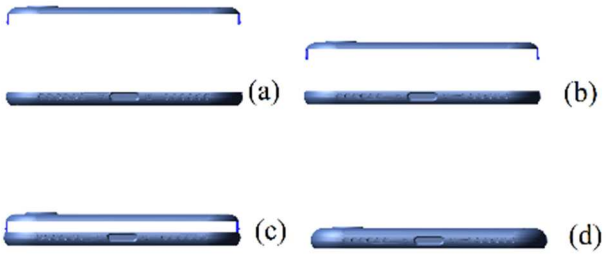

Fig.4 Translation-based relative motion.

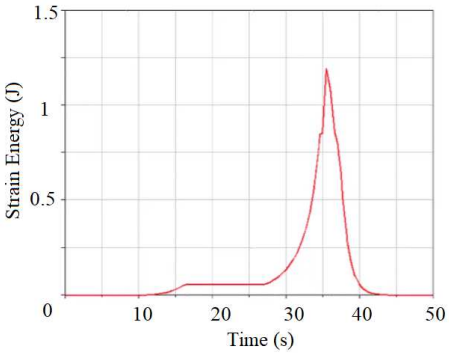

Fig. 5 Stain energy of 0mm position error in translation-based assembly

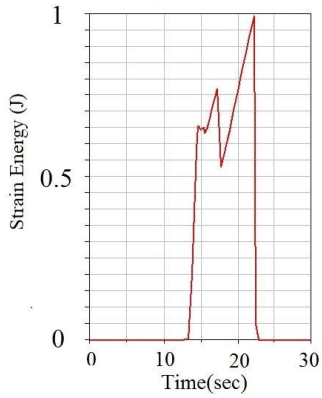

Fig. 6 Stain energy of 0mm position error in rotation-based assembly

Fig. 9 and Fig. 10 shows the simulation result when we set the initial position errors to 1mm. The result shown the strain energy of translation based-motion (3.51J) is bigger than the rotation-based motion (1.13J).

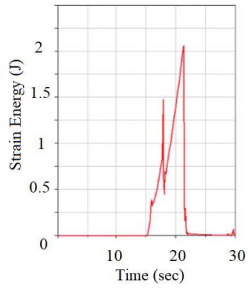

Fig. 7 Stain energy of 1mm position error in translation-based assembly

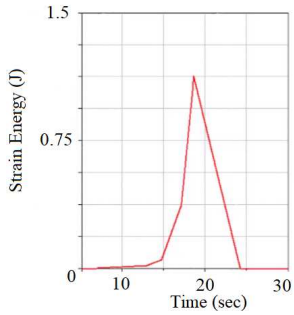

Fig. 8 Stain energy of 1mm position error in rotation-based assembly

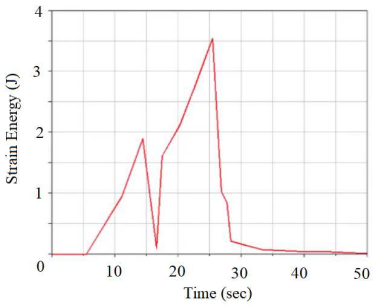

Fig. 9 Stain energy of 2mm position error in translation-based assembly

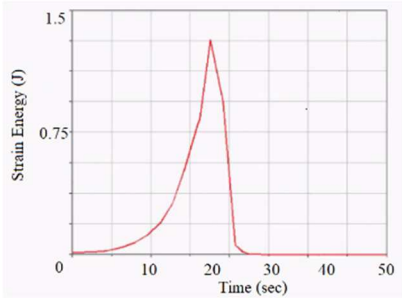

Fig. 10 Stain energy of 2mm position error in rotation-based assembly

The simulation result shown a conclusion: when we set the same initial position errors, the MEE in rotation-based assembly process is smaller than translation-based assembly process. And proved rotation-based assembly method has better robustness than translation-based assembly method.

3.2 difference of assembly and disassembly.

As the second point, we analyze the difference of assembly and disassembly in two kind of assembly methods. The MEE is different in assembly and disassembly when we use translation-based assembly method. Fig. 11 shows the MEE in assembly/disassembly process based on translation-based relative motion. The MEE in assembly process is 1.19J, it is smaller than the MEE in disassembly process (1.52J). Nevertheless, Fig. 12 shows the MEE in assembly/disassembly process when we use rotation-based assembly method, the MEE is almost same in assembly and disassembly process (0.94J).

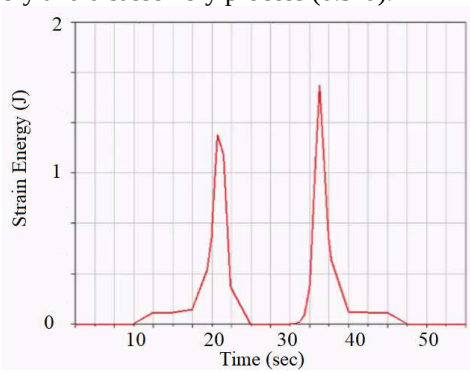

Fig. 11 Stain energy of assembly/disassembly process in translation-based assembly

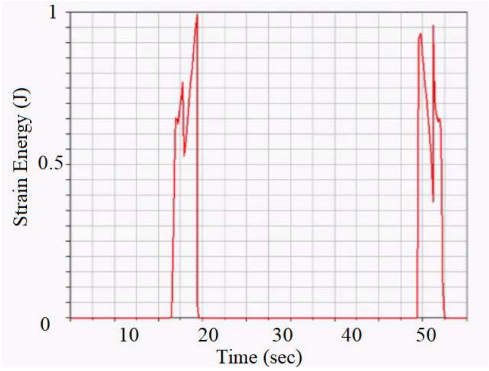

Fig. 12 Stain energy of assembly/disassembly process in rotation-based assembly

The simulation result shown that the rotation based assembly method is more effective when we disassembly the cellphone screen part.

Conclusions.

This paper analyzes the 3D cellphone snap joints assembly task. We compare two kinds of assembly method from the following points. First is the initial position errors of screen part. Second is difference between assembly and disassembly.

Based on the simulation result. We can draw the following conclusions: the rotation-based assembly method has better robustness than translation-based assembly method when we set same initial positon error. The rotation-based assembly method is more effective when we disassembly the cellphone screen part.

References

1. P. Shi, K. Harada et al., *Extended Directional Blocking Graph (EDBG) for Snap Joint Assembly*. (The 34-th Annual Conference of the RSJ, 2016)
2. Randall H. Wilson and Jean-Claude Latombe, *Geometric reasoning about mechanical assembly*, (Artificial Intelligence, 71, pp.371-396, 1994.)
3. [3] H. Chang and T.-Y. Li, *Assembly Maintainability Study with Motion Planning*, (Proc. of IEEE Int. Conf. on Robotics and Automation, 1995.)
4. D. Koditscheck, *An Approach to Autonomous Robot Assembly*, (Robotica, vol. 12, no. 2, pp. 137-155, 1994.)
5. J. Rojas, K. Harada et al., *A Constraint-Based Motion Control Strategy for Cantilever Snap Assemblies*, Proceedings of 2012 IEEE International Conference on Mechatronics and Automation, 2012, pp.1815-1821.
6. J. Rojas, K. Harada et al., *A Relative-Change-Based Hierarchical Taxonomy for Cantilever-Snap Assembly Verification*, IEEE/RSJ International Conference on Intelligent Robots and Systems, 2012, pp.356-363.
7. J. Rojas, K. Harada et al., *Early Failure Characterization of Cantilever Snap Assemblies using the PA-RCBHT*, IEEE International Conference on Robotics & Automation (ICRA), 2014, pp.3370-3377.
8. J. Rojas, K. Harada et al., *Strategies, Controllers, and Coordination: Bi-Manual Snap Assembly Automation*, International Conference on Robotics and Biomimetics, 2014, pp.1266-1271.
9. P. Shi, K. Harada et al., *Initial Motion Analysis for Robotic Snap Assembly*. (The 35-th Annual Conference of the RSJ, 2017)