Analysis and Synthesis of grasps in 2D articulated chains with 2 and 3 objects

Noé Alvarado Tovar[1]
‡

Abstract

This paper addresses the problem of analysis and synthesis of grasps in 2D articulated chains with 2 and 3 objects, using frictionless contacts. The objects of the chain are discretized in a cloud of points. The proposed approach for the analysis and synthesis of grasps is Geometric. The grasp analysis is carried out by verifying that the contact points placed on the objects satisfy the Force-Closure property. And for the synthesis, the proposed procedure finds one or more grasp with Force-Closure. In addition, we propose a procedure to find the elements of the vector of generalized forces to link chains of n objects. We have implemented the algorithms to chains with 2 and 3 objects with rotational joints.

1. INTRODUCTION

The grasp and manipulation of objects using robotic hands is a research area of great interest in robotics.The goal of a grasp, is to make the object does not move when being affected by an external disturbance. Therefore the grasp must satisfy one of the following properties:"force-closure" (the forces applied by the fingers ensure the object immobility, in future be named FC) or "form-closure" (the position of the fingers ensures the object immobility) [1].

Several works have been developed dealing with the grasp of 2D non-polygonal and polygonal objects, with n number of fingers and contacts with or without friction. Cornellà and Suárez [3] computed grasp with form-closure on non-polygonal objects. For polygonal objects some studies carried out include the following: the algorithm developed by Liu [2] calculated FC grasps with n fingers. In the work done by Niparnan and Sudsang [4], they propose an algorithm that reports each grasp FC with 3 fingers, from a given set of points. The algorithm presented by Ponce et al [5] obtains FC grasps with 3 fingers, considering contacts with friction. Park and Starr [6] develop a method that finds the best FC grasp using a hand with 3 fingers. The approach proposed by Cornellà and Suárez [7], [8] determines an optimum FC grasp, where starting from the given position of 3 fingers the position of the fourth finger is found, the contacts are frictionless.

The great majority of the work done in the area of grasps objects , with robotic hands are centered on a single object, either in 2D or 3D. However, in the grasp or manipulation of articulated chains with n objects there are few work done. Some of these works have different approaches, such as the use of spatial algebra when modeling and analyzing multiple parallel manipulators holding an object articulated [9];the assessment quantitatively of the grasp stability of multiple objects subject by a multi-fingered hand[10] and the manipulation of objects that have degrees of freedom inherent, using algorithms interactive of perception [11].

Van der Stappent et al [12],[13] and [14] studying the immobilization of a serial chain of polygons connected by rotational joints, or hinges, in a given placement with frictionless point contacts. In the first study show that a chain with polygons without parallel edges are immobilized with $(n+2)$ contacts. And that any chain with n polygons can be immobilized with $(n+4)$ contacts. Further that can robustly immobilize chains with polygons without parallel edges with $[\frac{6}{5}(n+2)]$ contacts and $[\frac{5}{4}(n+2)]$ contacts immobilize any chain with $n \neq 3$ polygons. While in the latter work, with $(n+2)$ contacts can immobilize a chain of $n \neq 3$ polygons without parallel edges. If the polygons have parallel edges the chain is immobilized with $(n+2$

**This work was not supported by any organization

†[1]H. Kwakernaak is with Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, 7500 AE Enschede, The Netherlands h.kwakernaak at papercept.net

contacts if n is even, and with $(n+3$ if n is odd. The robustness is achieved with $[\frac{6}{5}(n+2)]$ and $[\frac{5}{4}(n+2)]$ for polygons with and without parallel edges. The more recent work describes 2 approaches of immobilization based on geometric effects of first and second order. Based on second-order effects, chain $n \neq 3$ hinged polygons without parallel edges can be immobilized with $(n+2)$ fingers. Moreover, taking into account the effects of first order, any chain of n polygons are immobilized with $(n+3)$ fingers.

The motivation of this paper is to addresses the problem of analysis and synthesis of FC grasps in 2D articulated chains with 2 and 3 objects, using frictionless contacts. For this purpose, two algorithms are developed. The first procedure allows to find the elements that must contain the vector of generalized forces for each force applied to objects of the articulated chain. The second finds at least one FC grasp with a geometric procedure to check if the grasp is FC.

The rest of the paper is structured as follows. Section II provides the basic concepts used in this work. Section III provides an overview of the problem, including the main assumptions. Section IV presents the algorithm to find the elements of the vector of generalized forces for the chain with 2 and 3 objects. Section V shows the procedure for the analysis of force-closure grasp. Section VI presents the algorithm to compute at least one FC grasp. Section VII shows the results of the application of algoritms to chains with 2 and 3 objects.Finally, Section VI presents the conclusions of the work.

References

[1] Bicchi A.On the closure properties of robotic grasping.Int J Robotics Res 1995; 14(4):319-44.

[2] Y.H. Liu.Computing n-finger form-closure grasps on polygonal objects.Int. J. Robotics Research, 19(2):149-158, 2000.

[3] J. Cornell and R. Surez.On computing form-closure grasps/fixtures for non-polygonal objects.In Proc. IEEE Int. Symp. Assembly and Task Planning, ISATP 2005, pages 138-143, 2005.

[4] N. Niparnan and A. Sudsang.Computing all force-closure grasps of 2D objects from contact point set. In Proc. IEEE/RSJ IROS 2006, pp. 1599-1604.

[5] J. Ponce, D. Stam, and B. Faverjon.On Computing Three-Finger Force-Closure Grasps of Polygonal Objects.IEEE Transaction on robotics and Automation, vol. 11, NO. 6, December 1995.

[6] Young C. Park and Gregory P. Starr.Grasp Synthesis of Polygonal Objects.

[7] J. Cornell and R. Surez.On 2D 4-Finger Frictionless Optimal Grasps.

[8] J. Cornell and R. Surez.Efficient Determination of Four-Point Form-Closure Optimal Constraints of Polygonal Objects

[9] Jain, A.; Rodriguez, G.; Kreutz-Delgado, K.Multi-arm grasp and manipulation of objects with internal degrees of freedom. Decision and Control, 1990. Proceedings of the 29th IEEE Conference on Digital Object ,page(s): 3110 - 3111 vol.6.

[10] K.Yamada, T.; Ooba, T.; Yamamoto, T.; Mimura, N.; Funahashi, Y.Grasp Stability Analysis of Two Objects in Two Dimensions. Robotics and Automation.ICRA 2005. Proceedings of the 2005 IEEE International Conference on, page(s): 760 - 765.

[11] Katz, D.; Brock, O.Manipulating Articulated Objects with Interactive Perception.Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on, page(s): 272 - 277

[12] Jae-Sook Cheong, Ken Goldberg, Mark H. Overmarst ,A. Frank van der Stappent.Fixturing hinged polygons. Robotics and Automation, 2002. Proceedings. IEEE/ICRA 2002, Page(s): 876- 881 vol.1.

[13] Jae-Sook Cheong, A. Frank Van Der Stappent.Inmobilizing hinged polygons.International Journal of Computational Geometry & Applications Vol. 17, No. 1 (2007) 45-69.

[14] Rimon, E.; Van Der Stappen, A.F.Immobilizing 2-D Serial Chains in Form-Closure Grasps.IEEE Transaction on Robotics, vol. 28, no. 1, February 2012, Page(s): 32-43.

[15] Murray R.M.; Li. Z.; Sastry S.A mathematical introduction to robotic manipulation.Boca Raton, FL: CRC Press; 1994.

[16] Mishra B.; Schwartz J.T.; Sharir M. On the existence and synthesis of multifinger Positive grips.Algorithmica 1987;2(4):541-58.

[17] Liu Y. H.; Lam M. L.; Ding D.A complete and efficient algorithm for searching 3-Df orm closure grasps in the discrete domain.IEEE Trans Robotics 2004; 20(5):805-16

[18] Mximo A. Roa and Ral Surez.Finding locally optimum force-closure grasps.Robotics and Computer Integrated Manufacturing 25(2009) 536-544.