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A constraint-based taxonomy of grasp strategies for grasping flat objects

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***Abstract*— The dexterity with which humans manipulate a variety of flat objects is remarkable, as they cope with this task by not only utilizing contact with the environment, but also by using different strategies depending on constraints posed by the object or the environment. As a precedent, consider the case of the different strategies involved in grasping a smartphone, a book or a plate lying on a table. This work presents an approach for selecting a suitable grasp strategy for grasping flat objects from support surfaces. Grasp strategies generally involve contact with the support surface and are robust to object pose estimation errors. Apart from the feasibility of the approaching direction and the spread adequacy, this approach takes into account the geometric convexity of the object-surface combination yielding three main strategies.**

I. INTRODUCTION

In the literature, two approaches exist for tackling grasp synthesis, the analytical and the empirical [1]. Analytical approaches consider kinematics and dynamics formulations in order to determine contact points for stable grasps. On the other hand, empirical approaches are focused on techniques that involve classification of different grasps and learning methods that avoid the computation complexity of the analytical ones.

The constraint-based taxonomy presented in this work, consists an empirical methodology which classifies grasp strategies for flat objects. In this methodology we consider the object and the support surface as a combined structure of interest.

II. PRELIMINARIES

An object, $\mathcal{O} \subset \mathbb{R}^3$, placed on a support surface $\mathcal{S} \subset \mathbb{R}^3$ with normal vector $\hat{\boldsymbol{n}}_{\mathcal{S}}$, is *flat* if:

$$\sup\{|(\boldsymbol{o}-\boldsymbol{s})\hat{\boldsymbol{n}}_{\mathcal{S}}| : \boldsymbol{o} \in \mathcal{O}, \boldsymbol{s} \in \mathcal{S}\} < \epsilon$$

where $\epsilon \in \mathbb{R}$ depends on the hand in use. In particular, an object can be flat for a hand with bulky fingertips, but not for one with delicate tips. Furthermore, notice that flattness is not an intrinsic characteristic of the object because it depends on its pose; a lying bottle can be flat, in contrast to a standing one.

The *spread of the hand*, s_h, is the maximum distance between two opposable fingertips of the hand and the *spread of a flat object*, s_o, is the length of its smallest dimension, without considering the one along the direction of $\hat{\boldsymbol{n}}_{\mathcal{S}}$. We state that a flat object is *directly graspable* if $s_h > s_o$.

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Moreover, we consider the hand's palm, $\mathcal{P}$, as a surface with normal vector $\hat{\boldsymbol{n}}_{\mathcal{P}}$ pointing inwards the workspace of the fingers. An object is *top-reachable* if the palm of the robot can reach a position above the object with orientation $\hat{\boldsymbol{n}}_{\mathcal{P}} = -\hat{\boldsymbol{n}}_{\mathcal{S}}$.

Finally, consider $\mathcal{S}_O \subset \mathcal{S}$ to be the orthogonal projection of $\mathcal{O}$ on $\mathcal{S}$. If the set $\mathcal{S}_O \cup \mathcal{O}$ is not convex, then we state that *the object-surface combination is non-convex*. A non-convex example is a plate on a table or the handle of a cupboard while a book on a table is a convex case.

III. THE TAXONOMY

Fig. 1 depicts the proposed taxonomy of grasp strategies. Three strategies are developed, α, β and γ. Strategy-α is utilized for objects lying on a surface that can be approached from the top and can be grasped directly. An example is a pills box or a remote controller on a table or the floor. Strategy-β is performed for objects which either cannot be grasped from the top or directly, but present an non-convex geometry with the support surface, like a plate or a handle. Finally, strategy-γ utilizes non-prehensile manipulation in order to grasp the object by sliding to positions facilitating grasping. Examples of objects, are a wide book on a table, or a box on a high shelf following a similar grasping principal as in [2]. A demonstration of the strategies can be viewed in this video: https://goo.gl/MWqGoR.

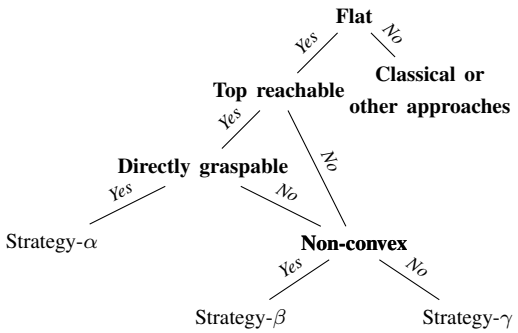

Fig. 1. The constraint-based taxonomy

REFERENCES

[1] A. Sahbani, S. El-Khoury, and P. Bidaud. An overview of 3d object grasp synthesis algorithms. *Robot. Auton. Syst.*, 60(3):326–336, March 2012.

[2] C. Eppner, R. Deimel, J. lvarez Ruiz, M. Maertens, and O. Brock. Exploitation of environmental constraints in human and robotic grasping. *International Journal of Robotics Research*, 34(7):1021–1038, 2015.