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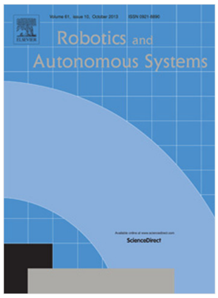

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Grasp Synthesis for Purposeful Fracturing of Object

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***Abstract*—This paper deals with the problem of purposefully failing (breaking) or yielding objects by a robotic gripper. Robotic harvesting is considered as an application domain that motivates this study. A definition of a failure task is first formulated using failure theories. Next, a grasp quality measure is presented to characterize a suitable grasp configuration and systematically control the failure behavior of the object. This approach combines the failure task and the capability of the gripper for wrench insertion. The friction between the object and the gripper is used to formulate the capability of the gripper for wrench insertion. A new method inspired by the human pre-manipulation process is introduced to utilize the gripper itself as the measurement tool and obtain a friction model. The developed friction model is capable of capturing the anisotropic behavior of materials which is the case for most fruits and vegetables. The evaluation method proposed in this study is formulated as a quasistatic grasp problem and can include both fully-actuated and under-actuated grippers. The proposed approach for purposefully breaking objects is validated using experimental results. Objects with different material properties are used to prove the generality of the method. KUKA LightWeight Robot IV is used as the manipulator.**

***Index Terms*—Agricultural Robotics, Robotic Grasp, Grasp Evaluation, Friction Modeling.**

I. INTRODUCTION

Harvesting is the process of gathering ripe crops that can be described as breaking objects into two or more pieces at desired locations. This process has to be systematically controlled to permit successful application of robotic hands and grasp theories in harvesting and avoiding damage to the crop (see Fig. 1). The complete separation of an anisotropic beam such as a fruit stem or a tree branch is difficult to model, since buckling and green-stick fracture in biological beams complicate the process of snapping. Buckling and green-stick fracture result from anisotropic nature of fiber cells along radial and tangential directions. [1]. Nevertheless, we propose a grasp evaluation method to systematically study the process of failure by taking into consideration the mechanical and physical properties of the material.

Over the last four decades, significant contributions have been made in the field of robotic grasping [2], [3], [4]. As massively reported in the literature, robotic grasp encompasses a broad range of tasks from a simple pick and place to a more advanced assembly task such as circuit chips insertion. A common element among these tasks is the process of putting the object(s) together. In contrast, in robotic harvesting, the primary goal is the failure and separation of the grasped objects at a certain location [5], [6]. To the best of our knowledge, there is no investigation on grasp planning to

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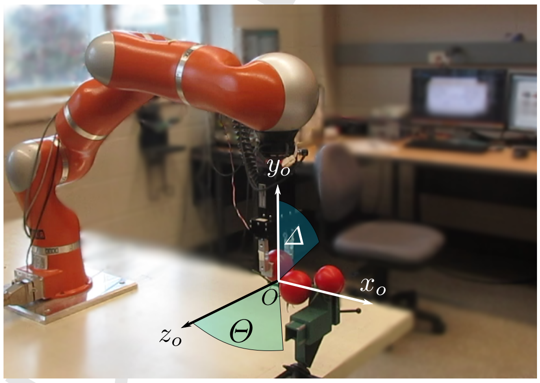

Fig. 1. Harvesting a Tomato using a robotic gripper while avoiding damage to the crop and its neighbours. Systematic object failure at the origin denoted by, O, within maximum allowable object twist denoted by Θ and maximum allowable object deflection denoted by Δ.

fail or separate a grasped object purposefully. The studies that emphasize on avoiding deflection and/or slippage of the object [7], [8], [9], [10] ignore the individual effects of bending, tension, or torsion on the object which is essential for obtaining an accurate characterization of grasp task intended for object failure.

A grasp task can be characterized by a set of expected wrenches that the grasp must withstand during the expected manipulation process [11]. A task polytope can be defined using all these wrenches [12] known as Task Wrench Space (TWS). A TWS can be approximated by an ellipsoid [13] or a convex polytope [14]. The TWS can be used to evaluate the quality of the grasp. For instance, a well-known task-oriented grasp metric is to choose an appropriate TWS such that it is well inscribed within the grasp wrench tolerance [15]. The core of our approach involves computing the maximum force that can be applied to a grasped object so as to yield a tensile object or fracture a brittle object while optimizing contact forces and analyzing force capabilities of the gripper. To this end, we propose a new definition of the failure task using mechanical failure theories and use it to evaluate the grasp so as to measure how well the TWS conforms with the capabilities of the gripper. The grasp capability is formulated using wrench insertion capability of the gripper and the friction between the gripper and object. Friction can play a major role in grasping. To apply bending moment, tension force, and torsion torque, contact points with friction are necessary when form closure is not achievable. It is common in the literature to use Coulomb's law to model the dynamic friction force between the gripper and the object [2]. However, friction in anisotropic materials such as fruits can vary significantly and cannot be characterized using a single Coulomb's friction coefficient. Thus we consider an anisotropic friction model