# Systematic Evaluation of Compliant Under-actuated Soft Manipulators in an Industrial Context - The Ocado Use Case

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## I. INTRODUCTION

With a focus on an impactful industrial use case of growing commercial interest, we build upon the benchmarking framework proposed in [1] to evaluate soft manipulators and environmental constraints (ECs) exploitation at task level. Whilst [1] concentrated on component and system tests, we address purposeful grasping and manipulation. We introduce the Ocado use case and define the relevant performance metrics to categorise the capabilities of soft manipulators. We also present a functional test method for systematic evaluation of grasp strategies and formulate hypotheses as a starting point for experiments.

## II. THE OCADO USE CASE

At Ocado, the world's largest online-only supermarket, over 2 million items are packed every day, comprising over 270,000 customer orders of 47,000 distinct products.

The variability of shape, size and weight in our product range imposes further challenges to robotic manipulation. Most of these products are delicate, deformable and present characteristics which make off-the-shelf hardware unsuitable for robotic picking in production environments.

In order to avoid damage to packaging and bruising of fruit and vegetables, robotic manipulators must be intrinsically compliant. Compared to more traditional robotic manipulators, soft manipulators are intuitively assumed to be more appropriate to handle our product range; we are seeking empirical evidence via our benchmarking framework.

In contrast to existing grasping benchmarks, the proposed framework does not attempt to rank manipulation, but rather highlight their capabilities and limitations based on attributes relevant to our use case. Moreover, existing sets of test objects for grasping have virtually no deformable/delicate objects, leaving our use case largely under-represented.

## III. BENCHMARKING FRAMEWORK

### A. Key attributes and assumptions

The object to be grasped is assumed to be **asymmetric** and **deformable**, which is very representative of the Ocado product range. These characteristics can be observed in products such as fruit and vegetables, which are amongst the most challenging objects for a robotic manipulator to reliably handle without damaging or bruising.

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In addition, objects are assumed to be inside a container accessible from the top. The container defines the number of ECs (and the possibility to exploit them), ranging from a table-like (bottom surface only) to a full box with top removed. Also, the number of objects within the container may vary, altering the degree of difficulty.

Furthermore, grasp strategies may be object-dependent. We believe that objects with similar attributes may be grouped into categories. Hence, from an extensive analysis, we derived a taxonomy whereby products are categorised by packaging type, deformability, shape, etc.

### B. Performance metric: successful grasp definition

A successful grasp in the Ocado use case is defined by:

- Robustness (secure and reliable) grasp
- Level of damage/bruising observed
- Pick-and-place cycle time

The above parameter space allows for a uniform reporting of functional capabilities of manipulators, defining their performance for distinct categories sampled from our taxonomy.

## IV. TEST METHOD

We consider a system pairing robotic arm and manipulator. Equidistant pre-grasp cartesian poses with pre-defined distance from the object are generated, and the manipulator is moved to such poses prior to executing a grasp strategy.

**Baseline grasp strategy**. We are initially testing a rather simple grasp strategy implementing the sequence: **a)** Move to pose, **b)** Move on a straight line towards the object, **c)** Stop upon contact, **d)** Close manipulator, **e)** Move upwards (world Z-axis direction), **f)** Evaluate grasp; where item **a** is the Non-contact Phase, items **b-d** are the Grasp Phase, and items **e-f** are the Manipulation Phase.

This sequence forms a pipeline which is easily repeatable, allowing for the use of different robotic manipulators and execution of progressively more complex grasp strategies.

## V. EXPERIMENTS

**Non-contact Phase**. *Hypothesis*: hand orientation and pre-grasp pose impact success rate.

**Grasp Phase**. *Hypothesis*: hand orientation and post-grasp pose impact robustness of grasps.

**Manipulation Phase**. *Hypothesis*: ECs exploitation increases grasp success rate when using soft manipulators.

## REFERENCES

[1] J. Falco, K. V. Wyk, S. Liu, and S. Carpin, "Grasping the performance: Facilitating replicable performance measures via benchmarking and standardized methodologies," *IEEE Robot. Automat. Mag.*, vol. 22, no. 4, pp. 125–136, 2015.