Robotic Untangling of Herbs with Parallel Grippers

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***Abstract*—Robotic packaging generally involves picking target objects from a pile consisting of many other similar or random objects. For a pile composed of herbs, the weight picked up can be controlled by varying the opening aperture width of a parallel gripper. However, the individual strands of herbs get entangled with each other, causing more to be picked up than desired. Here, it is shown that using a *spread-and-pick* approach the degree of entanglement in a herb pile can be reduced. Compared to the traditional approach of picking from an entanglement-free point in the pile, the proposed approach reduces the variance in picked weight for homogeneous piles of plastic and real herbs by 36.35 and 23.64 percent, respectively. These results demonstrate that using the proposed *spread-and-pick* approach, the stochasticity of a herb environment can be counterbalanced effectively.**

***Index Terms*—Robotics in Agriculture and Forestry, Agricultural Automation, Computer Vision for Automation**

I. Introduction

Industries manufacturing machinery, transportation equipment and various everyday retail products on a large scale have benefited immensely from intelligent and collaborative assembly-line robots. However, to date, the application of such technologies to the processing of fresh horticultural produce remains mostly dependent on manual labour. The suppliers of fresh herbs, for instance, grow stock under glass or in fields and then must transport them to packaging stations and pack them as per the weight requirements of retailers. The manual packaging process involved is not only costly in terms of labour but also suffers from human errors and low production efficiency.

A more scalable approach could be automation through adaptive robotic systems, however, deploying such a system presents several challenges. Fresh horticultural produce can be highly variable in terms of its handling properties, even within a single plant variety, making it difficult to design robotic controllers for their manipulation. Herbs, in particular, tend to present as a highly stochastic, tangled mass (see Fig. 1(a)), making it difficult for a robotic system to extract a uniform quantity suitable for presentation to the consumer. Smaller, fixed-mass portions must be extracted and fed via conveyor belt for packaging but the tangling (see Fig. 1(b)) makes the mass lifted in a simple pick operation difficult to predict.

Traditionally, researchers have studied bin-picking[1] in the context of two main challenges: (i) *gripper-object collision* and (ii) *object entanglement*. The use of simple geometric primitives such as planes, spheres, cylinders and cones for object recognition in the bin was proposed in [1]. Changes in surface types and depth discontinuities were then used to segment the cluttered scene. A novel vision-based algorithm was proposed in [2], which suggested resolving gripper-object collision by identifying and picking the topmost object in a pile. A deep learning approach for picking individual objects from a cluttered bin was proposed in [3]. These methods prove effective for avoiding gripper-object collision. However, they do not address the issue of object entanglement directly.

Fig. 1. (a) Handling fresh herbs and (b) entanglement.

In the past, the entanglement between the objects in a pile has been directly addressed through interaction with the pile [4], [5]. Known CAD models of the objects were used in [6] for planning singulation of individual objects from a heterogeneous pile. Although these methods address the issue of entanglement directly, their objective is to *extract a single, rigid object*, rather than *a uniform quantity of deformable, granular media*, such as herbs.

To this end, this paper proposes a *spread-and-pick* method, which reduces entanglement, and in turn, makes the pick operation more predictable in terms of the picking quantity. It has several advantages, including that (i) it does not require any large scale data collection and (ii) it does not depend on any geometrical information about the objects picked.

II. Method

A. Collision-free Gripper Pose: Graspability Index

The graspability index (GI) [7] is a vision-based measure for evaluating the candidate grasping poses, which has proved useful in industrial pick and place settings. It uses a single

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[1]Pile and bin are used interchangeably in this paper.

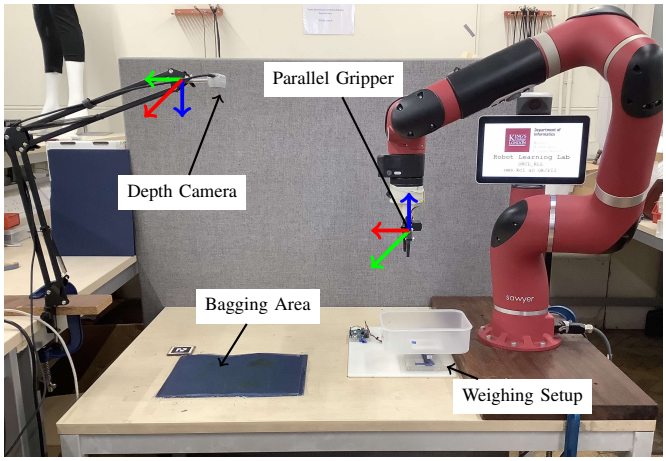

Fig. 2. Overview of the experimental setup. Red, Green and Blue arrows represent x, y and z axes respectively.

depth map of the scene to estimate the optimal gripper position and orientation for picking an individual object. Along with the parallel gripper, GI is also applicable to general grippers such as multi-finger and vacuum grippers. For an insertion depth (r_z), GI estimates a point $\mathbf{r} = (r_x, r_y, r_\theta)^\top$ in the bin such that the parallel plates of the gripper can be inserted without causing any collision between them and the objects inside. r_θ denotes the orientation of the gripper around its z-axis. A range of r_θ is evaluated using GI, and for the optimal r_θ^*, the optimal collision-free picking point (r_x^*, r_y^*) is estimated.

B. Tangle Reduction

A key problem with the use of GI is that it does not take account of tangling causing undesired objects to picked alongside the target one. For better control and accuracy, this paper proposes a means to adjust the picking action to reduce tangling and thereby achieve more consistent picking. For this, a *spread-and-pick* approach is proposed, whereby the pick operation is augmented with an extra detangling step using an extension to the GI. Humans frequently use their fingers to separate things while picking, especially when they have to work with one hand. The proposed *spread-and-pick* approach draws inspiration from this behaviour. Specifically, if the target object is between the two fingers of a parallel gripper, instead of moving inwards (closing) and picking the object, the fingers are moved outward to displace other objects entangled or close to the boundary of the target object. The proposed approach extends the GI by identifying regions of high entanglement in the scene and then defining a spreading movement to disentangle them: First, for a fixed insertion depth r_z and gripper orientation r_θ, the optimal collision-free picking point (r_x^*, r_y^*) is estimated using GI. Next, the peak entanglement point $\mathbf{r}' = (r'_x, r'_y)^\top$ is estimated using the collision map as obtained from the vision module. Finally, r_θ is updated as

$$\theta = \arccos\left(\frac{\mathbf{r}^{*\top}\mathbf{r}'}{|\mathbf{r}^*||\mathbf{r}'|}\right). \tag{1}$$

TABLE I

Picked weight (mean±s.d.) over 20 trials for plastic herbs.

Gripper Width(mm)	Method	Picked Weight(g)
20	Graspability Index	9.844±11.078
	Spread and Pick	8.247±7.635
30	Graspability Index	10.482±9.172
	Spread and Pick	7.501±5.839
40	Graspability Index	13.267±11.953
	Spread and Pick	14.333±8.480

TABLE II

Picked weight (mean±s.d.) over 10 trials for real herbs.

Gripper Width(mm)	Method	Picked Weight(g)
20	Graspability Index	3.712±3.028
	Spread and Pick	15.646±2.471
30	Graspability Index	8.622±3.480
	Spread and Pick	15.788±2.658
40	Graspability Index	19.192±7.273
	Spread and Pick	18.361±6.934

C. Procedure

Using the set up as shown in Fig. 2, a series of robotic picking operations are conducted for plastic and real herbs following a simple picking methodology as well as following the proposed *spread-and-pick* methodology. Each picking operation consists of the robot reaching into a pile of tangled media (herbs) of fixed mass, closing its gripper, and lifting what is grasped free of the surface of the bagging area. For simplicity and lower cycle-time, only 3-degrees of freedom of the robot are used for picking movements, and the highest point in the pile is chosen as the target picking location. To ensure a similar physical arrangement of the tangled media between trials, any media picked is returned to the bagging area and the entire quantity is transferred to a container of fixed dimension (18 cm x 13.5 cm) before being placed back on to the bagging area for the next pick. In the case of real herbs, for each method and each opening aperture width w of the gripper, a fresh batch of herbs is used to avoid variations due to changes in their physical state (*e.g.,* due to herbs drying out, or becoming damaged over successive picks). For *spread-and-pick*, the grasping manoeuvre consists of setting the gripper orientation r_θ according to (1) and the gripper aperture w to the chosen width prior to lowering it into the pile. Once lowered into the pile, instead of closing, the gripper plates are moved outwards and opened, leading to dispersion of the herbs. The mass of media picked is recorded for each trial.

III. Results

The results for picking real herbs are shown in TABLE II. As can be seen, there is a clear reduction in the variance of the picked mass for the *spread-and-pick*. The maximum percentage decrease in the variance for plastic and real herbs is 36.35% and 23.64%, respectively, for the intermediate $w = 30\,\text{mm}$. This suggests that the proposed approach is effective for improving the predictability of picking in this challenging automation task.

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