WRAPP-up: a dual arm robot for intralogistics

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Abstract—The diffusion of the e-commerce has produced larger and larger volumes and varieties of items to be handled in warehouses, with the effect to increase the research effort in picking automation. This can be conventionally achieved through a custom plant in case of large scale productions where the items are few and have well-known characteristics that are expected to change slowly and little over time. However, today this case is less and less common and the challenge is to realize a solution that is flexible enough to handle goods with different shapes, sizes, physical properties, and grasping modes. To solve this problem we first analyzed how humans perform picking and synthesize their behavior in four main tactics. These have been used as guidelines for the design, the planning and the control of WRAPP-up: a dual arm robot composed of two anthropomorphic manipulators, a Pisa/IIT SoftHand and a Velvet tray. Finally an extensive experimental validation and performance evaluation of the system is reported.

I. INTRODUCTION

E-commerce, i.e. buying and selling physical goods via services over the internet, has reached its full development today. Led by Amazon, which accounted for more than 50% of the growth of the whole e-commerce market, and by Alibaba, in 2017 retail e-commerce sales amounted to more than 2 USD trillion with an annual growth rate higher than 25% [1]. The expansion of the e-commerce is affecting the way warehouses work, especially the intralogistics, i.e. the internal flow of goods within a distribution center [2], [3]. On one side, the market growth led to an increase of the employment: data from the Census Bureau1 show that in U.S. there was an annual growth rate in the Warehousing and Storage (North American Industry Classification System - NAIC - 493) employment of the 28% (from 2015 to 2016) and that in 2016 the total workforce reached more than 600 K units. An analysis conducted by Data USA2 shows that material movers are the largest share (20%) of jobs. On the other side, a strong effort is devoted to maximize intralogistic efficiency by fully employing optimization techniques [4], by pushing the productivity of human operators even if it may cause harsh working conditions [5], and via the adoption of automated solutions [6]. Among the intralogistic operations, the picking, namely grasping of goods from bins, shelves, or pallets, is the last one that is still almost completely executed by humans operator and the push to increase the level of its automation is stronger and stronger.

This work is focused on the realization of an autonomous flexible picking solution leaving for future works the integration with the vision system. Despite the great effort in the development of picking robots and end-effectors, no existing automatic solution is flexible enough to solve at once the following challenges: i) inaccessibility of parts of the objects suitable for a direct grasp, ii) deformable objects, iii) pierced objects, iv) objects not graspable from the top. The key contributions, which are presented in this work, are: the concept, the prototype, and the experimental validation of WRAPP-up: a novel dual arm robot for intralogistics. The key novelty is that the development of this robot has been inspired by the techniques that the human pickers adopt. Observation of an expert operator at work highlighted that four are the main maneuvers that are employed to pick and place goods. Based on these findings we designed a dual arm robot composed of two 7 degrees-of-freedom manipulators and two different end-effectors: an adaptive end-effector able both to grasp a large variety of objects and to stably interact with different shapes, and a tray with an actuated belt. Moreover we encoded the human observed picking strategies into parametric motion primitives adopted in the trajectory planning of the robot. Finally an extensive experimental validation has been conducted.

II. TRANSLATING HUMAN PICKING SKILLS INTO ROBOT MOTION PRIMITIVES

Inspired by the observation of the strategies adopted by the operators parametric motion primitives have been defined to

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plan the motion of the robot during the task execution:

- **Sliding** one end-effector is used to push (or pull) an object towards the other end-effector, which secures the grasping and may support the weight of the object as shown in 2(a).

- **Horizontal Rotation Front** one end-effector is used to gently tilt the object about a horizontal axis ideally placed on the front-bottom edge of a box enveloping the object (see 2(b)). The rotation of the object will end when it will lay on the other end-effector. This strategy is intended to be used with objects (boxes, cylinders) of which the height is the largest dimension.

- **Horizontal Rotation Back** one end-effector is used to tilt the object about a horizontal axis ideally placed on the back-bottom edge of a box enveloping the object (see 2(c)). The rotation of the object will allow the second end-effector to be placed under the object itself as a support.

- **Vertical Rotation** One end-effector approaches the object’s side, then rotates it about a vertical axis ideally located at one edge of the object. Once the rotation has produced enough room for the end-effector, it slides inside this gap and proceeds sliding the object towards the exterior of the pallet. This strategy is suitable when the objects are compactly packed (see 2(e)) and it is necessary to make room for the end-effectors to perform a successful grasp.

### III. Conclusions and Future Works

In this work, we addressed the problem of realizing a proof-of-concept robot that is flexible enough to manipulate a variety of goods that is relevant for the intra logistics of warehouses.

Inspired by the picking strategies that skilled human operators adopt in the execution of these tasks, we realized a dual-arm robot provided with a Pisa/IIT SoftHand and a Velvet Tray. The first end-effector is adaptable hence it is used to establish stable grasp to rotate and slide goods with various shapes, while the second end-effector is mainly used to support the weight of the objects. The robot has been experimentally validated in picking several different objects.

Next steps will include on one side to provide the robot planning with an high level decision tool that is able to automatically generate the right strategy to adopt on the basis of features of the objects that can be detected by a vision system, on the other to adopt suitable feedback strategies based on vision, force feedback and tactile feedback in order to improve the robot reliability.

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