A robotic gripper for picking up two objects simultaneously

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ABSTRACT
Industrial robots are commonly used in a large number of applications because they present superior performance in terms of accuracy, precision, rigidity, and most importantly speed. Although they are fast enough for pick and place operations, sometimes they cannot catch up with the speed of objects on the conveyor thereby missing some pieces. Considering randomly arriving objects on a conveyor, this task becomes even more challenging. In this study, a two-degree-of-freedom gripper for industrial manipulators is developed in order to overcome this difficulty. First of all, design details of the gripper are presented. Second, preliminary analyses are performed using a three axis Delta-type manipulator for a typical pick-and-place task. Third, the developed gripper is integrated into the same manipulator and tested for certain performance criteria. The analysis and measurement results show that the manipulator performs a given task with reduced cycle time and energy consumption when integrated with the proposed gripper rather than a conventional one.

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1. Introduction
1.1. Background

Industrial robots provide numerous advantages to industry. They increase throughput by working faster and more accurately and ultimately boost overall profits. Moreover, they do not need a break and are able to work 24 hours a day [1] thereby decreasing production costs. Furthermore, they help to improve product quality and reliability, reduce waste, and increase safety. Therefore, the demand for industrial robots is dramatically increasing day by day [2]. For instance, parallel manipulators (PMs) have become widely popular in the last two decades [3–5]. PMs can be defined as closed-loop kinematic chains whose end-effectors are linked to the base by at least two independent kinematic chains [6]. They are composed of four main parts: actuators, links, joints, and end-effectors. They offer several benefits over serial manipulators (SMs). These advantages include higher load capacity, improved position accuracy, higher stiffness, less vibration, increased acceleration, and most importantly higher speed [7–11]. Moreover, high dynamic performance, which is a necessity for robotic systems, can be achieved with PMs because of low inertia and high stiffness of the parallel structure [12–14]. However, the main drawback of PMs is that they have singularity problems in their limited workspace [15,16]. PMs are very fast. For instance, ABB’s IRB 360 FlexPicker, which is the most sold parallel manipulator [17], can reach up to 100 pieces per min. However, it is observed that even parallel manipulators remain incapable of performing certain tasks, especially in the packaging in-

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dustry. Although they are very fast, sometimes they cannot catch up with the speed of the objects on the conveyor thereby missing some pieces.

The industry is trying to solve this problem by either using a couple of manipulators in order to pick up all goods on a production line [18], or reducing the conveyor speed of the line so that no goods are missed. However, these solutions lead to an increase in cost or time of the operation. Alternatively, grippers handling multiple objects are used as well [19]. This type of gripper is quite useful in industry, especially when the objects arrive in an orderly manner. However, this solution is not that much effective if the objects arrive randomly. Picking up randomly-arriving multiple objects poses a challenge to the robotic industry. This research is aimed at resolving this problem by designing a new gripper.

1.2. Literature review

With the introduction of robots in industry, tasks carried out by a human hand are replaced with more efficient handling equipment, called a gripper [19]. It is arduous for a robotic gripper to compete with a human hand in terms of dexterity [1]. For instance, a six-DOF motion can easily be achieved with a human hand, but not with an advanced and complicated robotic gripper. However, it is inevitable to use grippers in industrial operations when dirty, hazardous, and repetitive works are considered. Grippers play a crucial role in task performance of robots [20] because they are the parts interacting with the environment. They are capable of completing different tasks depending on the application. In this section, types of grippers are investigated according to their grasping principle, number of carried objects, and degree of freedom.

Grippers can be classified into four main groups considering their grasping principle: mechanical finger, vacuum, magnetic, and universal grippers [21]. Mechanical finger grippers are used to grasp objects by fingers. These fingers hold workpieces by either enclosing them or by clamping with friction force [22]. Alternatively, the fingers are mechanically pre-stressed by utilizing principles of compliant mechanisms [23,24]. As a second group, vacuum grippers hold objects having flat, smooth, and clean surfaces. They are based on suction cups handling the objects by applying pressure difference. Significant number of handling operations, such as clamping, sorting, feeding, stacking, and turning can be performed with suction cups [25]. Therefore, they are widely used in various fields of robotics [26–28], especially in the packaging industry [29]. Magnetic grippers, on the other hand, are used for holding metal objects. Although grippers of this type are very fast, they are heavy, and residual electromagnetic problems can be posed [22]. Finally, universal type grippers consist of an elastic membrane filled with mass of granular materials [30]. Granular materials encased in an elastic membrane can conform to the shape of the object to be picked up. Therefore, universal type grippers can pick up a wide variety of arbitrarily shaped objects with different materials, different textures, and different fragility. Grippers can also be classified according to the number of carried objects. A single gripper can pick up only one object, like the one in [31]. Double and dual grippers have two grasping devices to pick up two objects. The only difference between them is that dual grippers [32] hold two objects simultaneously whereas double grippers, as in [19], hold the objects independently. Multiple grippers, on the other hand, hold more than two objects, such as the one mentioned in [29]. According to DOF, mechanisms of grippers can be divided into three groups. These are immobile, 1-DOF, and multi-DOF grippers. Immobile grippers do not have any DOF. As the second group, 1-DOF grippers have either a translational, rotational, or combination of rotational and translational DOF. Finally, multi-DOF grippers have more than one DOF. The examples of the immobile, 1-DOF, and multi-DOF grippers can be found in [19]. Please keep in mind that multiplicity of jaws are not taken into account.

1.3. Contribution of the investigation

None of the state-of-the-art grippers discussed in the previous section is capable of picking randomly-arriving two objects simultaneously. To address this gap, a novel two degree-of-freedom (DOF) gripper for industrial robots is proposed in this investigation. The proposed gripper in this study falls into 2-DOF, dual gripper category. Its design differs from the state-of-the-art grippers significantly. The main idea behind this design is to pick two randomly-arriving objects at the same time. Therefore, the novel design, when integrated with an industrial robot, will result in reduced cycle time and reduced energy consumption for a given task.

1.4. Organization of the paper

The outline of the paper is reported as follows: in Section 2, the 2-DOF gripper is introduced with the design requirements, mechanical design, working principle, and prototype development. Section 3 covers evaluation methods such as characterization tests, integration into a PM, performance analyses, and measurements. Section 4 is dedicated to results of the characterization tests, performance analyses, and performance measurements of the 2-DOF gripper. In Section 5, the results are discussed and drawbacks and future work of the gripper are pointed out. Finally, contributions of the design are summarized in Section 6.
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