

PEG-IN-HOLE OPERATION USING A COBOT WITHOUT USING EXTERNAL SENSORS

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1. Introduction

Collaborative robots, or cobots, represents nowadays the technological challenge of industrial robotics. Unlike traditional industrial robots, that perform fully automated task and have to be confined in a protected environment, cobots are designed to share the environment and the task with the human operator. This results in a reduction of physical constraints to the production. Moreover, cobots are also designed to be easy to program and use, drastically reducing the need of extra costs for equipment integrators and experts. It is for these reasons that the use of cobots can be attractive for medium and small companies, with a limited capacity of investment. On the other end, peg-in-hole insertion is one of the most common automated task to be performed by an industrial robot. This kind of operation usually requires the use of a force and/or torque sensor to control robot trajectory [1], [2], thus raising again the costs and the complexity of development. In this paper, we present the automation of an industrial peg-in-hole operation, without the use of external force or torque sensors. The cobot used for the study is an UR5 from Universal Robots, equipped with a standard RG2 gripper and a simple pvc adaptor manufactured with 3D printing. This robot is one of the less expensive cobot actually on the market; therefore, it does not integrate joint force sensors. Nevertheless, it is possible to recover the value of the force vector at the tool center point (tcp) and the torque value at each of the 6 joints. These values are calculated based on the motor internal current consumption. The following paragraph describes the method used to perform an operation, that is at present performed by a human operator.

2. Methods

The part that has been used is a mechanical part from Brovedani Group, that has to be inserted in

the corresponding sawtoothed hole, as illustrated in the left side of Figure 1.

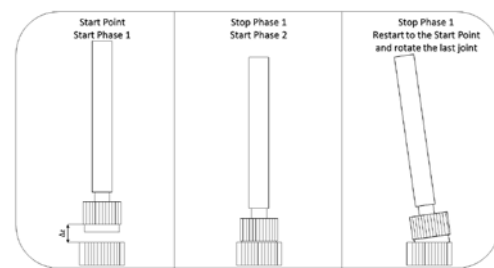


Fig. 1. Part configurations: initial (on the left), end of first phase (in the middle), stop dead (on the right).

The sawtoothed part has 48 tooth and the main risk during insertion is the stop dead of the part, causing the part blocking. Moreover, the part has a flat cylindrical first portion (at its bottom), that needs to be correctly centered in the sawtoothed hole before starting the real insertion. Therefore, the operation can be divided into 2 phases:

- a first phase, during which the part is centered and the robot performs a vertical descent till the very first contact among tooth (see middle part of Figure 1);
- a second phase, during which the robot continues the vertical descent and performs the part insertion.

During both phases, the UR5 performs a helicoidal descent: at each step the vertical z value is decreased of 1mm and the tcp frame is rotated of 2°. Several hundreds of insertion operations have been performed with the cobot and the following conclusions have been drawn:

- during the first phase, the value of the force vector applied at the tcp can be used to reliably monitor if the part is successfully centered;
- during the second phase, the variation of the shoulder torque of a step with respect to

the previous one can be used to monitor if the part has been successfully inserted.

The implemented algorithm is illustrated in Figure 2.

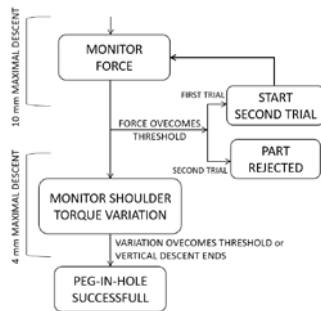


Fig. 2. Peg-in-hole algorithm.

During the first phase, the real-time force is compared to a threshold of 60N. This value, experimentally determined, is far enough to the UR5 maximal force limit of 150N and allows the detection of “bad” centered trials, as illustrated in the right side of Figure 1 and in the curves of Figure 3.

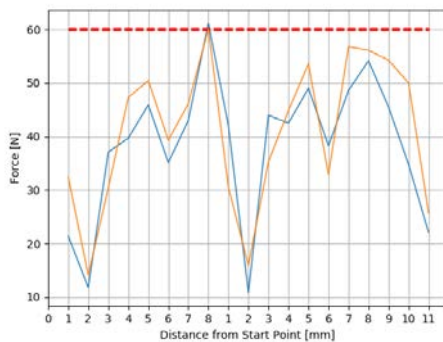


Fig. 3. The part is not correctly centered, the vertical force overcomes the limit threshold (horizontal line).

If it is the case, a second trial is performed (rise and again descent), at the end of which, either the part starts the second phase, or it is rejected. If the force threshold is not overcome, the first phase ends after a helicoidal descent of 10mm and the second phase begins. During this phase, the variation of the shoulder torque is calculated at each step and compared to a threshold, in percentage equal to 50%. This value has also been experimentally calculated: if the threshold is overcome, it means that the part has been successfully inserted and can be released and gripper opened (see curves of Figure 4). It is possible that the part is already correctly inserted from the beginning of the second phase: in this case, no important variation of the torque can be

observed and the descent continues because of the sliding of the grasping. It is for this reason that in any case, the descent is stopped at most after 4 mm, and the part is released.

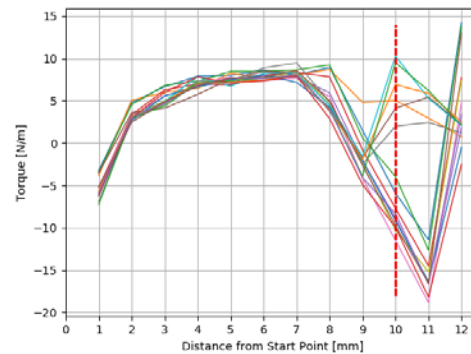


Fig. 4. The part is inserted after 12 mm of descent: 10mm for the first phase (vertical dotted line) and 2 more mm for the second phase.

3. Results

Over 1000 peg-in-hole operations, 967 have been successfully inserted, i.e. 96,7% of successful rate. Among these parts, 870 have been inserted at the first trial (90%). A second trial was needed for the remaining 10%. The overall mean time for an operation is 5,5 seconds. This value does not include part picking. The 3,3% of failure is certainly due to the lack of precision during part grasping, performed with a standard gripper and without any part positioning tool. The use of a customized tool will contribute to a vertically centered part grasping and will most likely improve the results.

Acknowledgements

This research is the result of an international collaboration started thanks to the Erasmus program, between the Department of Engineering and Architecture of Trieste in Italy and the engineering school of Toulouse, Icam, in France.

References

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34th Danubia-Adria Symposium on Advances in Experimental Mechanics
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