Automation and performance analysis of tea filter bags packing process using delta configured robot

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Abstract: A delta robot is a type of parallel robot that consists of three arms connected to universal joints at the base. Industries take advantage of these robots in packaging and pick and place operations due to its high accuracy and fastness. This three degrees of freedom robot is used in the process that automates the tea filter bags packing process through pick and place operation. Electrostatic gripper has been used as the end effectors. The tea filter bags are allowed to go through the conveyor and this delta configured robot is used for pick and place operation. This robot reduces the time complexity of the laborers and it also helps in increasing productivity by reducing the cost. Thus the tedious process becomes simpler through the delta configuration. Comparative analysis of the performance of robot with manual process is also shown in the results.

Keywords: Tea bags, Delta configuration, Electrostatic charges.

1. Introduction

A delta robot is a type of parallel robot that consists of three arms connected to universal joints at the base. The key design feature is the use of parallelograms in the arms which maintains the orientation of the end effectors. The delta robot allows for very high speed and high accelerations for very high speed and high accelerations. Having all the arms connected together to the end effector increases the robot stiffness but reduces its working volume. These delta robots are known for their fastness and high accuracy. Industries that take advantage of the high speed characteristic of delta robots are the packaging industry, pharmaceutical and medical industry. It can also be used for surgery because of its stiffness. Other applications may include high precision assembly operations. Today delta robots are well established in the automation industry. Unlike the larger articulated arms, delta robots are often kept as a stock item at many manufacturers such as yaskawa, Motoman and ABB. Such kinds of robots perform pick and place operations quickly and repeatedly too. The delta configured robot is also known as pickpac robot since it can pick one or more objects and pack or tray them. In this project the delta robot is used for the packing purpose. The tea filter bags are allowed to go through the conveyor and a delta configured robot is used to pick and place the tea filter bags process. Our delta robot has three degrees of freedom. Thus the tedious packing process becomes simpler through the delta configuration.

2. Literature survey

In [1], the paper deals with the handling materials and gives a brief idea about the vacuum gripper and electrostatic gripper. In [2], author discussed about a gripper that handles textile materials with the tactile sensors, camera modules, and it will be a type of two fingers which grasps the textile material. This gripper has been completely done for its flexibility. A complete case study of electro adhesion principle of handling flexible objects familiarly textile type objects are processed in a simple way through the electrostatic gripper.
in [3]. In [4], the paper completely explains about the direct and inverse kinematics of the geometric analysis of the manipulators and end effectors orientation. From the literature survey of the above mentioned papers and more, we analyzed various ways available for handling the flat and non-rigid objects like the tea filter bags that we are trying to handle during this automation process and came to the conclusion about using the Electro adhesive gripper which comes under Adhesive gripping principle [5].

3. Problem identification

Durga Garments, a small scale textile industry having more than 10 number of employees are doing the process of cutting and packing of tea filter bags. 1 pack consists of 100 pieces. The employees are taking around 6 hours of work for cutting and another 6 hours of work for packing. The calculations are given below,

- No of Employees = 10.
- Each Employee Contribution approx. = 12- 20 packs.
- Total amount of pieces per day = 20,000 pieces.
- Total amount of pieces per month = 4, 80,000 approx.

Since it is taking a huge time for the packing process rather than cutting process, we have come up with a solution. We have developed a delta configured robot can reduce the time into half of the cutting process.

4. Robot design and fabrication

Clavel’s delta robot design as shown in figure 1 is the best suited robot design structure according to their popularity in delta configured robots found in industries up to date. This delta robot has 4-degrees-of-freedom (DOF), 3-dof for XYZ interpretation, in addition to a fourth inward leg to control a solitary rotational opportunity toward the end-effector stage (about the hub opposite to the stage). This design serves us as the base design for our robot structure for the kinematics analysis.

![Figure 1. Clavel’s Delta Robot.](image)

The design objectives include low cost production, sustainability and maintenance, modularization, simplicity and order. The standard design is the initial process in any of the projects, the design includes the proper dimension of forearms, biceps, end effectors, motor coupler and frame of the robot. All the above said calculations and the analysis are considered while concluding with a standard design ready to be fabricated, purchased and assembled. The CAD model of the proposed setup is shown in figure 2.
4.1 Fabrication

Dimensions for special parts include the design of biceps, forearms and end effector for the delta robot in this automation. The biceps and forearms are used to lift the objects or used to move the end effector from place to place with some variations in the joint angles of the revolute joints designed in between the actuators and biceps of the robot. The actuators are grounded to the base of the robot as shown in the figure 3. These actuators are housed in very precisely calculated ways such that they work according to the previously discussed Clavel’s delta robot design.

Other special parts made for this robot are the horizontal and vertical pins used to form the required joint movements in between the biceps and the forearms and also in the joints between the end effector and the forearms. These pins are assembled in such a way that they provide revolute joints which are mutually perpendicular to each other as an alternative to the action provided by a spherical fisheye rod end intended to be connected at ends of the forearms first as shown in the figures 4 and 5.
4.2 Control and calibration

The control of each arm in the robot is one of the main goals in the project of pick and place the tea filter bags. The control flow of the robotic arm is as follows the figure 6.

When the desired trajectory for the end effector is requested by the user or the mode at which the machine is running, the controller generates the motor angles for each joint in the robot and passes these signals to the servo motors via PWM waves from the controller. These PWM signals are received by the driver modules in each servo motor, which takes the corresponding steps incremented or decremented according to the feedback signal from the position sensor attached to each joint.

The overall movement of these joints contributes the end effector being moved to the desired position.
4.3 Position Calibration

When the full robotic setup is complete and ready for user, it requires to provide the positional coordinates as the input. Therefore, the appropriate position of the end effector becomes the input to the algorithm that controls the robot, which then performs the inverse kinematic calculation and finds three angles that control the servo motor that places the robot’s arm in the correct position as requested by the user.

To perform these steps in the real world first the robot arms initial position needs to be calibrated. The calibration process involves manual calibration of the robot arm as the first step. As the first step the robot shoulder connected to the servo motor is removed. The robot's home location is then called through the interface on the command line. The disconnected arms are now precisely attached to the servo motor, so that the end effector lays neutral in its previously well-designed location at proper height. After the robot's manual calibration is finished in the real world then the joint movement machine checking is performed by calling a test function in the command line interface to ensure the proper movement of each joint up to its full extent.

5. Experimental verification

Experimental trials were run with robots performing the task of picking and placing tea filter bags in the correct orientation for particular times versus manual pick and place of the same amount of tea filter bags in the same orientation. Initially the orientation of tea filter bags varied but showed a much less time period for the task completion with the manual attempts. After the orientation error is addressed with correction procedure, the task came close to timing with the manual attempt of counting and orienting the tea filter bags in required count and position. Each test was measured by means of a stopwatch to record the completion
speed from the moment the operator pressed the start button on the controller until the last tea filter bag was placed.

Each pack was inspected for accuracy of placement. Each set of pack contains 50 tea filter bags, so each would receive an accuracy score out of 50 for correctly placed tea filter bag. The experimental data collected form running those trails are as follows in the Table 1.

**Table 1. Performance analysis of the developed Delta Robot.**

| Performance | Correctly packed packets | Time Taken(min) | Accuracy (%) |
|-------------|--------------------------|-----------------|--------------|
| Trial 1     | 23                       | 5.20            | 46           |
| Trial 2     | 41                       | 4.25            | 82           |
| Trial 3     | 39                       | 3.45            | 78           |
| Trial 4     | 48                       | 3.19            | 96           |
| Trial 5     | 49                       | 3.20            | 98           |
| Trial 6     | 50                       | 3.23            | 100          |
| Trial 7     | 47                       | 3.40            | 94           |
| Trial 8     | 49                       | 3.67            | 98           |

**Figure 8. Performance Chart of the Robot.**
6. Results and discussion

The experimental result suggests that the real time performance of the placement coordinates differ from actual position vs electronic coordinates calculated by the algorithm. The problem is with the slight backlash in the servo motor’s gearbox. After those first two trials the variation in the X-axis is manually adjusted with reference to the error value in the program using the Visual Delta 3 Controller software. Then the following trails showed accuracy nearer to the expected result. The initial trial showed much time taken as a result of electro adhesive gripper lag in charging to discharge period. This is then fine-tuned to acquire much lesser time taken for task completion.

The cost estimate for this project was around twelve thousand rupees as attached in the Bill of Material without the cost of labor for the entire project. Though the initial investment seems high for the task to be considered but the overall long-term cost including the labor charge and the time taken for the task completion seems reduced with the involvement of this project.

7. Conclusion

The pick and place Delta Robot system proved to be not an accurate process as expected but definitely improved packing process efficiency in terms of fast task completion. From the figure 8, it is observed that even though the robot had a placement accuracy off by as much as 4-9%, it showed a strong repeatability. On a good note, it was accurate enough to put into the process with the current accuracy which doesn’t matter in the packing process where count is perfect all time along the packing process.

Most importantly this system can easily differentiate the size of the product with ease making it more efficient for packing process. This proved to be more useful in the quick packing of tea filter bags.

References

[1]. Donfatto Paul Glick and Aaron Parness 2017 An Electrostatic Gripper for Picking an Object Proceeding of International Conference on Intelligent Robots and Systems pp 1172-1179
[2]. Erzincanli and J M Sharp 1997 Development of a non-contact end effector for robotic handling of non-rigid materials Cambridge University Press, Vol 15 No 3 pp 331-335
[3]. Hawkes E. W., Jiang H., and. Cutkosky M. R 2015 Three-dimensional dynamic surface grasping with dry adhesion The International Journal of Robotics Research
[4]. Kalantari A, Mahajan K, Ruffatto D, and Spenko M 2015 Autonomous perching and take-off on vertical walls for a quadrotor micro air vehicle in Proceedings of the IEEE International Conference on Robotics and Automation.
[5]. Parassidis Fahantidis N Petridis V Doulgeri Z. Petrou L and Hasapis G 1995 A robotic system for handling textile and non-rigid flat materials Computers in Industry Vol 26 No 3 pp 303-313
[6]. Ethan W. Schaler Donald Ruffatto Paul Glick Victor White Aaron Parness 2017 An Electrostatic Gripper for Flexible Objects Proceeding of International Conference on Intelligent Robots and Systems pp 1172-1179
[7]. Shin, K.G. and Mckay, N.D. 1984 Open Loop Minimum Time Control of Mechanical Manipulations and its Applications Proceedings of American Control Conference pp. 1231-1236.
[8]. Thuy-Hong-Loan Le Michal Jilich, Alberto Landini Matteo Zoppi, Dimiter Zlatanov and Rezia Molfino 2013 On the Development of a Specialized Flexible Gripper for Garment Handling Journal of Automation and Control Engineering Vol. 1 No. 3 pp 255-259
[9]. P.M. Taylor, A.J. Wilkinson, G.E. Taylor, M.B. Gunner, G.S. Palmer 1990 Automated Fabric Handling Problems and Techniques Proceeding of IEEE International Conference on Systems Engineering pp 367-370
[10]. P.J Zsombor-Murray 2004 Descriptive geometric kinematic analysis of clavel’s delta robot Centre of Intelligent Machines, McGill University