Development and Analysis of Robotic Arm with Multigripper Mechanism

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Abstract

In this project, however we use an entirely different approach where individual fingers are replaced by a single mass of granular material which when pressed onto a target object, flows around it and conforms to its shape. Upon application of a vacuum, the granular material contracts and hardens quickly to hold the object without requiring sensory feedback. The operating principle is the ability of granular materials to transition between an unjammed, deformable state and a jammed state with a solid-like rigidity. We delineate three separate mechanisms – friction, suction, and interlocking, that contribute to the gripping force. Using a simple model, we relate each of them to the mechanical strength of the jammed state. This advancement opens up new possibilities for the design of simple, yet highly adaptive systems that excel at fast gripping of complex objects.

Problem Definition

The use of the Granular Jamming Mechanism for a robotic gripper would provide various advantages like reliability of component, cost of product and gripping speed. The grippers available now all have fingers which require more joints and hence control which increases complexity and use of resources in development of a gripper. This reduces and almost nullifies its use in everyday applications as it is not economically feasible. Limited work is carried out to overcome these problems.

Objectives and Methodology

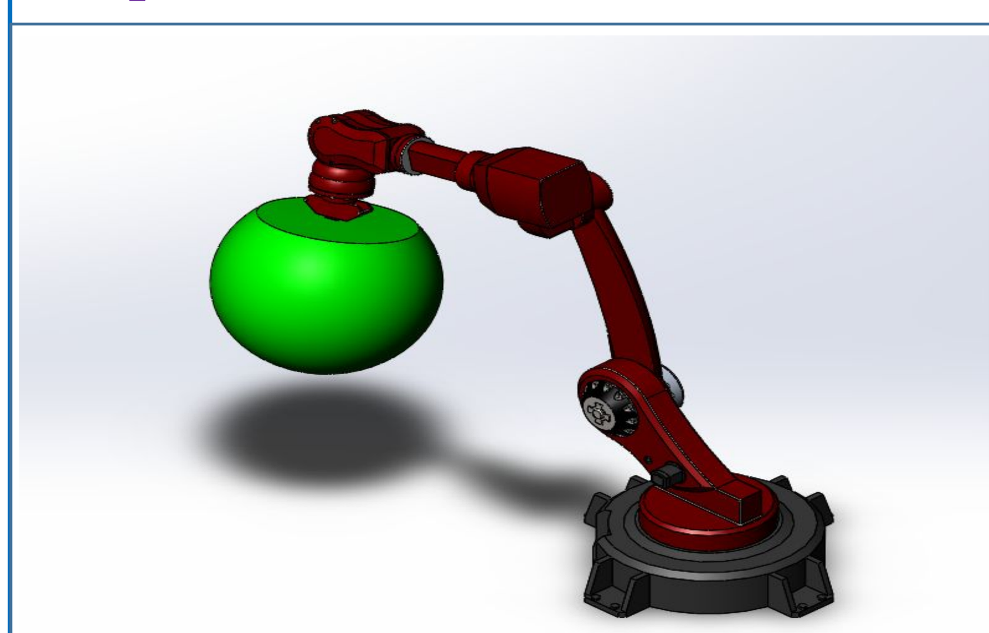
Objectives

- To develop a robotics gripper which works on the principle of jamming of granular material to transition between an unjammed, deformable state and a jammed state with a solid-like rigidity. This will help delineate three separate mechanisms – friction, suction, and interlocking, that contribute to the gripping force.

- **Methodology**

Literature Survey → Component Selection → 3-D CAD Modelling → Computational Simulation → Component Procurement → Machining → Fabrication → Testing

Experimental Work

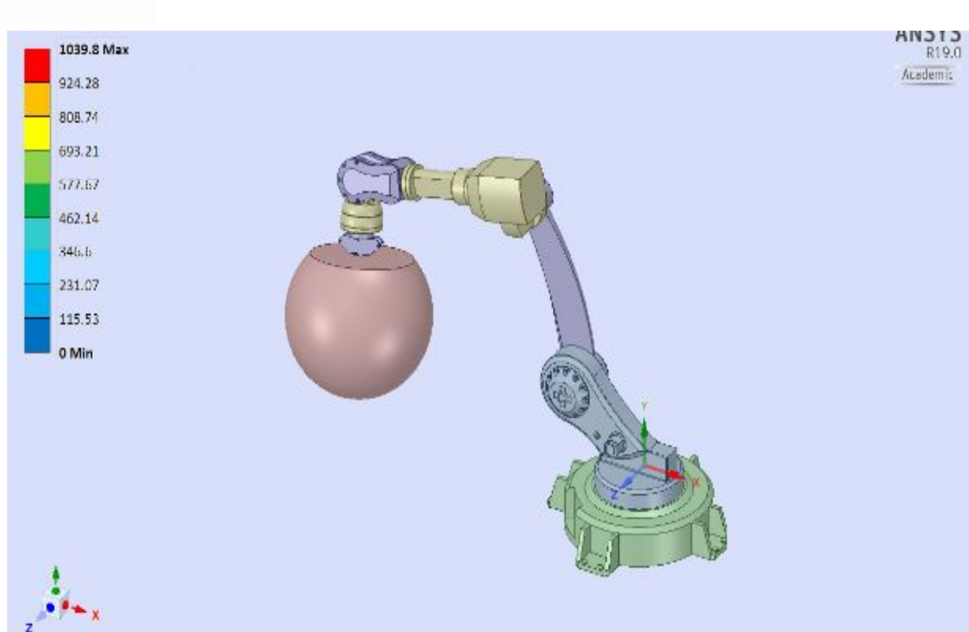


CAD Modelling

3D CAD Modelling of the proposed robotic arm multi-gripper mechanism is implemented in SolidWorks 2016.

Design Simulation

3D CAD Model is imported into ANSYS Workbench 19.0 and dynamic response is recorded through transient Analysis.

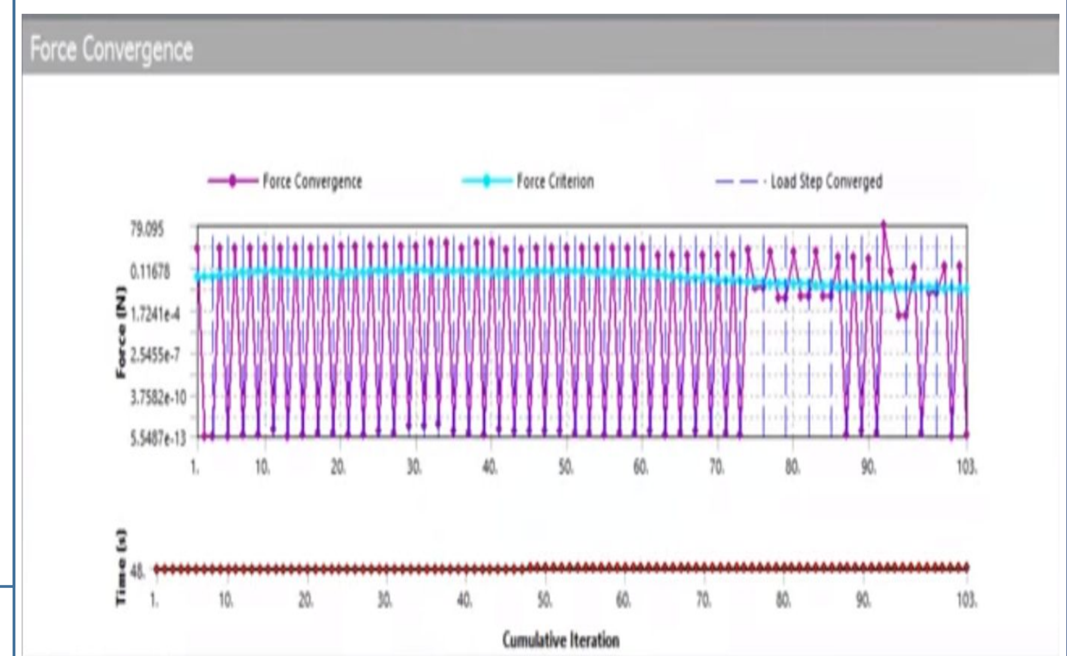


Prototype Test

A basic prototype was developed using some basic household materials and gripping effect/ lifting capacity of various granular materials was examined.

Results & Discussion

Force Convergence



Force Criterion (FC): This is defined as a percent of the applied load which includes is all the external forces applied to the model.

Force Convergence Value (FCV): This is the unbalanced force that is a result of the changing stiffness of the model caused by either geometric, material or contact nonlinearities. The FCV is the difference between the applied load and the summation of internal forces of the equilibrium iteration.

Load Step Convergence (LSC): This is the point of convergence and structural integrity of the model developed. This is where the FC and the FCV intersect in the graph. Convergence occurs when the FCV or Residual is less than the Convergence Criterion.

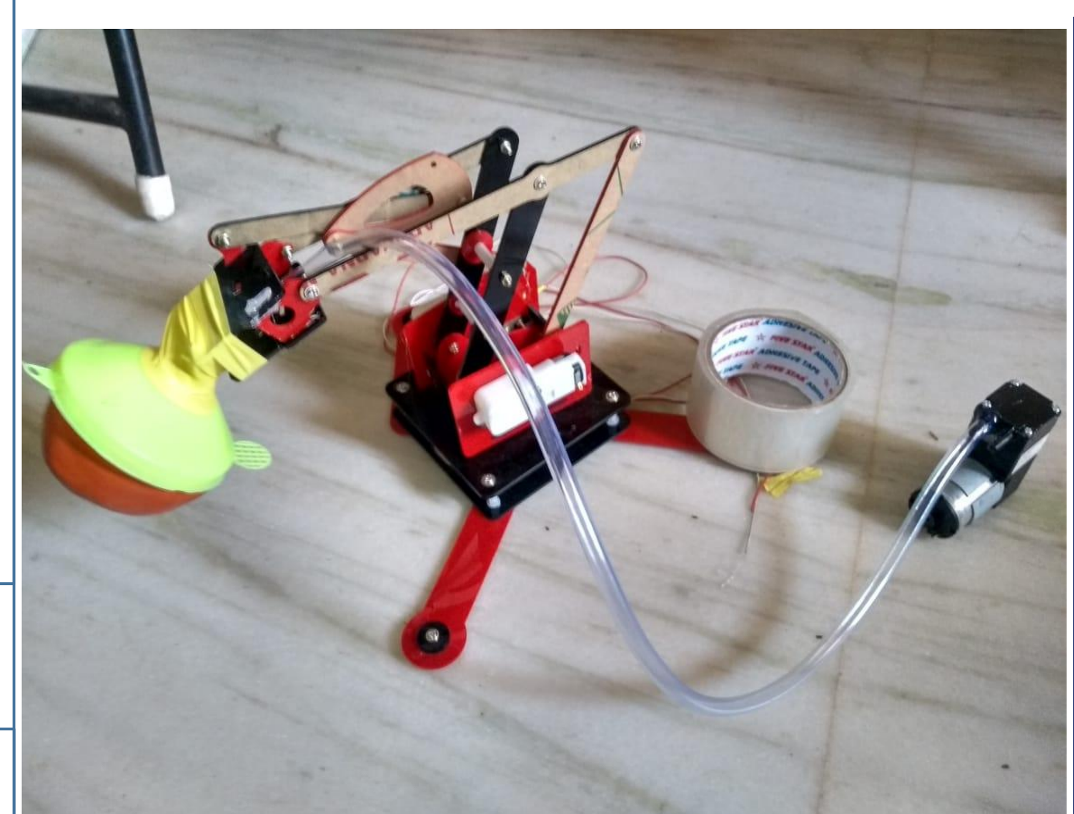
Prototype Testing

Material	Weight Lifted: Pencil (~50gms)	Canned Food (~500g)	Water Bottle (~1kg)	Laundry Detergent Bottle (~2.5kg)
Sand	Unsuccessful lift	Unsuccessful lift	Unsuccessful lift	Unsuccessful lift
Salt	Successful lift	Unsuccessful lift	Unsuccessful lift	Unsuccessful lift
Sugar	Successful lift	Successful lift	Unsuccessful lift	Unsuccessful lift
Coffee	Successful lift	Successful lift	Successful lift	Successful lift

Legend: Successful lift (green) | Unsuccessful lift (red)

The results obtain prove that this gripper is capable of lifting objects of arbitrary shapes and sizes and hence offers much advantage in the field of robotics.

Actual Test Results



The vacuum pump module was able to completely suck the air out of the multi-gripper and cause the jamming of the coffee powder. This ensured that all and any objects of arbitrary shapes were able to be lifted without much effort. The only drawback faced was that the robotic arm created out of plastic couldn't support the weight of the multi-gripper.

Conclusions

- The Solidworks model developed helped us get a general idea of the final model to be made by us. It also helped us understand the rotating and translating parts of the robotic arm. This model was later used for ANSYS analysis.

- ANSYS Workbench 19 was used to perform transient structural analysis. The results of which were conclusive and gave us an idea of how much load the model could support before collapse. The material used was titanium as it is lightweight and strong and hence provides maximum advantages. The maximum load lifted was found to be ~1000N.

- The prototype model was developed to test the best material for use in granular jamming. The results of which are tabulated earlier. Coffee was found to be the best material as it offered the best packing efficiency. The prototype also helped us get a general idea of the working of the multi-gripper.

- The robotic arm was finally developed after integrating the multi-gripper with the arm and the vacuum pump module. Load lifting tests were performed on the arm and it was found that the multi-gripper works perfectly.

Outcomes of the Work

The new type of robot gripper is developed that opens up a lot of advances in the field of robotics. This robotic gripper will be submitted for patent purposes.

Reference

L. Aksman, "Force Estimation Based Compliance Control of a Two Link Harmonically Driven Robotic Manipulator," Master's Thesis, University of Maryland, Dec. 2006.

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