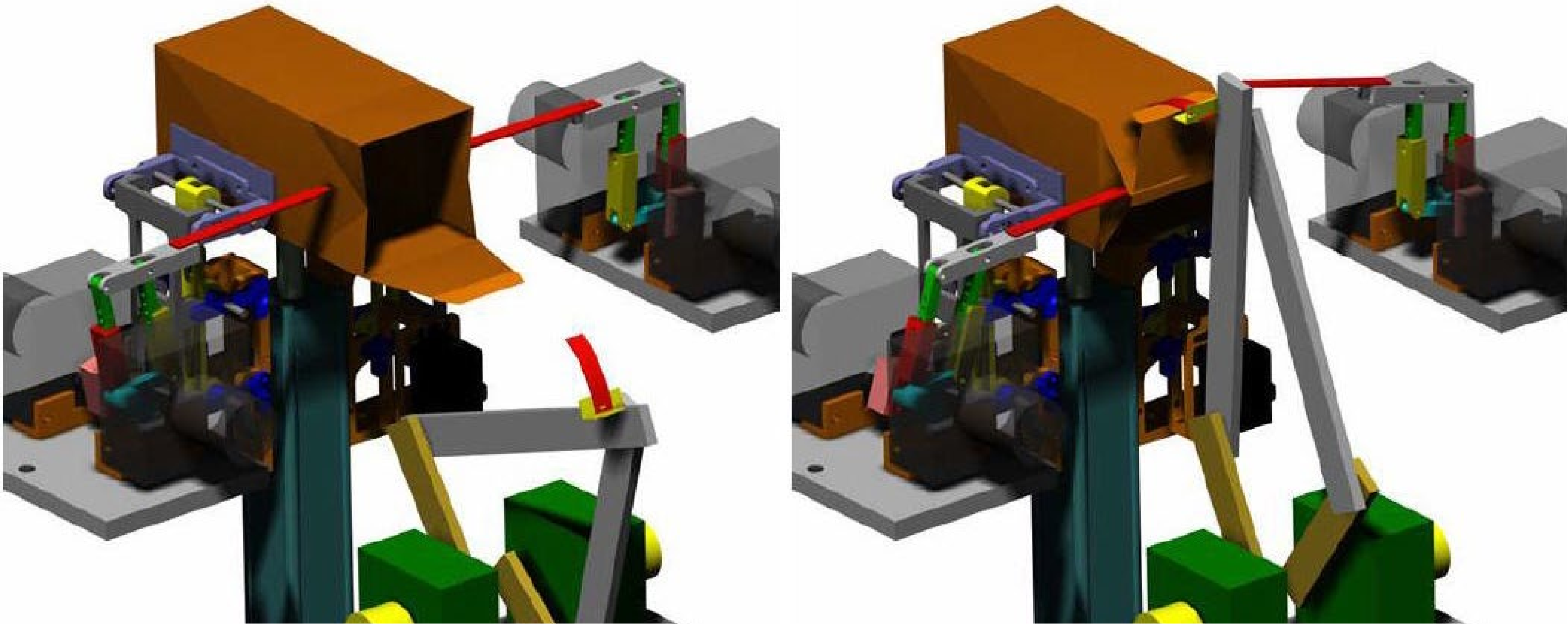
Case study

Italian institute of technology (IIT)

Adams used to simulate complex package folding machinery



The Adams model of the robot can be applied not only to package folding, but also to a wide range of other robotic applications.

Consumer products companies are continually developing innovative packaging methods. The highly competitive nature of this industry requires ever shorter development times and lower costs. Packaging plays a particularly important role in the high-quality confectionary market where producers produce elaborate cartons with complicated folding procedures that can be compared to origami.

Most of these packages are not secured by glue, but rather with complicated tuck-in operations, requiring that the carton be constructed with flaps and slots that mate to each other during the folding operation. Complex packages are traditionally built by human operators, because of the difficulty in developing automated machinery that can manage the complicated folding operations and also be readily adapted to new packaging styles as they are developed.

Challenge

One of the greatest challenges involved in the design of the carton and packaging equipment is understanding the behavior of the carton during the folding process. The cardboard consists of a multiply laminate with each ply providing high tensile stiffness and low compression stiffness. When the adjacent panels rotate around a crease, the outer plies are stretched and the inner plies are compressed, as shown in the figure 1.

Task 1 - Tack-in

The tuck-in operation, where the end flap of the lid is secured by inserting it into a slot, is the most complicated task of carton folding. The tuck-in operation is complicated by the fact that the lid is divided into three links whose kinematics must be well understood to insert the end plate into the small slit. The tuck-in operation on a relatively simple carton is shown in the figure 2. The fingers fold the first piece of the lid as shown in a, then break the end flap crease as shown in b. The tuck-in operation is shown in c and the completed package in d. This complex operation can be completed without difficulty by a skilled person, however, it much more challenging to automate the process so it can completed

Solution/validation

IIT engineers produced an Adams model of both the carton and robot to demonstrate how the folding operation could be performed. The robot has three finger with two degrees of freedom each whose layout is shown in the Figure 3. central finger provides yaw motion at the base and pitch motions on the following two joints. The side fingers have only pitch motions so they can move on a planar surface. Each moving element of the machine is connected kinematically to the carton model in order to fold the carton. This was accomplished by using Adams to develop the inverse kinematic solution of the fingers. The resulting joint angles were input to the multibody rotational and linear actuators to drive the simulation.

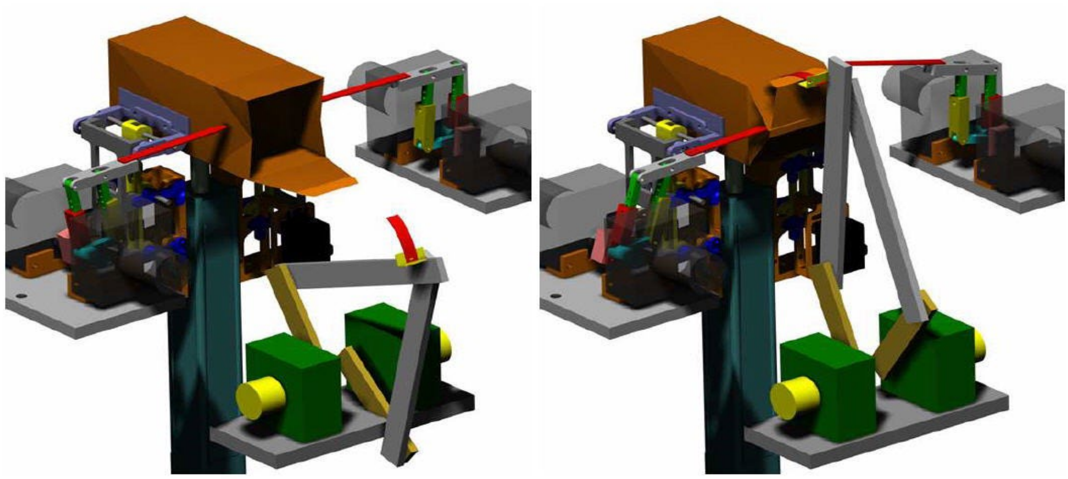


Figure 3. 3D ADAMS simulation for package folding machinery

Task 2 - Oragami Carton Folding

Automated folding machinery, on the other hand, is commonly used for simple packages that are produced in large volumes. Consumer products companies want to convert complex packages to automated production in order to improve quality and reduce the potential for repetitive motion injuries. But conventional automated folding machines are very difficult to adapt to new designs. So the industry is working on developing flexible automation systems based on programmable robots that can handle complicated packages and can accommodate new designs with software changes alone. The Dexterous Reconfigurable Assembly and Packaging Systems (D-RAPS) was developed by Prof. Jian S. Dai (Kings College London, London, UK) for use as a carton folding test rig to evaluate the use of robots in complex packaging operations, as shown in the figure 4.

Figure 4. D-RAPS robot in operation folding carton

Results

“The physical finger displacements correlate very well with the actual robot displacements,” said Ferdinando Cannella, Head of IIT’s Advanced Industrial Automation Lab of Advanced Robotic Department. “The carton folding sequence of the folding model also matched up perfectly to the actual robot. With the Adams simulation model validated against the physical D-RAPS robot, researchers are now able to evaluate different folding methods and new package designs with the simulation model as opposed to having to use the actual robot.

One the best result is that we computed the contact forces that were impossible to measure on the physical prototype, because the contact points were too small to install a pressure/force sensor and the motor typology was not suitable for this feature. This is an enormous advantage because many students use the robot for their research so it is often very difficult to get time on the actual robot. The Adams model of the robot, built by PhD candidate Mariapaola D’Imperio, can be applied not only to package folding, but also to a wide range of other robotic applications. IIT and Kings College London researchers are also working on introducing flexible materials into the model which will increase the accuracy of the simulation and make it possible to accurately simulate even more complicated folding operations.”

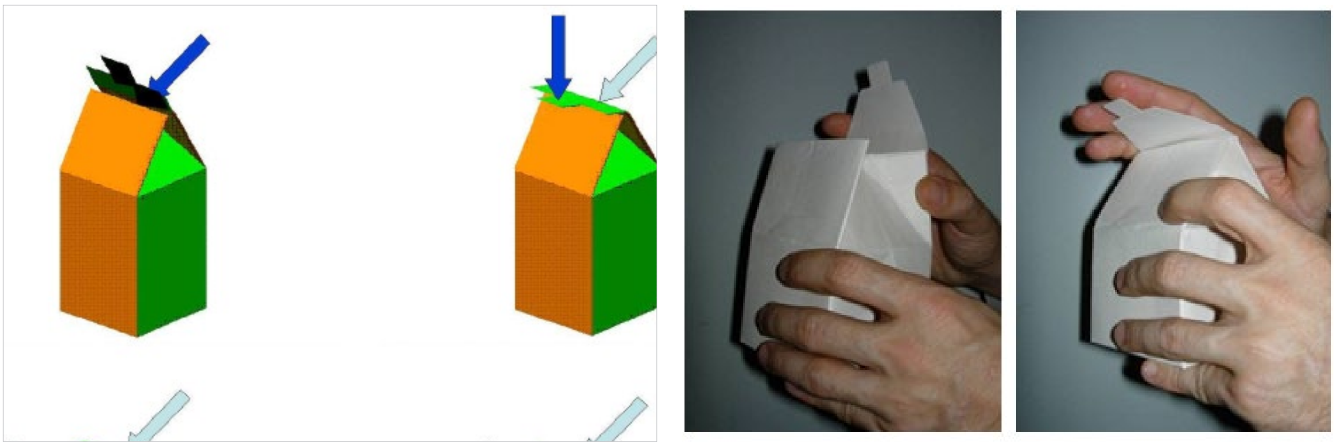


Figure 2. Tuck-in operation by human fingertip and kinematic analysis. From top left to the bottom right: a) first flap folding, b) second flap folding, c) the third flap folding, d) the tuck-in of the third flap.

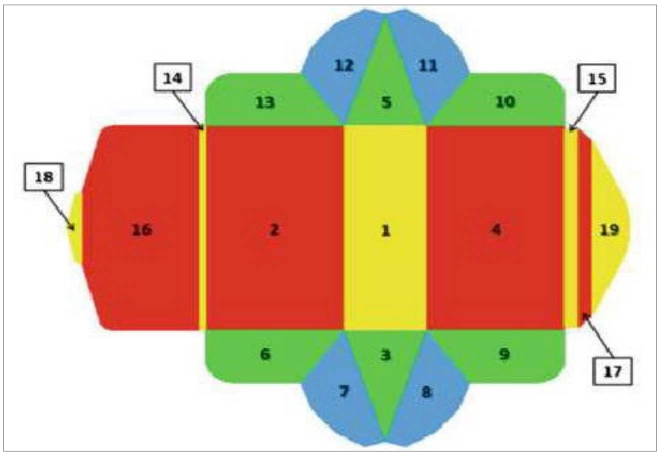


Figure 5. More complex folding operation: 19 panels and 15 creses

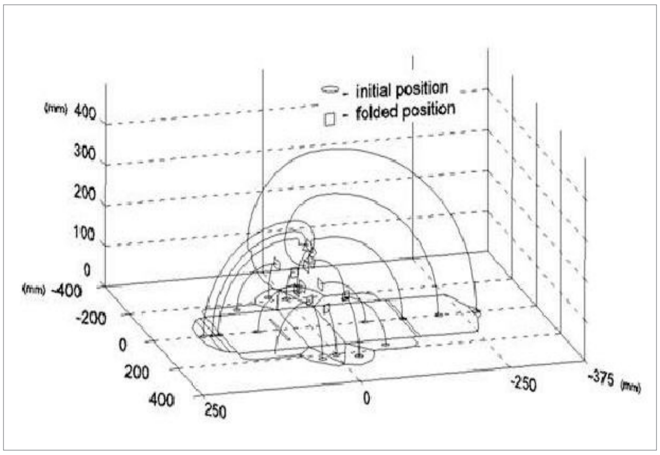


Figure 6. Carton folding trajectories for more complex folding operation

Key highlights:
Product: Adams
Industry: Robotics
Benefits:
Up to 90% correlation between physical tests and simulations on both robot displacements and contact forces
Researchers are now able to evaluate different folding methods and new package designs with the simulation model
Including flexibility into Adams model further increases the accuracy of predicting complex robotic behavior

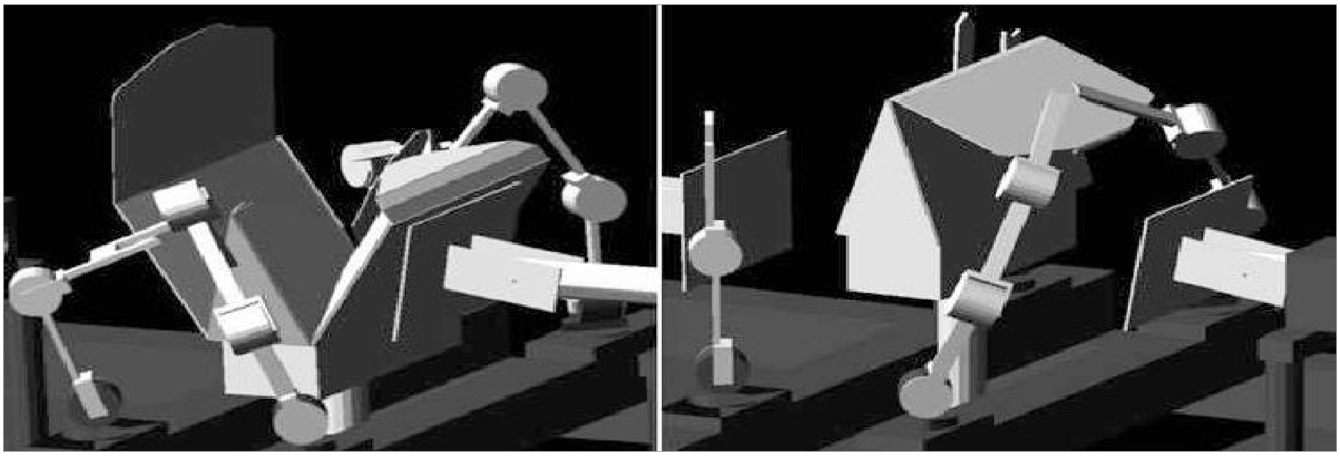


Figure 9. Carton folding simulation matches real-life robot

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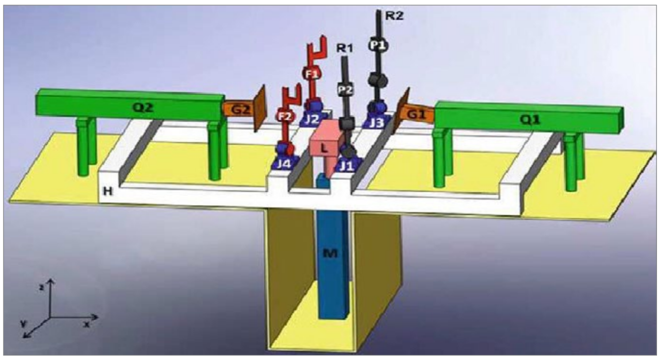

Figure 7. D-RAPS model created with Adamsn

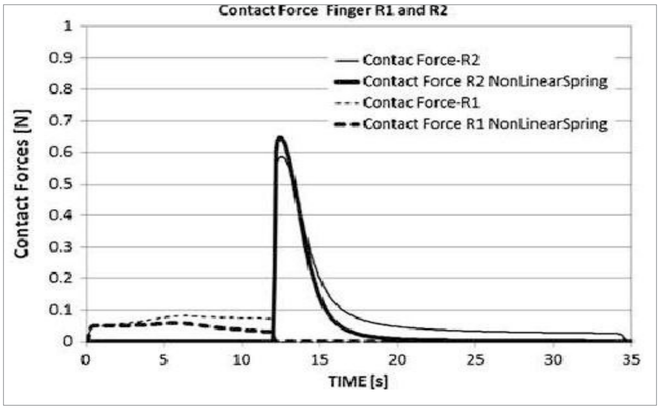

Figure 8. Finger contact force from simulation

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Ferdinando Cannella,
Head of IIT’s Advanced Industrial Automation Lab of Advanced Robotic Department

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