

CASE STUDY · AUTOMOTIVE

Adaptive Deformable Object Insertion

Use Case: Adaptive Insertion of Deformable Automotive Parts in High-Mix Assembly

95%

INSERTION RELIABILITY

5.03 s

CYCLE TIME

2 hrs

NEW PART SETUP

8x

ROI IN AUTOMOTIVE

01

SUMMARY

A ThoughtForge controlled robotic arm autonomously inserted deformable and rigid automotive parts into their housings in unpredictable, real world conditions with an insertion reliability of 95%. The ThoughtForge control model adaptively corrected misalignment in real time, completing insertions in 5.03 seconds and re-tasking to a new part in under 2 hours, providing our Fortune 100 automotive client with up to 8x ROI.

02

PROBLEM

Deformable object insertion tasks such as rubber parts and connectors are deceptively simple for humans to do but notoriously difficult for robots. A single assembly line worker at our Fortune 100 customer may perform thousands of insertions per shift, pressing rubber bumpers into housings, snapping plastic clips into place, or seating electrical connectors. The ergonomic toll is significant, with repetitive strain injuries among the most common occupational hazards. Variability in manual insertion also leads to quality issues, such as connectors not fully seated, which can cause intermittent faults, recalls, and warranty costs.

Our customer tried other solutions, but automation has been slow because parts deform, flex, or shift slightly, and traditional robots cannot adapt to these small but critical variations. Deterministic control systems fail when faced with part deformation, occlusion, or misalignment, and machine learning approaches, though flexible, are brittle when exposed to novel conditions and require impractically large datasets.

03

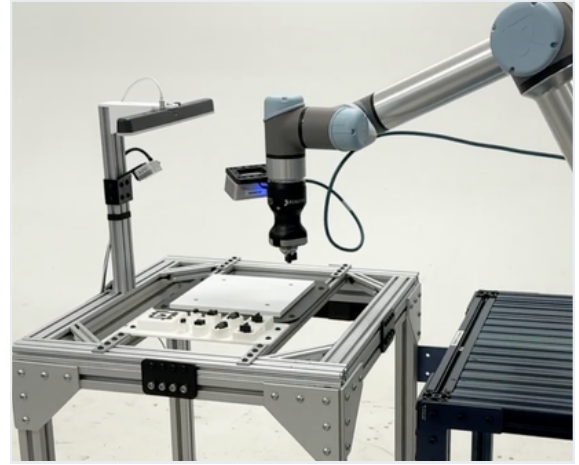
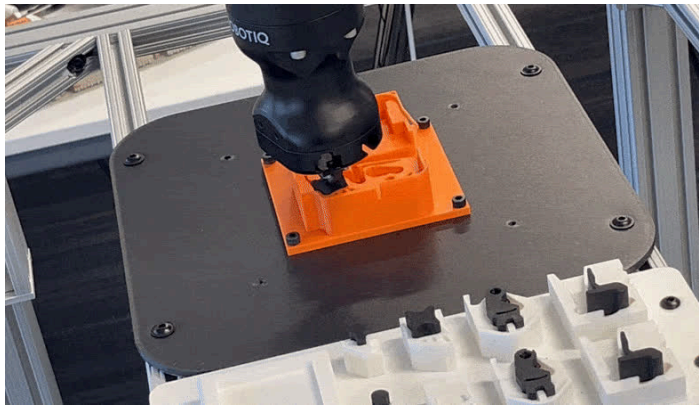
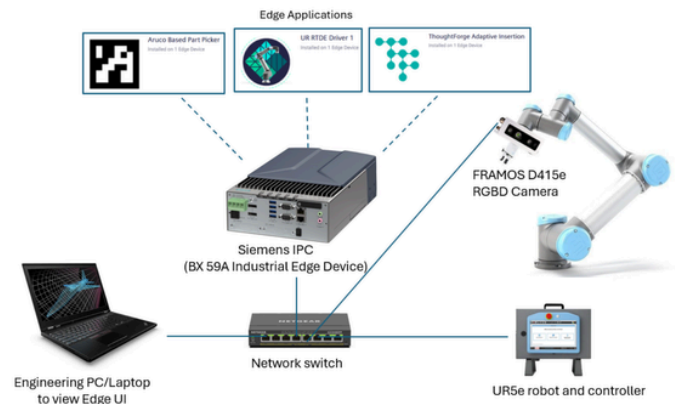
REQUIREMENTS

Our Fortune Automotive 100 customer needed an on-edge robotic control solution that could complete an insertion, reliably 95 out of 100 times in 5 seconds or less, across parts that deform, pivot, and vary in geometry. In addition, the housing where the parts were to be inserted could be rotated and/or in an unpredictable location. Setup for a new part family had to take less than 24 hours with worker touch time under 60 minutes, and the system had to re-task across part families without extensive reprogramming.

04

RESULTS

ThoughtForge's control model successfully guided a UR5e collaborative robot with a Robotiq Hand-E gripper, a wrist-mounted force/torque sensor, and RGB-D cameras through insertions of four representative parts, from rigid plastics to compliant rubbers. Across 100 trials per part, the system achieved an aggregate success rate of 95%, and ~97 out of 100 at the final demonstration in the customer's facility. Force/torque feedback at 500 Hz let the robot detect resistance and adjust its trajectory in milliseconds --- 68% of successful misalignment recoveries came from this loop. Rather than treating force anomalies as failures, the system uses them as cues to adjust the robot's trajectory, mirroring the way human operators "wiggle" a part into place when they sense resistance.



PART	INSERTION CHALLENGE	SUCCESS RATE	CYCLE TIME
S-Cam	Rigid plastic, prone to pivoting	96%	4.8 s
T-Bumper	Flexible rubber, deep insertion	96%	5.2 s
X-Bumper	Highly compliant, variable geometry	92%	6.5 s
P-Bumper	Millimeter scale, deforms under grasp	91%	5.6 s
AGGREGATE	All parts, 50+ trials each	95%	5.2 s

Aggregate std. dev. 2.6% | 95% confidence interval 93.5% --- 96.5%

Pre-trained Skills Library

Multiple industry-tested skills ready to use for your specific applications.

Application Flexibility

Modify existing applications and skills for new use cases.

Variance Handling

Able to handle variance in shape, position, torque, friction, and movement in real time.

ABOUT THOUGHTFORGE

ThoughtForge is an all in one robot control system for both simple and complex skills. Using our patented AI, ThoughtForge control intelligence easily adapts to dynamic changes and varying environments. Our real time motion and path planning control models allow robots to accurately adapt to dynamic movements and environmental conditions with unmatched accuracy. Using the ThoughtForge Platform, workers can teach and retrain a robot to do multiple tasks across multiple applications in just a few minutes.

ADAPTIVE APPLICATIONS

Assembly: Insertion & Removal	Adaptive Grasping
Connector Mating	Object Manipulation
Wire Manipulation	Material Handling
Inspection	Confined Space Inspection