ROBOTIC ASSEMBLY: CHALLENGES AND OPPORTUNITIES

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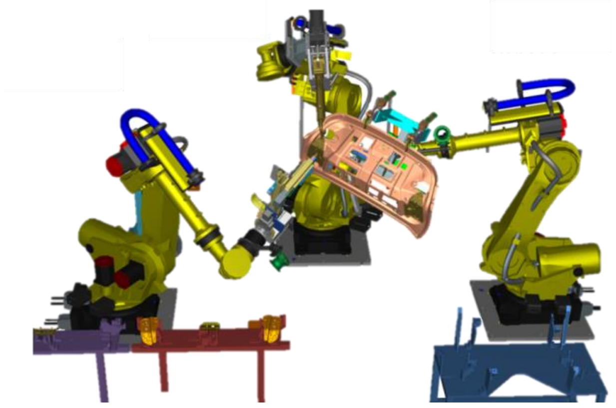
INTRODUCTION

What is Robotic Assembly?

Academia:

- Fixtureless Assembly: Use of robots to place parts in the proper position without the need of a dedicated fixture (Hoska, 1988)
- Vision-guided positioning : Interaction of multiple robots to position and hold parts to perform a task (Bone & Capson, 2003) (Novakovic et al. 2017)
- Coordinated motion: Control joint position and torque of multiple robots holding a single parts (Gueaieb et al., 2007) (Uchiyama et al, 1987)



Industry:

- Clutch insertion using vision and force sensing (Gravel et al., 2008)
- Robot-to-Robot handoff at GM body shop plants
- “Open-loop” positioning of sheet metal parts using multiple robot arms

KEY TECHNOLOGY FEATURES

- Perception: Use of sensors to understand the work environment and process requirements:
  - Exteroceptive:
    - Digital image: One or multiple cameras to identify target features
    - Laser: Point or line readings to create a point cloud or line
  - Enteroreceptive:
    - Load cells: Measure forces and/or torques in robot arm or end effector
    - Motor torque: Motor current feedback

- Robot coordination
  - Synchronous motions: Share positional and target information to execute separate tasks
  - Asynchronous motions: Share positional and target information to execute the same task

- Robot accuracy: Identify the actual and target pose of the robot arm

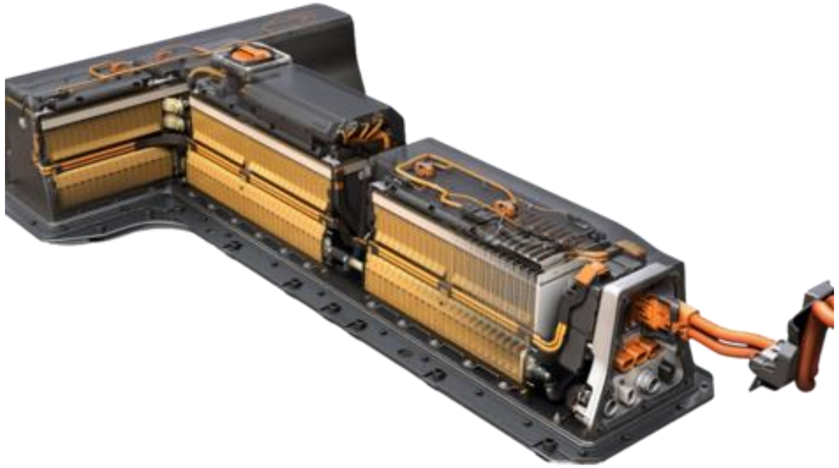
ASSEMBLY OPERATIONS

- Body Assembly:

- Vehicle Assembly

- Powertrain assembly

- Battery Assembly



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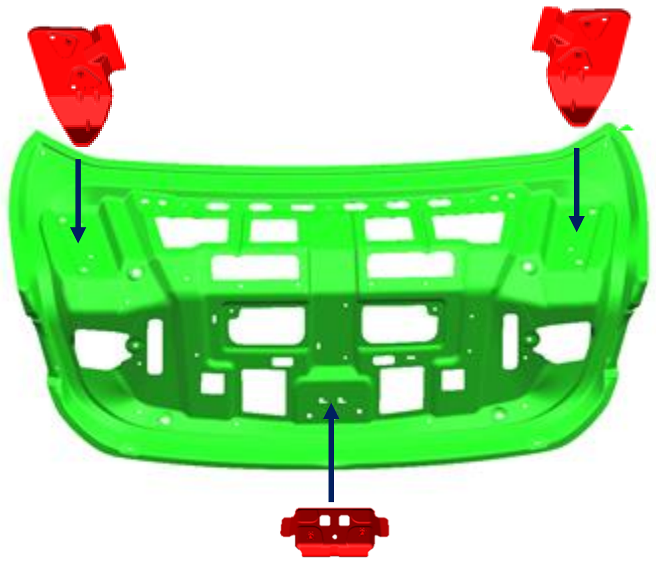
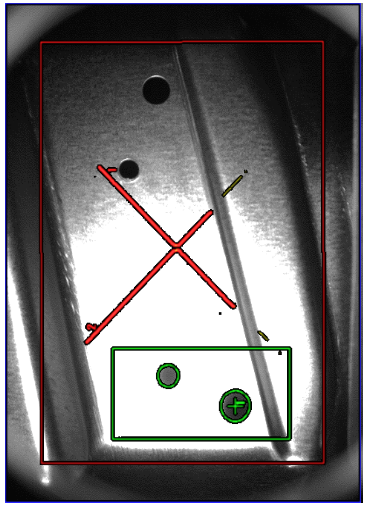
ASSEMBLY OPERATIONS

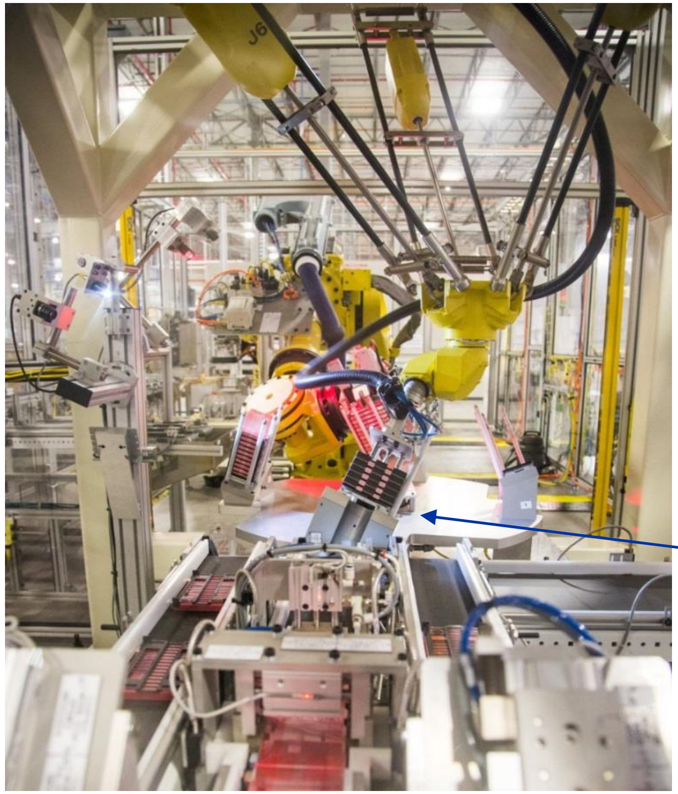
2D and 3D perception systems: Place parts in reference to a target feature (e.g.: holes) or surface matching

- **Body Assembly:** Sheet metal component with target features for positioning and alignments





- **Battery Assembly:** Metal and plastic components with locating features



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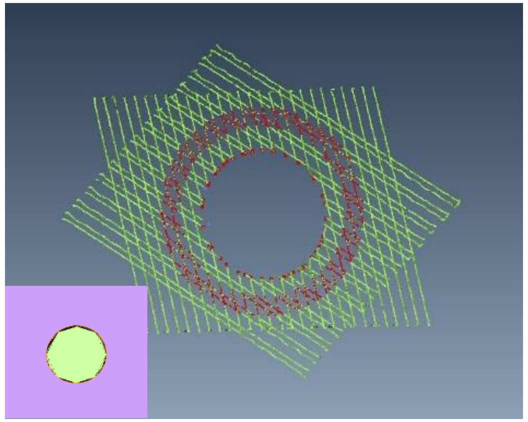
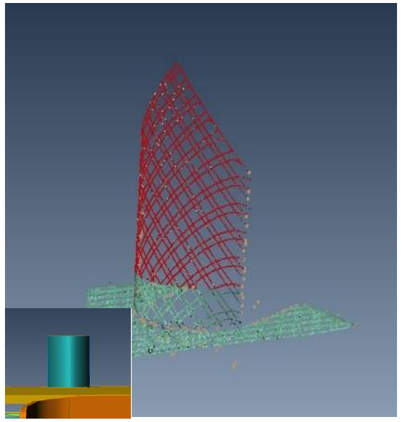
PERCEPTION IN MANUFACTURING

2D:
- Digital image: Detection of objects positioned in a work place (X,Y,R)
- Laser line: Detect object position in a single work plane (X,Z)
- 2D+Laser: Detection of objects positioned in two or more layers (X,Y,Z,R)





3D:
- Stereo vision: Detect object position and orientation based binocular vision and image processing
- Infrared: Use one image to map a part in 3D
- Laser point cloud: Structured and sparse laser reflection measurements to identify objects or features in robot workspace

Force sensing:
Identify forces and torque in 3DOF

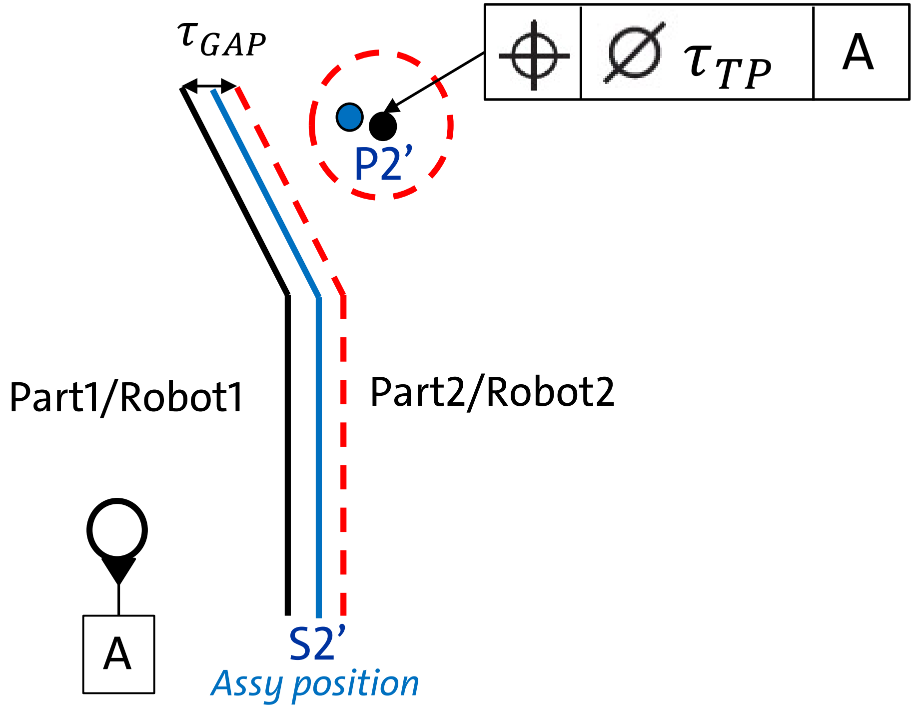
VISION FOR PATH PLANNING

- **Offset from taught points**

Relationship between datum and key feature is taught and vision is used to define an offset

- **Direct pose programming**

Relationship between datum and key feature programmed based on the product requirements



CHALLENGES: IMAGE ACQUISITION AND PROCESSING

- **Field of View:** Narrow FOV requires multiple robot movements which increases operation cycle time

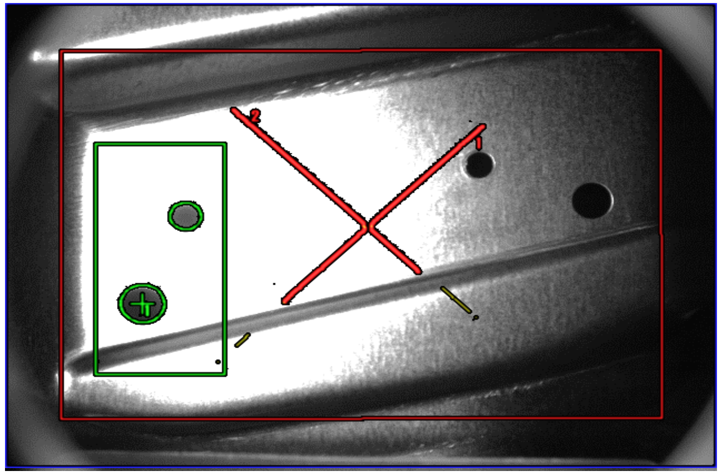
- **Accuracy:** Aggregated error of optical instruments, image processing and feature extraction algorithm and robot movements

- **Access:** Robot mounted sensors require might face access and constraints to get proper image

CHALLENGES: IMAGE ACQUISITION AND PROCESSING

- **Part properties:** Poor contrast or reflection. Images are required to have good contrast between the work environment, background, target feature

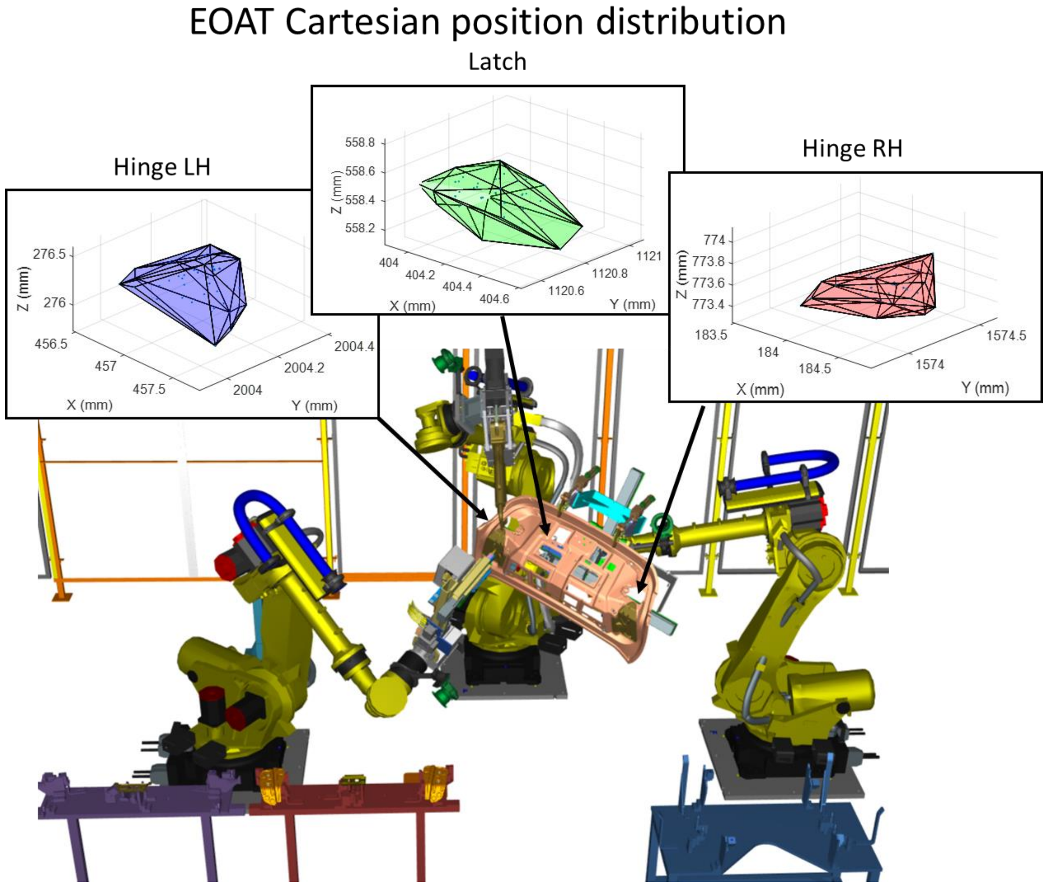
- **Environmental conditions:** Changes in ambient lighting can produce inconsistent performance.



CHALLENGES: INTEGRATION AND ROBOT ACCURACY

- **Integration:** Additional hardware and software requirements that increate system latency

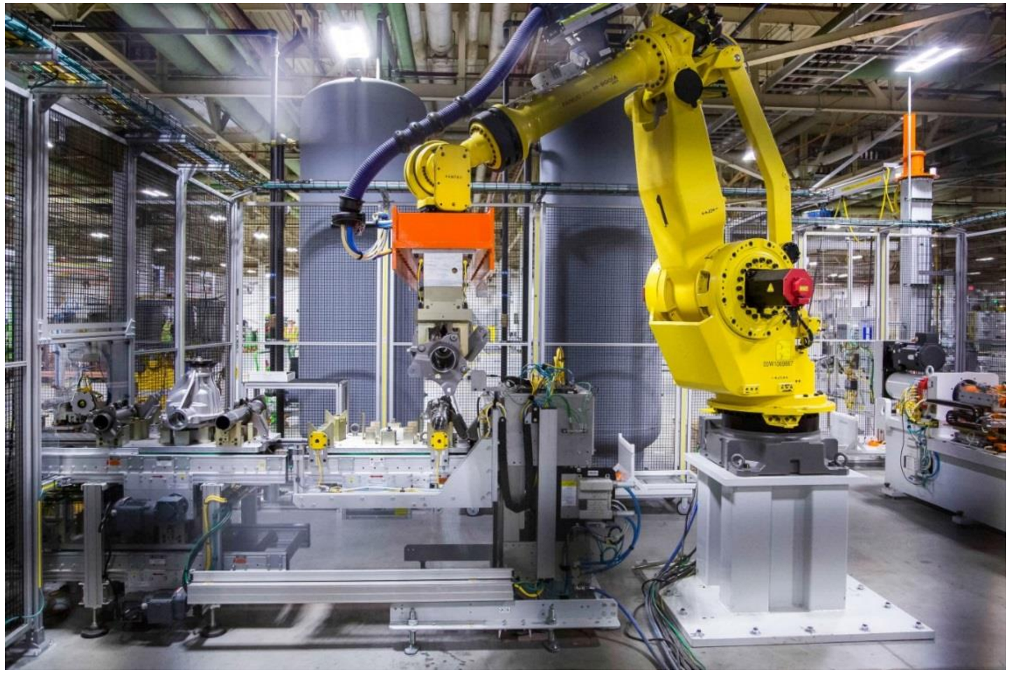
- **Robot accuracy:** Inherent errors in robot mastering and calibration along with thermal expansion/contraction of robot arm affect accuracy of vision system and commanded positions



OPPORTUNITIES: PRODUCTIVITY

- **Reduce robot movement:** Larger field of view would reduce the need to collect multiple images to command an absolute or relative position to one or multiple robots

- **Faster image acquisition:** Solutions robust to changes in part reflection, glare, or ambient light will prevent the system of having to take multiple images of a single feature



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OPPORTUNITIES: QUALITY

- **Accurate imaging:** Use solutions often used for metrology for accurate robot guidance

- **Accurate positioning:** Reduce the errors in robot positioning for both image acquisition and assembly

- **Post-process inspection:** Use vision system for robot guidance and inspection to enable "Built-in-quality" where no bad parts leave the cell

RESEARCH AND DEVELOPMENT REQUIREMENTS

- Extended Field of View: Increase the working distance to the observable world from a single or multiple camera locations
- Increase accuracy: Reduce or estimate error or vision system and robot arm
- Robust to different parts and work environment: Use of different wavelengths for perception
- Fast image acquisition: reduce time to acquire image and identify features

STANDARDIZATION REQUIREMENTS

- Define a common testing setup
- How to measure accuracy?
- How to differentiate between sensor, algorithm, and robot error?

QUESTIONS?


THANK YOU