Automating the Part Inspection Process in Automobile Manufacturing

Team Details:
Hemanth Joseph Raj
Vaibhav Jain
Bharath Bora
Sai Lohith Madala

UNIVERSITY OF MARYLAND

Motivation

…. Conversations lead to ideas

Background

- The vehicle manufacturing industry has always been on the cusp of innovation and implementation of new ideas.
- But there is one area where it still has a chance for improvement
- The car body parts once manufactured usually go through a manual inspection process. We intend to automate the inspection process.

Current Processes

- Manual Inspection as mentioned before - Prone to lapses in judgement

- Offline car body by use of robotic arms - Expensive setup of robotic arms, inspection is offline i.e. away from the production line

Current Processes

What we propose!

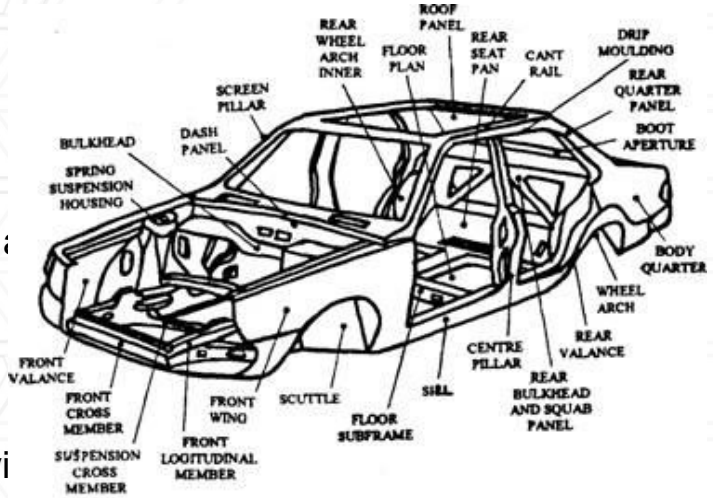
- Replacing the human in the loop with a camera array setup which takes images of the part from different orientations
- Apply, image processing techniques either through traditional computer vision approach or improving upon it by the usage of Machine Learning and Deep Learning algorithms
- For complicated parts we also propose to use a 2D LASER sensors to get intricate details

Anatomy of Automobiles

- The modern automobile is made up of over 14,000 pieces and many structural and mechanical systems. The Powertrain, chassis, exterior, and interior trims, and the vehicle body shell are the key components and subsystems of the vehicle.

- The prime mover (an internal combustion engine or an electric motor), the gear system, and the propulsion and driveshafts make up the powertrain, whereas the chassis houses the suspension and steering components, as well a

- The front and rear ends, the door system, and the cockpit trim are all made up of internal and exterior trims. Finally, the body consists of the closures (doors, hood, and tailgate) as well as the frame. They are also divi subparts as shown in the picture.



Steps involved in Automobile Manufacturing

There are four steps involved in the production of a vehicle:

- Firstly Blanking and Stamping of Parts,
- Secondly, Melting and fusing of two materials
- Nextly, automotive painting
- Finally process is assembly

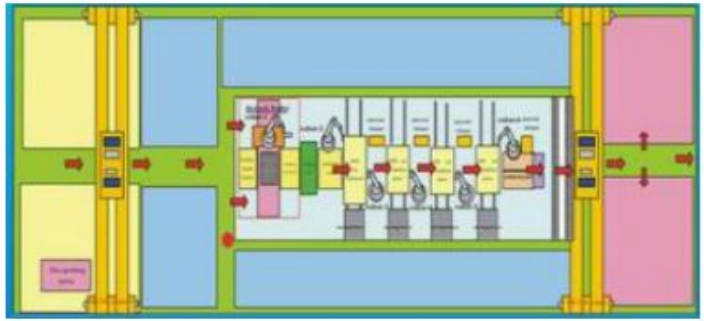
Steps involved in Automobile Manufacturing

Stamping | Welding | Painting | Assembly

Blanking Process

Blanking is the manufacturing process in which a flat shape is created by feeding a coil of sheet metal into a press and die. During the process through the machine, the blank is punched out from a large metal or aluminum sheet.

Stamping Process



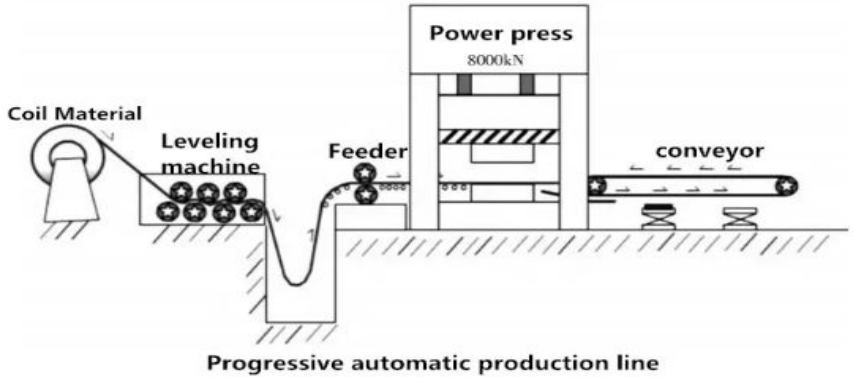
The automatic stamping production can be different types: **Progressive die stamping,**

Multi-station stamping,

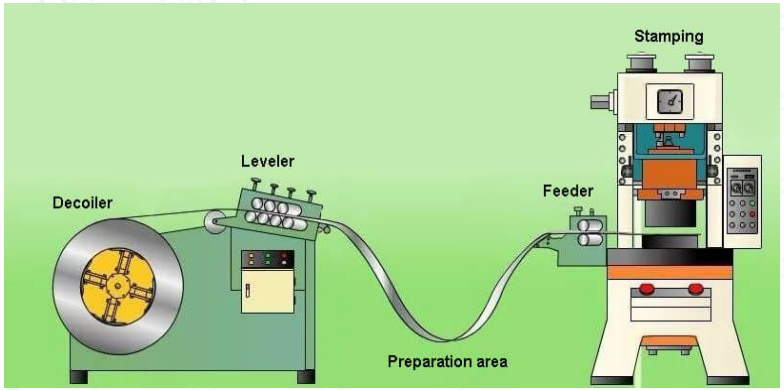
Tandem stamping.

Progressive die stamping production line:

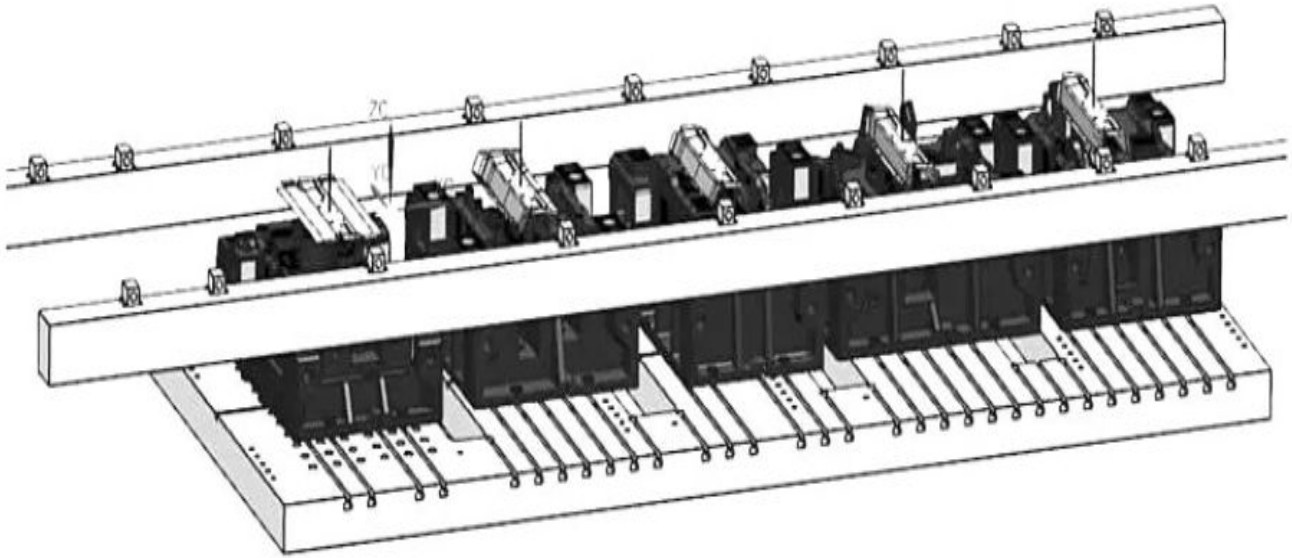
The automatic production line of progressive die stamping is a production line that uses progressive die stamping, which generally consists of an uncoiling feeder, a punch, a progressive die, and an automatic blanking line. Realize the automatic process of unwinding the coil, flattening the strip, oiling the strip, stamping into pieces, and collecting finished products offline.

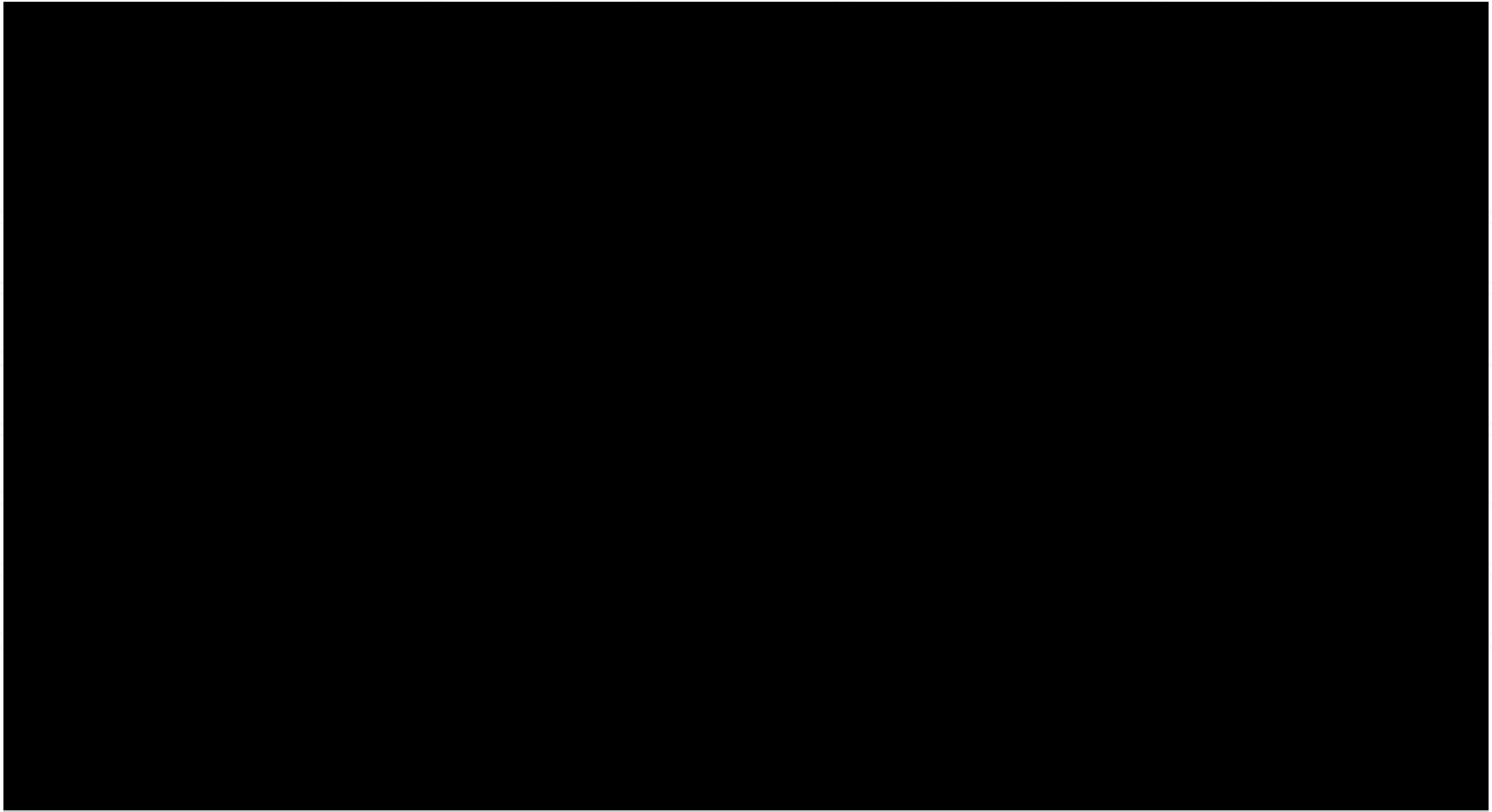


Progressive automatic production line

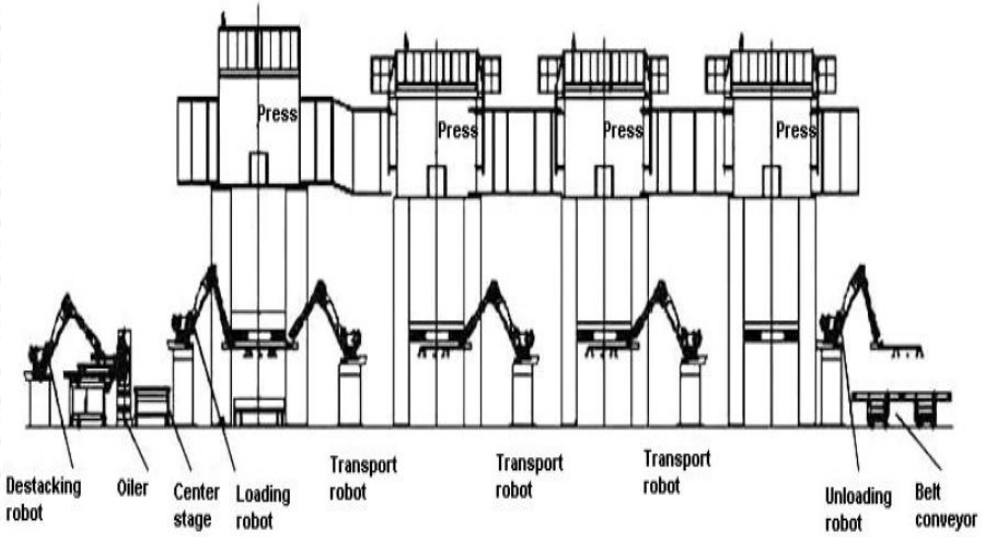


Multi-station stamping automation production line: A production line with multiple independent station molds (usually 4 to 5 molds) placed on a large tonnage press table. Use destacker or unwind feeder to load, transfer of process parts with automatic feed bar, and use an automatic conveyor belt to collect offline products.

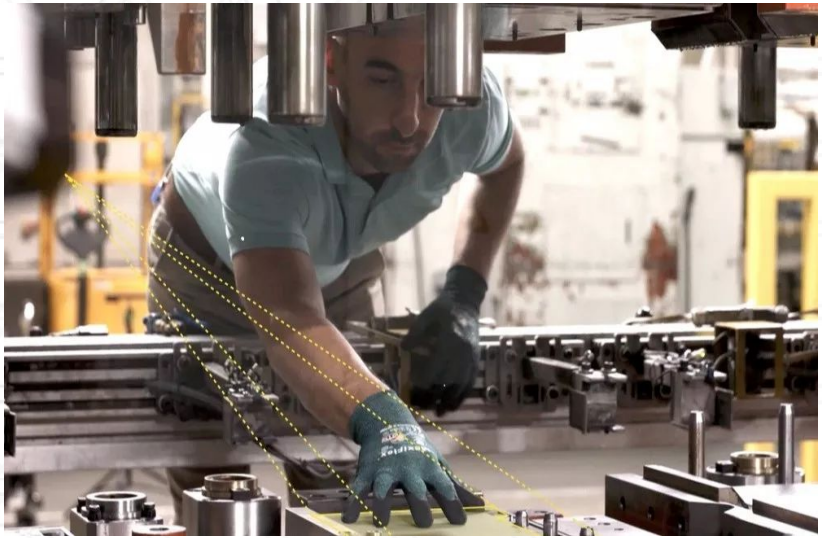




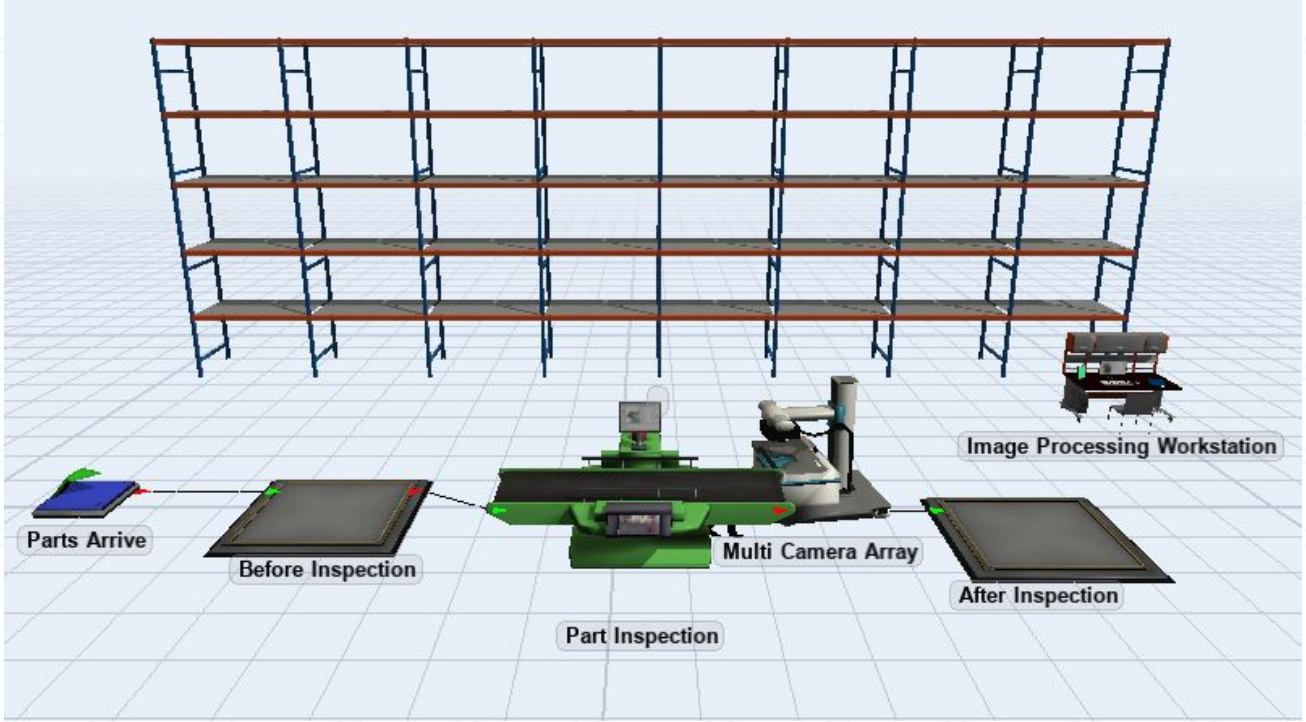
Tandem Stamping Automation Production Line: Multiple presses are arranged one after the other and connected in series to form an automated production line. A pair of molds is placed on each press table, and the automatic robot completes the loading, transfer of process parts, and the unpacking and packing work.



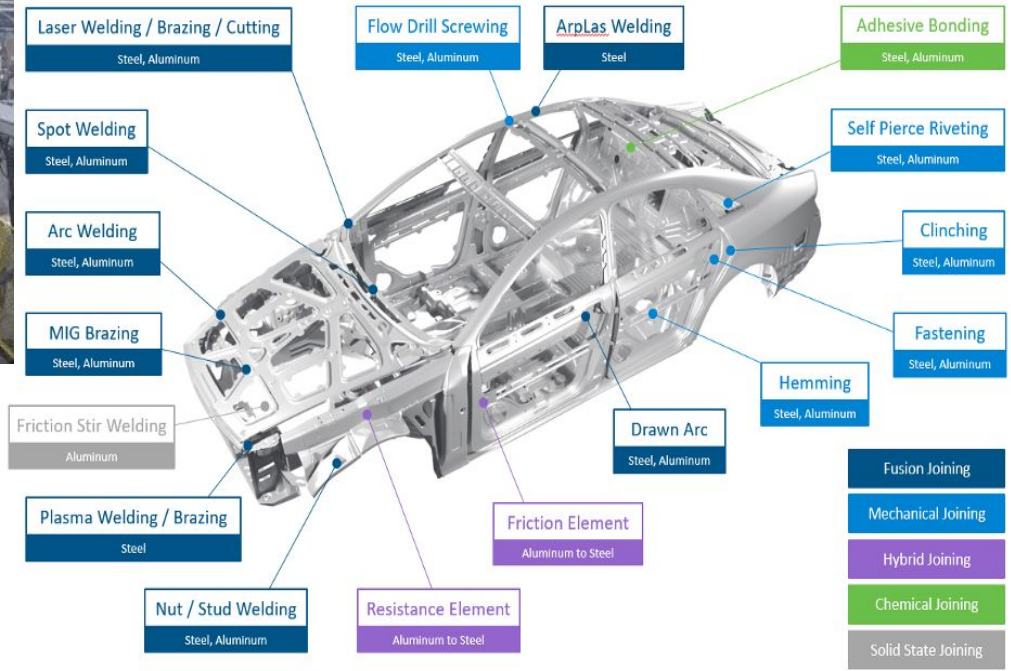
Inspecting the parts (In traditional method)



Inspecting the parts (Our Proposal)



Automotive Joining: This is a joining action. These operations primarily include: fusion-based joining techniques such as metal inert gas (MIG), tungsten inert gas (TIG), and resistance seam, projection, and spot welding. It is done in three different ways: automated, semi-automated, and non-automated.

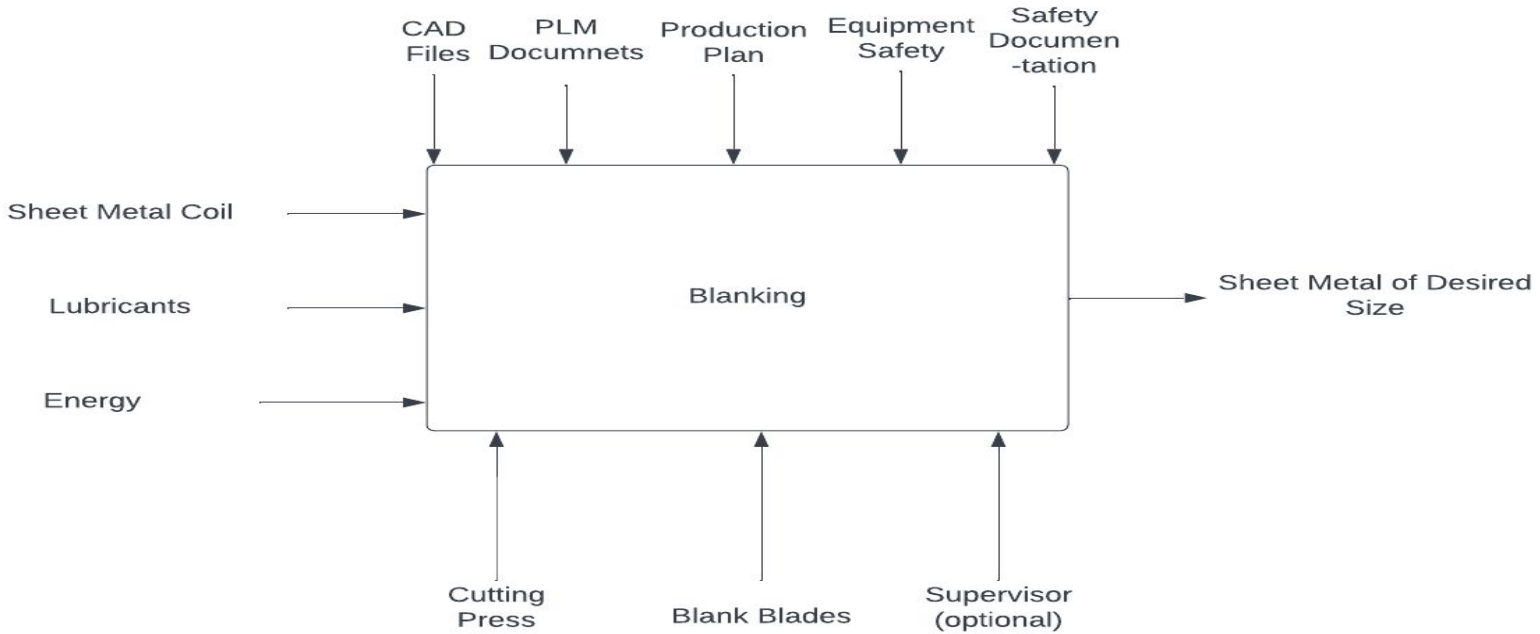


Automotive Painting

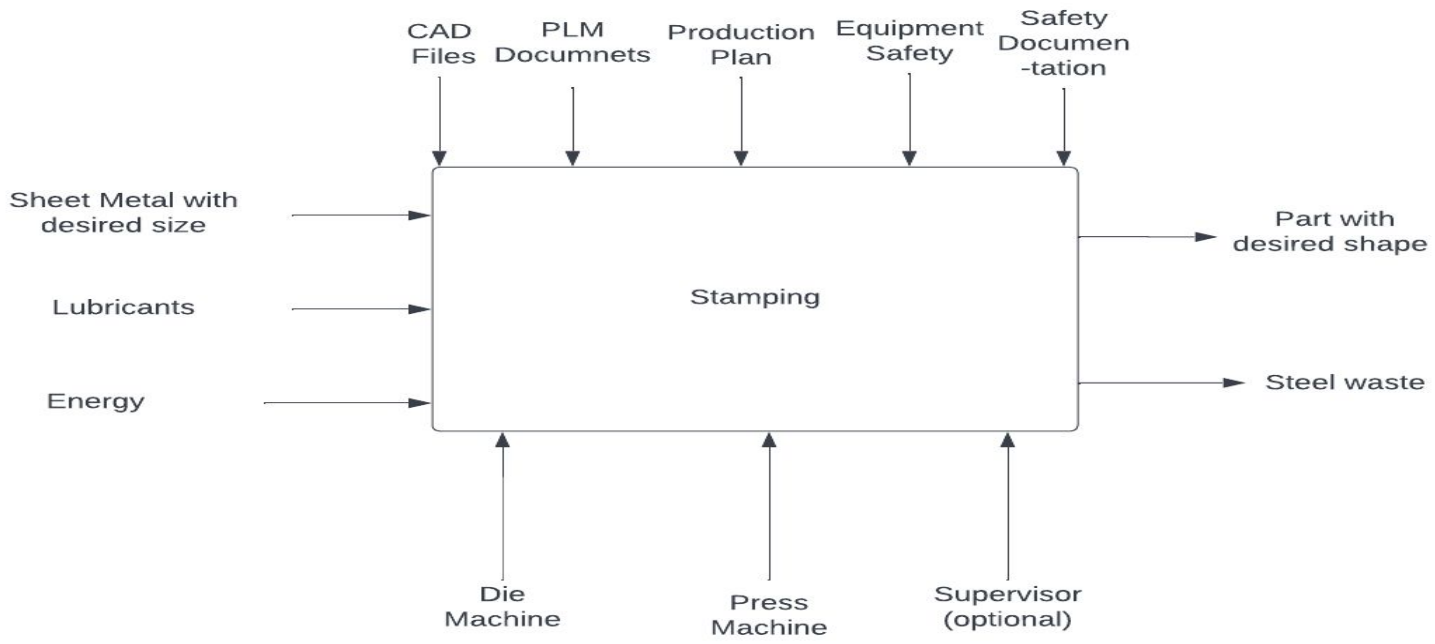
Final Assembly of Car

UNIT MANUFACTURING PROCESSES

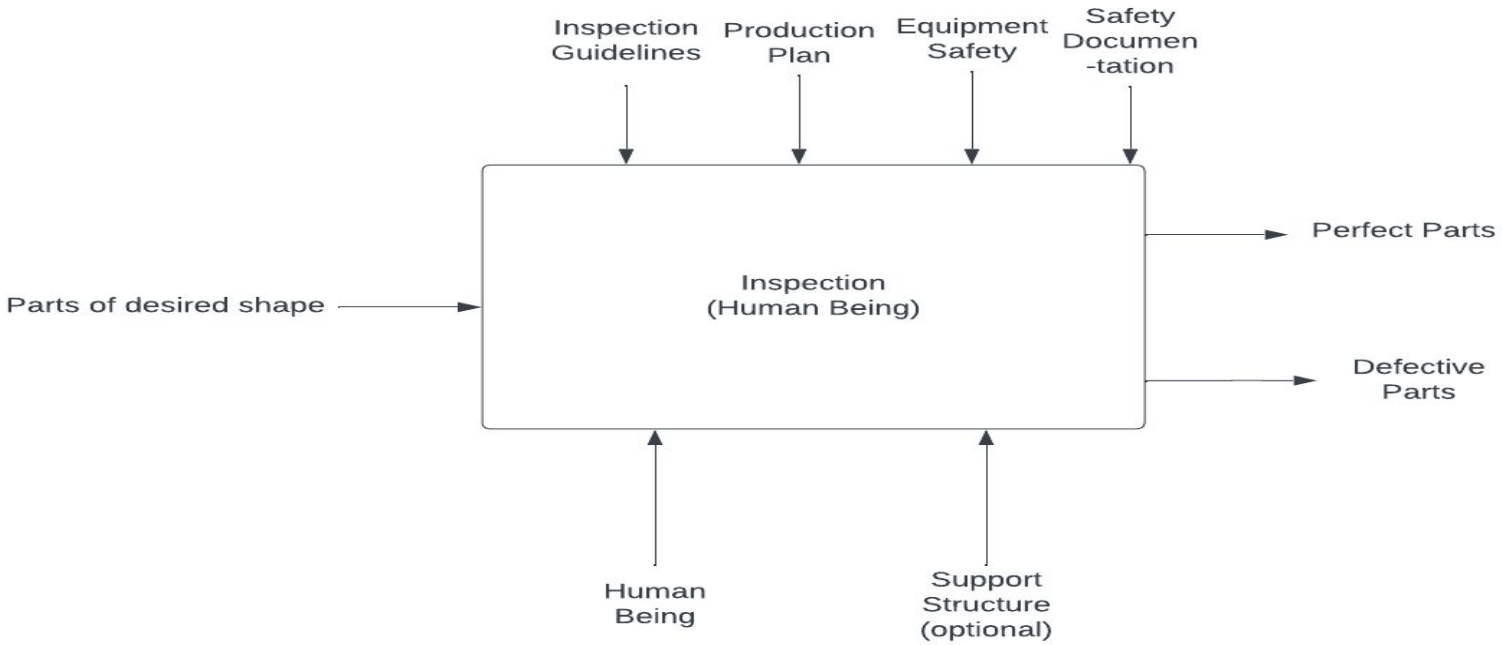
UMP 1: BLANKING



UMP 2: STAMPING



UMP 3: HUMAN INSPECTION



UMP 3 (proposed) : VISION-BASED INSPECTION

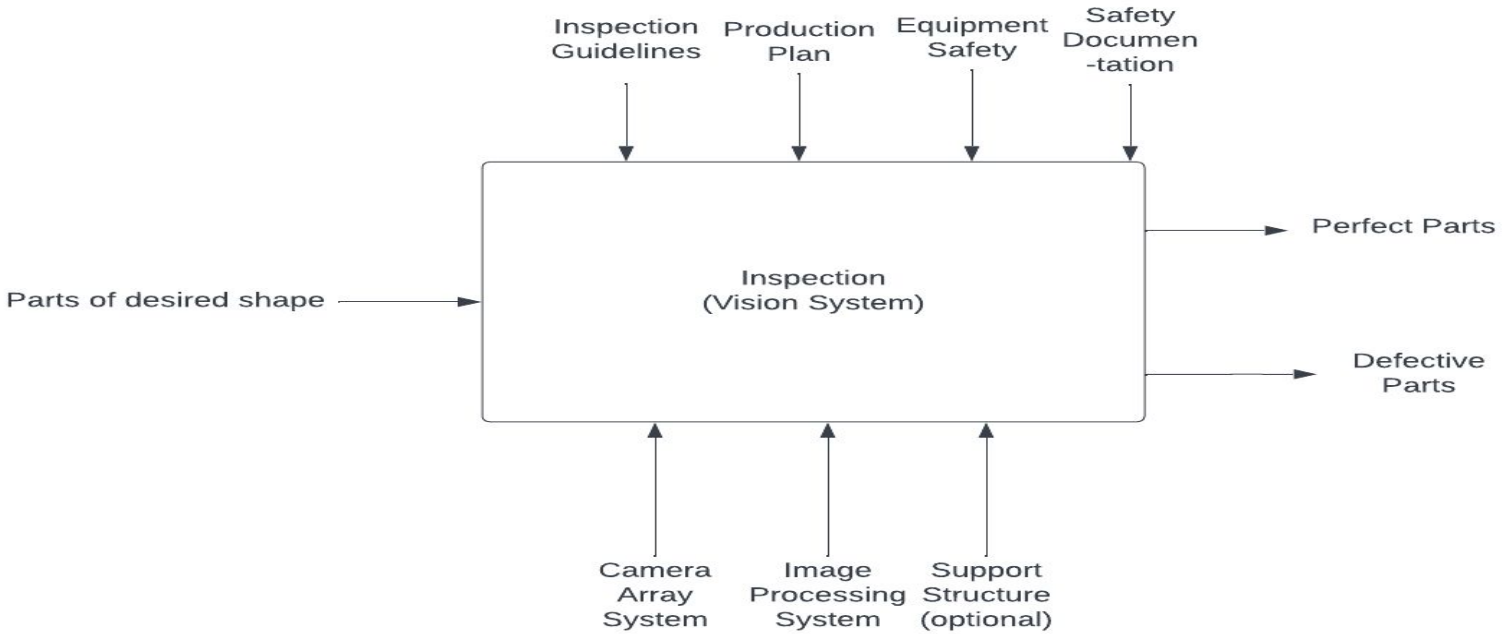
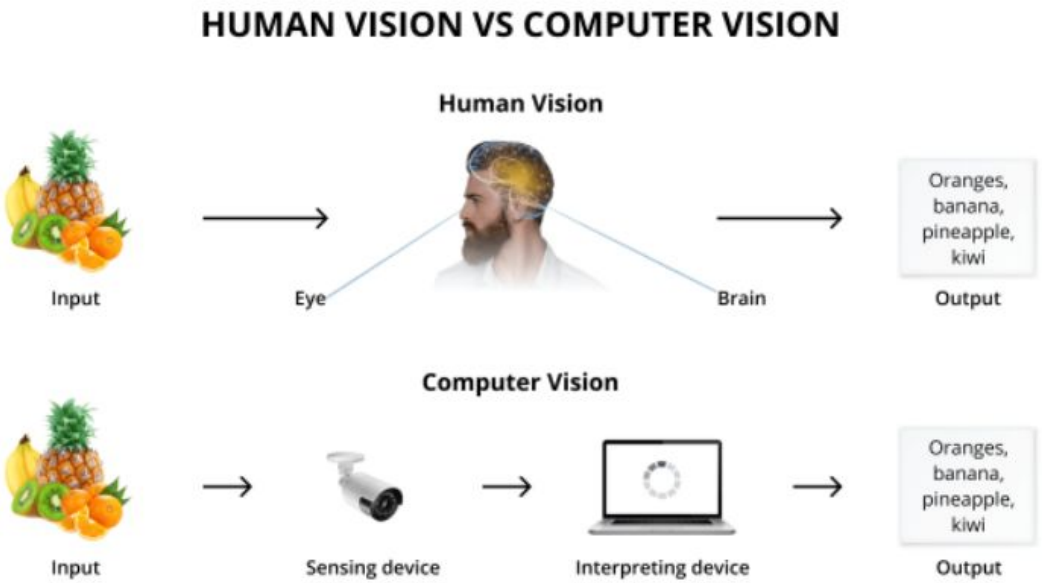


IMAGE PROCESSING

Computer Vision

Computer vision is a constantly evolving field of artificial intelligence that extracts crucial information from video feeds, digital images and/or other visual inputs. It enables computer systems to take actions or recommendations based on the extracted information.

Artificial intelligence helps the computer to think and computer vision enables the system to observe and understand.



Computer Vision Algorithms

1. Contour Detection: Boundary Detection, Marks changes in image colour as contours

2. Edge Detection and Line Detection: Canny edge Detection, Sharp changes in image brightness

3. Corner Detection: Harris Corner Detection or Shi-Tomasi, Identifies sharp changes in all directions

4. Surface Defect Detection: Semi-supervised Anomaly Detection, Deep learning model

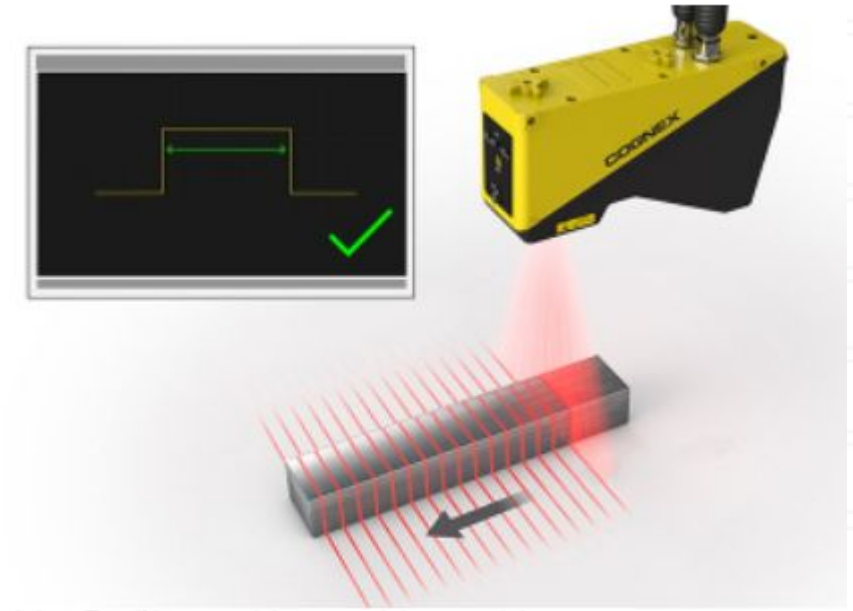
Deep learning: Subset of Machine
Learning which is essentially a neural network with 3 or more layers

Neural Network: A series of algorithms that attempts to find the underlying relationships in a set of data

2D Profile Laser Scanning

User a laser scanner we can have 2D profiles as visual input. This data is easier to read and implement in a machine learning environment.

Highly accurate part dimension verification.

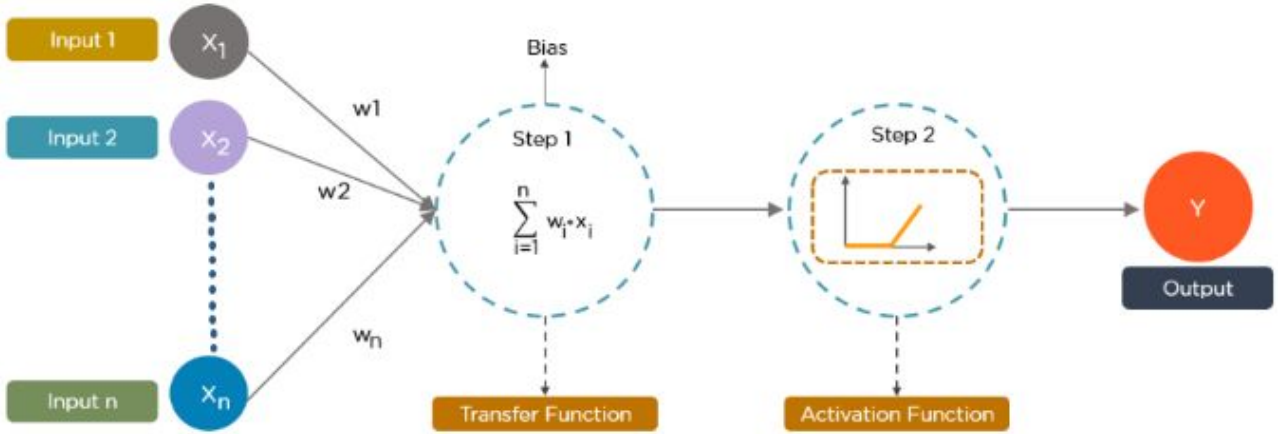


Cognex 2D laser profiler

What is Deep Learning?

Deep Learning uses artificial neural networks to perform complex computations on large amounts of data.

The structure of the human brain is mimicked by a neural network that consists of artificial neurons called nodes. These nodes are stacked in three layers. The nodes multiply the inputs with random weights, calculates them and adds a bias. Activation function is deployed to determine which neurons to fire.

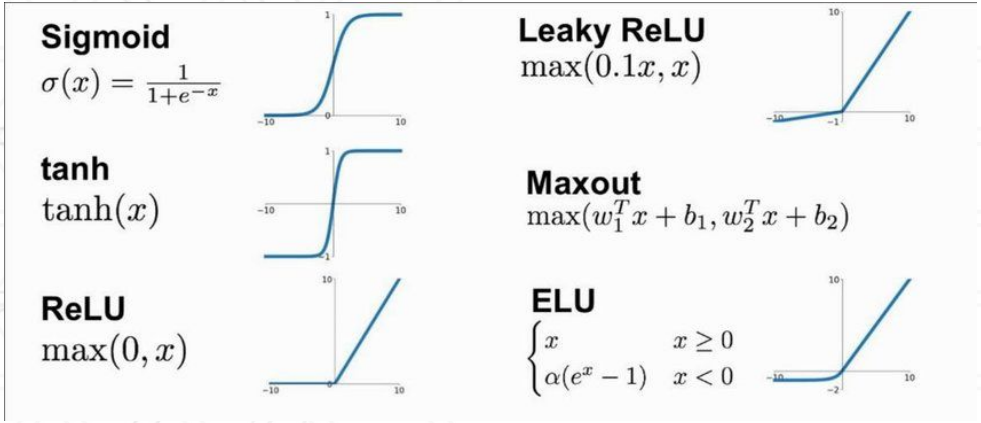


Machine Learning Steps

1. Problem Statement: Real time visual inspection
2. Gather and Prepare Data: Can be obtained from datasets of traditional computer vision method
3. Deep Learning Model selection: Advised to run an various models without bias
4. Train and Evaluate: Use a metric or combination of metrics to record objective permanence of each model
5. Parameter Tuning: Hyperparameters updated in each iteration step
6. Prediction: Reserved test data to test predictions for approximation of model performance in real world.

Activation Function

- The purpose of the activation function is to introduce non-linearity to the output.
- Without it the model is just linear regression. Enables complex learning.
- Controls if the neuron should be fired or not by calculation summation of weights and also adding bias.



Deep Learning Algorithms

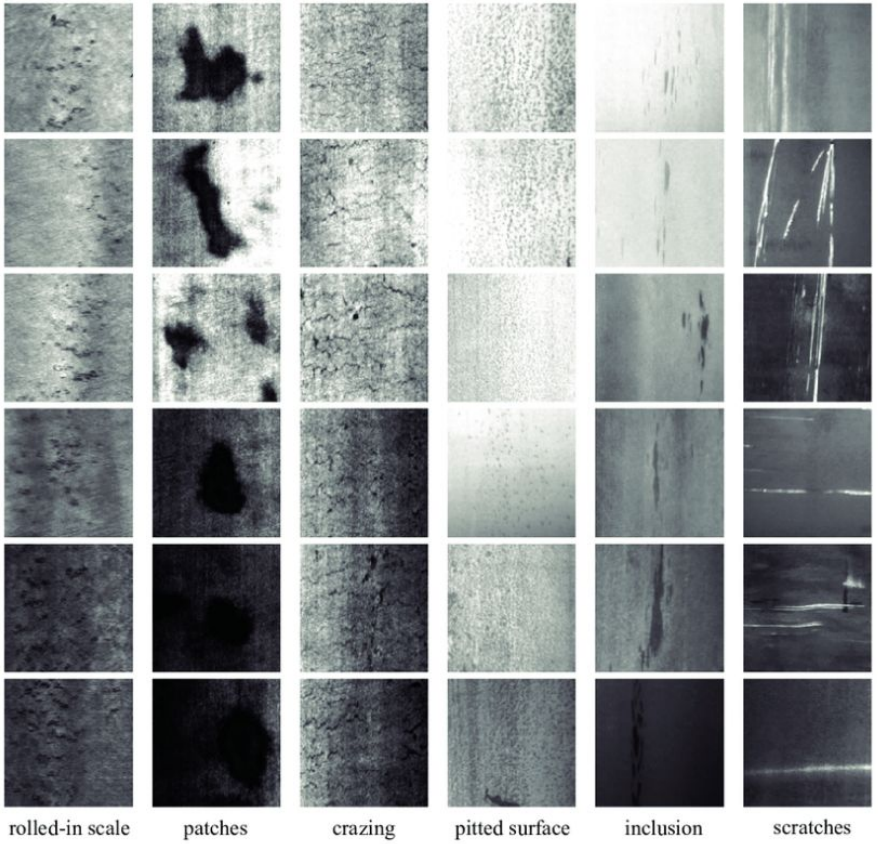
It is advised to train your dataset on multiple algorithms. No one network is perfect, some algorithms are better at some tasks.

- Convolutional Neural Networks
- Long Short Term Memory Networks
- Recurrent Neural Networks
- Multilayer Perceptrons

It is important to have a good understanding of these algorithms to choose the right ones.

Semi Supervised Learning

Supervised detection contains both the defect-free and defective labelled samples in the training test. However, semi supervised learning only contains the defect free labelled dataset. (also known as one-class classification method). This method is useful as it does not require a large quantity of defective samples.



SIMULATION

Simulation

- What is simulation?
  A tool to analyse our design and process our models before heading into real-world deployment.

- The kinds of simulation
  - Continuous Event Simulation
  - Discrete Event Simulation
  - Monte Carlo Simulation

- Why do we need simulation?

Simulation

The problem solving process lifecycle

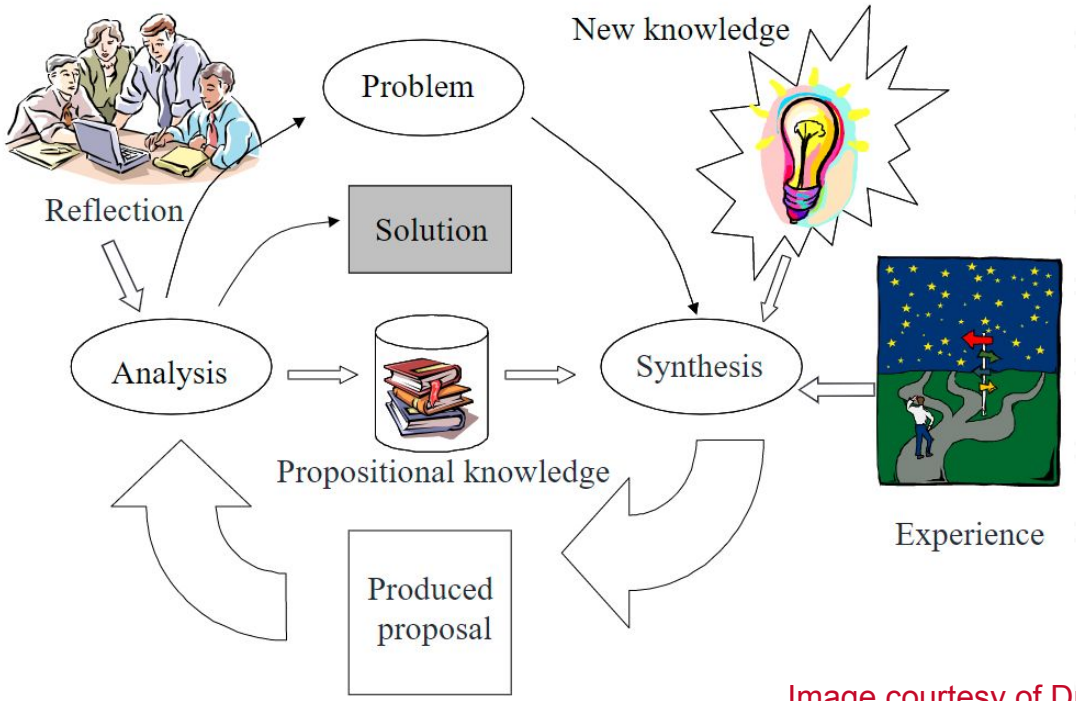
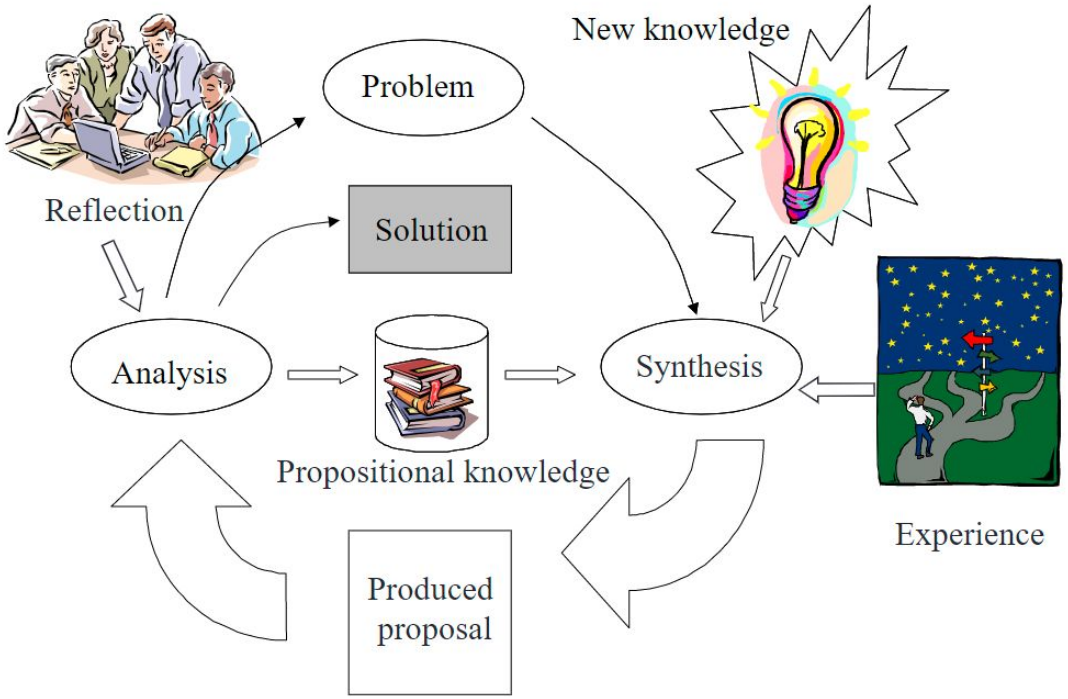


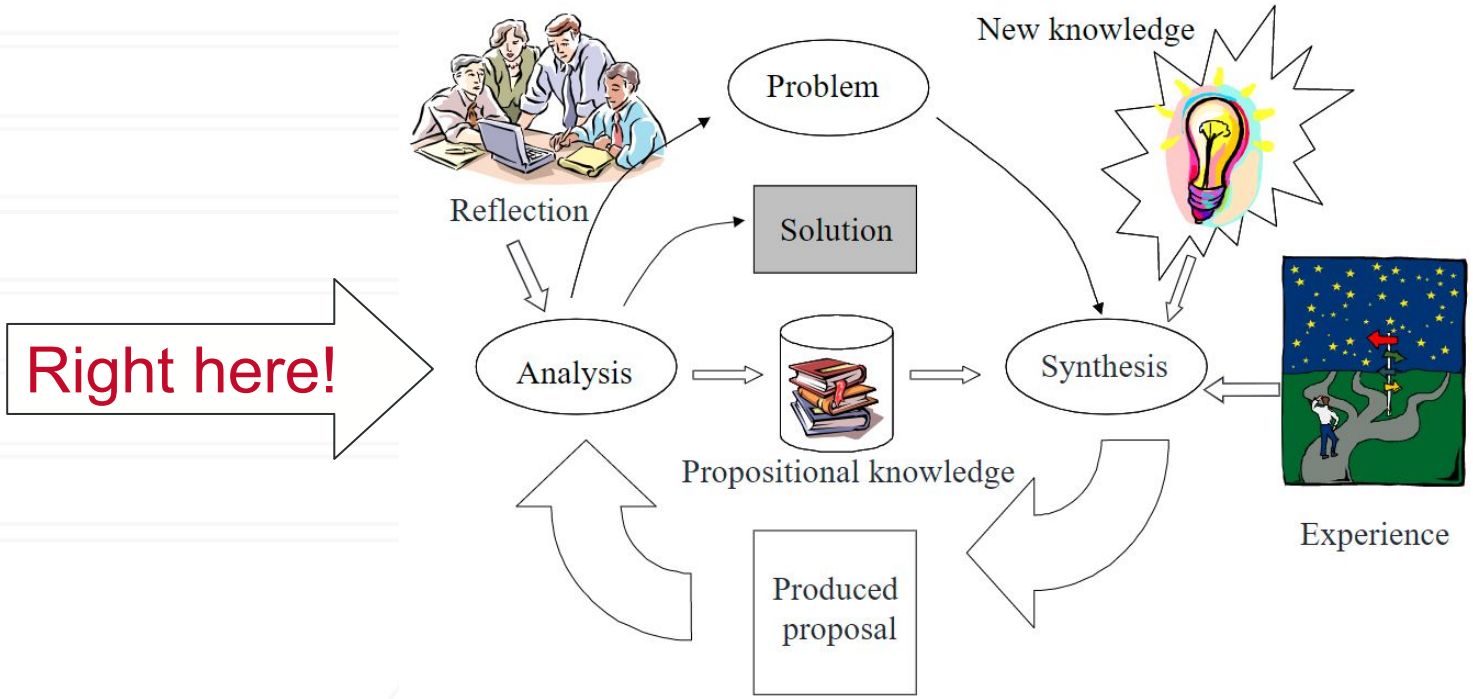
Image courtesy of Dr. Mahesh Mani, Ph. D

Simulation



Which part of the lifecycle does simulation fit into?

Simulation


Right here!
Problem
New knowledge
Reflection
Solution
Analysis
Synthesis
Propositional knowledge
Experience
Produced proposal

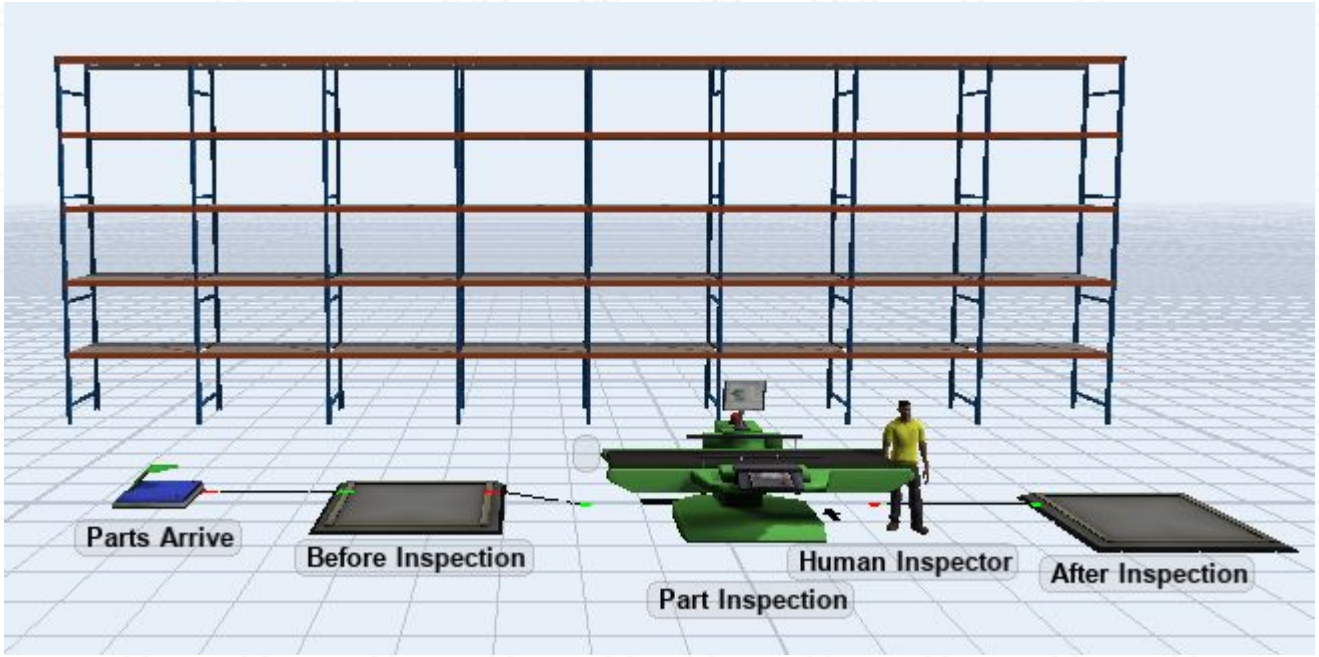
Simulation

- Approaches to simulation
  - Process Flow Models
  - 3D Models
- Both use some sort of an assessment factor

Simulation

- 3D simulation is made up of objects
  - Source - Sources create flow items.
  - Queue - Queues store flow items until they can be sent to another object
  - Processor - Processors process flow items, which are typically simulated as a time delay
  - Sink - Sinks remove flow items from the simulation model

Simulation Model



Simulation Model - Human Inspection

Simulation Model - Vision System Inspection

Outcomes

- By replacing the human in the loop at the inspection station with a vision based system we can improve the efficiency of the inspection process
- The human can be better used in any other area of the production line

Outcomes: Parts Inspected in an 8-hour shift

- Human Inspection: 2299 parts (inspection rate of 10 to 15 seconds per part)
- Vision-based Inspection: 4797 parts (inspection rate of 5 to 7 seconds per part)
- The camera array system is just over 2 times as efficient as a human for the same amount of time.

Questions ?

UNIVERSITY OF
MARYLAND

Thank You!

UNIVERSITY OF
MARYLAND