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Background

This paper will cover AI methods for industrial inspection, namely transfer learning performed with convolutional neural networks.

Industrial inspection can be defined as simply the process of attempting to identify defects or issues that may impact an industrially produced product's quality or value throughout its expected lifecycle. The goal of inspection or quality control in industry generally would be to identify and understand the cause of any defects within the manufacturing environment, in order to minimize the number of defects that escape the manufacturing environment to a satisfactory level, while still keeping cost of inspection or quality control methods as low as possible. Traditional inspection methods include human visual inspection, manual computer vision or computer-aided inspection - but these methods invite a lot of room for human error and bias. Rules-based algorithm inspection methods are also commonly used, but are prone to errors and often require human verification. At the end of the day, with inspection it is difficult to ensure quality without some cost of human verification - whether that be initial cost of labeled data sets or the cost of human labor for inspection.

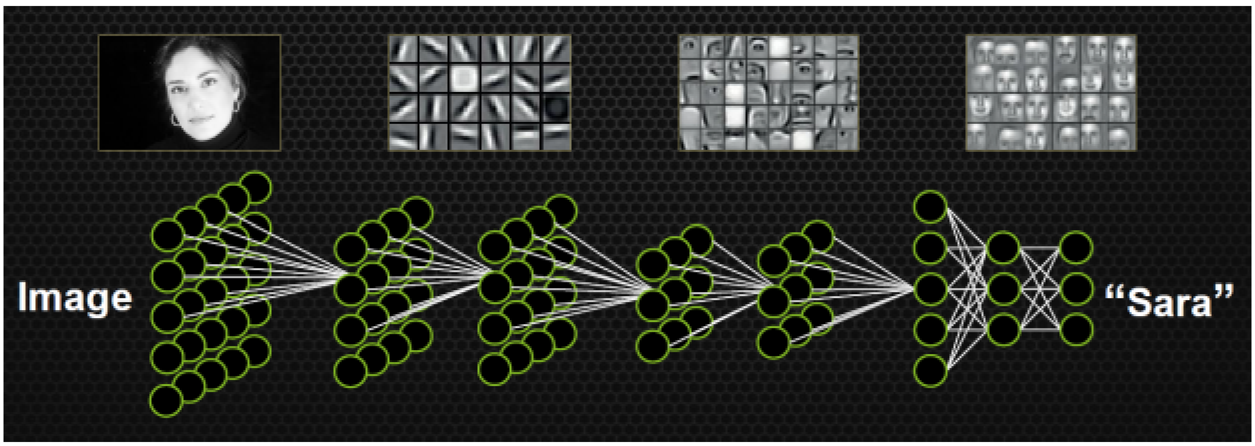
Transfer learning with CNNs can be employed in industrial inspection environments to reduce the human labor cost, increase efficiency, increase accuracy, and result in a better product and more profit.

Value	Low cost, very flexible, decrease human error and human labor cost
Model	CNN, VGG16
Deployment Platform	Cloud, Mobile, Local Hardware, etc.
Input Corpus	Image data, RGB images, 3D images (more complex)
Problem	Industrial Quality Inspection: Defect classification
Performance	Training, Test, Val Accuracy, Loss, Error Analysis
Training Costs	Considerable time, labeled data needed (possible human labor)
Advantages	Low cost, low data requirement, flexibility
Drawbacks	Long training time, struggle with rotation and scale invariance

Transfer Learning with CNNs

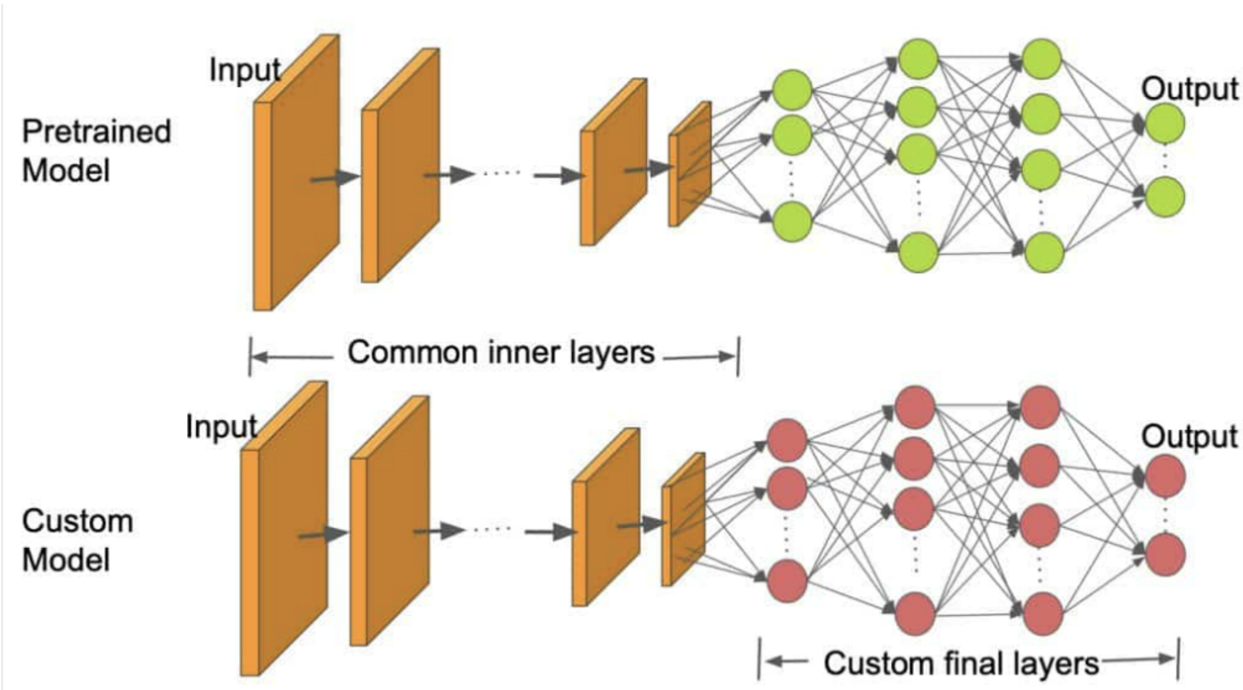
Computer vision leveraged with special hardware and software and optical inspection is widely used in industry today. However, these methods are only available at a higher cost, longer time to productionisation, and lack of flexibility for other purposes.

Transfer Learning on Convolutional Neural Networks can be used to solve this problem. Low cost, high performance, and reduced training time are all factors in this decision. Because of ease of access to high-performance open source pre-trained deep learning models and transfer learning, a relatively high performing model can be reached at low cost, time, and power. The image below maps out a very basic architecture of layers in the application of a Deep Learning Neural Network used for Facial Recognition.



Source: NVIDIA, https://developer.nvidia.com/discover/artificial-neural-network

Transfer learning can be used in this case to transfer learned features from one model to another. This shortens the time to model acquisition, and most importantly reduces the amount of training data needed (oftentimes a huge limiting factor in industrial or manufacturing environments). In practice, a pre-trained model like VGG16 which has already learned basic image features (such as edges, lines, etc.) from a very large image set can be leveraged on a custom data set, with customized final layers, to apply to a wide variety of situations where there may not be enough image data, or labeled data, to build a model from scratch.
Some downsides to transfer learning with CNNs can include a long training time and struggle with rotational and scale invariance in features, but some of this can be mitigated through data augmentation and increased volume of training data.



Transfer Learning, learnopencv.com, [Image Classification using Transfer Learning in PyTorch | LearnOpenCV #]

Stakeholder Values

Some examples of stakeholders and their values can be considered in the table below.

Stakeholders	Values (Prioritized L->R)
Executive Management	Risk, Cost, Feasibility, Consumer Safety
Quality Engineers	Feasibility, Consumer Safety, Quality, Cost
Regulators	Consumer Safety, Quality, Feasibility, Cost

There can absolutely be value tensions that arise between stakeholders, even amongst stakeholders within the same organization. For example, the conflicts between Executive Management and Quality Engineers may involve conflicts in priority between the perceived feasibility of new inspection methods, risk to the company (impacts to volume, cost not recuperated, impacts to product and/or company reputation), and consumer safety. An executive is responsible for protecting the company from risk, but this is complex. A good executive would seek to find a balance between reducing costs and increasing quality - because while no inspection would reduce inspection cost to zero, the impact could damage reputation and may place the company at risk for lower sales or regulatory action. However, a quality engineer may be primarily concerned with feasibility of inspection methods and any impact to the current workflow in her day-to-day job, but also have a secondary concern with consumer safety and product quality. Meanwhile, regulators or government agencies may have little or no concern with risk to individual companies, while still recognizing that unrealistic requirements may have a negative impact on industries or supply chains throughout the national economy. Consumer safety would be paramount. Key in addressing these tensions would be frequent communication and understanding between stakeholders of each stakeholder's responsibility to their own values.

Exploration of Error

		Predicted	
		Positive	Negative
Actual	Positive	**True Positive**	**False Negative**
	Negative	**False Positive**	**True Negative**

For classification problems, we can discuss two main types of errors.
False Positive: Predicted as defective when it is not
False Negative: Predicted as non-defective when it is

For regulatory agencies, the priority would certainly be to reduce False Negatives, since those have the greatest impact to the consumers and/or the public. However, for stakeholders within companies it may be more complicated. Their top priority would still be to reduce False Negatives, but False Positives also contain a lot of risk for the company, depending on the cost of parts, cost of rework, etc.

Error reduction requires error analysis to attempt to understand or explain what characteristics of a model may be causing the error. Improving model performance could involve methods such as increasing the volume or quality of data available for training, test, and validation, data augmentation, or increasing model complexity.