AI-Driven Innovation in Quality Control: Harnessing CNN and Deep Learning in Metal Parts Manufacturing

1. Problem Statement Formation

The main problem is the need to automate the quality control process in the manufacturing of metal casting products, such as submersible pump impellers. Currently, this inspection process is conducted manually, which is time-consuming, labor-intensive, and prone to errors due to human factors. Defects like blow holes, pinholes, burrs, shrinkage defects, and more are common in metal casting, and even small errors in inspection can lead to the rejection of entire orders, resulting in significant financial losses. By implementing a Deep Learning classification model, we aim to automate this inspection process, improving both accuracy and efficiency, and ultimately reducing costs associated with defective products.

2. Context

In the metal casting industry, ensuring the quality of each product is critical to maintaining standards and avoiding costly rework or rejected shipments. Manual inspection methods are not only slow but also inconsistent, as they rely heavily on the subjective judgment of human operators. This project aims to automate the inspection process for submersible pump impellers using a dataset of 7,348 gray-scale images, each sized at 300x300 pixels. These images have been pre-processed with data augmentation to enhance the robustness of the training samples and are categorized into two classes: “Defective” and “Ok,” with separate folders for training and testing data. The goal is to develop a Deep Learning Convolutional Neural Network (CNN) model that can reliably classify these images, thereby improving the efficiency and reliability of the quality control process in metal casting manufacturing.

3. Criteria for Success

- **Model Accuracy:** Achieve a minimum classification accuracy of 95% in distinguishing between defective and non-defective metal casting products.
- **Inspection Time Reduction:** Reduce the time required for quality inspections by at least 50%.
- **Cost Savings:** Demonstrate a measurable reduction in costs related to rejected orders and rework due to undetected defects.
- **Deployment:** Successfully integrate the trained model into the production line for real-time quality control.

4. Scope of Solution Space

The solution will focus on:

- **Model Development:** Focus on training a CNN using the provided dataset, incorporating techniques such as data augmentation to improve model robustness.
- **Real-Time Application:** Develop a system capable of real-time image processing and defect detection during the manufacturing process.
- **Scalability:** Ensure the solution is scalable and adaptable to other metal casting products beyond submersible pump impellers.
- **Transfer Learning:** Exploring pre-trained models to review if accuracy can be further improved.

5. Constraints

- Limited data availability: The dataset provided may not cover all possible defect scenarios.
- Computational resources: Training deep learning models, especially CNNs, require significant computational power.
- Integration with existing manufacturing systems: The model must be compatible with current manufacturing workflows.

6. Stakeholders

- **Manufacturing Plant Management**: Interested in reducing labor costs and increasing efficiency.
- **Quality Assurance Team**: Looking for ways to minimize human error in quality inspections.
- **IT/AI Development Team**: Responsible for the implementation and integration of the AI model.
- **Production Line Operators**: May be impacted by the automation of the inspection process.

7. Data Sources

The primary dataset for this project is the **“Real Life Industrial Dataset of Casting Products”** available on Kaggle.

This dataset includes a comprehensive collection of images from the metal casting process, specifically focusing on the identification of defective and non-defective submersible pump impellers.

Q&A

Q1: What is the problem you aim to solve?
We aim to automate the quality control process in metal casting manufacturing, specifically for submersible pump impellers. By using a Convolutional Neural Network (CNN) model, we seek to accurately identify defective parts, reducing the reliance on human inspectors and enhancing the overall inspection accuracy.

Q2: Who is your client and why is this problem important to them?
Our client is the management team of the manufacturing plant. They are invested in this solution because automating quality control can significantly reduce labor costs, improve production efficiency, and minimize the risk of defective products reaching customers, thereby protecting the company's reputation and reducing financial losses.

Q3: What data are you using, and how will you acquire it?
We are utilizing the "Real Life Industrial Dataset of Casting Products" available on Kaggle. This dataset is readily accessible and will be downloaded directly from the Kaggle platform for use in training our model.

Q4: How will you approach solving this problem?
The problem will be tackled by developing a CNN trained on the provided dataset. The model will undergo thorough testing and validation, and we may employ data augmentation and transfer learning techniques to enhance its performance. Once the model demonstrates sufficient accuracy, it will be prepared for integration into the manufacturing process.

Q5: What are the expected deliverables?
The deliverables will include:

- The trained CNN model code and weights.
- A detailed report or paper outlining the methodology, results, and recommendations.
- A presentation slide deck summarizing the project's outcomes.
- A deployment plan or script for integrating the model into the production environment.