Defect Detection in Manufacturing using AI

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1. Introduction

In modern manufacturing, ensuring product quality is critical to maintaining competitiveness and customer satisfaction. Manual inspection of surface defects is labor-intensive, error-prone, and often inconsistent. This project presents an AI-powered **Defect Detection System** designed to automatically identify and classify surface defects in manufacturing materials using **Computer Vision** and **Deep Learning**. The system leverages Convolutional Neural Networks (CNNs) to detect six common types of surface defects, enabling faster, accurate, and real-time quality control.

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2. Objectives

- Automate the identification of surface defects in manufacturing materials.
- Classify defects into six predefined categories: Crazing, Inclusion, Pitted Surface, Scratches, Rolled-in Scale, and Patch.
- Provide a simple, user-friendly interface for real-time defect detection.
- Facilitate data logging and reporting for industrial quality assurance.

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3. Dataset

The project uses the **NEU Surface Defect Database (NEU-DET)**, which contains steel surface images labeled into six defect categories:

Defect Type	Description
Crazing	Fine cracks on the surface
Inclusion	Embedded foreign particles
Pitted Surface	Small depressions or holes
Scratches	Surface scratches
Rolled-in Scale	Material scale rolled into the surface

Defect Type	Description
Patch	Uneven surface patches

The dataset is split into training and validation subsets, with images organized in corresponding class folders.

Source: NEU Surface Defect Database (NEU-DET)

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4. Methodology

4.1 Data Preprocessing

- Images resized to **128×128 pixels**.
- Normalization of pixel values to [0,1] range.
- Data augmentation (rotation, flipping, and scaling) applied to improve model generalization.

4.2 Model Architecture

- **Type:** Convolutional Neural Network (CNN)
- **Framework:** TensorFlow / Keras
- **Input:** 128×128 RGB images
- **Output:** 6 classes
- **Optimizer:** Adam
- **Loss Function:** Categorical Cross-Entropy
- **Validation Accuracy:** ~94%

4.3 Training

- Data split: 80% training, 20% validation
- Batch size: 32
- Epochs: 50
- Early stopping and model checkpoints implemented to prevent overfitting.

4.4 Deployment

- **Streamlit** web application for real-time defect detection.
- Users can upload an image, and the model predicts the defect type along with the confidence score.

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5. Tech Stack

Languages & Libraries:

- Python
- TensorFlow / Keras
- NumPy
- Pillow
- Streamlit

Tools:

- Jupyter Notebook
- VS Code

Project Structure:

```
defect_detection_project/
├── data/
|   └── NEU-DET/
|       ├── train/validation
|       |   ├── images / annotations
|       |   └── 6 defect subfolders
├── docs/
|   ├── img1.png ... img13.jpeg
|   └── output.png
├── notebook/
|   ├── train_defect_detector.ipynb
```

```
|   └── models/
|       ├── defect_detection_model.h5
|       ├── defect_detector_model.keras
|       └── defect_detector_model.h5
├── app.py
├── presentation.pptx
└── project_report.pdf
```

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6. Results

- The trained CNN model achieved a **validation accuracy of ~94%**, demonstrating strong capability in identifying surface defects.
- Example predictions:

Input Image	**Predicted Output**
	Scratches (Confidence: 0.99)
	Inclusion (Confidence: 0.97)

- **Streamlit UI** allows operators to upload images and receive instant defect predictions.

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7. Advantages

- Reduces human error and manual inspection efforts.
- Real-time defect detection suitable for industrial production lines.
- Provides extensible data logging for quality control dashboards.
- Simple, intuitive interface for non-technical operators.

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8. Future Work

- Integrate **live camera feed** for continuous real-time defect detection.

- Expand dataset to cover additional materials beyond steel.
- Deploy using cloud platforms such as **AWS** or **Streamlit Cloud** for scalability.
- Implement **feedback-based retraining** to improve model performance over time.

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9. Installation & Usage

Clone the repository:

git clone https://github.com/yourusername/defect_detection_project.git

cd defect_detection_project

Install dependencies:

pip install tensorflow keras streamlit numpy pillow matplotlib

Run the application:

streamlit run app.py

Usage: Upload an image from the validation set or new material image. The model predicts the defect type with confidence.

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10. Conclusion

This project demonstrates how **AI-powered computer vision** can effectively automate surface defect detection in manufacturing. By using CNNs, the system achieves high accuracy in identifying defects while providing a real-time, user-friendly interface. The framework can be extended to integrate with industrial production lines, improving overall product quality, efficiency, and operational consistency.

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11. References

- NEU Surface Defect Database (NEU-DET) – NEU Surface Defect Database
- TensorFlow Documentation – TensorFlow
- Keras Documentation –Keras: Deep Learning for humans
- Streamlit Documentation – Streamlit • A faster way to build and share data apps