Defect Detection In Vehicle Painting: Case Study

Advances in Reliability, Safety and Security

ESREL 2024
Collection of Extended Abstracts

Defect Detection In Vehicle Painting: Case Study

Doaa Almhaithawi[a], Alessandro Bellini[b]

[a]*Department of Control and Computer Engineering, Politecnico di Torino, Torino, Italy*
[b]*Mathema srl, Firenze, Italy*

Keywords: defect detection, vehicle painting, Artificial Intelligence, latent spaces

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Defect detection is a cross-sectoral problem that is being intensively addressed in manufacturing, primarily with the help of computer vision and image processing-based systems. From fabric to surface to mechanical parts, defect detection approaches have assisted human operators and reduced human eye strain. However, many case-specific challenges arise in vehicle painting. Although few authors have addressed them, research is still active due to the high-quality demand and competition in manufacturing. In this study, we present a case study on paint defect detection in IVECO vehicle production, listing the problem description, challenges, literature review, and proposed solution.

Defects in vehicle painting. In the production of vehicles, the high-quality standards require vehicles to be free from defects, including structure, engine, functionality and also appearance. The quality of the paint finish is very important to attract customers as it is the first thing you see. However, depending on the process and painting machines, many parameters and operators are involved and should therefore be controlled. Quality assurance is usually the last step of the production cycle and various errors can occur, either due to machine misconfigurations or human factors.

Although different types of defects have different causes, the detection of a defect can be the same. However, the further classification of the defect and the analysis of its cause depends on the experts in the field. Artificial Intelligence (AI) solutions can be effectively used to support the operator in the detection phase to mitigate the defects and improve the production cycle.

Challenges. The vehicle painting use case presents the following challenges, among others:

- no (or only a very small) image data set is available;
- the lighting system required for human detection may not be suitable for an automated system;
- not all defects are easy to recognize, even for experts;
- defects are diverse and their distribution over time is generally uncertain;
- the color of the vehicle has an impact on the detection process;
- the surface is very wide.

Literature Review. Some researchers are investigating the design of the illumination system to improve detection, while others have begun using AI-based systems to detect defects from image datasets. Armesto (2011) describes the design and implementation of a defect detection system at Ford Spain; the system is based on the flash with a static image system that analyses the shadows around the defects. Kamani and Afshar (2011) recognises the defects using a One-Against-All Support Vector Machine classifier, while Kieselbach (2019) describes a surface inspection system developed at the Volkswagen plant in Wolfsburg, Germany, which improves the detection of paint defects using an image processing system.

In addition, Akhtar (2019) describes a system for detecting defects on semi-specular/painted surfaces. This system consists of a robotic arm carrying camera equipment that can detect defects on large surfaces. The tests were conducted at the Robotics Institute Guelph laboratory and the vehicle parts were provided by an original equipment manufacturer of car body parts. (Xu et al., 2020) detects the edge of the defect location in the image of the vehicle paint using ant colony optimisation, eliminates reflections and then detects defects of 5 different types: Scratches, drops, paint fold, raindrops and hair. Finally, (Jiang et al., 2023) creates a dataset of 2468 images containing 7 types of car body defects: Bubbles, dust, fouling, pinholes, sagging, scratches and shrinkage, exploiting convolution-based models such as MobileNet-V2, Vgg16 and ResNet34 for paint defects detection.

In all previous work, neither the dataset used nor details of the data collection methods were provided. Therefore, we aim to collect a new dataset at IVECO plant while reducing the samples for training the network to the minimum due to the difficulty of collecting large amount of data at industrial site.

Proposed Solution. To train an effective AI system with relatively scarce amount of data, with respect to the usual datasets, our approach aims to reduce the dataset dimension for defect detection by moving from the image's pixels to more abstract representation, namely Latent Space, which many models use to embed real data into a numerical vectoral space. These latent spaces are built and modified through the training phase and the resulted space is used later for inference or to generate new samples. Our methodology will follow the steps shown in Figure 1:

1) using the latent space of the images of an existing trained model;
2) fitting the model to the defect dataset by projecting its samples into this latent space to obtain the case-specific new space;
3) investigating the similarities and differences in the latent representations of the samples;
4) using this new space for inferring new samples.

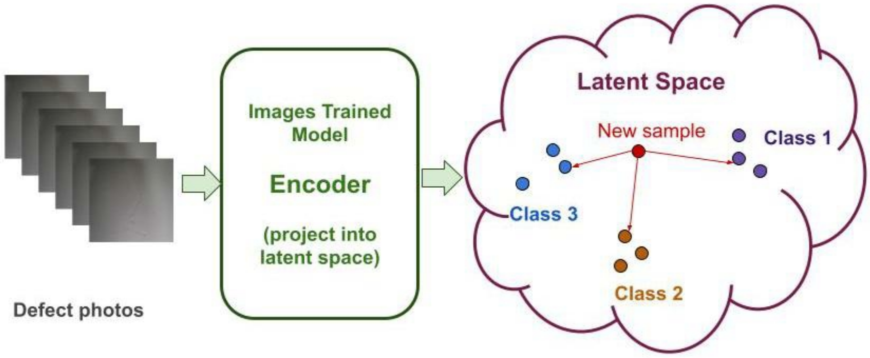

Fig. 1. Proposed solution methodology.

Acknowledgements

This research project has been supported by a Marie Skłodowska-Curie Innovative Training Network Fellowship of the European Commission's Horizon 2020 Programme under contract number 955901 CISC.

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