In-Line Sealing Inspection

Degree programme: Master of Science in Engineering | Specialisation: Mechatronics and Automation
Thesis advisor: Prof. Dr. Gabriel Gruener
Expert: Matthias Höchemer (CSEM SA)
Industrial partner: Rychiger AG, Steffisburg

In-line quality control is very important in automatic production systems. For Rychiger AG, one such task entails detecting leaks in coffee capsule seals. This work demonstrates that a system that uses a visible-spectrum camera and deep-learning–based defect detection works quite well. Shape-from-shading algorithms achieve even better feature extraction for more robust results at the cost of process speed.

Motivation

Rychiger AG manufactures advanced filling and sealing machines for coffee capsules. The process runs very stably. Rarely, defective coffee capsules are produced. In particular, coffee particles in the sealing seam can lead to leaking capsules, which need to be sorted out. On behalf of Rychiger, different technologies for in-line sealing inspection were analysed. The most appropriate method was implemented and evaluated.

Method Evaluation

A wide variety of non-destructive test technologies are available to ensure sealed seam tightness. Vacuum, acoustical, capacitive, and optical technologies were studied in collaboration with sensor manufacturers. It was then decided to continue with industrial cameras operating in the visible spectrum. These cameras can be used to detect a wide range of defects. A Cognex smart camera D900 was selected. The focus was set on processing the images using deep-learning defect detection due to its recent success.

Implementation

Five supervised and unsupervised defect-detection models were implemented, evaluated, and compared with the commercial Vidi software from Cognex:

- 1: Unsupervised anomaly detection using convolutional autoencoder (Tsai and Jen, 2021)
- 2: Unsupervised anomaly segmentation via deep feature reconstruction (Shi et al., 2021)
- 3: Adapting pretrained features for anomaly detection (Reiss et al., 2021)
- 4: Unsupervised defect detection using patch features in memory bank (Roth et al., 2021)
- 5: Mixed supervised learning (Bozic et al., 2022)

Supervised learning uses labelled, defect-free and defective samples. Unsupervised learning only requires defect-free samples, thus detecting deviations as anomalies. This means less effort to train the system, but the false-positive rate tends to be higher. In addition, a setup was created that enables generating shape-from-shading images, which enables improved feature extraction.

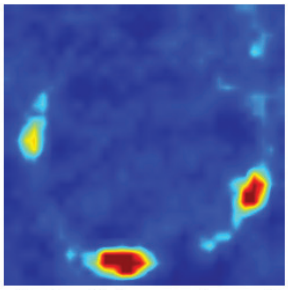
Results

Supervised learning outperforms unsupervised methods. Better results are achieved with shape-from-shading images. An implementation of the deep-learning approaches is not yet necessary, as Cognex's Vidi tools achieve good results. To detect small defects (few pixels) Cognex's tools are not suitable. Here, method 4 or 5 could provide a solution. Shape-from-shading shows potential and is recommended for future Rychiger projects.

Simon Raphael Werner
079 254 44 43
simon.werner95@gmail.com

Coffee capsule: Coffee particles in the sealing seam

Surface FX image of coffee capsule



Predicted defect map: Detected by supervised deep-learning model