Product inspection

Artificial Intelligence (AI) in food production

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Introduction

X-ray product inspection is a highly advanced technology that plays a crucial role in ensuring the safety and quality of food products within the food and beverage industry. One of the most common applications for this technology is to scan and detect any foreign objects or contaminants that may be present, such as metal, glass, or plastic, in the product to prevent potential hazards to consumers and protect the manufacturers brand name.

There are also applications where innovative X-ray technology can be utilized to ensure specific visual quality characteristics are achieved during the manufacturing process. This technology is Artificial Intelligence or AI, which in manufacturing refers to the application of advanced technologies and algorithms to enhance various aspects of the manufacturing process. It involves the use of intelligent systems and machines that can perform tasks traditionally requiring human intelligence, such as perception, reasoning, learning, and decision-making. AI in manufacturing aims to optimize production, improve efficiency, reduce costs, enhance product quality, and enable machine learning, computer vision, robotics, and other AI techniques. The integration of AI into manufacturing processes can lead to increased productivity, improved safety, and the ability to adapt to changing market demands.

This application note will explore the integration of AI with X-ray inspection software and how it supports the food manufacturing industry—looking at two specific applications of cheese production and packaging of bakery bread products.

X-ray inspection and AI

The Thermo Scientific™ Xpert™ C series and Xpert C HD series are advanced X-ray product inspection systems designed for industrial applications. These systems utilize cutting-edge technology to provide high-performance and reliable inspection capabilities. Xpert C is specifically designed for inspecting bags, boxes, and other packaged products, while Xpert C HD is designed to manage larger and heavier packages. The Xpert software utilizes sophisticated algorithms and image processing techniques to detect and identify foreign objects, contaminants, and defects and can be customized to support different applications.

The Xpert software can be enhanced with a new AI module for the purpose of identifying and classifying product images. This AI software module operates on the same PC as the X-ray instrument. Once a trained model is incorporated into the X-ray software, it can effectively evaluate products and classify them based on predefined thresholds, such as determining whether they are compliant or non-compliant.

Optimizing performance: Exploring the AI module in our software

The Thermo Scientific Xpert AI software module incorporates artificial intelligence to enhance the imaging algorithm. In addition to the traditional image processing techniques, it also utilizes advanced algorithms that analyze pixels and gray levels commonly found in conventional software. The AI system will categorize each scanned image of the product into distinct classes, with a minimum of two classes and up to a maximum of five classes. For instance, a product can be classified based on its shape, such as square, rectangular, round, oval, or triangular, representing the maximum number of classes. Alternatively, the minimum number of classes could be divided into compliant and non-compliant.

To ensure the proper functioning of this module, our application team will conduct one or more training cycles for each product/recipe. During these training cycles, they will utilize the classified images provided by the customer.

AI learning process

The software can utilize a distinct model for each product file or recipe loaded into the machine.

The learning process for AI guided Xpert software involves training the AI algorithms using a dataset of X-ray images. This typically includes a four-step process:

1. Data collection: A diverse dataset of X-ray images is provided by the customer. These images are divided into different "classes" by the customer, typically ranging from two to five categories. These classes correspond to different images with specific details. For instance, in the case of classifying chicken parts, the classes could be "full chicken," "breast," "wing," or "leg." This dataset then serves as the foundation for training the AI model.
2. Machine learning process: The collected dataset is then used to train the AI model through a process called machine learning. This involves feeding the AI algorithms with labeled examples of X-ray images, where the desired features or defects are identified. The AI model learns from these examples and adjusts its internal parameters to recognize and classify similar features or defects in new, unseen X-ray images.
3. Customer test: Customer receives the AI software model and tests on their production line. Additional images are then provided to our engineering team in order to refine image accuracy.
4. Optimized software: Additional images from the previous step are now "learned" by the software. An optimized software model will then be finalized for production usage and provided to the customer.

The learning process aims to optimize the AI model's accuracy and performance, allowing it to effectively identify and classify specific features or anomalies in X-ray images during real-time inspection.

AI applications

Artificial intelligence has proven to be effective in various applications where traditional image processing methods were overly complicated or it was challenging to determine the appropriate approach to employ. Now, let's explore two examples of artificial intelligence being employed: cheese production and the packaging of bakery bread products.

Cheese evaluation application

The AI software played a crucial role in a cheese manufacturer's application for classifying cheese products. The customer faced the challenge of categorizing cheeses as either matured or not yet matured based on factors such as the number, shape, size, distribution, and placement of holes. Initially, a human inspector would manually assess the products by visually examining x-ray images on a large screen. However, due to the inherent variability of the product and the complexity of the evaluation parameters, traditional methods of analytical inspection proved impractical.

To address this challenge, the AI module was trained to classify the cheese into five distinct categories, emulating the role of a human operator. The categories were divided into A1, A2, B (see Figure 1 below) for the cheeses that are not yet ready and need more time to mature, while C and D (see Figure 2 below) represented cheeses that were fully matured and ready for consumption.

Figure 1: Images A1, A2, and B (left to right) are classified as not fully matured cheeses.

In order to perform an initial evaluation of the artificial intelligence algorithms, a total of 500 cheeses were analyzed. The sample of 500 cheeses was made up of 100 samples from each of the five classes (A1, A2, B, C, D). Table 1 below contains results from this initial classification test on a very complex cheese application.

By leveraging AI technology, the cheese company was able to automate and streamline the cheese classification process, overcoming the limitations posed by manual inspection methods. This resulted in increased efficiency, accuracy, and consistency in categorizing and assessing the maturity of their cheeses; ensuring only the highest-quality cheese products are delivered to their customers. This commitment to quality helps to enhance their brand reputation and maintain customer satisfaction.

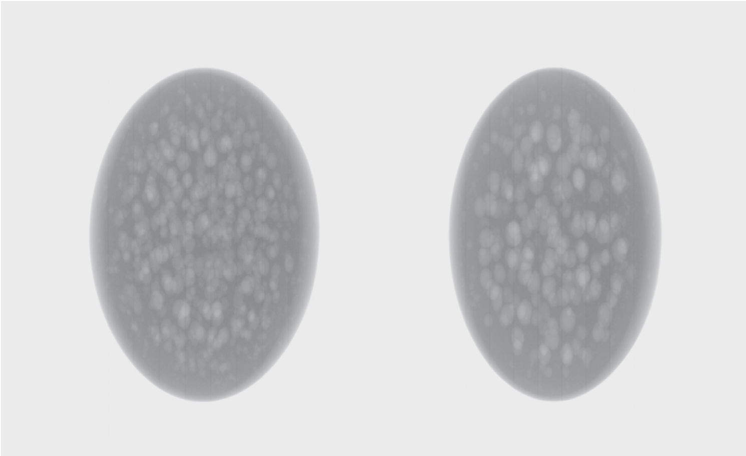

Figure 2: Images C and D (left to right) are classified as fully matured cheeses.

	Images	Detected as fully matured cheese	Detected as not fully matured cheese	Error %
A1 products	100	0	100	0
A2 products	100	0	100	0
B products	100	5	95	5
C products	100	99	1	1
D products	100	100	0	0

Table 1: Initial assessment using 500 images where a total error of 1.2% was captured.

Bakery bread application

A baked goods manufacturer had an application where AI software was needed in order to classify the positioning of panettone within its packaging. The goal of this project was to identify and reject any panettone that was rotated 90° inside the carton box. Due to the varying size and shape of the product, a conventional approach was not feasible as it would not account for the potential variations observed over time.

To address this challenge, the AI model was trained to classify the product into two categories: "A" represents product that does not meet standard (indicating a product rotated 90°) and "B" represents product that does meet standard (indicating a product aligned correctly in the box). Figures 3 and 4 below showcase examples of images provided by the customer, which were utilized in the AI learning process.

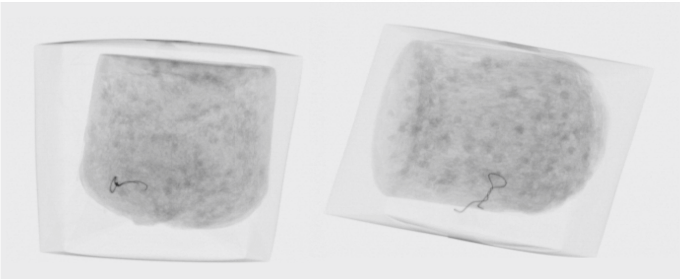

Figure 3: Images of product that does not meet standard (rotated 90°).

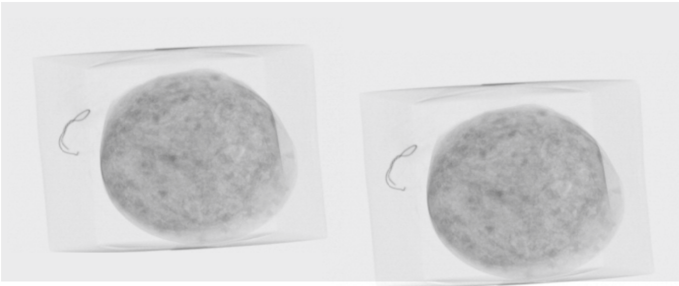

Figure 4: Images of product that does meet standard (aligned correctly).

An initial assessment of the artificial intelligence algorithms was conducted using 1,994 images from the manufacturer. The results are summarized in Table 2 below, indicating an evaluation error of 0.11%. This error rate aligns with the production line's error rate of 0.10%.

The implementation of X-ray and AI technology has played a crucial role in supporting the panettone manufacturer by substantially reducing both their quality control and inspection time. This technology ensures efficient and accurate assessment of product quality, guaranteeing that the desired position of the product is consistently maintained when it reaches the market—thereby protecting the brand's reputation.

	Images	Product evaluated as good from software	Product evaluated as bad from software	Evaluation error
Good products (B)	1,894	1,892	2	0.11%
Bad products (A)	100	0	100	0%

Table 2: Initial assessment using 1,994 images where a total error of 0.11% was captured.

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