Snapshot Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Bone Belt Monitoring

Bone Belt Monitoring – Vision combined with DEXA Stage 2

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Project Description

The yield performance of a boning room can indirectly be monitored by what leaves the room on the waste/bone belt. The method of removing by-products from the room is also a common way to forget mistakes at the boning line, out of sight, out of mind. In some cases, even foreign objects may end up on the bone belt; objects not fit for human consumption like gloves, string, plastic etc. causing additional issues and costs for the subsequent food business operator. A monitoring solution for both missed product yield and alerts for noncomplying foreign objects will create significant value for the food processors.

The aim of the project “Bone Belt Monitoring – Vision combined with DEXA Stage 2” is to adapt and refine an existing Vision and x-ray (Dual-Energy X-ray Absorptiometry – DEXA) system for monitoring the product stream of a bone belt and develop algorithms capable of determining the trim quality of different types of bones as well as foreign object detection within the product stream.

Project Content

The project focussed on the following topics and activities:

- Adapt and configure the chosen Vision & DEXA measurement system to be used for scanning bones from cattle on a customized conveyor bone belt.
- Performing lab sessions for large-scale data collection of different kinds of bone segments, both well-trimmed and poorly trimmed, sourced from two local beef processor facilities in the meat industry.
- Design and execution of detailed trimming tests in order to produce specific yield-based datasets divided into trimming levels. The yield tests also included registration of the weight of the recoverable meat between each trimming level.
- Analysis and data modelling on all datasets collected during the project. The analytic process included prediction models for automatic recognition of multiple types of bone segments and the estimation of meat-to-product ratios. Furthermore, prediction models for trim quality and weight of recoverable meat were developed as well as algorithms for detection of foreign objects, such as small pieces of low-density plastics and strings.
- Provide the industry with knowledge and a recommendation for the next step in the development of an in-line Bone Belt Monitoring system based on advanced Vision & DEXA technology.

Project Outcome

DMRI has developed a high-end Vision & DEXA platform, which consists of combined vision and x-ray sensors, capable of continuously scanning meat products through fast line-scan measuring. The equipment was adapted for the purpose of this project to provide multiple image data (RGB+NIR and low+high energy X-ray) of bones on a conveyor system customized for bone belt monitoring. The measurement system was configured, and software was developed to enable automatic collection of full images of each bone segment in the subsequent data collection sessions.

Bones from cattle were sourced from separate processors from the local meat industry and used in lab sessions. The learnings from these lab experiments were used to design larger data collection sessions where the purpose was to gather large, suitable Vision and x-ray datasets from all bone segments as well as collecting trimming data for yield tests with the help of skilled trimming operators. The data collection sessions were performed in the pilot plant facility at DMRI where meat and bone products can be handled under food safety conditions and controlled temperatures similar to normal food production within the industry.

During the trimming and yield test, poorly trimmed bones were trimmed in steps into levels of progressively better quality. Through dialogue with yield and production experts, the different levels were defined as a 5-scale trimming score used by the trimming operators at DMRI. The definition is listed below:

1. Optimal (ideal master trimmer level, no time pressure, no recoverable meat)
2. Accepted and nearly optimal (achievable at very focused deboning operations and very skilled and motivated operators)
3. Acceptable (average performance for variable trained and motivated operators)
4. Barely acceptable (only a few should occur, full focus on yield management and motivation)
5. Not acceptable, needs rework (may require a more skilled operator)

During yield testing, the weight of the recovered meat was registered for each level of the defined trimming score.

The datasets from the large-scale tests were used in various analytic approaches for data modelling to produce results on the practices of continuous Bone Belt Monitoring.

Figure 1. Picture from one of the data collection sessions involving trimming and yield test on loin bones (*lumbar vertebrae*).

Using modern AI machine learning (*Deep Learning Neural Networks*), classification models were created for the automatic location and recognition of several different bone segments. The excellent identification results were subsequently applied for the development of individual segmentation models to estimate specific meat-to-product ratios for different bone segments.

When applying DEXA data, the meat and bone segmentation was achieved through a combination of specialized DEXA analysis methods and machine learning models that were trained on reference data material from CT scanners available at DMRI. It was found that thick bone segments would invalidate the prediction of soft (meat, fat, cartilage, etc.) tissue thickness, so that only soft tissue on the edges of the bone would contribute to the meat-to-product ratio. Therefore, the ratio was more accurate for bone segments that exposed soft tissue outside the bone structure, e.g., the loin bone (*lumbar vertebrae*) whereas for the blade bone (*scapula*) most of the soft tissue was naturally obscured by the bone.

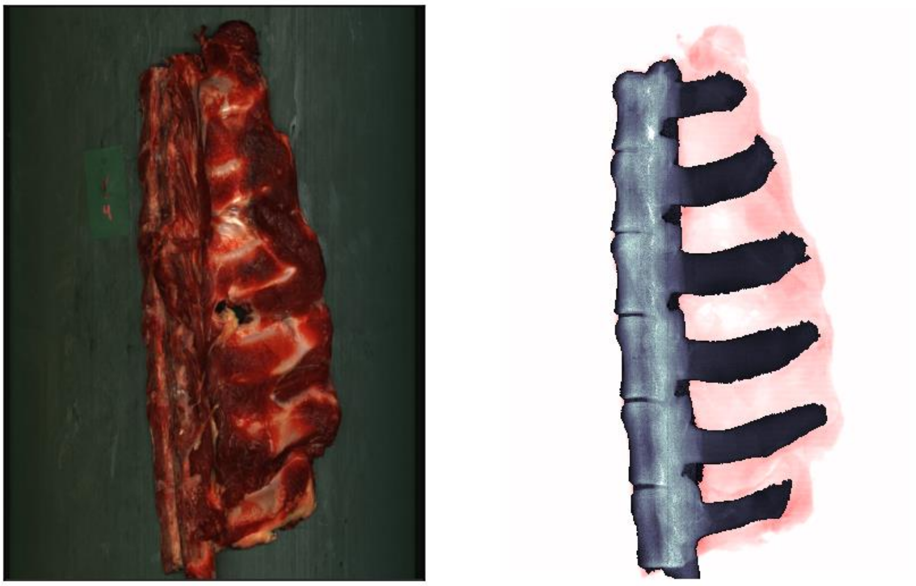

Figure 2. Meat and bone segmentation for a loin bone (*lumbar vertebrae*) using DEXA data.

The meat-to-product estimates from both RGB+NIR and DEXA were mean averaged and used as input to the trim quality prediction model. This yielded a single model capable of predicting the trim quality for a selection of individual bones with a fair confidence. The basic trend that higher meat-to-product ratio implied worse trim quality was also clear.

Using linear regression methods, a weight prediction model was developed for estimating the amount of recoverable meat between trimming scores. The slope of the regression line indicated an approximate 200 g of recoverable meat per trim level, based on the weight data from the yield test performed on multiple loin bones (*lumbar vertebrae*). The weight prediction model gives an indication of the amount of recoverable meat and thereby the specific value that is lost at the bone belt.

Finally, algorithms for automatic detection of foreign objects were demonstrated for low density plastics and pieces of rope and string of blue colour. Low-density objects down to a few millimetres were successfully detected.

The two measurement technologies, Vision and DEXA, each has its advantages and disadvantages. For vision-based methods, the surface is visible but offers only indirect evaluation of the thickness of the material. This makes vision well suited for bone segments, where the bone is presented visible and visually distinct from the meat. In contrast, DEXA technology can detect the soft tissue and bone thicknesses but is incapable of measuring meat on top of the bone. The combination of the two technologies is promising in that the combined prediction model performs better than the individual models, but also due to the fact that with both technologies more advanced model selection is possible. After identifying a bone segment, the technology that is best suited can be used for prediction. On the other hand, having both technologies will significantly increase the equipment cost, the complexity, and the operating costs; especially since the x-ray system requires special shielding, more involved safety testing and documented radiation approval.

As the DEXA technology comes at both a higher CAPEX and OPEX, it is relevant to balance whether the proven, but minor, increase in precision of the recoverable meat to be harvested, can justify the increased complexity and cost over a simpler vision solution.

In the AMPC and industry context, it is recommended to start out at an Australian processor’s bone belt with focus on validating how much of the potential can be harvested by a vision setup alone. If the potential and value creation is very significant, the next likely step up could be to explore either a 2 or 3 side free fall/waterfall vision solution compared with a combined DEXA and RGB+NIR solution.

Benefit for Industry

In a production setup, the trim score of the individual bone is of less interest than the development in the average trim score over time (say, a few hours). By monitoring the continuous average of trim quality by a constant unbiased method, the recoverable meat can be measured, and corrective actions taken to harvest. It is expected that the prediction models are sufficiently accurate for monitoring the recoverable meat level or trim quality as a KPI for the full production and even at specific bone segment level, over specific time periods. Thus, the solution can be used as a valuable optimisation tool for the overall performance of the boning room.