Snapshot Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Bone Belt Monitoring

Bone Belt Monitoring – Vision RGB+NIR Stage 2

Project Code	Prepared by	Date Submitted
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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. This 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 RGB + NIR Stage 2" is to adapt and refine an existing high-end Vision System for monitoring the product stream of a bone belt and develop algorithms capable of determining the trim quality of different types of bones and the possible existence of foreign objects in the product stream.

Project Content

The project focussed on the following topics and activities:

- Adapt and configure the chosen measurement system to be used for scanning bones from cattle in movement on a customized conveyor bone belt.
- Perform 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 to produce a specific yield-based dataset 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 inline Bone Belt Monitoring system based on advanced Vision technology.

Project Outcome

DMRI has developed a high-end Vision Platform, which consists of a multispectral camera system (RGB+NIR) capable of continuously scanning meat products through fast line-scan measuring. The equipment was adapted for the purpose of this project to provide image data of bones on a conveyor system customized for bone belt monitoring. The Vision system was configured, and software was developed to enable automatic collection of full images of each bone segment in the subsequent lab sessions.

Bones from cattle were sourced from separate processors from the local meat industry to be used in lab sessions. The learnings from the lab experiments were used to design larger data collection sessions, where the purpose was to gather large and suitable datasets of images from all types of 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 temperature 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 recoverable trimmed-off 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. Pictures from data collection sessions involving trimming and yield test on bone segments (Vision equipment is placed in front in the picture to the left).

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

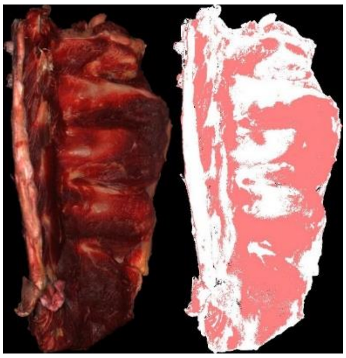
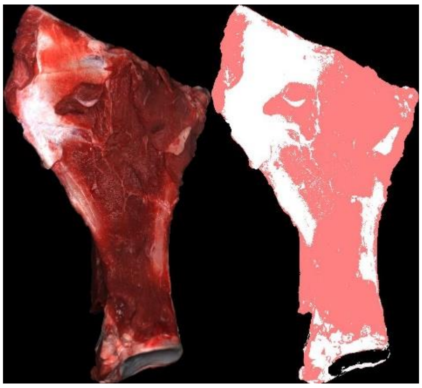
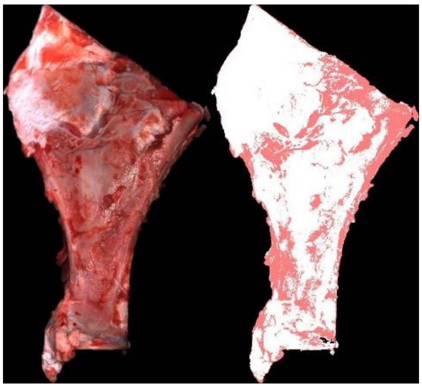
	Trim score 5	**Trim score 1**
Loin bone *Lumbar Vertebrae*	 Meat/Product ratio: 51%	 Meat/Product ratio: 10%
Blade bone *Scapula*	 Meat/Product ratio: 64%	 Meat/Product ratio: 28%

Figure 2. Examples of different types of bone segments for trim score level 1 (very good) and 5 (very poor), and the results of the segmentation models into meat and bone. The false colour grading to the right is given by: Red = meat and White = bone. The meat-to-product ratio is estimated by the proportion of pixels belonging to meat vs. the entire product.

From the segmentation models, the trim quality could be predicted as well. It was found that most of the examined bone segments followed the basic trend that higher meat-to-product ratio implied worse trim quality.

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 of 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 robe and strings. The Vision System is designed to detect many types of coloured foreign objects down to a few millimetres in size and at a very fast pace, up to 1 meter per second. This allows the foreign detection to be featured alongside a setup for continuous Bone Belt Monitoring.

The business case and payback time for the individual processor using this Bone belt monitoring solution will depend on many factors, e.g., the current level of performance in the boning room, the price of beef, the production volume, the carcasses processed, and not least how well the users are able to apply the data for a continuous improvement of the operation, by correction and training instructions etc.

With the feedback of data on KPI's from the solution, it is considered feasible changing the boning room performance for many processors by harvesting an additional 500 g of meat product on average, from the full bone segments of each carcass. In this case, the payback time for the investment would be in the order of approx. 3-6 months depending on production volume.

In the subsequent project Stages, it is recommended to build and install an in-line equipment at an AU processor facility to further develop and test the solution from a continuous product stream. The measurement system must run for an extended period of time for fine tuning and validation of the estimated KPI's, along with some sample verifications of the individual bone segments by actual weight of recoverable meat, for necessary bias adjustment at bone level.

Benefit for the 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.

Useful resources

DMRI, Plastic Detection made Easy, 2022, https://www.dti.dk/specialists/plastic-detection-made-easy/39325