final report

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P.PSH.0909 Automated 3D Non-Uniform Volumetric Primal Box Packing for Beef

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Abstract

The automation of box packing in the meat processing industry has been identified as function that offers high levels of return on investment. Packing chilled beef primals has been highlighted as having high OHS risk, low added value and a significant error rate.

The work presented investigates a typical beef packing process and developing a compatible concept to identify primal beef cuts, track, pick from the conveyor and place into the correct carton. A proof of concept machine has been built and trialled at a beef processing site.

Executive summary

Observations have shown the beef box packing process is very labour intensive as a result the packing rooms are often congested and disorganised. This often leads to incorrect products being packed or boxes being labelled mistakenly. The process also requires staff to lift large pieces of meat over long periods of the day leading to health and safety risks. The use of automation in this process offers attractive returns for the processor.

An automated packing machine has the requirement to identify the correct primal items, pick up this product and pack into the correct box. Key to the effectiveness of this system will be to optimise how the products are packed to ensure the least number of boxes are consumed and distribution costs are minimised.

An investigation of previous work and visits to processing sites has allowed engineers to develop some raw concepts of what an automated packing machine could look like. A set of primary components were identified; these include a vision system to classify the primal product, encoded conveying to allow for tracking of the product, a gripping tool to pick and place the product and a robotic arm to transfer the primal into the box.

In the initial phase of this project a site was chosen to trial the collection of vision data and observe the current packing process to understand the challenges for machine design and operation.

A requirement of this project, was to identify a single product that would be used for the proof of concept trial. The short-loin primal was chosen, as it is produced in significant production volume, relatively easy to recognise and is of a shape that was challenging to pick and pack using automation.

A gripping mechanism has been designed that is compatible with the environment and provides a robust mechanism for picking accentuated shapes, such as the short-loin product. The transfer from conveyor to box is conducted by a 6 axis robot that provides the required capacity and reach for this process.

Vision systems have been built with two key tasks. Firstly to capture the external surface geometrical information that will provide coordinates to allow tracking and robotic picking and optimised packing of the product. Secondly, to capture images and subsequent vision analysis that can identify and classify the primal product so it can be packed into the correct box.

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1 Background

1.1 Design Process

1.1.1 Identification of Primal

Report A.TEC.0093 Picking, Packing and Materials Handling Review had identified primal visioning systems as an enabling technology with the potential to enhance and support different materials handling applications across the meat industry. In particular, the Greenleaf authored report had highlighted primal identification as a priority consideration. Work has been completed, P.PSH.0739 Objective Primal Measurement, investigating the possibility of identifying specific geometrical characteristics for each primal based on 3D images.

A careful approach was taken, the trial was performed offline. This meant we were taking images of a known product and we were able to record how each box was packed.To do this an image capturing unit was designed and built that could be placed over the top of a conveyor, it was designed so that it could be fitted over existing conveyors also. The over conveyor frame supported multiple three-dimensional line rulers and high definition colour cameras. Data capture involved removing boxes of primal products from a packing line removing each in turn and placing on the scanning conveyor.

Some processors are also using barcodes to identify the cuts in the report A.TEC.0107 Concept Design and Feasibility Assessment for Picking and Packing Automation Solution. This is recognised as widely used across industries. The authors did refer to limitations where barcodes are not clearly visual to the barcode reader. Often barcodes are obscured, water or blood damaged or the label printing machine is malfunctioning.

1.1.2 End of Arm Tool (Gripper)

Engineers were also able to observe and understand the physical process of packing primals into preformed boxes. Decisions were made for the likely design required to pick and transfer the primal from the conveyor to the box. Report A.TEC.0107 had proposed a gripping tool to utilise vacuum and gripping mechanisms that would be most likely to pick the large products to be packed. However, there were limitations, these became apparent when the site visits were made.

1.1.3 Proof of Concept Development

Report A.TEC.0117 does point out that “It is generally cost prohibitive to develop a solution that can automate a task 100%”. It is also noted in a study previously conducted (A.TEC.0108) that due to the wide range of cuts often processed, that a system “that detected and sorted the top 10 cuts would be a good starting point”. The observations made at JBS Brooklyn do confirm these observations. The concepts and designs developed are looking primarily at the larger cuts, as these represent the majority of boxes that are packed. These are often packed 2-4 cuts per box whereas other products may be pack 8, 10 or even more cuts per box, often in a complex arrangement.

2 Project Objectives

The first core development will be the Vision required to identify the primal pieces and box barcode scanning. A series of site trials using colour camera and 3D scanning will be undertaken. A full range of primals will be scanned and analysis done to identify how reliably each primal can be identified. From this 1 primal will be selected for the proof of concept packing rigs. Further vision work will be done to develop an analysis algorithm to determine box fill optimisation based on primal volume, shape and box fill level.

The second core development will be a proof of concept robotic product tracking to enable product to be tracked and picked off a moving belt.

The Third core development will be a proof of concept load station which will magazine boxes, incorporate a load fixture for controlled loading of the primals to the correct fill. A refinement of gripper concept to reliably pick up a range of primals and proof of concept product loading for the primal identified in the vision development above will be trailed at a factory level.

The final stage will be a concept design to tie the above developments together to form a concept for an Alpha prototype pick and pack machine that can be put forward as a subsequent project.

3 Methodology

3.1 Milestone 1b – Vision and Sensing

Applicable Vision and sensing means prior art was researched and background established. A processor site was visited and the packing process investigated.

Vision and sensing alternatives have been established and the preferred solution proposed. A "prototype" rig was built with the preferred vision and sensing solution and taken to the processor production site and run to capture a significant quantity of product data. With the product data the product identification analysis has been developed.

Measurements were taken to capture a full range of beef primal cuts, at JBS Brooklyn site.

3.2 Milestone 2 – Production Prototype Machine for trials at Processor site

The scope for the design of the production prototype machine, including the vision and sensing means, conveyance and robotic pickup and placement was formed out of the outcomes from Milestone 1b.

The design was done and prototype machine built by Scott Technology in Dunedin.

3.3 Milestone 3 – Concept design of Production system for subsequent project

A literature search and review of prior art was performed to form a baseline for creating a concept design of the robotic picking and packing system. Additionally the concept drew, particularly, on the vision and sensing means and site trials that we performed in milestone 1b.

The concept has been 3D modelled for ease of visualisation.

3.4 Milestone 4 – Final Milestone

The final milestone is to demonstrate the objectives. The three core objectives are;

1. 3D and colour scanning to identify one model of primal piece. And box fill optimisation based on primal volume, shape and box fill level

2. Proof of concept product tracking to enable robotic picking of the product off a moving conveyor.
3. Loading primals to the correct fill, with refined gripper concept and box loading, trialled at processor production site.

The first step employed was to commission the production prototype machine to demonstrate core objectives 1 & 2, on sample parts, at Scott's development facility.

The second step was to install the production prototype "off line" at the processors production site and run a batch of products through the machine. The trial is to demonstrate the correct identification of the one primal model, from representative production, determine the appropriate pickup position, make the correct volumetric determination and place the product in the box.

4 Results

4.1 Milestone 1b – Vision and Sensing

Applicable Vision and sensing means prior art was researched and background established. A processor site was visited and the packing process investigated.

Vision and sensing alternatives have been established and the preferred solution proposed. A "prototype" rig was built with the preferred vision and sensing solution.

4.1.1 Results of Site visits

Currently primal cuts are placed inside plastic bags, these bags are then vacuum sealed before being fed into a linear packing line conveyor. As the specific cut is identified, by the packer responsible for this product, it is picked off the conveyor and packed into the correct sized box. Boxes, or more correctly corrugated trays, are machine erected in an external location and typically conveyed to the packing room.

The unique shape of each primal means that a specific packing pattern is used for each primal type and size. This schedule of primal type plus primal size being aligned to a specific packing arrangement ensures an experienced operator can optimise the packing.

There are three different box sizes.

At the processor production site, they have three Cryovac vacuum packing machines which all feed into the manual packing line. It has been proposed that identifying primals automatically would significantly benefit from replication of the sensing means on each Cryovac line.

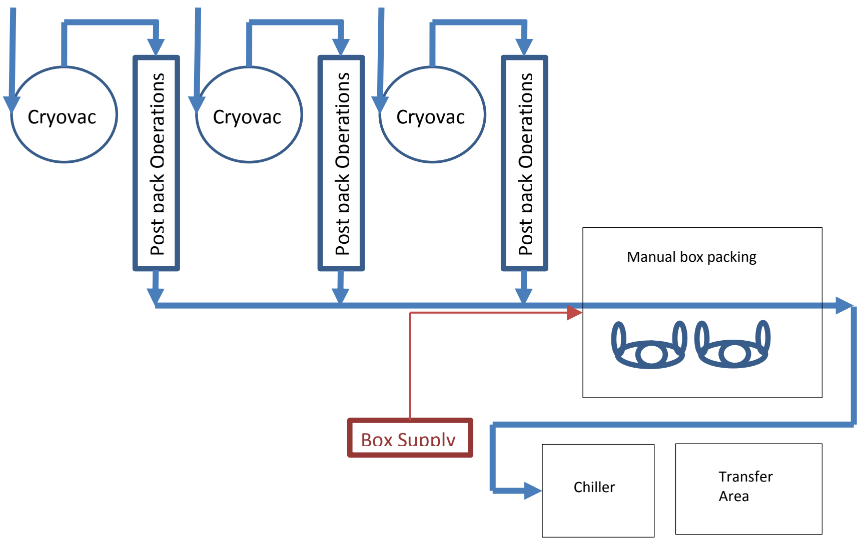

Figure 1: Simplistic schematic of relevant portion of existing box packing processor production process

4.2 Milestone 2 – Production Prototype Machine for trials at Processor site Development outcome

The production prototype machine has been developed and built, based on positive results from milestone 1b.

The machine consists of;

- A vacuum packed product conveyor
- Two Line rulers, which are designed to capture precise dimensions on a moving belt
- Three industrial cameras, to collect high definition colour photographs
- Kuka KR60 robot with a custom developed end effector to pick up the irregular product shapes
- 3D vision analysis system which is used to locate the pickup position on the product and contribute to the model identification
- 2D vision system and model identification.
- Box station, where the robot loads the product.

Fig. 2 Production Prototype machine robot cell

Fig. 3 Infeed conveyor and Sick ruler scanner housing

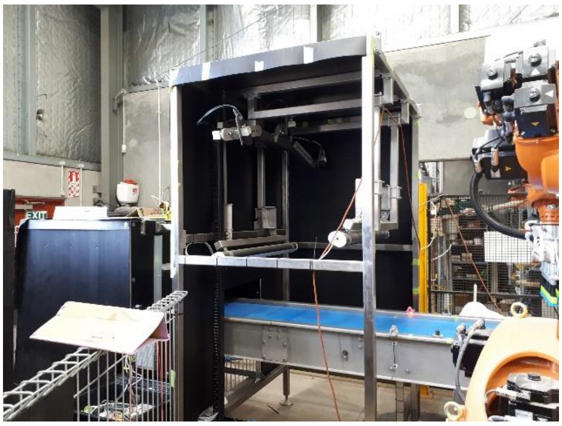

Fig. 4 Three Baumer cameras mounted up in a frame

4.3 Milestone 4 – Final Milestone

4.3.1 Second Core Development – Product Tracking

Video, photos and output tables showing product tracking functionality

4.3.2 Third Core Development – Proof of Concept Pick & Pack

4.3.2.1 Trials at Scott's factory

Trials have been completed using large short-loins. These are NZ produced short-loins and are much larger (9kg average) than the short-loins observed in JBS Brooklyn (6kg average). These have however been picked from the belt and placed accurately inside the box. These large short-loins are placed 2 per box typically, hence we have packed these 2 per box for this trial.

4.3.2.2 Trials at Processor production facility

Photos and percentage accuracy data to be added after the trial at processor.
Photos to show adaptive pickup position and angle.
Photos to show representative sample of short-loin packing end result.
Output tables to show accuracy of pickup, robustness of holding product, success of placement, correct volumetric determination, accuracy of inferred weight determination.

5 Discussion

5.1 Packing Arrangements

During data collection trials observations were made on the packing process. Photo records were made of orientation of the different primals inside the box, a production report has also been used to build an understanding of the optimum count of primals per box.

Figure 5 Simple placement (prime chuck roll). Complex placement (Short-loin)

Some primals items are specifically packed with fat side to top, this is important to prevent discolouration of the fat side.

Figure 6 Fat side up placement - Strip-loin

The picking, transfer and placement has been designed around simplicity of process as a guiding principle. This will require some behavioural change for the bagging operators, all items will need to be located in the vacuum packing tunnel fat side up, so we can replicate packing shown in Figure 22. From our observations there is a single exception to this rule, the short-loin is packed with fat side toward the side wall of the box. It is highly likely short-loin is the only cut that does not follow this "fat side up" rule. We do recognise that there will be a need to flip a small number of products over however this will be considered as we learn more about the production requirements and cycle times demanded.

5.2 Optimised Box Fill

Each primal type is a unique shape, the dimensions also influence the arrangement on how these pieces are placed inside a box. This project has engaged discussions and observations with the packing people, we will follow the standard packing patterns that are used to ensure the packing is as efficient as possible. Figure 23 -26 show the same product, but packed in differing arrangements according to the size of the product. This will be an important feature in optimising the box fill optimisation. Data collected from the processors production data indicate that across a week of production there will be a mix of packing arrangements, for example of 1592 boxes of Prime Chuck Roll produced 1459 boxes were packed 2 per box and 133 boxes were packed 3 per box.

Figure 7 Prime chuck roll with 3 (Weight 22.9) and 2 (Weight 16.8kg) per box

In the proposed automation, the vision system will recognise the primal type and measure dimensions, an estimation of the product weight will be made. This combination of factors will determine the appropriate packing pattern. Essentially this is replicating the current decisions that the packing personnel are making, however the ability to be more accurate and allow software interventions will allow the processor to optimise the packing efficiency directly.

Figure 8 YG-Rump with 4 per box (695 box across chosen week) and 3 per box (25 boxes on chosen week)

6 Conclusions/recommendations

The identification of vacuumed packed beef primals with the application of vision has been demonstrated to give reasonable accuracy for short loin primals. The application of 3D ruler scanners and associated analysis software to determine the robot pick-up position for consequential correct product placement in the box has been successfully demonstrated at a processor production facility. The concept for a subsequent project has been proposed. Establishing the value proposition and aligning the opportunities presented in this project will be a key starting point for a subsequent project.

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