AUTOMATED SHEEP BRISKET CUTTING

Peter Condie, Kym MacRae, Peter Ring and Philip Boyce
Food Science Australia (CSIRO)
Cnr Creek and Wynnum Roads, CANNON HILL 4170, AUSTRALIA
Peter.Condie@csiro.au, Kym.MacRae@csiro.au, Peter.Ring@csiro.au, Philip.Boyce@csiro.au,

Abstract

Food Science Australia has been developing sensing systems that are suitable for use in automating tasks commonly seen in Australian meat processing plants. This paper discusses the process of automating the sheep brisket cutting task. The prototype automated system was defined and developed and a standard manual brisket cutter was adapted to an ABB industrial robot for demonstration to industry. The prototype system scanned, analysed and cut the brisket of sheep carcases in less than 6 seconds to conform with Australian production speed.

1 Introduction

The meat processing industry in Australia is continually aiming to reduce the labour intensity of processing operations through the research and development of automation in slaughter facilities.

The AMPC[1] and MLA[2] have funded Food Science Australia, a division of the CSIRO to investigate automation within meat processing plants.

The successful development of an automated brisket cutting system for sheep processing plants is an example of the potential of modern sensing technology to increase the feasibility of automation in meat processing.

1.1 Background

Literature on techniques to implement automation of meat processing includes discussion of sensing for beef scribing [Li and Hinsch, 2003] using colour extraction, threshold, and parameter removal functions; Y-cut for sheep pelt opening via specialised tool design and fuzzy nueral network trained paths [Hurd *et al*., 2005; Tuck *et al*., 1999]; and tactile contour following sensing and carcass stabilisation for beef brisket cutting [Templer *et al*,. 2002]. The success behind the development under discussion was due to extensive investigation of the manual task and working environment, so that clear understanding of the prototype specification could be achieved, before implementation.

Sheep, as a product, are relatively more consistent in size and weight during production than beef. The lower variation in the presentation of sheep carcases opens the possibility of investigating the application of new sensing technologies for the automation of meat processing in general.

While some semi-automated systems or operator-assist equipment have been developed for existing tasks on the slaughter floor, the fully automated system must allow for sufficient variation of the presented product. The automation of more complex processing tasks must include advanced sensing in the system to provide more detailed information on each carcase.

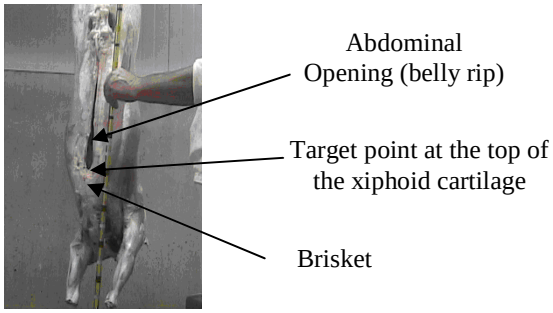

Figure 1 - Carcase

The manual task of brisket cutting was investigated (see Figure 1) for automation because of the perceived simplicity of locating the xiphoid cartilage at the bottom of the abdominal opening on the carcase.

2 Task Definition

Previous projects have demonstrated that Australian processors require that the goals of automation projects need to be defined as a project target before the system can be considered for implementation into a plant.

Manual brisket cutting (see Figure 2) was studied at different plants and a specification of a successful cut was established [Boyce and Ring, 2005].

1 Australian Meat Processor Corporation.
2 Meat and Livestock Australia

Figure 2 - Manual Brisket Cutting

The specification referred to the results of an automated cutting system in terms of the observed results of manual cutting systems. The definition included the central location and accuracy of the cut through the brisket, along with requirements to avoid damage to organs (heart and lungs, refer Figure 3) adjacent to the brisket during the cutting process.

The organs are separated from the carcase during processing, and are sold by the plant as a by-product. The quality of the organs as a product is reduced by any damage that occurs during brisket cutting.

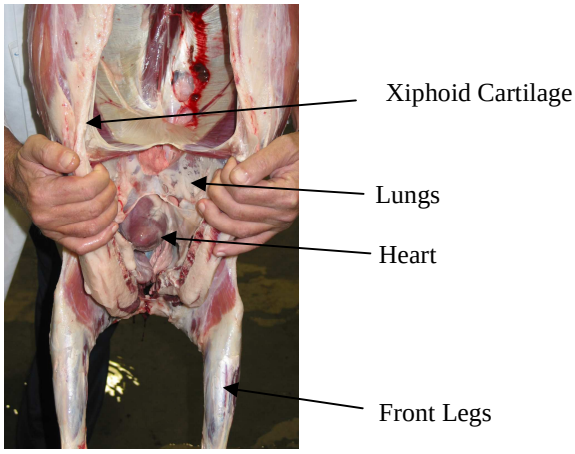

Figure 3 – Location of Organs

The specification also gave limits to time allowed to perform the task so that the automated system could be retrofitted to existing processing plants without reducing the speed of production.

3 Sensing Sub-systems

The development of an automated brisket cutting system firstly required the testing and selection of sensing equipment for this application. The sensing sub-system tests were firstly performed during plant visits and subsequently in the laboratory as part of a complete robotic system development.

3.1 Sick LMS400 Laser Profiling System

A LMS400 (*SICK Sensors, Waldkirch, Germany*) laser profiling system, shown in Figure 4, was firstly tested as a possible method of detecting the three dimensional location of the xiphoid cartilage at the bottom of the abdominal opening.

Figure 4 – Sick LMS 400

The laser profile scanner provided a two dimensional (2D) scan of distance measurements (in millimetres) to the sensor over a 70 degree angle at 0.2 degree steps.

The laser profile data displayed a detectable change in distance measurements as scans were acquired across the abdominal opening. This transition was tracked over several scans so that the bottom of the abdominal opening (Z plane) could be found. The measurement at this point also gave the horizontal distance from the sensor to the chest (Y plane).

The data from multiple laser scans was compiled to display a three dimensional (3D) laser map of the carcase, shown in Figure 6. The compiled scans could then be analysed to detect cuts that projected below the top of the xiphoid cartilage point.

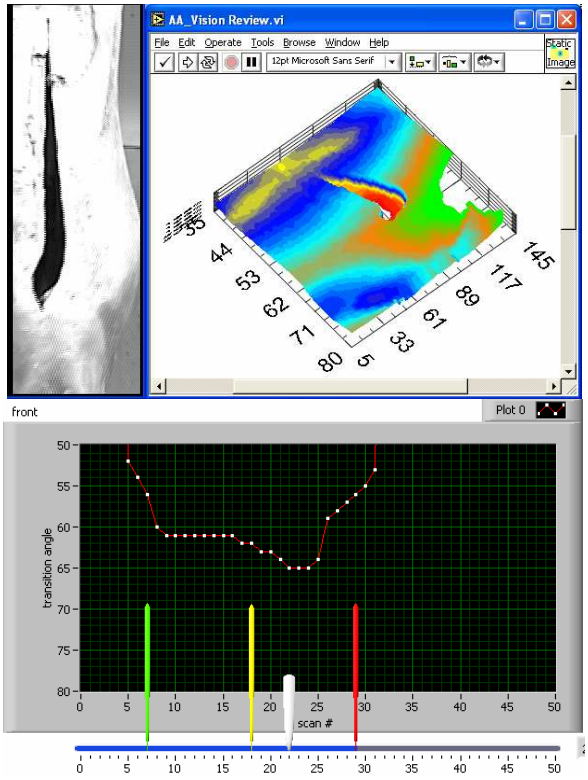

Figure 6 - Results of 3D laser profile showing how the xiphoid cartilage point is determined for horizontal distance measurement

The conclusion drawn from the testing of the LMS400 was that it is suitable to measure horizontal distance (Y plane) and vertical height (Z plane) co-ordinates. However any excessive carcass movement through the scanning beam on the production line, could cause the 3D map to be unreliable.

3.2 Video Image Acquisition and Processing

An image processing system was developed for plant and laboratory testing using a CV-3200 (*JAI Cameras ,Glostrup, Denmark*) camera connected to a PCI-1411 *(National Instruments, Austin, USA)* image capture board configured to capture and process grey scale images.

Figure 7 – CV 3200 Camera

The resulting live image was captured at 25 frames per second. Captured grey scale images were analysed to detect and track the shadow of the cavity.

Lighting was critical with the imaging system, as the function of the image analysis software was to analyse the shadow created by the cavity above the xiphoid cartilage. Under ideal conditions lighting should be maximised from below and minimized from above the carcase. During plant testing the lighting conditions were not able to be altered, so the image quality was improved by altering the camera aperture to give a workable image

Once the cavity shadow had been identified it was analysed with the original image in a four stage process as shown in Figure 8, to find the equivalent position of the centre and the top of the xiphoid cartilage located near (but not always at) the bottom of the cavity. Unusually shaped cuts also had to be detected when the abdominal opening had extended beyond or around the xiphoid cartilage. A final image showing the original carcase overlaid with the co-ordinates of the analysed xiphoid cartilage (brisket point) was shown on the computer screen for validation.

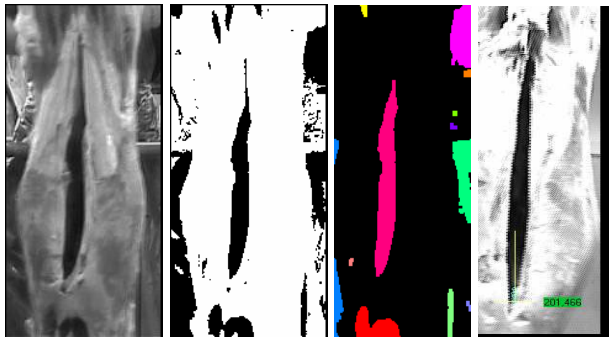

Figure 8 – Four Stages of Image Processing

The processing of carcase images from a single camera provided quality location data in two planes, but is not capable of measuring horizontal (Y plane) distances to the carcass.

Image processing did however have the advantage of requiring less time to identify the target feature on the carcass. Less carcass stabilisation was also required, provided lighting was selected and placed correctly.

3.3 The Effect of Carcase Stabilisation

The data collected during plant visits for this project included tests to quantify the effect of carcase stability on the reliability of data collected with sensing equipment. The results of measurements acquired during two plant visits are summarised in Tables 1 and 2. The results from the second plant visit include 175 laser scan measurements that were taken with the carcases manually stabilised on the conveyor chain.

Location	Number Scanned	Ave Y (mm)	Min (mm)	Max Y (mm)	Std Dev Y
Plant A	700	1206	1078	1308	13.7
Plant B (Total)	700	1837	1762	1932	70
Plant B (Stabilised)	175	1839	1809	1875	11.5

Table 1 – Variation in LMS400 Distance (Y) Measurements from Plant Visits

Location	Number Scanned	Ave Z (mm)	Min Z (mm)	Max Z (mm)	Std Dev Z
Plant A	700	8	-167	-162	57
Plant B (Video)	80	77	0	160	30
Plant B (Total)	700	34	-175	179	34
Plant B (Stabilised)	175	36	16	97	25

Table 2 – Variation in LMS400 and Video Image Analysis Height (Z) Measurements from Plant Visits

The accuracy of both the laser and imaging systems was found to correlate to the stability of the carcase.

Considering the size of the standard deviations of this information indicates that stabilizing carcases dramatically improves the quality of the horizontal measurements, while the vertical measurements are

slightly improved.

3.4 Combined Sensing System

The final measurement system combined image and laser profiling equipment with analysis software. The system is controlled by a Labview program that incorporates algorithms for detecting the bottom of the abdominal opening and measuring the location of the target point in the horizontal (X) and vertical height (Z) planes.

The program calculates the horizontal distance (Y) to the target point using the data acquired from the LMS400 and displays all three co-ordinates (X, Y and Z) in millimetres.

The camera and laser were mounted on a single tripod during testing to avoid interfering with normal production.

4 Carcase Stabilisation

The carcase is required to be presented with the abdominal opening facing the sensing equipment during detection and location of the point of the xiphoid cartilage. A double rail system was developed at the FSA Cannon Hill test facility to maintain stabilisation of the carcase.

Once the carcase has been oriented (carried out manually for testing), the holding gambrel that suspends the carcase can be captured by the double rail system to stabilise of the carcase. The double rail system, as shown in Figure 9, contains the gambrel and prevents the carcase spinning, while still allowing normal travel along the rail.

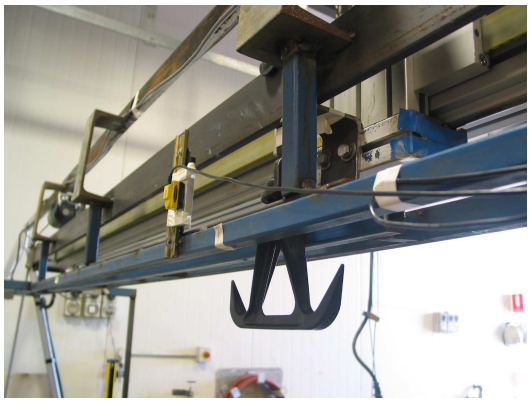

Figure 9 - Double Rail Conveyor System for Gambrel Stabilisation

5 Automated Robot System

5.1 Tool Selection and Sterilisation

There are mainly two types of brisket cutting tools used by the Australian Processors. They are either a circular saw or pair of shears.

The shear type tool is the most commonly used throughout the industry and can be pneumatically or hydraulically operated. The main advantage of the shears is that they do not produce bone dust during the cutting process. The bone dust can become airborne and possibly directly or indirectly contaminate other carcases.

A suitable cutting tool, the EFA Z100 *(SKF, Goteborg, Sweeden)* best met the requirements for mounting onto the robot for this project.

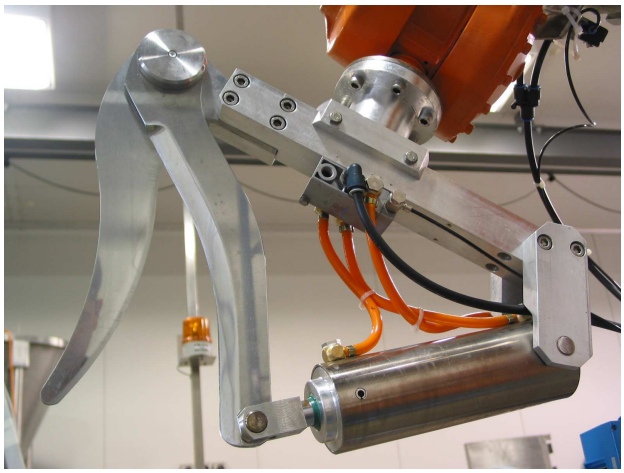

Figure 10 – EFA Z100 Shears and Robot Adaptor

Shown in Figure 10, the brisket shear end effector developed for the project is a pneumatically operated device incorporating a solenoid valve to control the air flow to the air cylinder. The solenoid is driven by a +24VDC digital output inside the robot's controller module.

The brisket cutting stations on sheep slaughter floors are required to have sterilising facilities for cutting equipment [AQIS, 1988]. One of the major advantages of using an automated system in preference to manual brisket cutting is that a wash cycle of the shear device can be designed into the process. The automated system can be monitored through data logging, to guarantee that washing or sterilising is carried out after every cut for quality assurance. For this reason a steriliser containing hot water was placed on the processing floor so that it could be included into the complete process and robotic path.

5.2 Robot

The development robot used in the trials at the processing facilities at FSA was an ABB 4400 robot (shown in Figure 11) controlled by an ABB S4+ robot controller. The S4+ controller was fitted with an ABB DSQC 354 encoder interface unit to allow product to be tracked on the conveyor system. Conveyor tracking software was also installed on the S4+ controller.

The motivation to use commercial industrial robots rather than purpose built machines is that industrial robots possess proven positioning performance, sound safety records, operational reliability and have replacement parts and service technicians readily available [Li et al, 2004].

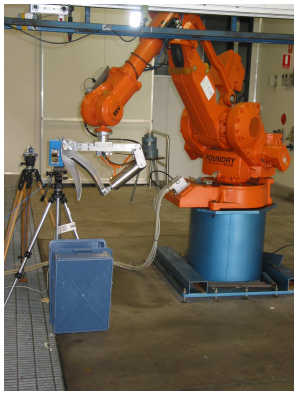

Figure 11 – ABB 4400 Industrial Robot

5.2 Communications Interface to the Robot

An RS232 serial interface was used to communicate between the robot and the PC based sensing software. The amount of information that is required to be transmitted was reduced to a text string of 10 characters containing the co-ordinate offsets of the target point in the Y and Z robot reference planes, relative to a designated brisket marker point.

For a horizontal offset of -150 and vertical offset of -100 a co-ordinate transmission would look like:

-150-100<CR><LF>

A carriage return (<CR>) and line feed (<LF>) terminate the string. The robot program returns the full offset position as a string as:

[0,-150,-100]

The transmission time for the co-ordinate offsets from the computer is under 20 milliseconds. The text string is processed and a reply transmitted in under 200 milliseconds from the robot. The latency period for data transmission was low enough to not require high speed transmission.

5.3 Systems Component Integration and Timing

A normal small stock processing line is susceptible to stopping and starting at irregular intervals. For this reason a conveyor tracking system was installed at the test facility at FSA [Ring, 2005].

The imaging automatically started processing as soon as the carcase arrived at the camera. The laser was activated by a proximity switch mounted on the conveyor when the carcase moved into to the scanning position. The conveyor tracking was integrated as part of the ABB S4+ robot controller and also required a trigger signal from a proximity switch. The system diagram is shown in Figure 12.

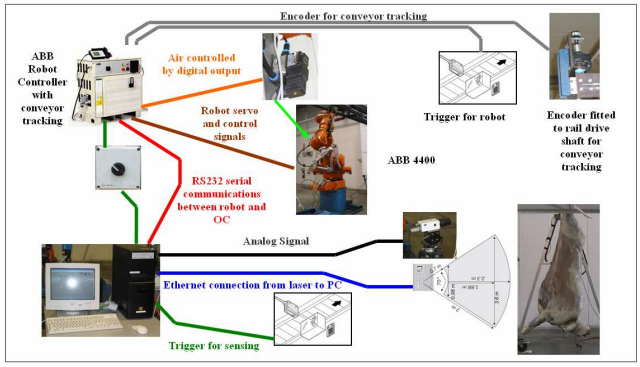

Figure 12 – Complete System

The processing times for the complete system were monitored and recorded using time lines. The analysis of time lines throughout robot path development showed cycle times were generally dependent on optimising the position of the sterilisation unit relative to the robot and carcase, and well within industry six second cycle requirements.

5.4 Robot Cutting Path

The target point at the bottom of abdominal opening on each carcase was located by the sensing system and transmitted to the robot controller. This point was used as a reference to place the meeting points of the brisket shear blades [Ring, 2005].

The correct placement of the cutting tool was achieved, by moving the top blade of the brisket shear inside the empty abdominal cavity to pierce the diaphragm. The diaphragm was pierced to the right of the carcase centreline, and towards the back of the carcase. This alignment prevented contact between the heart and lungs of the carcase and the sharp edges of the blades to avoid damage to these organs.

Once the diaphragm had been pierced, the blade was moved down the length of the carcase towards the neck, before being tilted to match the preset angle of the inside of the brisket. As the blade contacted the brisket bones the robot continued to move the tool vertically down an additional distance, stretching the carcass slightly and providing additional stabilisation to the carcase prior to the cutting action (refer Figure 13).

Figure 13 – Robot's Cutting Position

The tool was removed from the carcase using the reverse of the entry path. The reverse action allowed the organs to return to their original position without contacting the sharp edges of the blades.

5.5 Cutting Results

Following each robot test the organs on each carcase were inspected for damage and photographed. Examples are shown in Figures 14 to 16.

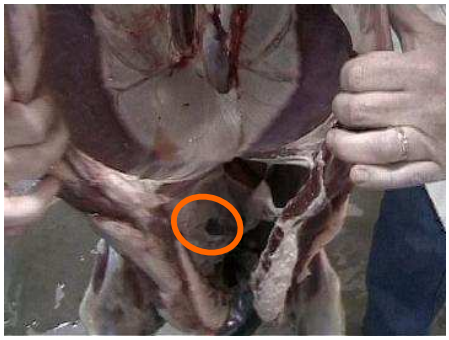

Figure 14 – Small cut in heart sack, organs remain untouched

Figure 15 – Small cut in heart, lungs remain untouched

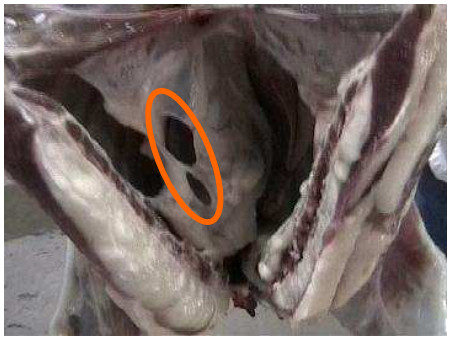

Figure 16 – Small cut in heart sack, organs remain untouched

The damage to the organs that occurred during robotic brisket cutting trials was reduced through optimisation of the robot path. The robot path was tested on twenty carcases at the FSA testing facility and the last twelve did not receive any organ damage. All carcases were cut precisely along the centreline of the brisket as specified.

Figure 17 – A chilled carcase that has been successfully cut along the centreline of the brisket

6 Conclusion

The major advantage of automating brisket cutting in sheep processing plants was the ability of the system to replace up to one labour unit per shift. However the replacement of staff at this station impacts not only labour costs, but also improves workplace health and safety in the plant through the avoidance of repetitive strain injuries and accidental lacerations, and food quality through sterilisation. Savings are also achieved through repeated accurate processing of carcass product.

The successful results of sensing system trials during plant visits, and robotic path demonstrations at the FSA testing facilities have resulted in this system being recommended by Meat and Livestock Australia for commercialisation. The result of this recommendation is that two Australian plants have agreed to install automated systems for ongoing testing and development with Machinery Automation and Robotics appointed as the commercialiser [MAR, 2007].

The commercialisation process will require further communication with Food Science Australia to ensure the resultant system meets the requirements of the meat processing industry and government regulators.

References

[AQIS, 1988] Australian Quarantine Inspection Service. *Construction and Equipment Guidelines for Export Meat.* Australian Government Publishing Service, Canberra, Australia, 1988.

[Boyce and Ring, 2005] Phillip Boyce and Peter Ring. *Robotic Sheep Brisket Cutter PRTEC.030, Site Visits to Evaluate Current Manual Brisket Cutting Task - Milestone 1 Report.* MLA Report – PRTEC.030 Milestone 1, 2005.

[Hurd *et al.*, 2005] S. A. Hurd, D. A. Carnegie, N. R. Brown and P. T. Graynor. Development of an intelligent robotic system for the automation of a meat-processing

task. *International Journal of Intelligent Systems Technologies and Applications (IJISTA)*, 1(1/2): 32-48, 2005.

[Li *et al*, 2003] Zeng Li, Peter Ring, Kym MacRae and Andrew Hinsch. Control of industrial robots for meat processing applications. In *Proceedings of the Australasian Conference on Robotics and Automation*, Brisbane, Australia, December 2003. Australian Robotics and Automation Association.

[MAR 2007] MAR - Machinery Automation and Robitics. *Brisket Shear* Accessed October 2007. < http://www.machineryautomation.com.au/robotic/brisket.html >

[Ring, 2005] Peter Ring, *Robotic Sheep Brisket Cutting (PRTEC.030) Milestone 9 Report – System Integration.* MLA Report – PRTEC.030 Milestone 9, 2005.

[Templer *et al*., 2002] R. Templer, A. Osborn, A. Nanu, K. Blenkinsopp and W. Friedrich. Innovative robotic applications for beef processing. In *Proceedings of 2002 Australasian Conference on Robotics and Automation*, Auckland 27-29 November 2002.

[Tuck *et al*., 1999] D. Tuck, M. Watts, Q. Song and N. Kasabov. A practical and flexible environment for adaptive knowledge and data fusion applications. In: *Proceedings of International Conference on Applications of Intelligent Systems*, Melbourne, September 1999.