final report

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STAGE 2 OF THE VISION AND LASER SENSING SYSTEMS SUITABLE FOR BEEF AND SHEEP SLAUGHTER TASKS

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EXECUTIVE SUMMARY

This report presents the executive summary from all project step reports with some supplementary information to provide an overview of the work with additional information on the individual project. For more information on individual topics please refer to the individual project reports.

This report also includes the robot path demonstration reports and the following overview of each individual development.

Beef RFID Tag Identification
Initial focus of directly identifying the RFID tag using colour imaging was not robust due to similar tag/hide colours in a number of cases. Project focus was redirected to identify the ear against the background of the head and neck using thermal, vision and laser imaging. This was found to be successful.

Implementation of this technology will require the development of a suitable tool to remove the tag, after the controlled apparatus positioning over the ear is achieved.

As well as tool development, further simplification and cost reduction of the control system should be considered. For example this may be achieved by using a thermal camera to identify the ear position, and a laser pointer mounted on the tool to provide distance measurement.

Sheep Sensing for Head Removal
This sensing task development focused on sensing the neck and head regions adjacent to the a*tlantal* joint to determine the feature profile and position at and adjacent to the narrowest part of the neck. All sheep head severance systems using a mechanical cutting device require the tool to be positioned at the neck with a downward force applied to pull the tool against the back of the skull and jawbone in order that the cut can be made as close to the *atlantal* joint as possible. The accurate measurement of each carcass could provide input to a control system that can adjust to the variability of individual carcass shapes and sizes and could also be used to set the opening of the cutting tool, after positioning at the neck, to the appropriate size for the cut.

Beef Hoof Identification for Shackling
Thermal image processing was tested on over 100 animals and results were shown to an AMPC/MLA representative on May 11th, 2007. Using thermal image analysis to identify the hoof against the background of a slat conveyor was effective provided there was at least 5 degrees Celsius temperature separation between the slat conveyor and the carcass. The temperature of the slat conveyor and the carcasses could be altered using existing wash procedures with small modifications. Testing was also carried out to investigate the potential of using a colour camera system and colouring the slat conveyor blue or green to give a contrast to the hide. The colour system using contrast was trialled with dark animals on the existing metallic-silver

(light) slat conveyor in a plant. A single laser scan, used in conjunction with the thermal vision analysis, determines the upper and lower leg and produces information about the leg position in three dimensions. The thermal – laser sensing system was integrated with Food Science Australia's ABB robot, using a purpose built tool that combined sensor mounting and pointer functions. This system was demonstrated successfully to an MLA representative. It was recommended that the sensing system be developed further to allow real-time tracking of the hooves as required for installation into a processor plant. This system would only be effective on stationary carcasses as outlined by the project requirements.

Sheep Front Leg Spread

Two sensing systems were developed to control this task operation using a laser scan system and a two camera system. Both methods were successful but would require a specialised leg capture system to work with the sensing system to complete the task. The project recommendation is to progress this work to develop the leg capture system.

Beef Leg Roller Insertion

This sensing task development focused on sensing and locating the position where the hook of the meat roller is inserted prior to hanging the carcass on the conveyor rail. The control system positively identified the correct position regardless of whether or not the opening adjacent to the Achilles tendon was cleared. The control system required to insert both left and right meat rollers is the same. Future tool development could include a mechanism to sever the hock after insertion of the roller prior to hoist, as well as positioning the roller on the meat rail, providing automatic operation of these sub tasks.

Sheep Gambrel Insertion

The focus of this task was to develop a system which could identify the gambrel insertion position adjacent to the Achilles tendons on both rear legs of a sheep carcass. The developed sensing system uses two computer-linked cameras to identify the gambrel insertion point.

A method of integrating the developed sensing system with a capture system for the legs which would subsequently position them onto the gambrel has been included. A suggestion to further develop the process to incorporate the sensing system onto the capture tool has also been investigated.

Sheep Hock Cut and Neck Tip

The previously developed control system for sheep neck tipping has been combined with the development of a fore hoof cutting control system to merge both tasks. The developed control system will allow the cutting mechanism to accurately select the fore hoof cut position regardless of the actual position on the gambrel.

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1. INTRODUCTION

Commencing in 2004, the Sensing and Automation science group in Food Science Australia has developed automatic vision and laser scanning systems to accurately detect the location and shape of beef and sheep carcass features, with an aim towards further development of systems to automate processing work task operations.

Also, during 2005, the Sensing and Automation science group completed a project funded by AMPC and MLA: “Investigation and evaluation of Sensors for Adaptation to the Meat Industry” (PRTEC.032) [1] that outlined beef and sheep slaughter tasks suitable to the application and development of vision and laser sensing systems.

During 2005, the “Robotic sheep brisket cutting” project was undertaken to develop a means to detect the location and shape of the abdominal opening, the tip of the brisket for the insertion and application of a robotic brisket shear.

The “Development of vision and laser sensing systems suitable for beef and sheep slaughter tasks” (PRTEC.042) [2] followed in the following (2005-06) financial year. This project progressed further the above work to develop vision and laser sensing for beef and sheep slaughter tasks.

Beef tasks developed under this project were:

- Abdominal-thoracic Hide Opening
- Front Hoof Removal
- Brisket Cut (Hide Removed)
- Horn Removal

Sheep tasks developed under this project were:

- Front Y-Cut VacSan
- Front Leg Reposition
- VacSan Rump Region
- Neck Tipping

Stage 2 of the vision & laser sensing systems suitable for beef and sheep slaughter tasks progresses further the development of sensing systems for process task automation. The tasks investigated in this project are as follows:

Beef tasks:
1. RFD Tag Location for Removal (Vision/Thermal and Robot Path)
2. Hoof Identification (For Tracking) (Vision/Thermal and Robot Path)
3. 1^{st} Leg Roller Insertion (Vision/Thermal only)

Sheep tasks:
1. Sensing for Head Removal (Vision only)
2. Front Leg Spread (Vision only)
3. Rear Leg Gambrel Insertion (Vision only)
4. Front Leg Hock cutting & Neck Tip - combined (Vision + X-ray and Robot Path)

This report provides a summary of the individual reports produced as a result of each of these sensing tasks. If further information is required on any topic, please refer to the individual report for each milestone, with the exception of Milestones 4, 4a, 9, 9a, 18 and 18a, “the robot process path development and demonstration”, where all information is in this document only.

Videos of the developed sensing systems, site and robot demonstrations of the processes in each milestone are included in a CD attached to this report.

2. EVALUATE AND SELECT BEEF AND SHEEP TASKS FROM CATEGORY 1 LIST

2.1 MILESTONE 1: SELECT TASKS

Milestone 1 involved the evaluation and selection of at least 3 sheep and 3 beef slaughter tasks from those identified as "Category 1" in the previous project - "Sensors for Adaptation to the Meat Industry" (PRTEC.032) [1]

Following the evaluation of all the "Category 1" slaughter tasks, FSA pre-selected 7 sheep and 7 beef tasks. The list of proposed tasks, as seen in the table below "First Pass Stage 2 vision & laser tasks" (Table 1), was submitted to the key representative from the MLA (Mr David Doral) for selection and final approval of the minimum 3 sheep and 3 beef slaughter tasks.

Sheep Tasks	Beef Tasks
1. Front Leg Spread	1. Stamp Position (Hind & Forequarter)
2. Rear Hock Tipping	2. P8 Position Measurement
3. Front Leg Hock Cutting	3. RFD Tag Location for Removal
4. Branding & Marking	4. Hoof Identification (For Tracking)
5. Sensing for Head Removal	5. Remove Hock Rear 2nd Leg
6. Abdominal Cavity Cut Path	6. 1st Leg Roller Insertion
7. Rear Leg Gambrel Insertion	7. Dentition

Table 1: First Pass Stage 2 Vision and Laser Tasks

It was initially envisaged that, as in the previous stage 1 project, "Development of Vision & Laser Sensing Systems Suitable for Beef and Sheep Slaughter Tasks" (PRTEC.042) [2], each of the 3 sheep and 3 beef slaughter tasks would include the software development of a vision, thermal or laser sensing system as well as the identification of 3D coordinates and a demonstrated robot path. However during project discussions, MLA indicated a preference for FSA to focus more on sensing software than robot paths for the tasks.

The agreed tasks are listed in Table 2: "Agreed Stage 2 Vision and Laser Sensing Systems Suitable for Beef and Sheep Slaughter Tasks", for development to progress.

The list is made up of 4 sheep and 3 beef tasks. The sheep tasks will involve the development of vision, thermal and/or laser sensing software for 3 of the tasks with 1 task involving the development of the sensing software plus the robot path. The beef tasks will involve the sensing software for 2 of the tasks with 1 task involving the development of the sensing software plus the robot path.

Sheep Tasks	Beef Tasks
1. Sensing for Head Removal (Vision only)	1. RFD Tag Location for Removal (Vision/Thermal and Robot Path)
2. Front Leg Spread (Vision only)	2. Hoof Identification (For Tracking) (Vision/Thermal and Robot Path)
3. Rear Leg Gambrel Insertion (Vision only)	3. 1st Leg Roller Insertion (Vision/Thermal only)
4. Front Leg Hock cutting & Neck Tip - combined (Vision + x-ray and Robot Path)	

Table 2: Agreed Stage 2 Vision and Laser Sensing Systems Suitable for Beef and Sheep Slaughter Tasks

3. 1ST BEEF TASK – RFID TAG LOCATION FOR REMOVAL

3.1. MILESTONE 2: DATA GATHERING - RFID TAG LOCATION FOR REMOVAL

The Radio Frequency Identification Device (RFID) tag removal is currently a manual task to collect RFID tags for disposal. Generally, the tags are destroyed after reading, to prevent unauthorised reuse.

This project focuses on sensing the RFID tag for removal. Automatic sensing systems to read the tag information are available and are not included in the scope of this project.

The time available for this task to be carried out will be related to the plant throughput speed, however a generic task time was set at 40 seconds.

The data collection for algorithm development was carried out using vision sensing only, incorporating two Oscar 510 Firewire cameras, located at different angles to the carcass, to allow the tag position coordinates to be calculated in three dimensions. The camera pairs were placed at three locations, and images from 85 carcasses were collected.

Ten images were taken with a thermal camera to determine if a significant thermal contrast existed between the ear tags and the carcase.

The use of a single Firewire camera and laser combination was considered but it was found that the close proximity of the head, ear and RFID tag made this arrangement unsuitable. The laser system may have an application in this process through locating reference features.

Figure 1: RFID and Barcode Ear Tags on a Hereford Steer

Figure 2: RFID and Barcode Ear Tags on a Brahman Steer

Figure 1 and Figure 2 show the variation of ear types that can occur between different cattle breeds.

3.2. Milestone 3: Develop Software – RFID Tag Location for Removal

The objective of this milestone was the direct detection of the Radio Frequency Identification (RFID) ear tag on a beef carcass for subsequent removal (not reading). The project commenced with in plant data acquisition tests, initially focussed on direct RFID tag detection using colour image processing. The bulk of the subsequent work performed revolved around efforts to use either Red-Green-Blue (RGB) or Hue-Saturation-Value (HSV) colour systems, colour plane extraction and manipulation, and particle analysis to directly and uniquely identify the RFID tag.

It became clear that within (and in spite of) the existing standards, variation was so great with: (a) tag colour; and (b) tag presentation (i.e. placement on the ear); and also given variation in beef carcass hide colouring & markings; that a static, colour-imaging system alone would not be successful within the constraints of the current project. The decision was made, in agreement with MLA, to refocus the project towards direct thermal detection of the ear, and either direct (if possible), or indirect detection of the RFID tag. It was noted for consideration that mechanical methods of tag detection and removal can be employed when the ear is successfully located and then grasped.

Figure 3 shows typical examples of thermal images of Hereford and Brahman steers. In these figures warmer temperatures are bright and colder temperatures are dark. In both cases the ear (cool) can be clear distinguished against the background of the warmer head.

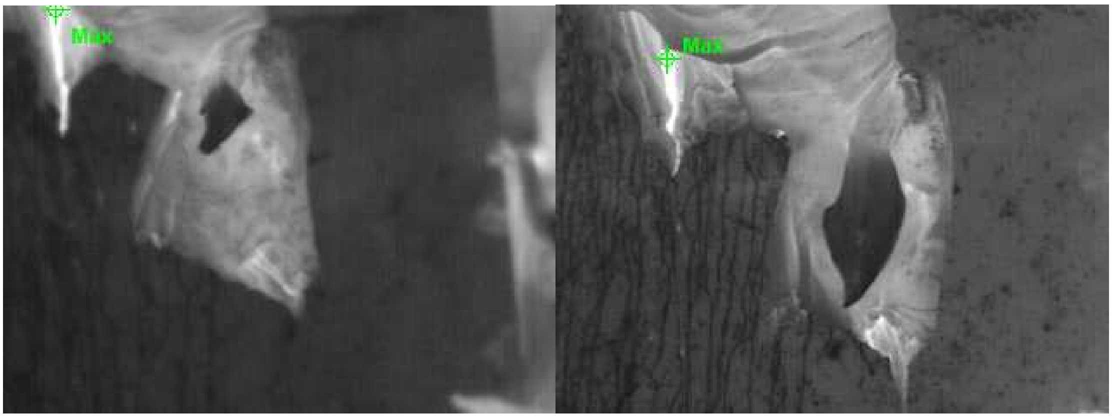

Figure 3: Thermal Ear Images

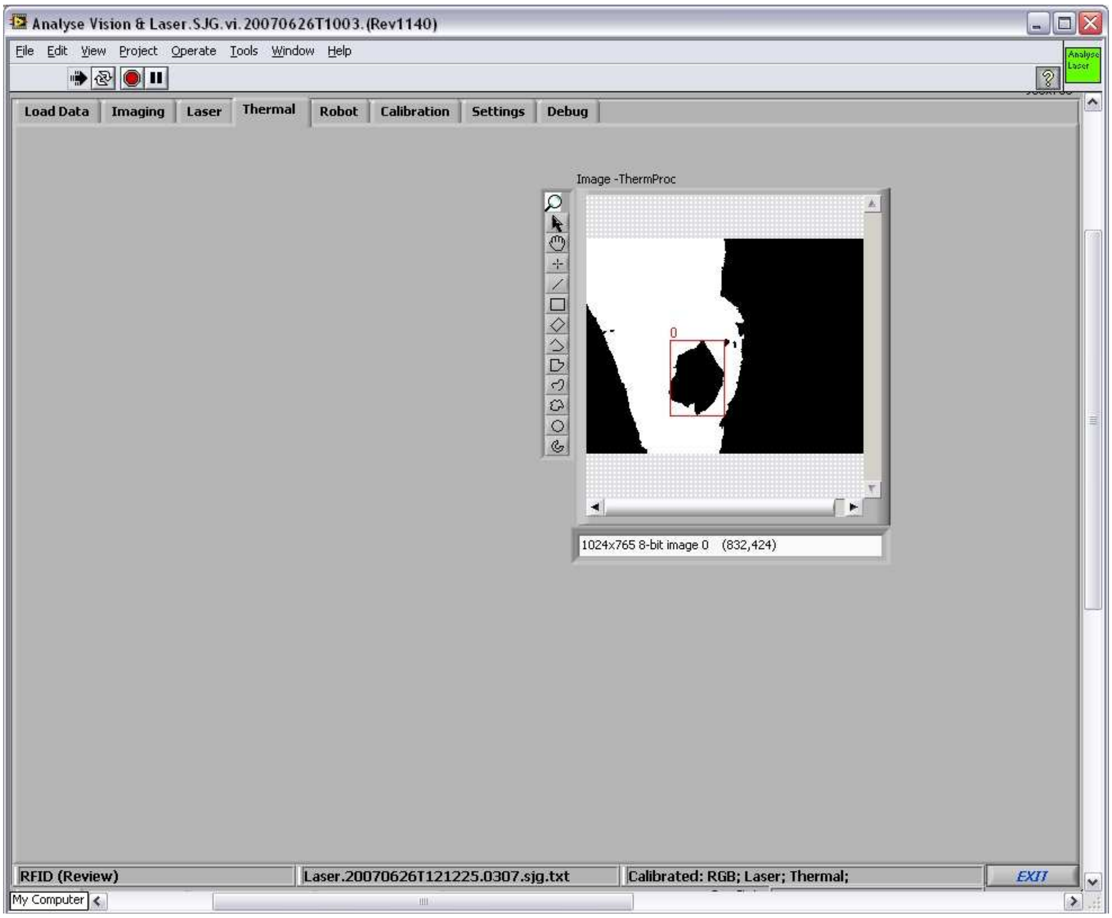

Figure 4: Processed Thermal Image of Ear

Figure 4 shows an example of a processed thermal image used in ear detection. For the purpose of this project the centre of the ear was identified, however coding could relatively easily reference other points if chosen. Further coding could also identify other reference points of interest (on the edges of head for example) that could be used in defining a narrower region of interest (ROI) to aid in RFID detection.

Figure 5: Final Image of System Showing Target Point (Red Spot)

The raw images were taken from the RGB Camera, the scanned laser data and the thermal camera from Left to Right respectively after acquisition has been initiated and data has been acquired.

The data is then displayed while image processing is conducted. Figure 5 shows the same three images with the calibration applied. This screen is displayed after image processing (registration and detection) is completed. In this image the centroid of the detected ear is identified by a red spot on all three images.

When enabled by the appropriate software settings the ear detection centroid coordinate is transformed from the sensing coordinate system to the robot coordinate system, reformatted to a protocol specified for Robot communications, before transmission via serial cable to the robot. Images of the robot path demonstration are presented in the following milestone 4 report.

3.3. Milestone 4: Develop Robot Process Path – RFID Tag Location for Removal

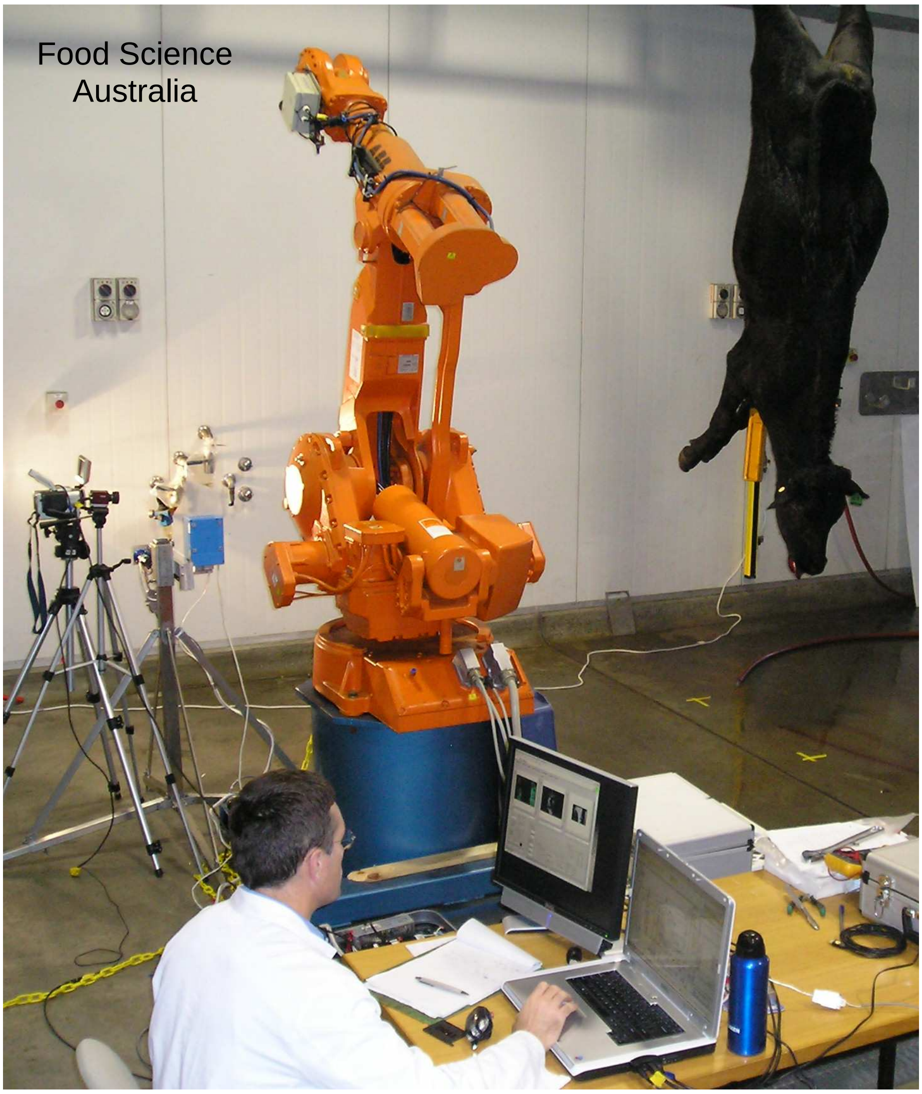

Figure 6: RFID Equipment Configuration

The RFID Tag robot path development was set up as shown above (Figure 6) using a thermal camera, laser sensor and firewire colour camera mounted on stands to image the carcass target area of the head and neck region. The sensor image and scanning position is also shown above, on computer.

A location pointer was mounted on the end of the robot, with the robot mechanical arm positioned such that it did not prevent the sensing cameras from visioning the carcass.

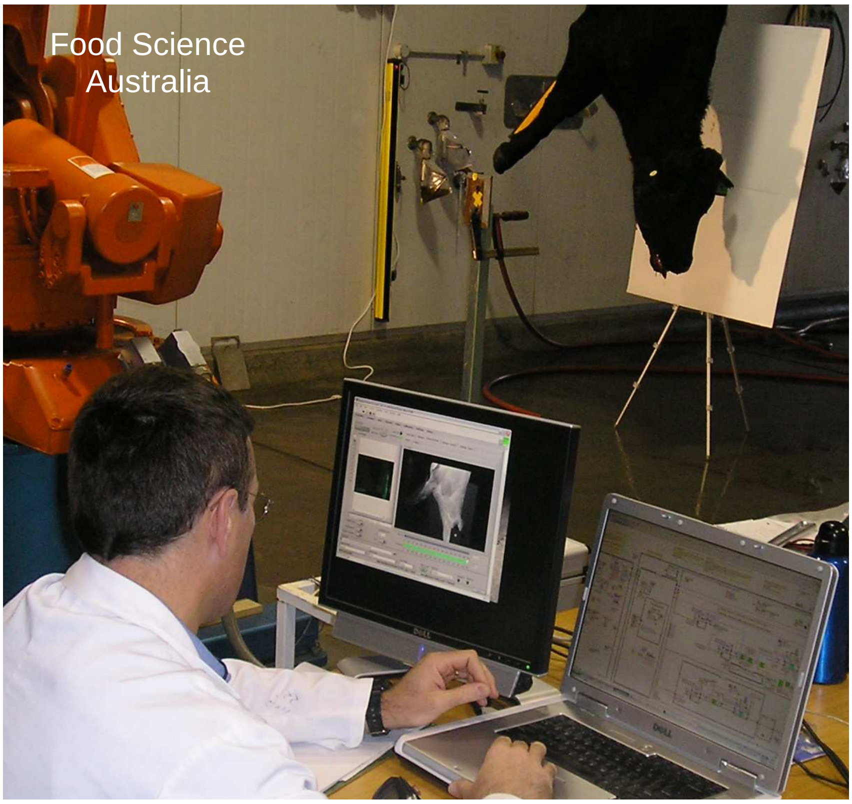

Figure 7: RFID Thermal Analysis

After image registration, the system identifies the positional coordinates of the ear and directs a pointer mounted on the robot (Figure 8, shown below) to confirm the position on the carcass. The image on the computer screen above in Figure 7 shows the thermal image of the carcass identifying the ear by sensing the thermal signature of the head.

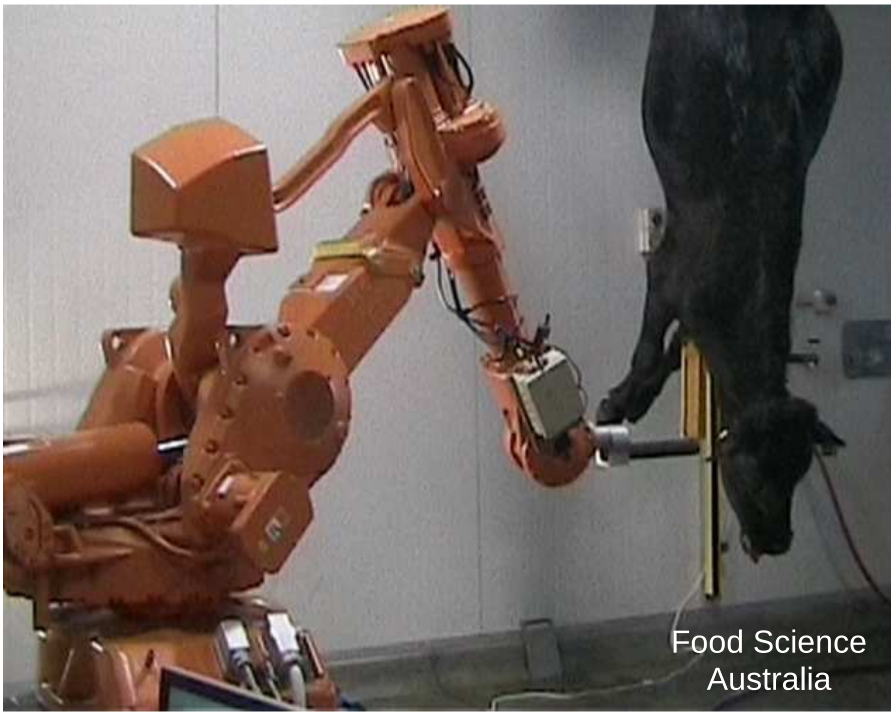

Figure 8: RFID Analysed Position

4. FIRST SHEEP TASK – SENSING FOR HEAD REMOVAL

4.1. MILESTONE 5: DATA GATHERING – SENSING FOR HEAD REMOVAL

The removal of the sheep's head is one of the early tasks carried out in most high throughput sheep processing operations.

The cut made to sever the head from the neck is performed at the *atlantal* joint (i.e. head - spine connection), after most soft tissue at the front of the neck has been severed by a cut under the jaw (Halal stick wound) to bleed the animal. In practice, the head is generally severed using a powered shear that cuts through the neck adjacent to the Atlantal joint. This process requires a second cut of the neck (tipping) after the pelt is removed to discard contamination on the bone and tissue remaining in the cut area.

This project focused on sensing the neck and head regions adjacent to the *atlantal* joint with the aim of determining the correct cut position.

The time available for this task to be carried out will be a function of the plant throughput speed; this usually ranges from 5.8 to 10 seconds in high throughput sheep processing lines.

The data collection for algorithm development was carried out using vision and laser sensing systems, incorporating an Oscar 510 firewire camera and a Sick LMS-400 laser profiling device to enable the head severance cut position to be calculated.

Further data was also obtained through the use of a “Guide” thermal camera, Model IR928.

The data gathered for the Sheep Head Removal task included laser profile data in eighty-four spreadsheet files, digitised video stored in AVI format, digital images in bitmap (.bmp) format and thermal images in a proprietary format set by the manufacturers of the thermal camera.

Figure 9: Sheep Head Removal Data

The image above (Figure 9) shows an example of the raw images taken with the Oscar camera during data collection. The positional data using the laser sensor was also captured with the carcass in the same position. The laser sensing light stripe can be seen on right ear and shoulder region of the carcass.

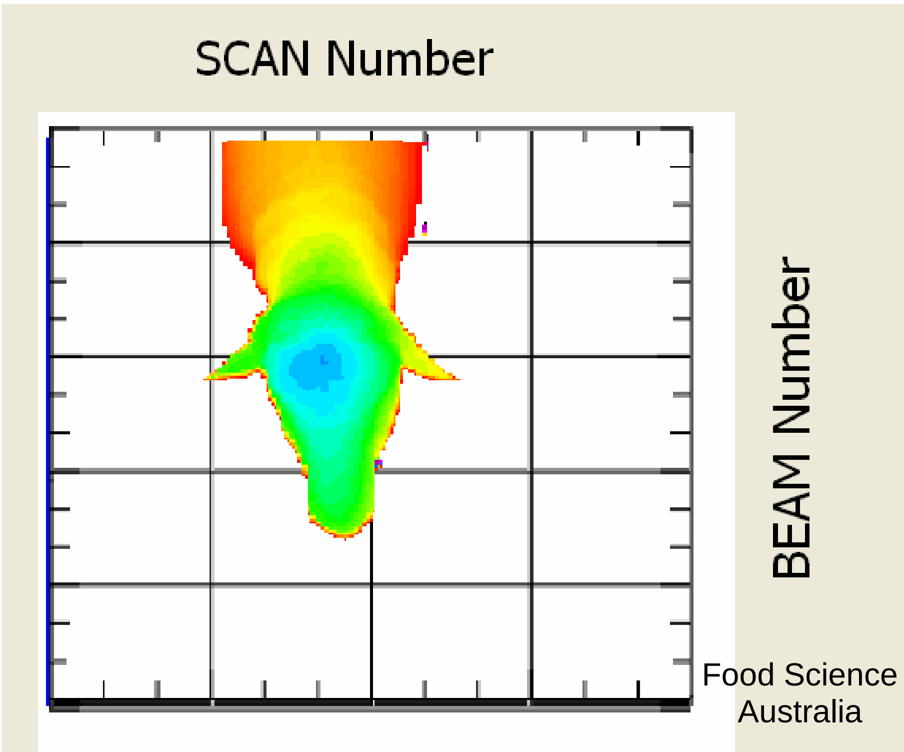

Figure 10: Head Removal Laser Data

The image in Figure 10 shows a three dimensional graph of data collected using the laser profiling system. This equipment was originally thought to be unsuitable for distance measurement in this application due to the uneven nature of the wool surface. However, some data containing observable features was obtained during testing.

4.2 MILESTONE 6: DEVELOP SOFTWARE – SENSING FOR HEAD REMOVAL

The automated sheep head removal task required the development of a sensing system to detect and locate carcass features in three dimensions relative to a datum. The location of these features will allow an automated system to sever the head from the neck at the a*tlantal* joint (head - spine connection), with the soft tissue of the neck being previously severed by a cut performed under the jaw to bleed the animal, (aka *halal* stick wound).

The *atlantal* joint however is not a visible external feature prior to head removal and therefore cannot be identified to locate the required position of the cutting tool through image analysis. The joint is also not distinctly visible to operators currently removing the heads manually. Operators are instructed to cut along an imaginary plane between the top of the stick wound and a position on the neck immediately above the ears or horns (if present) on the carcass.

Two different methods of manual head removal were observed during plant visits. The first involves approaching the carcass from the side and aligning the shears along a cut line between the stick wound and the neck of the carcass. The second is to approach the carcass from above the head and position the shears at the narrowest section of the neck above both of the ears or horns. The shears are then pushed downwards against the ears and the back of the jaw bone to tilt the head into the correct position for cutting.

Thermal image analysis is able to overcome variations in factors such as wool thickness, colour, wound size and blood splatter by highlighting temperature differences between the comparative warmth of the carcass without hide covering (such as the stick wound, nose and ears) compared with the hide itself. Thermal image analysis successfully identified the top left hand corner of the stick wound on images collected during early plant visits.

Laser data analysis was used to identify and locate the extremity of the neck (when viewed from above the head) in 3 dimensions to provide the location of head features required to automate the aforementioned “second” method of head removal. The ability of the laser analysis software developed for this project to consistently and reliably locate the carcass features required to automatically place a cutting tool at the thinnest section of the neck of a carcass was proved by the analysis of data collected during plant visits.

The laser analysis software was selected for demonstration in a plant and incorporated with the data collection software developed for Milestone 5 to create a real time sensing system for sheep head removal.

A demonstration of the real time detection of sheep carcass features for automated head removal using the laser profiling system was arranged for an AMPC/MLA representative at a sheep plant. The selected plant was chosen as most suitable because of the availability of space in the region before the head removal stage, in which the laser equipment could be placed without disrupting plant operation or employees.

The arrangement of equipment for the demonstration was identical to that used for trials at Food Science Australia, as shown below (Figure 11).

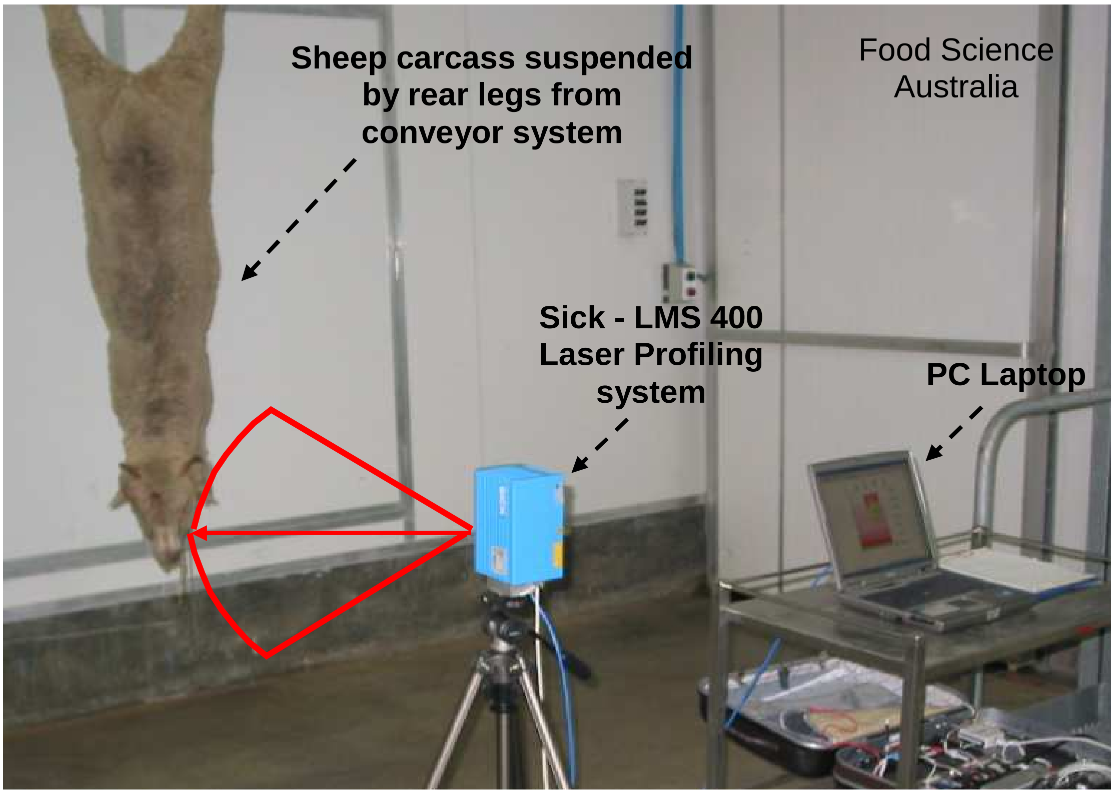

Figure 11: The Arrangement of Equipment at FSA Trials

The laser profiling equipment was mounted on a tripod adjusted vertically to align the laser with the height of the head, and was positioned perpendicular to the head at a horizontal distance of 1000 millimetres from the vertical plane of the conveyor system. The actual distances and heights were recorded during the demonstration and these values were entered into the software to assist data analysis.

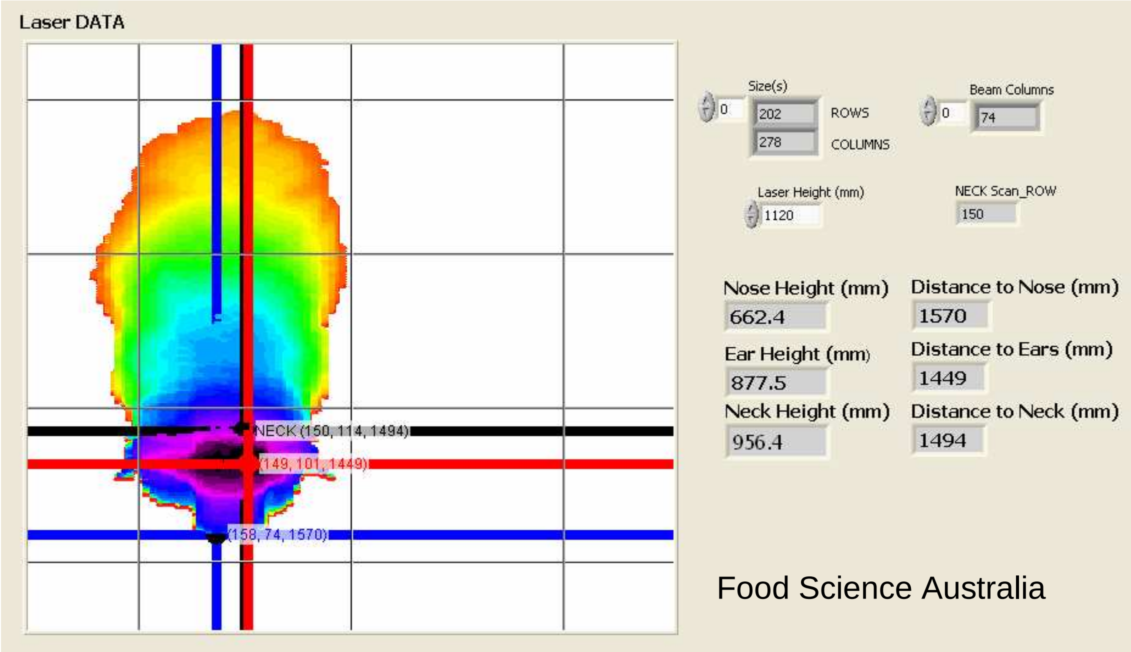

Figure 12: Robustness Test

The example shown above was used to test the robustness of the feature detection system by rotating the head of the carcass, thus causing the target features to be out of alignment.

The colours relate to the distance from the laser to the surface of the carcass.

At plant visits for this project, laser profiling data was collected from 132 carcasses. During the plant demonstration laser profiling data was collected from 21 carcasses. The collected data was analysed and a statistical analysis was undertaken to assist with future tool development.

Although feature detection using laser profile measurement and analysis for this task was successful, the feedback from the MLA representative during the plant demonstration was that consideration should be given to automating head removal at a plant where the head is removed whilst the carcass is suspended by all feet. The carcass would be much more stable at this stage of the process, and the head and neck would possibly be easier to detect with the laser profiling system. However, the implications of how this would affect the accuracy and repeatability of an automated cutting system would require further investigation.

5. 2ND BEEF TASK – HOOF IDENTIFICATION

5.1. MILESTONE 7: DATA GATHERING – HOOF IDENTIFICATION (FOR TRACKING)

The beef shackle and hoist process operation is a manual task that carries high occupational health and safety risk from the rear leg, which is often kicking, and other carcass movements that occur immediately after the stun/stick process tasks. Automating the shackling operation would address this OH&S issue.

This project focused on sensing the appropriate rear leg to identify and locate the correct position to allow automated shackling of cattle. Outside of the scope of this project were the required developments of separate systems to track the correct shackle position in real time and to fit the shackle chain to the leg.

In the typical present situation, the operator is required to loop the shackle chain around the specified rear leg, proximal to the hock, select a chain link in accordance with the size of the animal and place that link on the shackle conveyor roller for hoisting.

The data collection to develop the required sensing system for hoof identification was carried out using an Oscar 510 Firewire camera and a Guide IR928 thermal camera. Carcass profile data was captured using a Sick LMS-400 laser profiling system. Carcasses were imaged with the Oscar camera and scanned with the laser system. Eighty carcasses were imaged with the thermal camera from four different positions.

Figure 13: The laser profiling system setup.

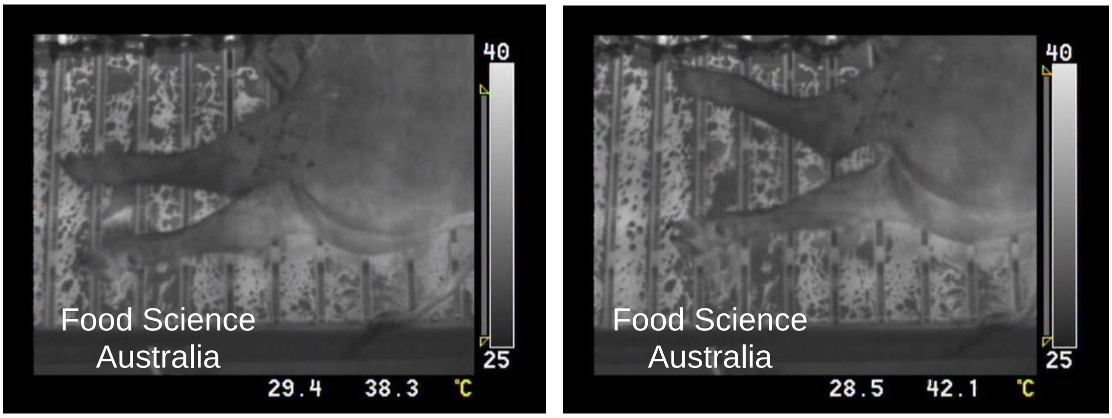

Figure 14: Thermal images of carcass on slat conveyor

5.2. Milestone 8: Develop Software – Hoof Identification (for Tracking)

Sensing has been identified as an important step in the development of automated systems suitable for beef and sheep slaughter tasks. This report covers project work developed for the identification of a beef hoof for shackling.

The main alternatives for carcass presentation for the shackling task, namely a cradle or slat conveyor, were reviewed. The automation of beef shackling on a slat conveyor system was considered the most likely configuration that would be adopted by the Australian beef processing industry. This is the mode that was pursued.

Two imaging techniques were developed, one using a thermal camera and the other a colour camera, to investigate options for a robust hoof sensing system on a moving slat conveyor.

Using thermal image analysis it was found that the temperature of the slat conveyor could be altered using the existing slat conveyor wash system to allow for suitably differentiation between the leg and the conveyor (Figure 15 and Figure 16). The temperature of the carcasses on the slat conveyor also had to be controlled by using a small modification on the existing manual anal wash procedure. A requirement of at least 5 degrees Celsius separation between the slat conveyor and the general carcass temperature was established. Thermal image processing was performed on over 100 animals and results were shown to an AMPC/MLA representative on May 11th, 2007.

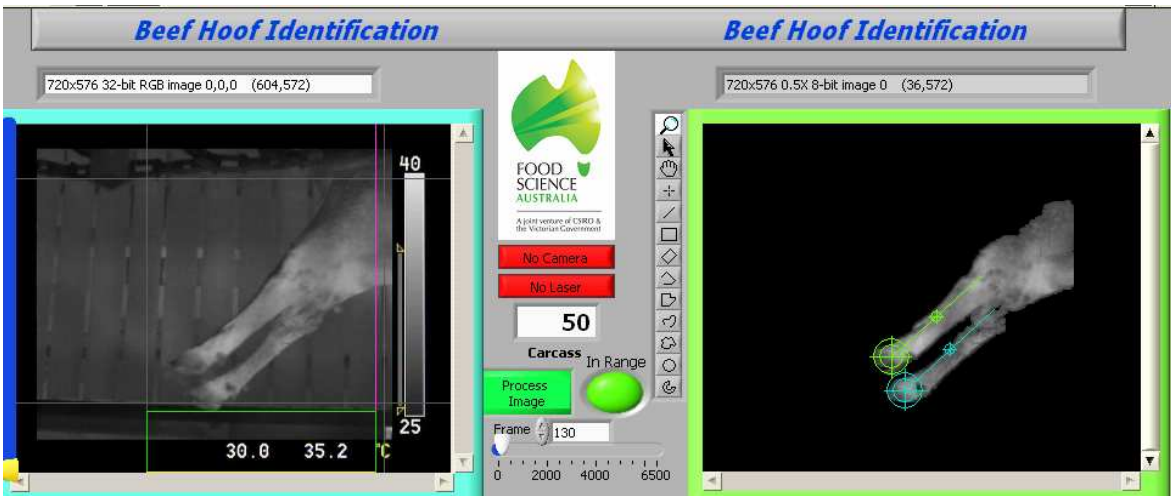

Figure 15: Legs analysed thermally showing hoof location and capture point

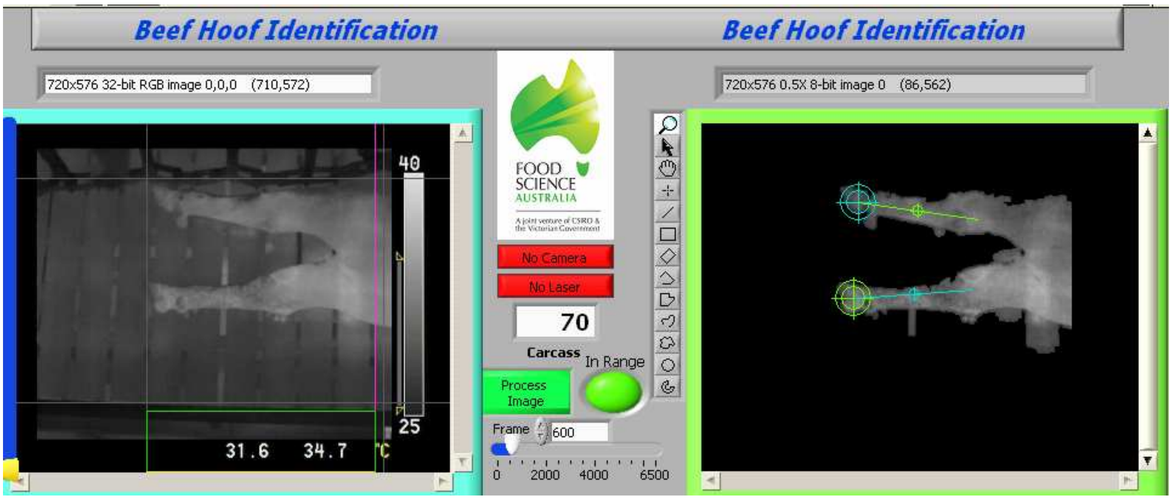

Figure 16: Legs analysed thermally showing hoof location and capture point

The variation in hide colour of beef cattle in most Australian beef processing plants has been previously identified as the main reason that thermal image processing is preferred to colour image processing when analysing hide-on carcasses. However, testing was done using a colour camera system to prove that if the slat conveyor has a colour contrast compared to the hide then that system could be used successfully (Figure 17). Blue or green have been suggested as suitable colours for the slat conveyor when performing image analysis. Methods of applying a coloured surface to the slats have been suggested. To prove the colour system using contrast, a trial was undertaken with dark animals on the existing metallic silver slat conveyor in a plant. The colour imaging system was tested on over 50 animals of varying colours, and a sample of these results was shown to an AMPC/MLA representative.

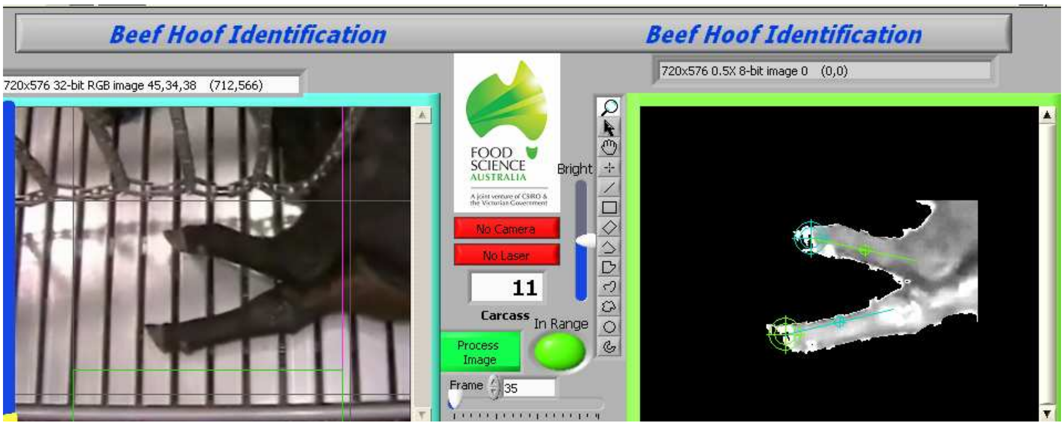

Figure 17: Alternate colour image analysis using contrasting carcass colour to slat colour

A laser profiling system taking scans at a rate of up to 70 scans per second provides unreliable three-dimensional information when animals are allowed to move relative to the conveyor. However a single scan, taken just prior to capturing an image for processing, can be used in conjunction with the vision analysis to determine which of the two legs extracted from the image is the one most distant from the conveyor; separating the upper, and lower leg (see Figure 18).

The final sensing system developed produces information about the leg in three dimensions and this data can be sent to a robot or automated tool for shackling of the leg. This concept was demonstrated as part of milestone 9 of “Stage 2 Vision and Laser Sensing Systems”.

It has been recommended that the sensing system be developed further to allow real-time tracking of the hooves, as would be required for a system to be installed into a processing plant using a slat conveyor.

It has also been recommended that long-term testing should be carried out on applying colour surfaces to conveyor slats to check the effects of normal slaughter processes on the colour deterioration over time.

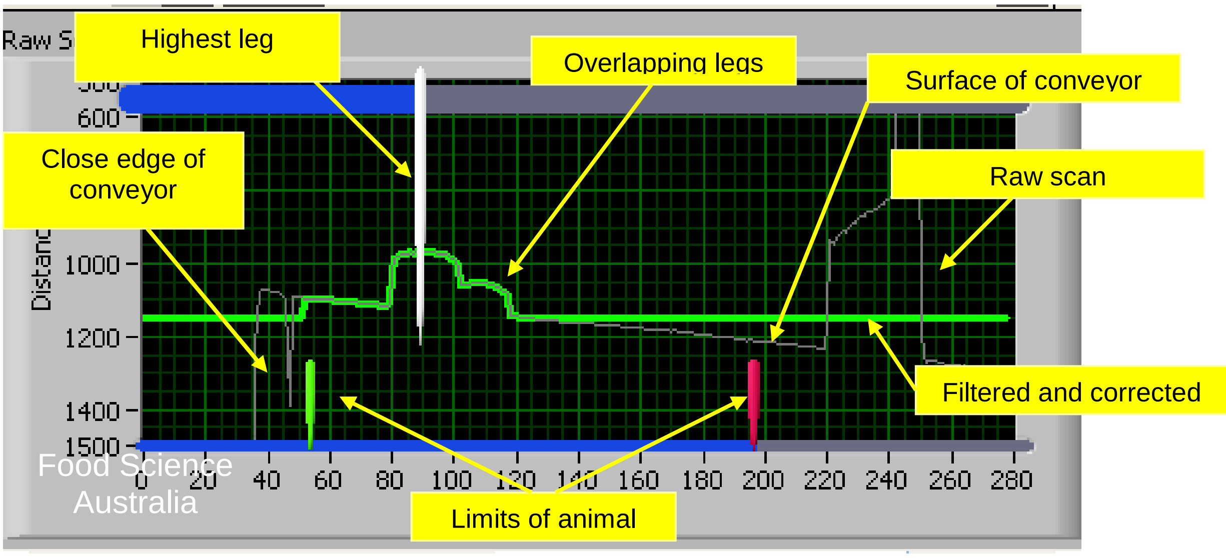

Figure 18: Example of laser profile across carcass legs

5.3. MILESTONE 9: DEVELOP ROBOT PATH PROCESS – HOOF IDENTIFICATION (FOR TRACKING)

The sensing system using thermal image techniques to identify hooves for shackling developed during milestone 8 of "Stage 2 Vision and Laser Sensing Systems" was integrated to Food Science Australia's ABB4400 robot located on the export-quality boning room floor at Cannon Hill.

A rudimentary pointing tool was fitted to the robot to facilitate demonstrations of the hoof sensing system. The dexterity of the ABB4400 robot was used to reduce the infrastructure of the equipment supports and each piece of equipment was located as required. The thermal camera was mounted high on the pointing tool to simulate a high mount position for the camera. The laser profiling unit was mounted just below the centre of the tool and was moved to a fixed height above the floor when required to measure the height of the legs. The pointer extended below the laser unit and the tip of the tool was used to demonstrate the final capture location for a single image.

The facilities at Food Science Australia at Cannon Hill do not include a slat conveyor. The conveyor was simulated by laying the carcass on the floor and allowing a small water flow under the carcass to simulate the controlled conveyor temperature. The carcass was then hosed in the region of the rump and anus with warm water similar to normal production practice.

The robot was given three main configuration areas. The highest configuration held the thermal camera above the carcass obtaining largest field of view possible for the imaging (Figure 19). This was a fixed location to simulate the camera mounted in a production environment.

The second configuration (shown in Figure 20) locates the laser at 1000 mm above the height of the conveyor (floor). This position is located directly above the capture point as established by the processed thermal image. The distance to the leg was established using the laser profile of the carcass across the capture co-ordinates. This laser profile also confirmed which leg was farthest away from the conveyor (floor) to account for legs that may be crossed.

The final robot configuration was delivering the pointer to just above the leg at the capture location (Figure 21). This final location is determined by combining the information from the thermal camera and the laser profile.

The automated system was successfully demonstrated to a MLA representative on June 26th, 2007. Only a single carcass was used during the demonstration, but that carcass was moved to several different locations to show the automated system locating the leg each time.

This system only demonstrates the effectiveness of the sensing system on a stationary carcass as outlined by the requirements of the project. The system would have to be developed further to allow real-time tracking of a moving carcass, or integration of the system into a plant where the carcasses are at least substantially immobilised.

A video presentation of the robot path demonstration is included as part of "APPENDIX A – Video Presentations".

Figure 19: Configuration of sensing system for rudimentary demonstration (imaging location)

Figure 20: Robot position during laser scanning

Figure 21: Pointer delivered at capture point along the leg

6. 2ND SHEEP TASK – FRONT LEG SPREAD

6.1. MILESTONE 10: DATA GATHERING – FRONT LEG SPREAD

Many Australian sheep processing plants transfer the carcass from being suspended by the rear legs only, to being suspended by all four legs. This is achieved by an operator lifting and securing the front legs into shackles fitted to the conveyor running in parallel with the conveyor carrying the rear legs. To automate this work task, a sensing system would be required to identify and locate the front legs of a suspended sheep carcass at production speed.

Some differences were found in the work task specifications for the processing plants studied, and these have been taken into account for the sensing specification.

A vision/laser sensing system suitable for automating the sheep front leg spread task will be required to:

1. Identify the front legs.
2. Locate the 3D position and orientation of both front legs.
3. Thickness of each leg to allow a “gripper” to be positioned.
4. The 3D position of the end of each leg.

Three sensing arrangements were identified:

1. A single laser unit with appropriate software to identify and locate the legs in three dimensions.
2. A pair of Oscar 510 Firewire cameras at approximately 90º to each other to allow 3D positional information to be gathered.
3. A thermal camera as an alternative vision system.

Data was collected on 82 sheep carcasses and includes a 3D laser profile of each carcass, and a matching set of images from the Oscar firewire cameras. An additional 17 carcasses were imaged using the thermal camera.

6.2. MILESTONE 11: DEVELOP SOFTWARE – FRONT LEG SPREAD

Sensing has been identified as an important step in the development of automatic process systems suitable for beef of sheep slaughter tasks.

The selection of tasks which can be used as platforms for the development of vision and laser sensing systems was finalised in Milestone 1 of this project. The task investigated for this part of the project is the sheep front leg spread.

Data collected as part of Milestone 10 of this project, in the form of laser profiling, colour image capture and thermal image capture was reviewed. The carcass leg length, width and spacing were investigated for the purpose of tool and sensing system design.

The final leg placement into gambrels as defined by previous projects was considered and a definition of the legs being captured in space was developed.

Two methods of sensing were considered to locate the legs and features of the sheep legs as they were hanging in space.

The first method (Figure 23 and Figure 24) was to use laser profiling to locate features along each of the leg in three dimensions. This method required the carcass to be stabilised for between 4 and 5 seconds while the carcass is scanned. This method would suggest scanning at one work station and performing the task at the following workstation. The total time required to scan and analyse data with this method was 5.15 seconds. This method would require the tool to capture the leg as it hangs freely in space.

The second method (Figure 25 and Figure 26) requires a specific tool to work in conjunction with an imaging system, and the analysis of two or more images to define the coordinates of a grip location on each leg. This method requires the carcass to be stabilised for a very short time and would need a tool to partially control the carcass during the image analysis. The total time to analyse each image is approximately 300 milliseconds and this analysis could be done at the same work station as the leg capture.

It was established that each method would require a specialised leg capture mechanism to complete the task successfully.

Both vision and laser systems were successfully demonstrated to the satisfaction of the AMPC/MLA representative in an operating plant on 16th March 2007. In both cases large numbers of carcasses were scanned and the system was proved before the demonstration.

It is recommended that this project be advanced to the leg capture tool development stage as part of step 3 of the AMPC automation strategy.

Figure 22 shows a side view of a carcass as it hangs. The details measured are outlined in this image.

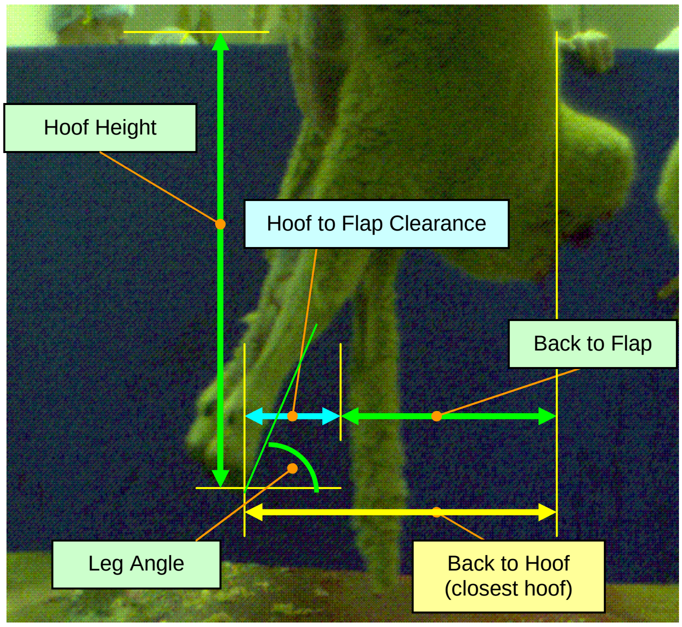

Figure 22: Outline of features detected by sensing system

To determine the requirements of tools and sensing for leg capture, a study of carcasses in a production plant was carried out. The height of the hoof was measured from a datum to determine the expected span of leg length. Table 3 shows that these distances ranged over a value of almost 400mm, but indications were that the hoof height has no correlation between one carcass and the next. Each carcass would need the hoof height measured to supply input data for an automated system.

The preceding figure illustrates the location of the flap of skin hangs freely and a tool could easily move it away as the legs are positioned.

	Average	Minimum	Maximum
Back to Hoof (closest hoof)	498	358	654
Back to Flap	297	202	388
Hoof to Flap Clearance	200	132	298
Leg Angle	61	52	70
Hoof Height	802	602	984

Table 3: Distance statistics on hoof relative to the back of the animal.

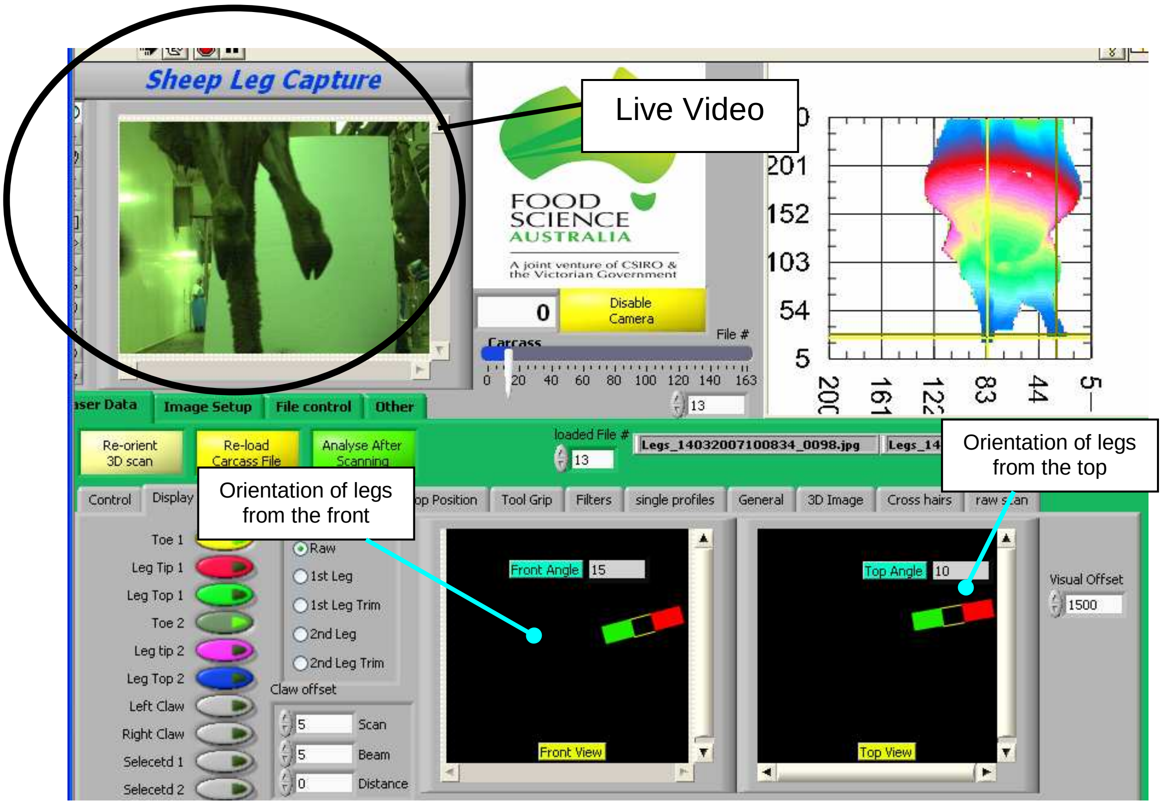

Figure 23: Screen capture of an analysed laser scan of a sheep carcass

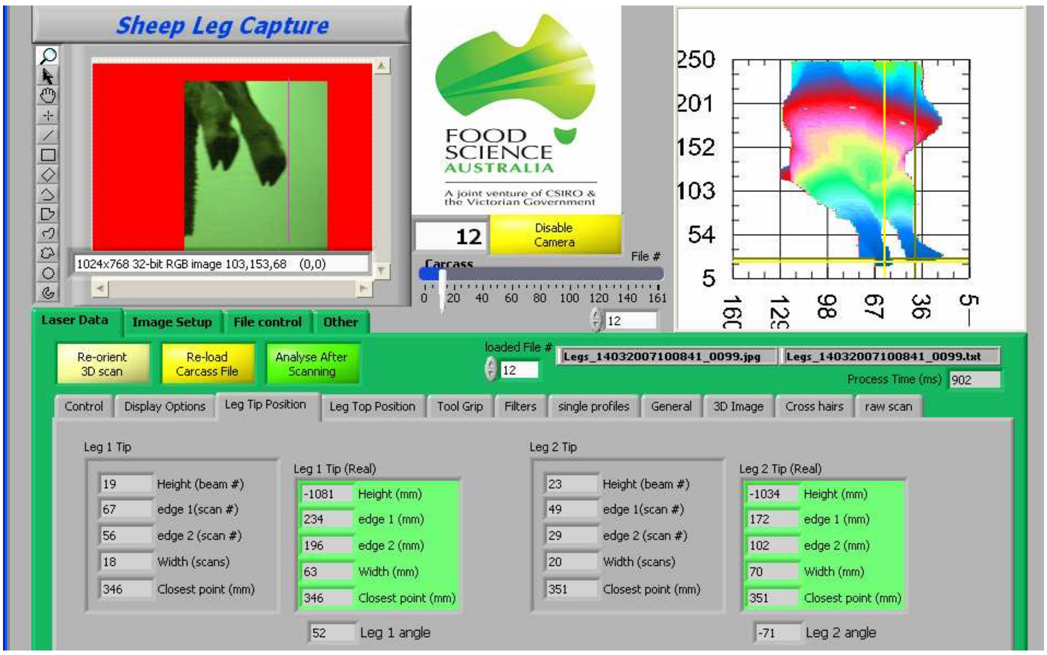

Figure 24: Example of analysed sheep carcass showing three dimensional locations in space

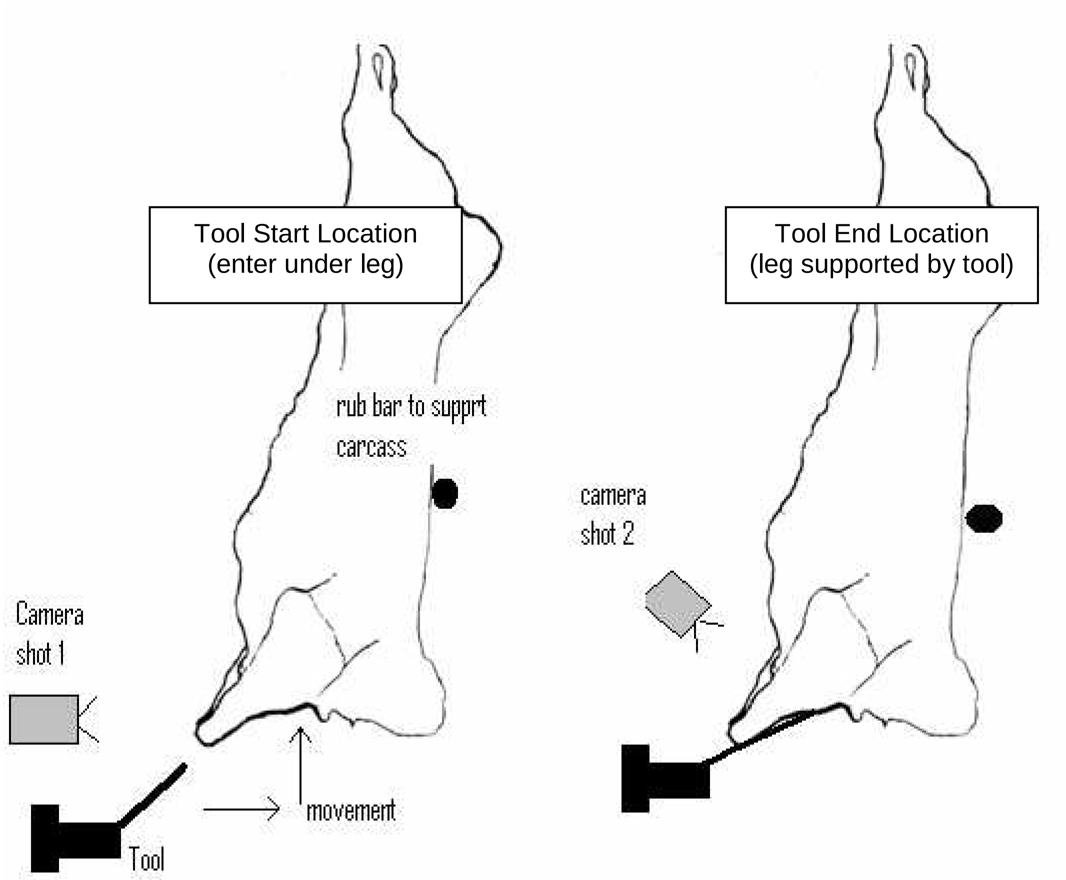

Figure 25: Tool movements to support fore legs when using the alternative sensing method for the second image

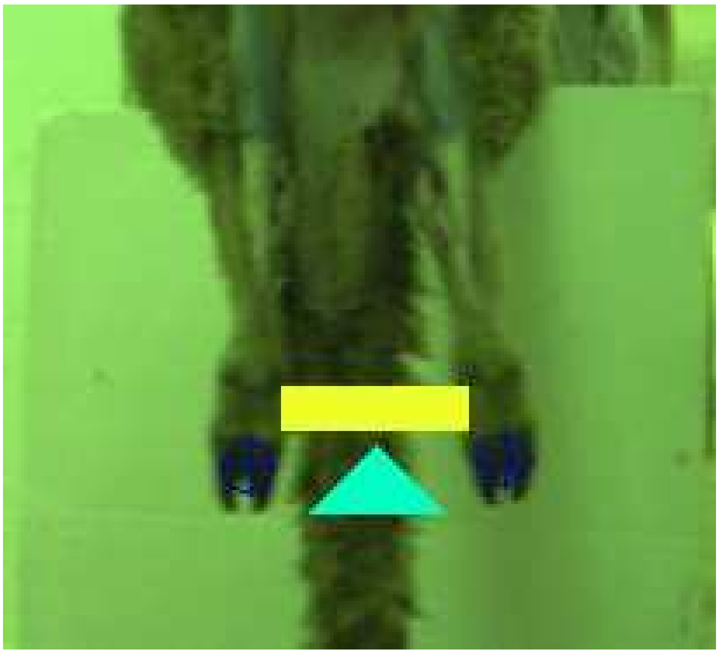

Figure 26: Features sensed using one camera only, but from two different directions

7. 3RD BEEF TASK – LEG ROLLER INSERTION

7.1. MILESTONE 12: DATA GATHERING – FIRST LEG ROLLER INSERTION

Roller insertion is a manual task carried out on both rear legs of a beef carcass during the preparation procedures for hide removal.

This project focuses on sensing and locating the opening in the rear leg adjacent to the Achilles tendon where the hook of the meat roller is inserted to eventually support the carcass on the conveyor rail.

Due to high levels of operator activity and the required research equipment, the data collection site was located in the area between the second leg dressing and roller insertion. This area was the most appropriate mainly due to a change of direction in the conveyor rail which provided an unused space in the corner of the work platform where cameras could be set up and data recorded.

The data collection for algorithm development was carried out using two Oscar 510 Firewire cameras, located at different angles to the carcass, to allow the positional co-ordinates of the “opening” adjacent to the Achilles tendon to be calculated in three dimensions. Images were also acquired using a Guide IR928 Industrial Infrared (IR) Thermal Camera to test the ability of this technology to remove background details from digital images and increase the reliability of feature detection through image analysis.

The use of the Firewire cameras and laser combination was considered but due to the type of carcass movement (lateral speed and rotation) during scanning, it was felt that the laser would not provide reliable data; however, the laser system would have an application in the location of reference features if the carcass was stationery.

The following image (Figure 27) shows the carcass target area and lower leg against an image calibration background board.

Figure 27: Leg Against Image Calibration Background Board

The video data capture process for each file was triggered manually using the developed software. The aim of each video session was to capture carcasses with a variety of hide, fat and background colours within each file, and for each camera position.

Figure 28: Plant Data Using Blue Background Board and Camera Position 1

Figure 28 shows the raw image of the hind leg from the Oscar camera 1 position and using a blue background during data collection. The hole near the Achilles tendon is clearly visible when using the background board.

Figure 29: Plant Data Using Blue Background Board and Camera Position 2

The above image shows a raw image of the hind leg from the Oscar camera 2 position and using the blue background board to highlight the opening near the achilles tendon.

7.2. Milestone 13: Develop Software – First Leg Roller Insertion

The third beef task to be investigated to progress the technology development is the Beef Task - Leg Roller Insertion [2]. The first and second leg rollers are inserted after dressing (removing) the hide from each leg to support and transport the carcass prior to full hide removal.

This milestone involved the development of a sensing system to identify the reference point on the leg adjacent to the Achilles tendon. Following the identification, algorithms were developed to display a set of positional co-ordinates indicating the position selected where the leg roller hook could be inserted. The developed sensing system consisting of both hardware and software could form part of a guidance system to control a robotic arm fitted with a suitable tool to hold the leg roller, position the hook in the Achilles tendon, and position the leg roller wheel on the carcass conveying system.

During visits to beef processing plants digital images were acquired from 164 carcasses immediately prior to the leg roller insertion task. In 114 of these images the insertion point had been cleared with a knife prior to the insertion of the leg roller, and in fifty images this had not occurred. The software developed to locate the insertion point using digital images has been designed to locate this position using two methods, as follows:

1. The first method locates the visible insertion point that has been cut with a knife by searching for a white region in the processed image that is within a range of area measurements.
2. The second method uses the outside edges of the hock joint to locate the insertion point. This method is used if the insertion point has not been cut open.

These two positions are not always identical because the knife cut is not always at the centre of the insertion point. It should be pointed out that in reality there is a tolerance regarding the cut position.

The accuracy of the location of the sensing system insertion point using the second method was tested using software that compares the location of the insertion point manually selected by an experienced operator with the location selected by the software on fifty unprocessed images of uncut legs. The difference between the manually and automatically selected insertion points were calculated as a percentage of the width of the leg. The maximum distance recorded between these points in all images was within the target area for correct roller insertion and is not considered large enough to result in the failure of an automated system to correctly insert a leg roller. The method used to calculate these results could also be used to further optimise the software if required.

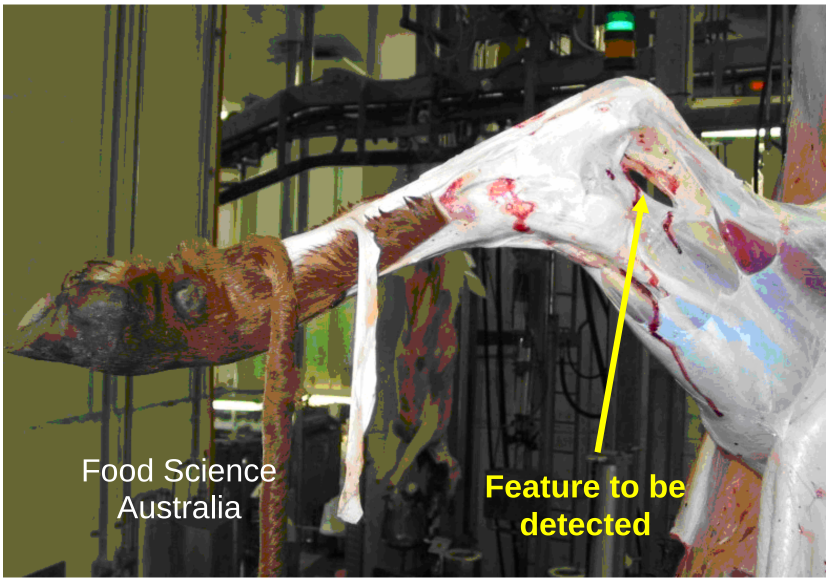

Figure 30: Leg with Roller Insertion Point Cut Opening

Figure 30 shows the “Achilles” leg opening for roller hook insertion that has been cleared with a knife cut.

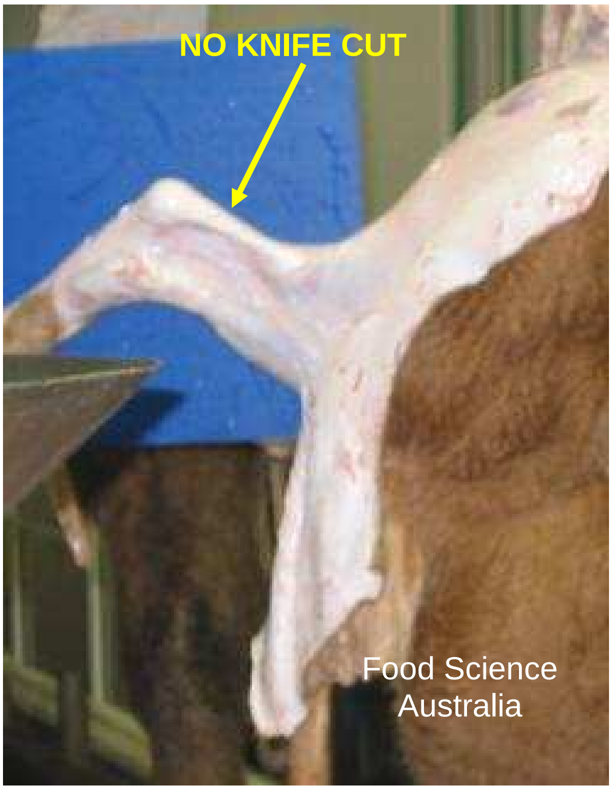

Figure 31: Leg without Roller Insertion Cut Point

Figure 31 shows the "Achilles" leg opening for roller hook insertion that has NOT been cleared with a knife cut.

It was determined that the sensing system developed for this project would be able to detect and locate the area underneath the Achilles tendon in three dimensions whether or NOT the area has been opened with a knife. Where the area has not been opened, features along the outside edge of the leg (such as the joints and hock) must be used to locate this feature.

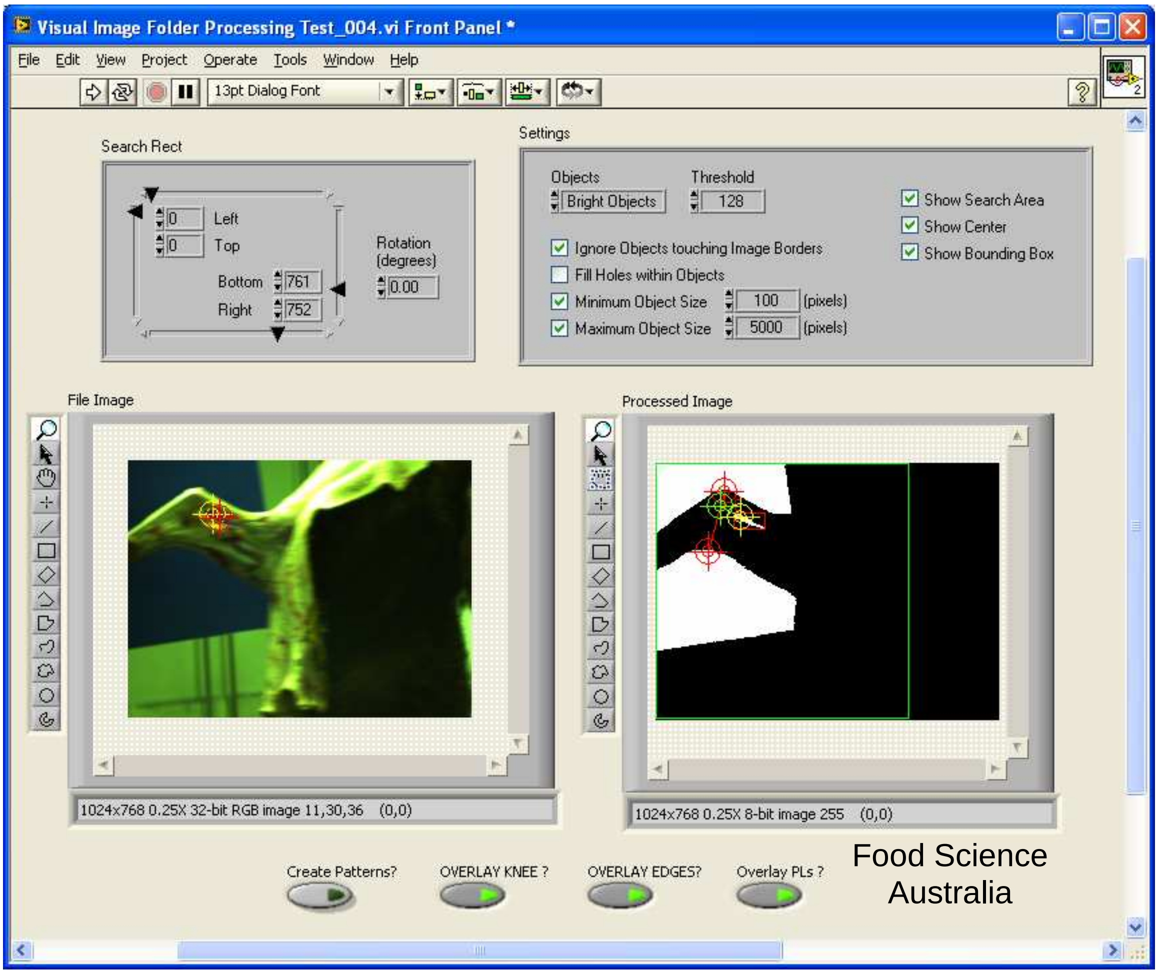

Figure 32 Leg Roller Insertion Image Analysis User Interface

The image above (Figure 32) shows the user interface of image analysis software developed to locate the leg roller insertion point.

The following screen captures (shown in Figure 33, Figure 34 and Figure 35) are from images acquired and analysed during the plant demonstration. Each carcass has hide hanging from the bottom of the leg in different patterns. This does not affect the analysis process.

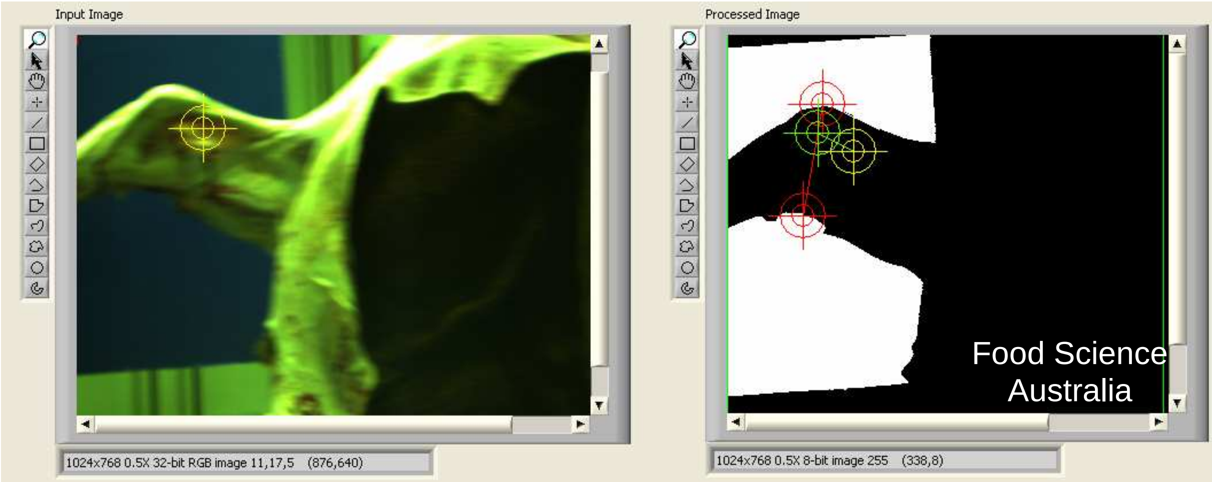

Figure 33: Leg Roller Insertion Analysis Result Example 1

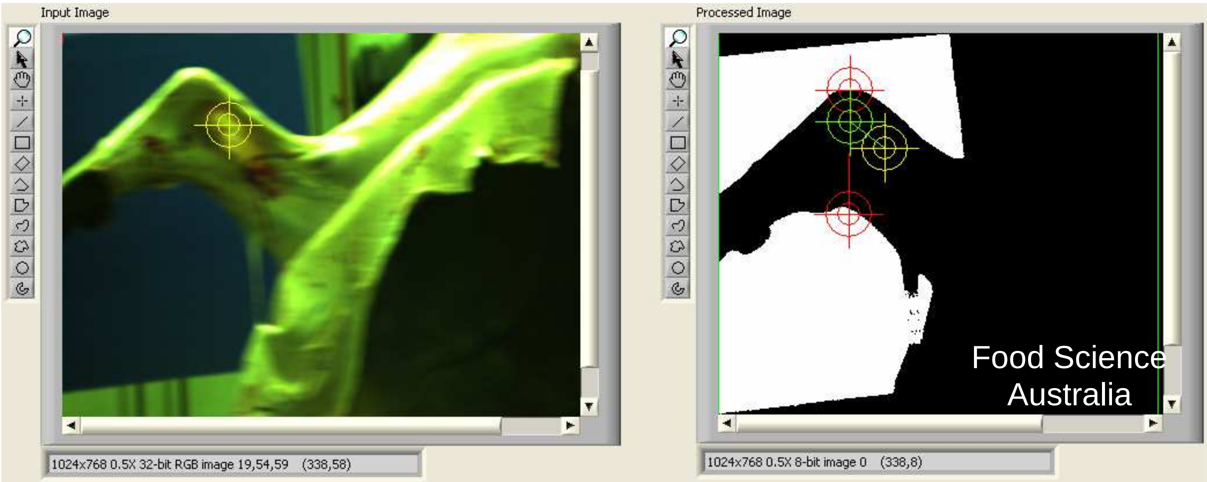

Figure 34: Leg Roller Insertion Analysis Result Example 2

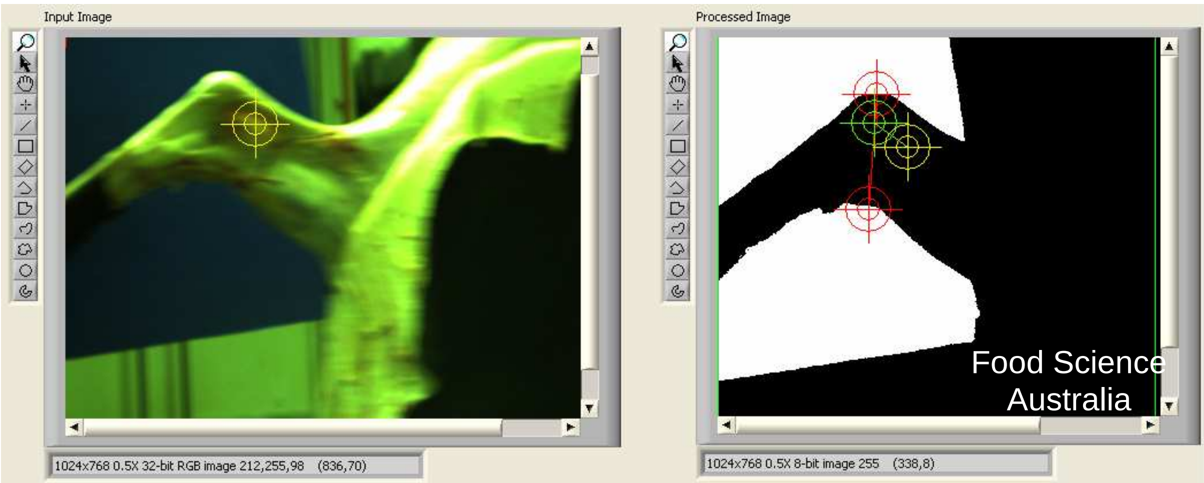

Figure 35: Leg Roller Insertion Analysis Result Example 3

8. 3RD SHEEP TASK – REAR LEG GAMBREL INSERTION

8.1. MILESTONE 14: DATA GATHERING – REAR LEG GAMBREL INSERTION

The rear leg gambrel insertion is a manual task performed as part of the sheep dressing operation. In so-called “traditional dressing” plants the carcass is transferred from hanging by forks that grip the *phalanges* (toes) to a dual-ended symmetrical gambrel inserted through the tissue under the *tuber calcis*, on both rear legs.

In “inverted dressing” sheep slaughter lines, the task is performed at the point where the carcass is transferred from front leg suspension to all-leg suspension; after the *metatarsus* and *phalanges* have been removed, and the hide around the *tibia* has been fleeced. To automate this work task, a sensing system would be required to identify and locate the rear legs of a suspended sheep carcass moving at production speed.

This project focuses on sensing the rear legs and particularly the section proximal from the junction between the *tibia* and *tuber calcis*. This area of concern is a “pocket” of relatively thin tissue between the bone and the Achilles tendon, i.e. the tendon connected at its distal end to the *tuber calcis*. Data gathering software developed for other slaughter tasks in this project was modified and customised for this task.

Some differences were found in the specifications for the processing plants studied, and these have been taken into account for the sensing specification.

The data collection for software development was carried out using vision sensing, involving two Oscar 510 “Firewire” cameras located at different orientations to allow the positional coordinates of the pocket to be determined.

Data was collected on 82 sheep carcasses during the plant visit. The data will be used to develop a vision/laser sensing system suitable for automating the sheep front leg spread task. The system will be required to:

1. Identify the front legs
2. Locate the 3D position and orientation of both front legs
3. Thickness of each leg to allow a “gripper” to be positioned
4. The 3D position of the end of each leg.

Both a blue and a green background board were trialled in conjunction with the CCD cameras to eliminate background changes and interference. The thermal camera did not require the background board.

Figure 36: Gambrel Insertion - Rear Legs with Background Board

An image of the rear legs with background board is shown above in Figure 36.

The data collected from the plant visit consisted of twelve video files in AVI format from each of the Firewire cameras positioned at differing angles to the conveyor rail. Video files of 86 carcasses were also recorded in the plant for subsequent testing during the development of image analysis software.

8.2. MILESTONE 15: DEVELOP SOFTWARE – REAR LEG GAMBREL INSERTION

The selection of tasks which can be developed under a vision and laser sensing systems platform was finalised in Milestone 1 [1] of this project. One of the tasks to be undertaken as a basis for the progression of the technologies was from the sheep slaughter process – Rear Leg Gambrel Insertion. This task is one of the final parts of the dressing process and involves the opening up of the tissue in the area, referred to here as the "*pocket*", between the *tibia* and *tuber calcis,* proximal to the joint of the *tibia* and *metatarsus*.

Digital video and still images were collected during plant visits using two industrial Firewire (IEEE 1394) cameras. The cameras were placed at various angles to the carcasses to determine an optimal position for detection of the required features. The interference of background objects in feature detection was avoided by placing boards behind the carcasses.

The results of the tests and observations taken during initial plant visits were that the insertion point was translucent and background lighting could therefore be used to highlight the insertion point while it was within a light beam. The lights and cameras would need to be placed at the correct angle relative to the legs, and extensive laboratory testing would be required to determine the type of lighting and camera angles necessary. The laboratory testing was carried out at the Food Science Australia – Cannon Hill facilities using a test rig to move sheep carcasses (suspended by the front legs) through a beam of light. The insertion points were viewed by two Oscar Firewire cameras (fitted with 25 mm lenses) positioned at 90 degrees to each other in the horizontal plane.

The collection of data during initial plant visits involved observing operators who approach the legs from the abdomen side (front) of the carcass to insert the gambrel. The leg features visible from the front of the carcass and used to position the gambrel by the operators were recorded. These include the tips of the legs, the hock joint or thickest section of the lower leg and the thinnest section of the leg above the joint. The operators place the gambrel half way between the aforementioned thinnest and thickest sections of the leg when viewed from the front of the carcass. The locations of these features could also be used to guide an automated gambrel insertion system to the correct insertion point. Image analysis software was developed to detect and locate this point on images acquired from a camera placed in front of the carcass.

The image analysis software for the Frontal View camera arrangements was also used for the demonstration of this sensing system in a selected plant to a MLA/AMPC representative. The Background Lighting camera arrangement was not able to be demonstrated in the plant as the amount of lighting and the background boards required disrupted the process workers at this station. The demonstration of this system was therefore arranged for the facilities at FSA – Cannon Hill following agreement with the MLA/AMPC representative.

The most feasible design of a tool for the automation of gambrel insertion would incorporate both of the sensing methods tested for this project to measure the three dimensional location of the insertion points. The tool would approach the legs from the abdomen side of the carcass and use the frontal approach software described to measure the height and lateral position of the insertion point. The system would only require two dimensional co-ordinates to guide the system if it included a tool that stabilised the leg as it approached the carcass, and included proximity transducers to stop the tool moving forward once the leg was engaged.

The configuration of background lighting, background boards and cameras tested in the laboratory may possibly be added to increase the accuracy and precision of the gambrel insertion once the tool has stabilised the carcass within a beam of light.

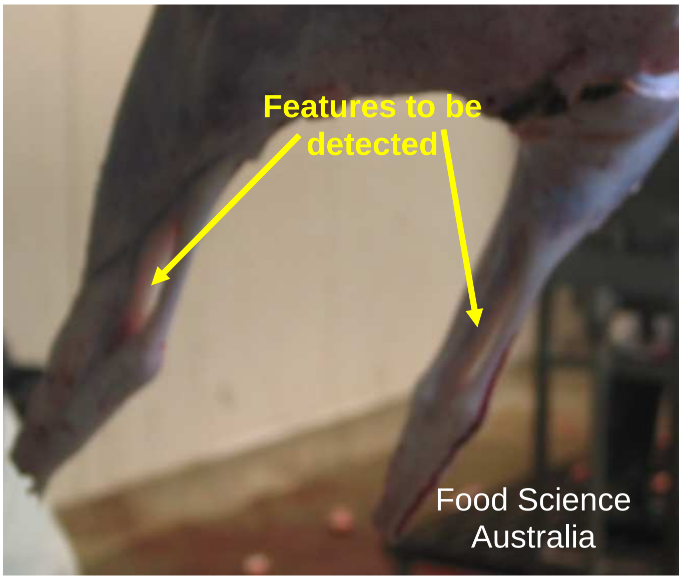

Figure 37: Dressed Sheep Legs, Rear View

The insertion points were viewed by two Oscar Firewire cameras (fitted with 25 mm lenses) positioned at 90 degrees to each other. The images acquired from each camera as the insertion points on each leg of the carcass moved through the light beam are shown in Figure 39 and Figure 40.

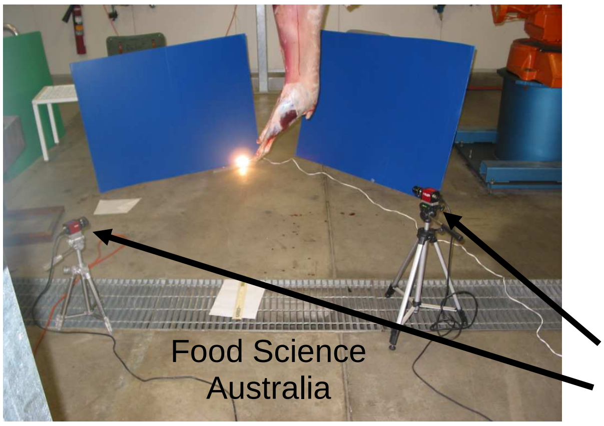

Figure 38: Backlighting Tests at FSA - Cannon Hill

Figure 39: Image from Left Camera (CAM 1)

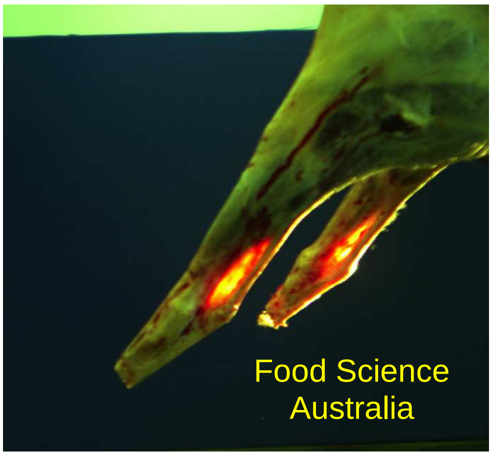

Figure 40: Image from Right Camera (CAM 2)

The cameras were positioned so that both legs were visible with the right side of the CAM 1 image and the left side of the CAM 2 image intersecting as shown in Figure 41 and Figure 42.

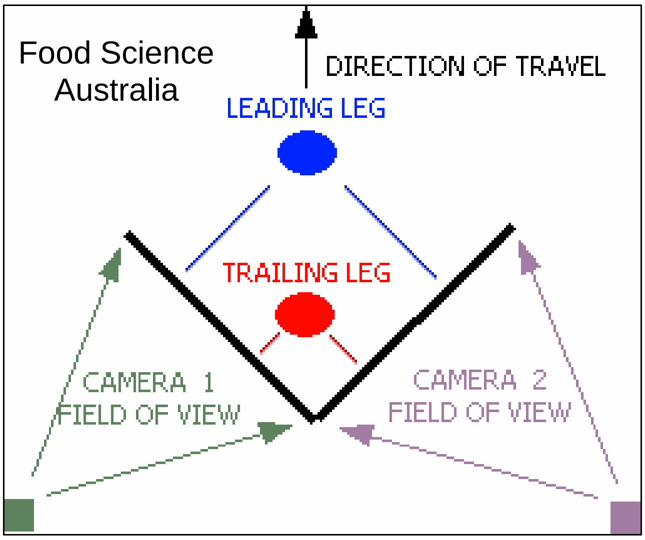

Figure 41: Camera Arrangement Plan for Background Lighting

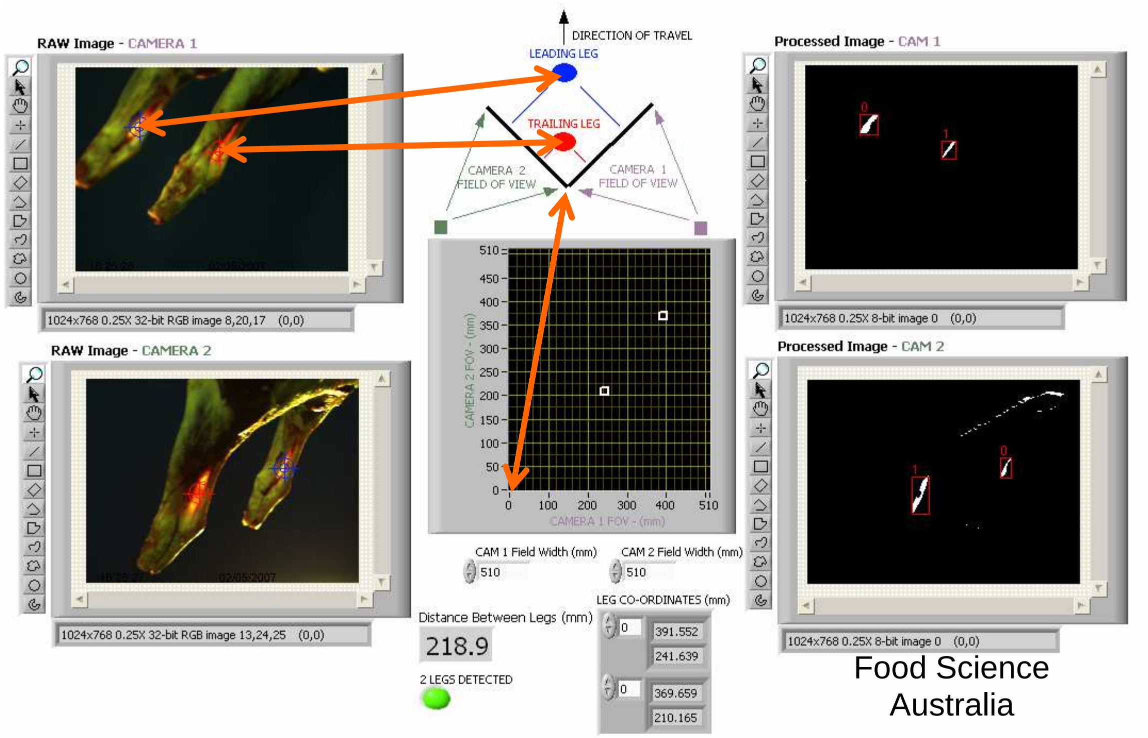

Figure 42: Image Analysis Software - User Interface

9. 4TH SHEEP TASK – COMBINED HOCK CUT AND NECK TIP

9.1. MILESTONE 16: DATA GATHERING – FRONT LET HOCK CUTTING AND NECK TIP, COMBINED

Data Gathering for Sheep Front Hock and Neck Tip required new sensing development in fore hock cutting and the integration with previous work in neck tipping carried out in AMPC/MLA project Development of vision and laser sensing systems suitable for beef and sheep slaughter tasks (PRTEC.042) - Milestone 5 "Sheep – Neck Tipping".

The sensing system is required to locate the neck and front legs of the sheep in three dimensions, so an automatic system can be used to identify the correct cut positions to remove the tip of the neck and cut through the forelegs releasing the carcass to hang by the rear legs only. This resulted in clean cut surfaces and minimises or eliminates residual contamination from the head removal task.

The hardware used to gather the data included:

- Two colour firewire cameras
- A laptop for data recording
- Different coloured backboards.

Imaging data from the hocks was captured during the site visits as data for sensing the neck region complete with the corresponding neck tip sensing system that had been previously developed. Site data collected was 225 still images of sheep hocks and 250 video images of the hock cut task. Data previously collected for neck tip includes over 280 still images and over 500 video images in the same plant.

For the front hock cut, the task definition requires that the shanks be removed at the cut line through the centre of the carpal joint. The neck tip task definition requires a cut approximately 10-15 mm from the first cut surface transverse to the neck. On investigation of manual task studies, it was found that the variation from the definition for neck tipping was dependant on the operator's ability to comfortably hold the tool with a change of cutting angle seen between short or tall cutting operators. The variation of the hock cut position was found to be dependant on the carcass shape and the mounting of the leg in the gambrel. Analysis showed that the manual hock cut position was close to ideal when the operator was aware of a formal study of the task; however researchers made observations of greater variation of cut accuracy at other times, when operators were unaware of being monitored. Accuracy also depended upon operator skill.

The sensing specification requires that the carcase is suspended by four legs. Data capture was achieved using one camera for the neck tip task and one for the fore hock removal task.

Cut location for neck tipping was based on:

- The tip of the neck
- The base of the neck at the head removal cut and the top of the neck
- The angle of the cut based on a reference to the angle of the neck as it hangs (operator adjustment allowed).

The location of the cut was based on the location of the analysed features of the neck. An operator parameter shall allow the cut position to be altered to plant specification, based on the location of the features. The sensing system for this operation can be reduced to image analysis using a camera to locate the cut position horizontally and vertically.

The hock cut analysis was based on:

- The position of the legs referenced to the gambrel
- Narrow point of the leg
- Location of the hock/carpal joint referenced to the external shape of the joint in the leg.

The location of the cut was based on the shape of the foreleg shank and carpal joint. Most of the foreleg (between the shackle and the shoulder) was analysed and operator parameters allowed the gambrel and leg areas to be defined from that analysis to determine the required features.

As the fore legs were captured and positioned by the gambrel, there was only the need to analyse the position the fore legs in two dimensions. This suits a sensing method only requiring a single camera.

It was concluded that enough data was collected to allow data analysis for the project to advance.

9.2. MILESTONE 17: DEVELOP SOFTWARE – FRONT LEG HOCK CUTTING AND NECK TIP, COMBINED

Sensing has been identified as an important step in the development of automated systems suitable for beef and sheep slaughter tasks.

A sensing system for sheep neck tipping was previously developed and demonstrated as part of “Development of Vision & Laser Sensing Systems Suitable for Beef and Sheep Slaughter” (Neck Tipping). Examples of this analysis can be seen in Figure 43 and Figure 44.

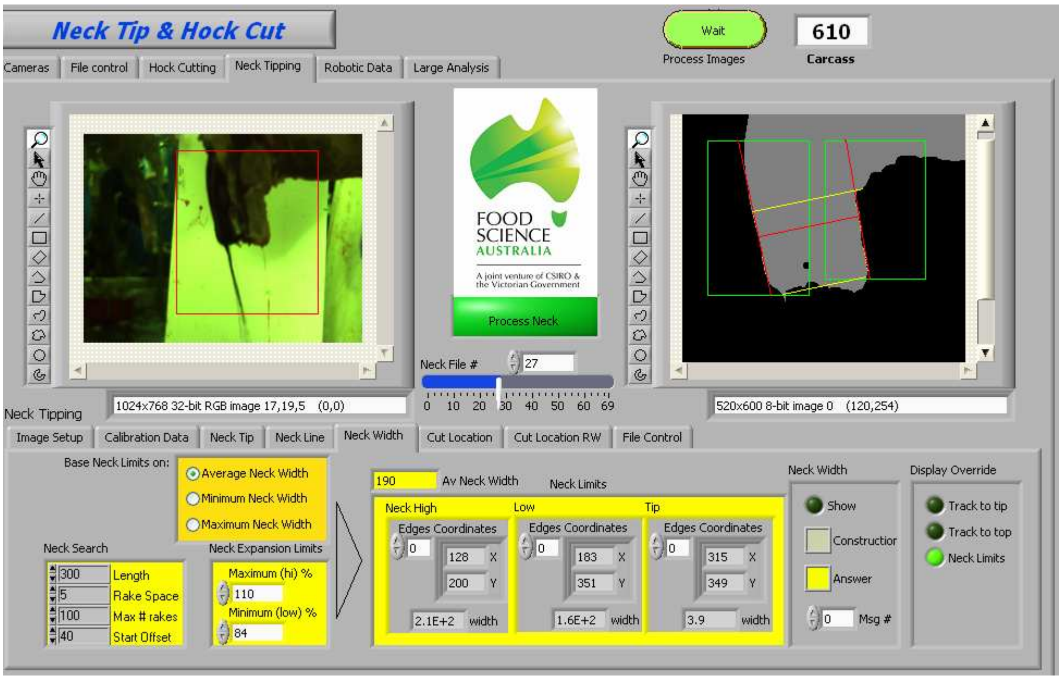

Figure 43: Example of analysed neck image for automated tipping

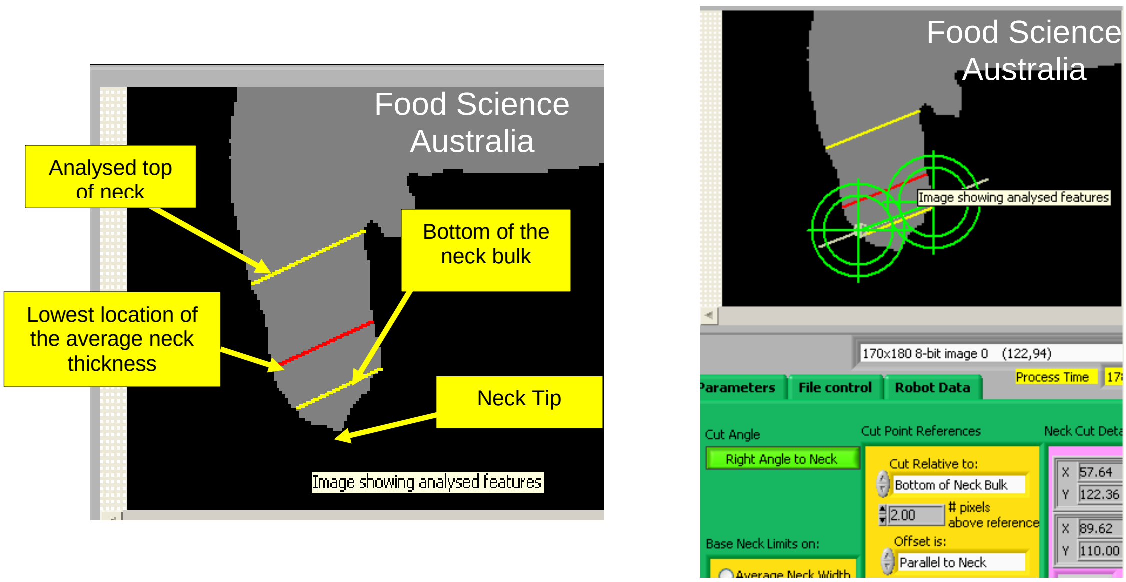

Figure 44: Reference points and final cut position for neck tipping

Milestone 17 of “Stage 2 Vision and Laser Sensing Systems“ developed a sensing system suitable for detecting the hock cut location based on the features on the surface of the fore leg. The features analysed as part of hock cutting were based on information gathered as part of milestone 16 of “Stage 2 Vision and Laser Sensing Systems” and the accuracy of the manual procedure studied as part of that milestone. Selected examples of the hock cutting analysis can be seen in Figure 45, Figure 46 and Figure 47.

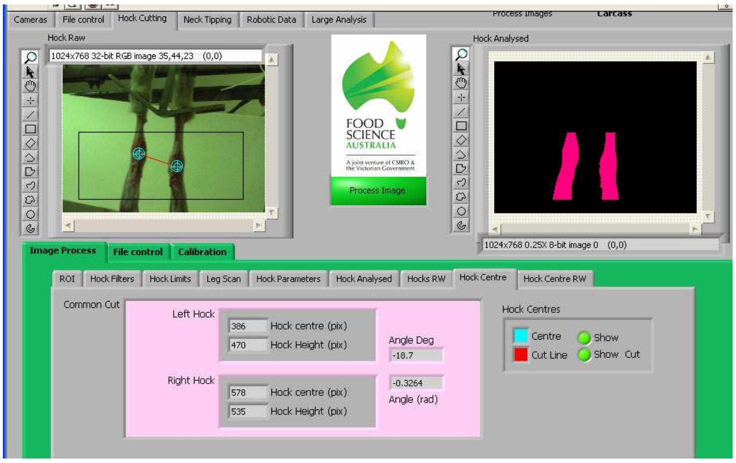

Figure 45: The centre and angle between the hocks are analysed and can be shown

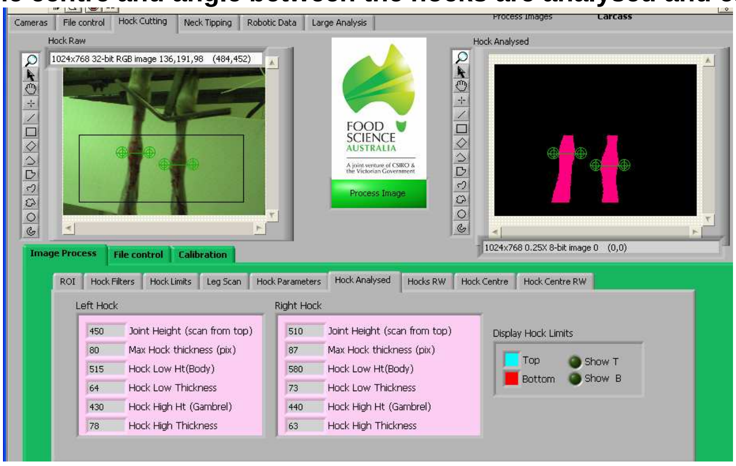

Figure 46: The height of each hock is analysed and can be shown

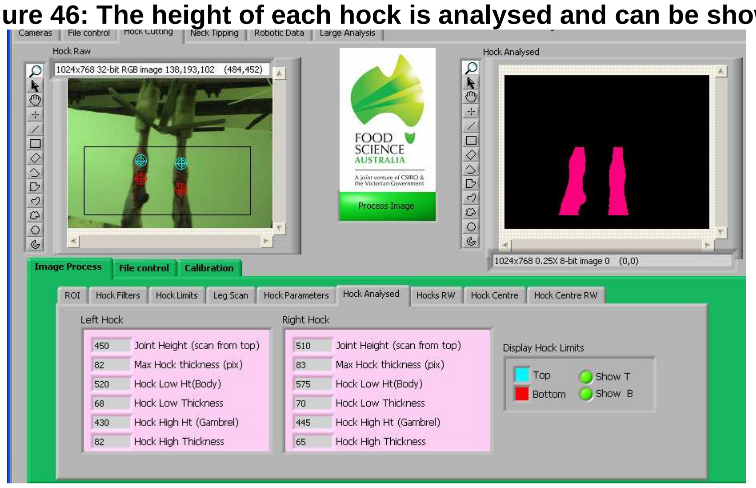

Figure 47: Alternative cut locations at the extremities of the hock are analysed and can be shown

Both sensing systems were then integrated into a single sequenced system to provide a path for automation of a combined neck tip and hock cutting operation (Figure 48).

The combined system was successfully demonstrated to an MLA/AMPC representative in a plant operating at normal production speed of approximately 1 carcass every 7 seconds on June 8th, 2007.

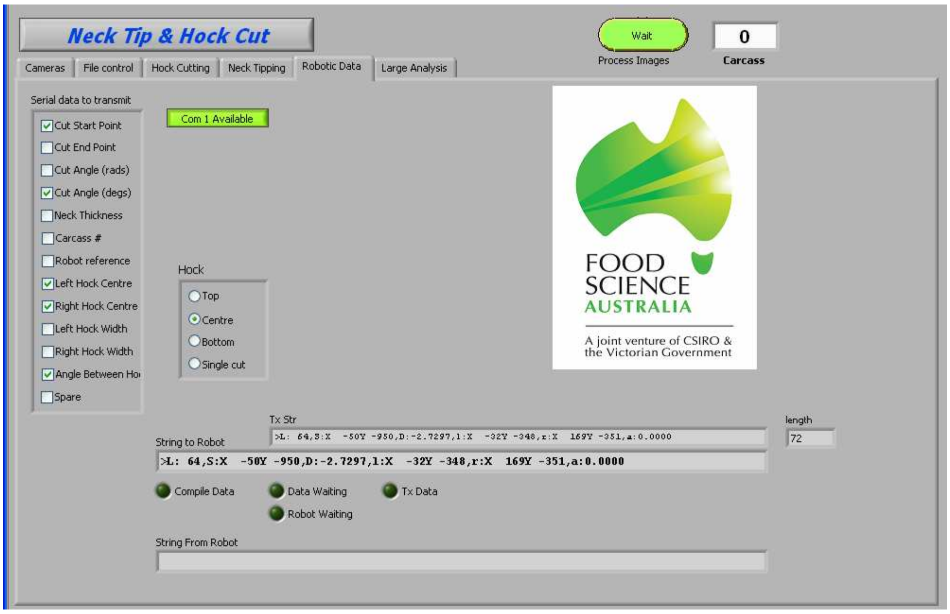

Figure 48: Analysis of the neck is integrated to the hock analysis and all the data becomes available for transmission to the cutting tool

The accuracy of the hock cut location based on surface features can be influenced by the condition of the leg and the only way an accurate cut between bones can be established is to look at the internal structure of the leg around the joint (Figure 49). Food Science Australia further investigated the use of X-ray equipment and its possible suitability for the application to hock cutting in a production environment. This investigation provided an alternative solution to vision analysis for detecting the cut location (Figure 50).

It was concluded that the combine sensing system for neck tipping and hock cutting has been developed and demonstrated successfully to the stage that it should be integrated to a robotic system to confirm that the complete automated system could operate at production speed. This will be done as part of milestone 18 of “Stage 2 Vision and Laser Sensing Systems”.

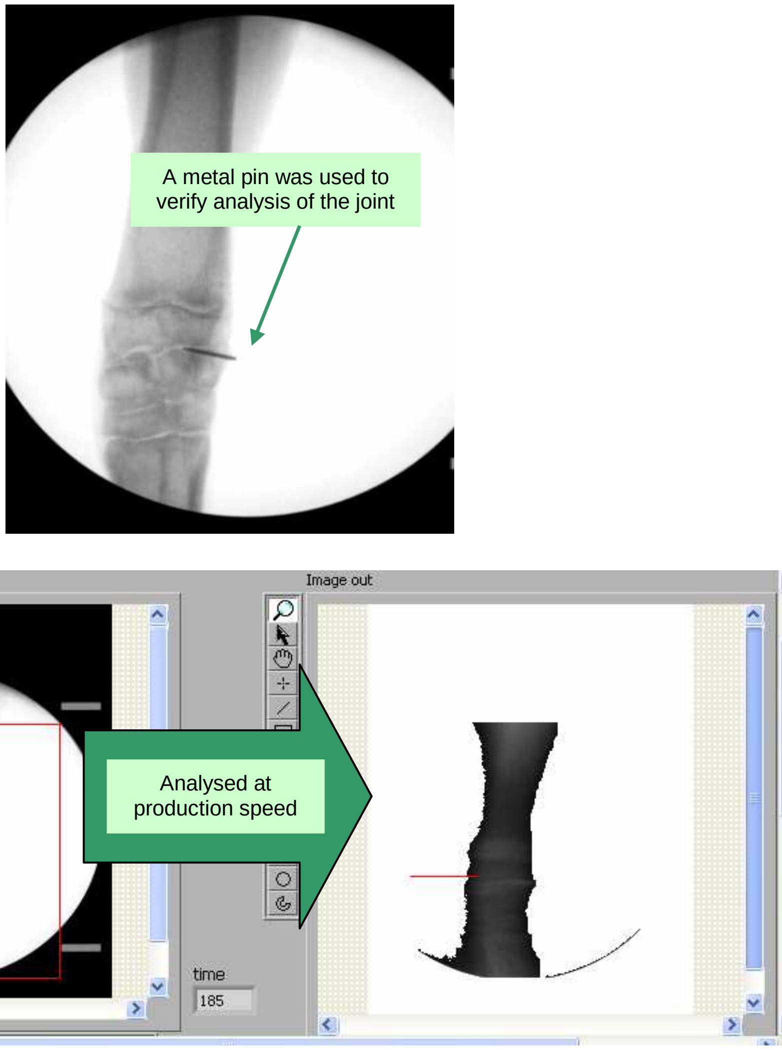

Figure 49: Only internal imaging (using X-ray images) can give an absolute location of the joint

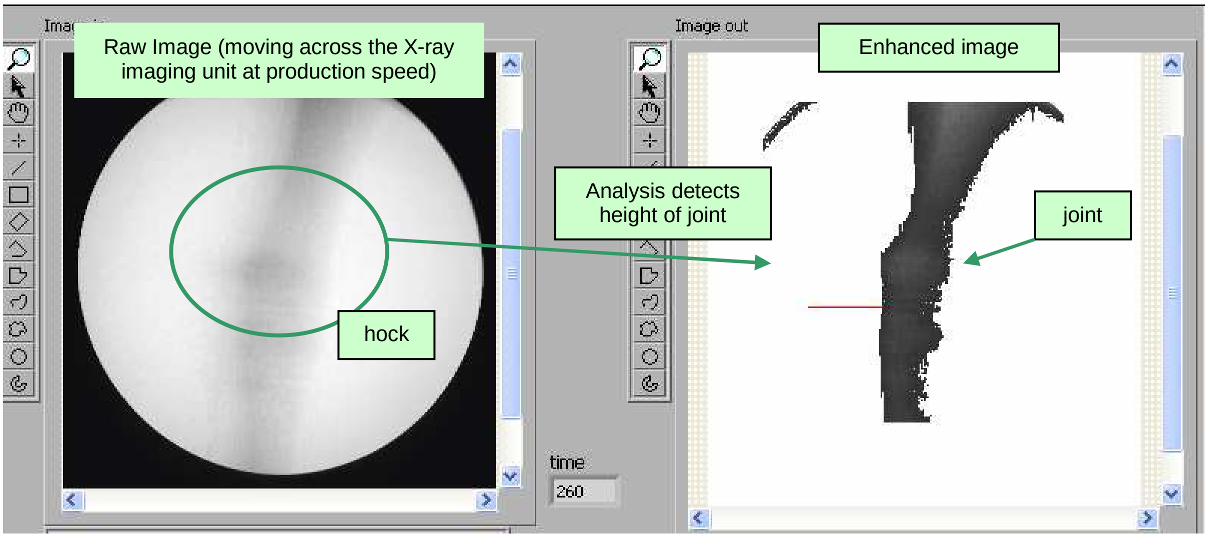

Figure 50: Alternative joint detection using X-rays was investigated for the hocks at production speed

9.3. Milestone 18: Develop Robot Process Path – Front Leg Hock Cutting and Neck Tip, Combined

Milestone 18 of "Stage 2 Vision and Laser Sensing Systems" required that the neck tipping and hock cutting sensing system be demonstrated (in simulation format) as an integrated cutting system. The combined sensing system developed in milestone 17 of "Stage 2 Vision and Laser Sensing Systems" was integrated to Food Science Australia's ABB4400 robot on the export quality boning room in Cannon Hill for that demonstration.

An indicative mock tool (Figure 51), very similar in shape to the tool used for the manual operation of neck tipping and hock cutting was fitted to the robot for visualisation purposes during the demonstration. The mock tool was only used to show placement and the cutting operation was not performed at any time.

The cutting of the hocks on a carcass during normal production clears it from the camera's field of view such that the next carcass can be imaged and processed for neck tipping. Because the mock tool did not perform any cutting operations only a single carcass was used during the demonstration.

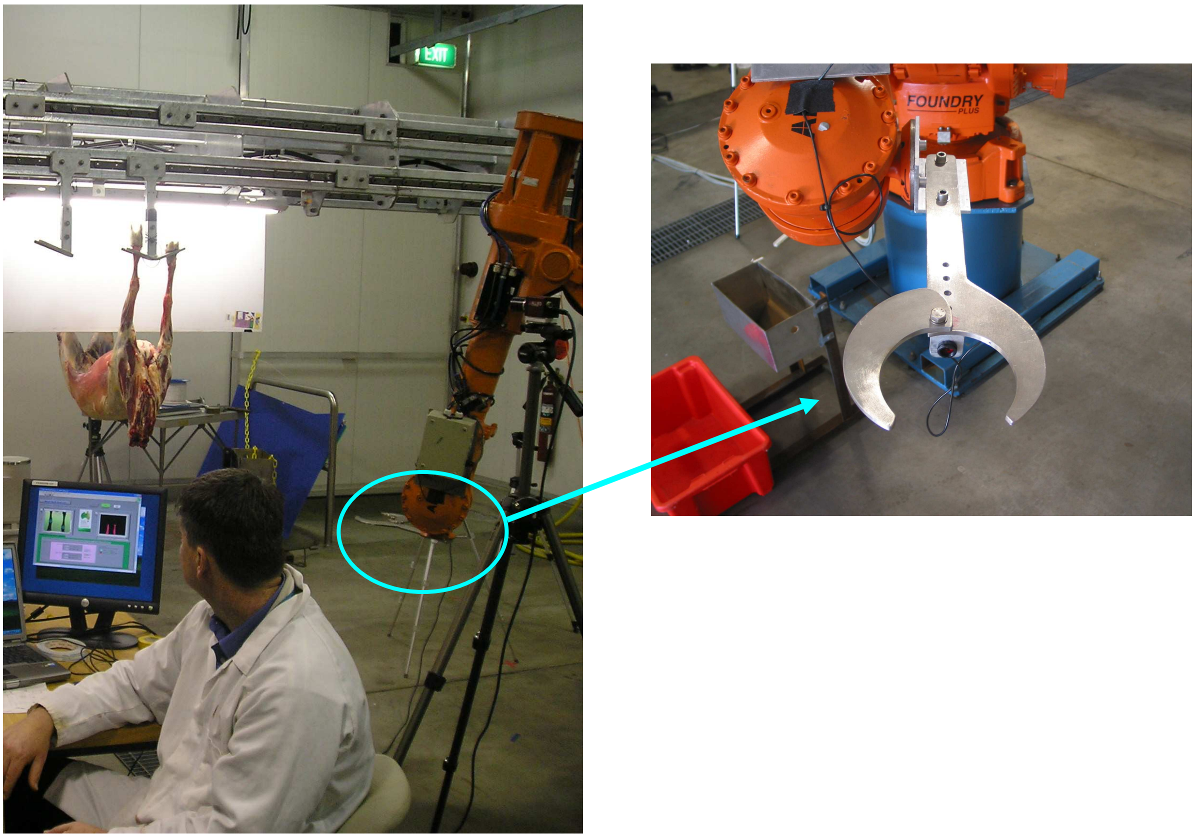

Figure 51: Configuration of sensing equipment integrated to robot and cutting tool (indicative tool)

The fully integrated equipment was successfully demonstrated to an MLA/AMPC representative on June 26th, 2007 by using a single carcass on a variety of placement configurations of the carcass (Figure 52).

The automation of a fully integrated neck tipping system had previously been successfully demonstrated to the MLA/AMPC representative. As such the demonstration concentrated on the integration of neck tipping and hock cutting, with emphasis on the hock cutting operation.

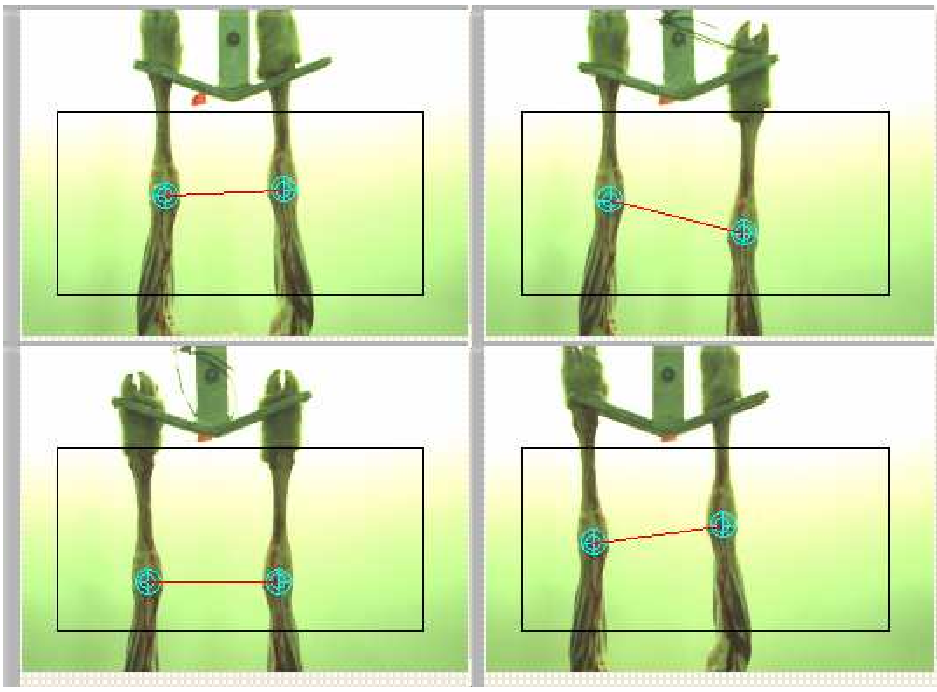

Figure 52: A variety of leg orientations were demonstrated

Figure 53: Neck tip and hock cut during demonstration

The demonstration was completed using a production speed equivalent to one carcass every 7 seconds and rudimentary path tipping the neck and cutting each hock individually was completed with the tool being delivered to a wash location at the end of the path (Figure 54, Figure 55 and Figure 56). This path would have to be altered for individual plants depending on the tool type and conveyor configuration in the plant.

The demonstration of the combined sensing system integrated to the cutting path of the robot operating at normal production speed helps to give industry the confidence to progress the automated neck tipping and hock cutting system to the next stage of developing the tool to be fitted to a robot.

The next stage of development of the automated neck tip and hock cut system would be to integrate a proper cutting tool to a robot. Once the cutting tool is installed the prototype robotic cutting system for installation into an operating sheep plant should be configured.

A video presentation of the robot cutting demonstration is included as part of “APPENDIX A – Video Presentations”.

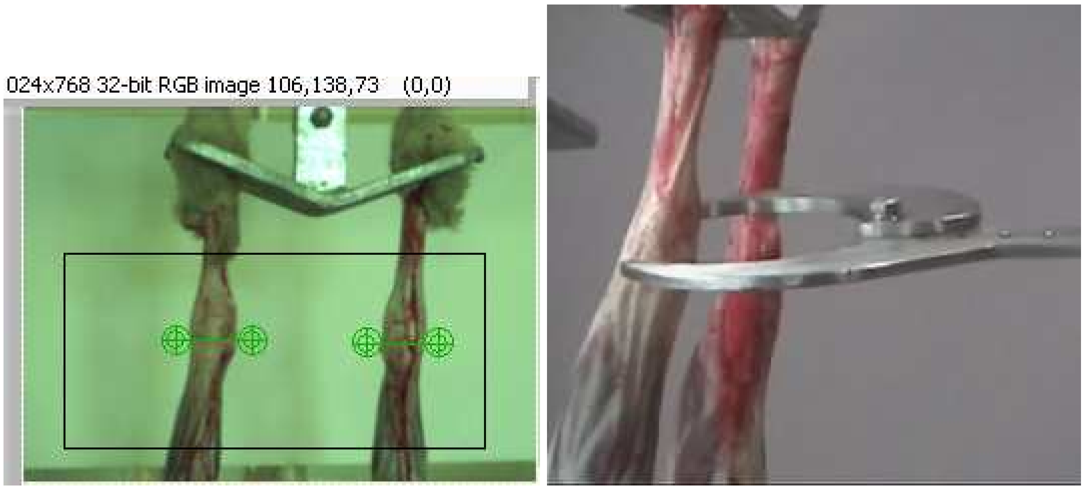

Figure 54: Hocks being cut centrally during the demonstration

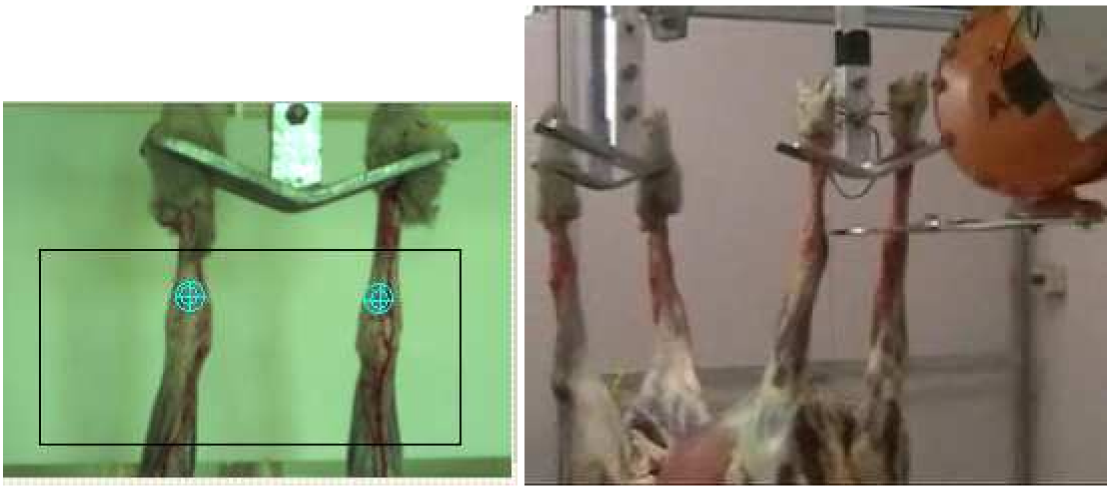

Figure 55: Optional cut above hock demonstration

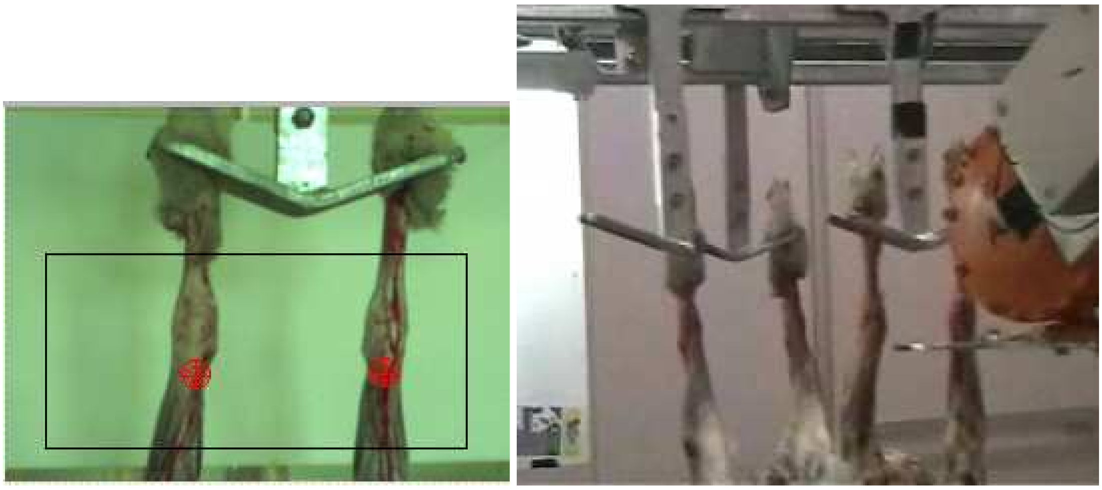

Figure 56: Optional cut below hock demonstration

10. SELECTION OF DEVELOPMENT SOFTWARE

There are many optional programming languages and environments available that are suitable for developing the vision and laser systems. These include C, BASIC or the Visual Net or SCADA environments, along with camera systems such as Cognex or DVT. Food Science Australia has chosen to develop the sensing systems for these projects under the National Instruments' Labview programming environment.

National Instruments equipment provides a system that allows rapid prototyping of concepts – the main aim of the first stage of the vision and laser sensing systems.

All the software development and testing for Labview can be completed on a standard personal computer. This allows for proof of concept equipment and systems to be developed while minimising the expense of the equipment required.

National Instruments also develop a comprehensive range of hardware, along with their development software. For this reason, the amount of interfacing problems that can be encountered by integrating different systems can be reduced. Integration to generic equipment is also possible and accommodated by using the standard development tools in Labview – this is demonstrated by the interface to the SICK LMS400 laser system working on an Ethernet connection.

National instruments also produce their own real-time industrial grade equipment. This provides a clear path for robust equipment selection starting at the development environment and ending on the production floor. Again, the same software that has been developed and proven on the personal computer can be transferred to the industrial real-time system, without having to modify or re-interface the program.

The National Instruments equipment is industrial grade and industry accepted for use in industrial controls in harsh environments.

Labview also has the facility to be able to assimilate programs written in other languages (including C, MatLab and BASIC). This can be desirable if a certain function runs more effectively in another environment.

Labview's performance is considered to be comparable to compiled C code. All vision and laser systems developed as part of "Stage 2 Vision and Laser Sensing Systems" were demonstrated on a laptop computer operating under Windows XP environment. The computer also ran other programs in background (such as a virus scanner, or screen capture software) further slowing the computer down. The times quoted for image or laser processing times for any milestone of "Stage 2 Vision and Laser Sensing Systems" are only indicative, and once the programs are fully compiled and transferred to a

National Instruments real-time computer, it is anticipated that these processing times would be dramatically reduced.

The Labview development environment or software runs on all versions of MS Windows, Linux, Solaris and Mac OSX. Once compiled a Labview program can run in real-time on an industrial grade computer, or embedded operating system.

To summarise, the National Instruments Labview system provides a seamless development path for both software and hardware from concept through to production equipment. More importantly, integration of equipment provides reduced costs at the concept stage, while still allowing for robust industrial equipment for the production environment.

11. RECOMMENDATION

Review of developed automation strategies and recommendations for progression

The sensing and automation development work for beef and sheep slaughter tasks over the last three years has focussed on a total of 10 sheep and 8 beef slaughter task operations. The sensing development has evolved from applying laser distance sensors to full area surface mapping of carcass features and the use of colour imaging through to thermal and X Ray image processing. The strength of the sensing development has been in integrating different image and sensing systems to identify the required carcass features in their operational space to allow the imaging output to direct a mechanical or robotic arm to a single position or move through a sequence of positions to perform a functional process task.

The recommendation of this report is to conduct a review of the learning's gained over this period to identify areas where sensing and control systems could be simplified and/or improved, to identify work tasks that are now commercial ready, tasks that require further development, tasks that could be achieved with minimal development and tasks that could be achieved with emerging sensing technologies such as integrating X Ray imaging with other formats to create a sensing platform.

12. REFERENCES

[1] Aust P, Heidke D, MacRae K, White, R. *Investigation and Evaluation of Sensors for Adaptation to the Meat Industry – Milestone 1: Sensing Requirements for Beef and Sheep Slaughter Tasks & Milestone 2: Identify "Manual" Assist Sensing Techniques (PRTEC.032),* Food Science Australia. Cannon Hill, Qld., 2005

[2] *Development of Vision & Laser Sensing Systems Suitable for Beef and Sheep Slaughter Tasks (PRTEC.042)- Selected Beef & Sheep Tasks for Milestone 1,* Food Science Australia. Cannon Hill, Qld., 2006

APPENDIX A – VIDEO PRESENTATIONS

Beef RFID Tag Identification
A brief video showing the combined laser analysis with colour and thermal imaging integrated to control a robotic system. The sensing system locates the capture point on a beef ear for removal of the RFID tag.
File: Beef RFID detection.wmv

Sheep Sensing for Head Removal
A brief video showing how laser profile analysis software was developed to identify the head removal position on sheep carcasses.
File: Sheep Head Removal.wmv

Beef Hoof Identification for Shackling
Thermal Beef Hoof Identification
A brief video presentation using thermal imaging techniques to identify and track beef hooves on a slat conveyor.
File: Thermal Hoof Identification.wmv

Colour Beef Hoof Identification
A brief video presentation using colour imaging techniques to identify and track beef hooves on a slat conveyor.
File: Colour Hoof Identification.wmv

Hoof ID for Shackling
A brief video showing the combined vision and laser analysis integrated to a robotic system locating the capture point on cattle.
File: Hoof ID for shackling.wmv

Sheep Front Leg Spread

Colour image system

A video presentation showing the sensing of sheep fore legs for capture to allow placement of the legs into gambrels using colour image processing only.
File: Sheep Leg Capture – Image Only.wmv

Laser analysis system

A video presentation showing the sensing of sheep fore legs for capture to allow placement of the legs into gambrels using laser analysis only.
File: Sheep Leg Capture - Laser.wmv

Beef Leg Roller Insertion

A video presentation showing the vision & laser profile sensing integrated to identify the position for insertion of the meat roller hook into the beef legs.
File: Leg Roller Insertion .wmv

Sheep Gambrel Insertion

A video of the image analysis software developed by integrating images from two colour cameras and from a single camera to identify the correct position for inserting the gambrel into the rear legs of the sheep carcass.
File: Sheep Gambrel Insertion.wmv

Sheep Hock Cut and Neck Tip

Neck and Hock Process

A video presentation showing the image sensing of sheep necks for tipping and hocks for cutting. The sensing is interfaced to a robot and demonstrations of the complete system are also shown.
File: Neck and Hock Process.wmv