final report

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Development of Vision & Laser Sensing Systems Suitable for Beef and Sheep Slaughter Tasks

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INTRODUCTION

During the 2004-2005 “Robotic Sheep Brisket Cutting” project, Food Science Australia developed an automatic vision and laser scanning system to accurately detect the location and shape of the abdominal opening and the tip of the brisket for the insertion and application of a robotic sheep brisket shear.

Also during 2005 Food Science Australia completed a project funded by AMPC and MLA PRTEC.032 “Investigation and Evaluation of Sensors for Adaptation to the Meat Industry” that outlined beef and sheep slaughter tasks suitable to applying and developing vision and laser sensing systems.

PRTEC.042 “Development of Vision and Laser Sensing Systems Suitable for Beef and Sheep Slaughter Tasks” is a further progression of the above projects to develop vision and laser sensing for beef and sheep slaughter tasks.

The tasks included for laser and vision sensing for beef in PRTEC.042 were:

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

The tasks included for laser and vision sensing for sheep in PRTEC.042 are:

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

This report provides a summary of the reports produced as a result of each of these sensing tasks.

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.

MILESTONE 1: BEEF - ABDOMINAL-THROCIC HIDE OPENING

The beef task selected for sensing for milestone 1 of PRTEC.042 was the hide opening from the abdominal to the thoracic region of the carcass as it is suspended by the rear legs.

The task has been considered as suitable only after the udder or pizzle has been removed, but prior to the flanking operation. The task is also considered to be a partial operator task, as the opening cut is presently done as part of the normal flanking operation.

The process was studied at meat processing plants to view the process as it is manually performed and to establish a specification of the open cut required, although this may be varied depending upon individual plant requirements.

It was determined that the start point of the cut would be established by finding the low point of the hide opening after the udder or pizzle had been removed. The trajectory of the cutting tool would then be determined by a profile of the abdomen and chest gathered through a laser profiling unit.

A number of processing plants were inspected to determine their suitability to participate in the development of the task. The plant eventually chosen was selected for its access to a clear station suitable for both image capture and laser scanning.

A scanning rig has been developed that allows researchers to set up in an abattoir and gather data on the carcasses without interfering with normal production. The scanning rig included suitable mounts for a digital camera and a scanning laser. The height of the camera and laser could be independently set to heights between 700mm and 2400mm from the floor, with the laser being able to be traversed over a distance of 300mm horizontally. The complete rig was designed to be installed on an operating slaughter floor very quickly and with little or no interruption to normal production.

Software has also been developed that is able to gather image and 3D laser data at production speeds. Image analysis and cutting path determination were included as part of the data gathering software, and all processing was completed at production speed.

A second program was developed that allows the data to be reviewed and alternate image and data processing algorithms to be tested in a controlled environment.

During the first data gathering trials, over 250 cattle were scanned. 175 of these carcasses were of the weight range 200 – 250kg, while the remainder were calves. This allowed the initial data analysis to not only to be tested on uniform carcasses, but confirmed on a large size variation in carcasses also.

An Allied Video Technologies Oscar 510 Firewire digital camera was selected to capture colour images of each carcass to analyse the hide after the udder or pizzle was removed.

The image analysis performed very well in carcasses where the outside of the hide was a dark colour but where the hide was a light colour, a contrast between the internal fat and external hide of the carcass became harder to establish and the image analysis became less reliable. This large variation in carcass hide colours and body condition required several different image analysis algorithms to be developed. It was also proposed that the development of image analysis in this format would be an ongoing process, with new algorithms being required to analyse additional colour or condition parameters of carcasses

As an alternative to digital image analysis, thermal imaging techniques were also investigated to find the starting point of the opening cut. The difference in temperature between the hotter inner carcass surface and the cooler outer surface of the carcass varied at least 5ºC over a tuned temperature range of 20ºC across the carcass and was proven to be an extremely reliable sensing system. Thermal imaging cameras would increase initial costs, but this increased cost would be far offset by the system becoming more robust.

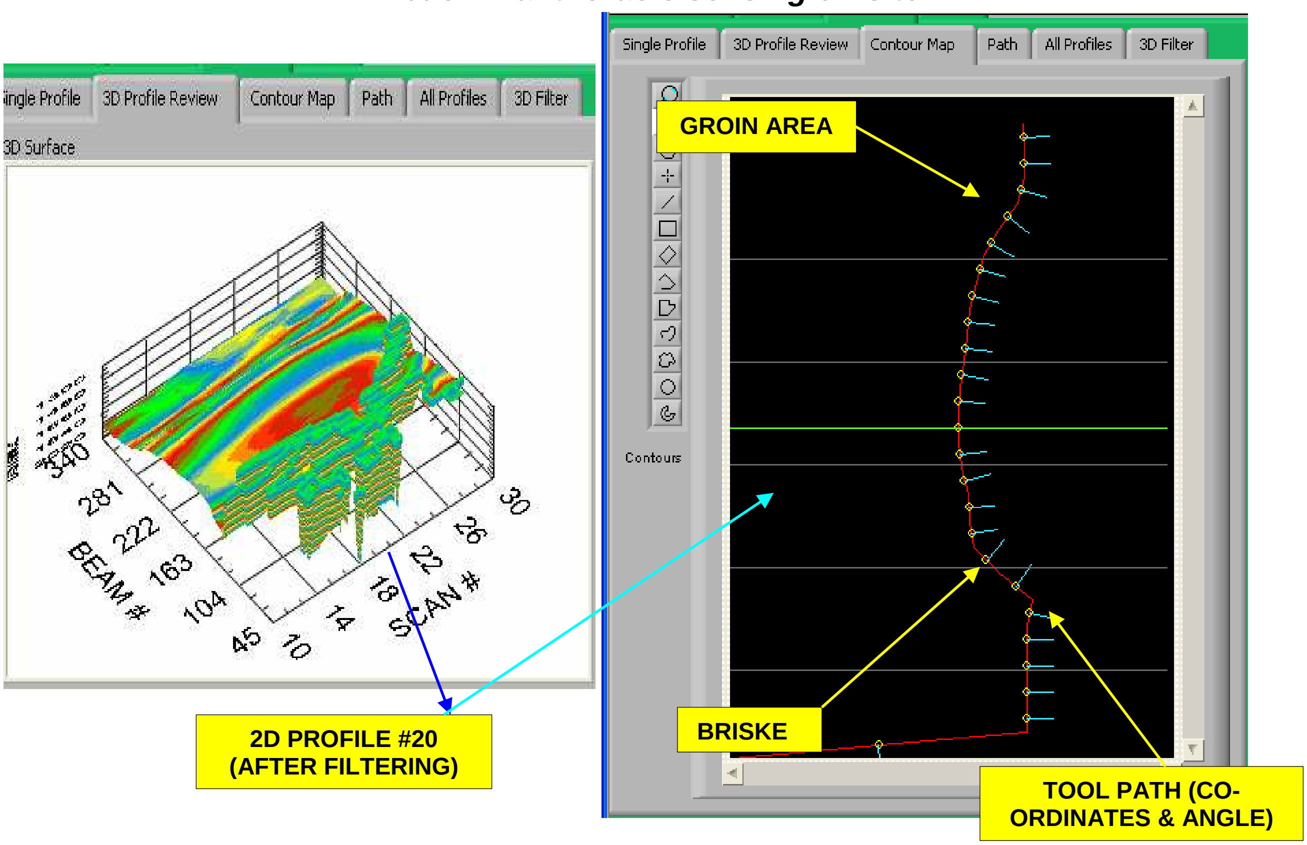
The report concludes that colour image analysis can be used to find the interface between the outside of the hide and the surface of the inside of the body when the hide surface is largely dark, but the analysis for light carcasses becomes unreliable. A recommended method of determining this interface would be to use thermal sensing technology.

Profiles of the abdomen and chest regions were gathered by using multiple scans of the carcass using a SICK LMS400-0000 laser system. Several scans were taken while the laser was moved over a 300mm horizontal path. For indexed lines, this had the advantage of accounting for carcasses not stopping in exactly the same location each time. Concurrently the system was being proved as if were working on a continuous line moving at up to 100mm/sec.

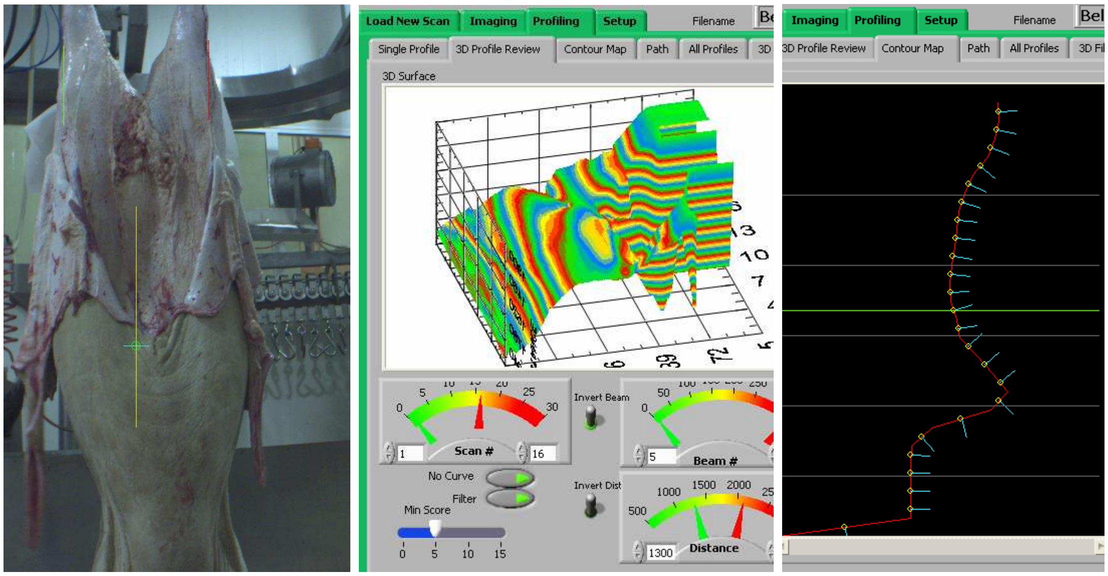
The SICK LMS400-0000 laser system used in the initial trials was found to have an unacceptable amount of bad scan data on very dark and black carcasses. SICK have recently released the model LMS400-1000 with a stronger laser, and tests using this second laser showed substantial reduction in the amount of lost scan data. It is considered that the amount of lost data when scanning carcasses with the newer laser could be filtered out using the algorithms developed to recover data on the older laser.

This study has also confirmed that the profile of both light and dark carcasses can be determined for the purposes of generating a cutting path by using a SICK LMS400 laser profiling system, although a stronger laser used for measurements – as in the LMS400-1000 – must be selected to obtain good results over a large range of carcasses. The contour of light coloured carcasses can be sensed using the older SICK LMS400-0000 laser, but for light and dark carcasses the more recent SICK LMS400-1000 is recommended.

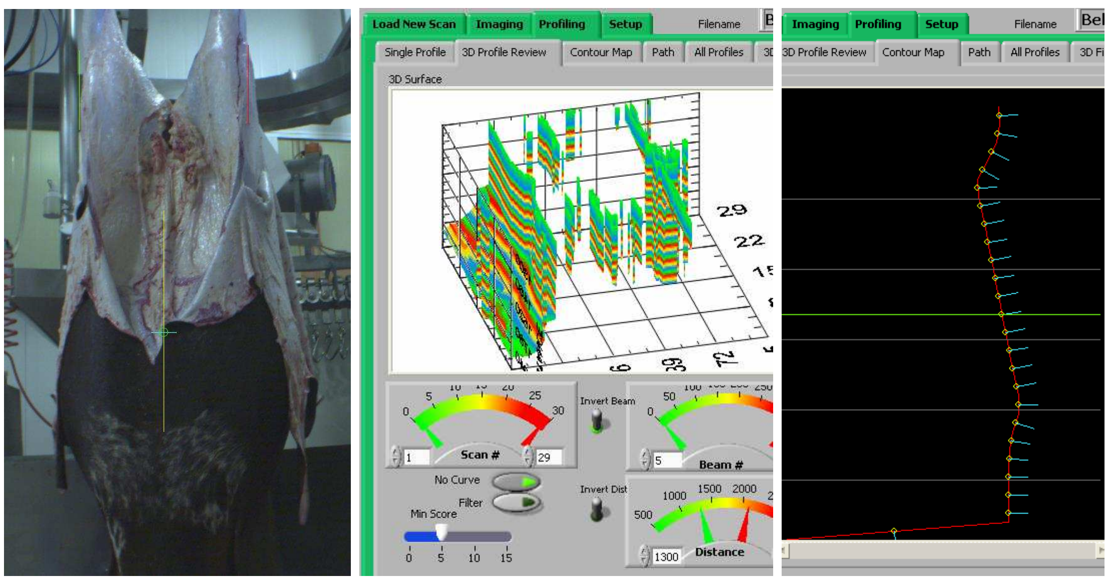
Abdominal-thoracic sensing on-site



Typical laser profiling results of carcass underside



Light carcass gives poor image analysis, but good laser analysis



Dark carcass gives good image analysis, but poor laser analysis

MILESTONE 1: BEEF – ABDOMINAL-THORACIC HIDE OPEN SUPPLEMENTAL

This report is a supplemental report to milestone 1 of PRTEC.042 "Development of Vision & Laser Sensing Systems Suitable for Beef and Sheep Slaughter Tasks, Beef – Abdominal-thoracic Hide Open".

When this project was originally undertaken, the technology chosen included a colour camera analysis and a low power laser scanning unit.

It was found in milestone 1 that the variation in the colour of carcasses hides had a large impact on the image analysis when trying to find the opened hide, and the analysis was unstable and unreliable. In milestone 1 thermal imaging was suggested as a potential replacement to the colour camera. This reports shows that thermal imaging for the detection of the opened hide is very robust and can be automatically tuned to the individual temperature of each carcass.

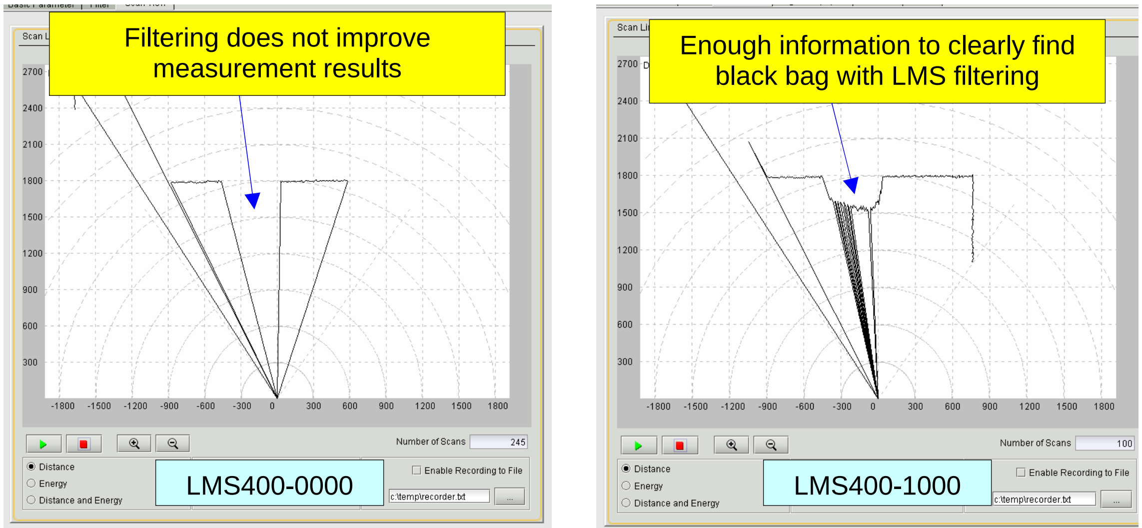
In milestone 1 it was found that the SICK LMS400-0000 laser measuring sensor was not reliable on dark coloured carcasses, and large amounts of data regarding the carcass profile were not gathered. Initial investigations from milestone 1 indicated that the SICK LMS400-1000 using a 7.5mW laser could better suit the application. Testing of the sensing system using the new LMS400-1000 laser unit produced results with less than 5% faulty readings per scan, which gathered enough data on the carcass profile to produce a cutting path reliably.

The image and laser sensing systems were combined and able to scan a carcass at production speed, taking less than 3 seconds to gather and analyse data on each carcass.

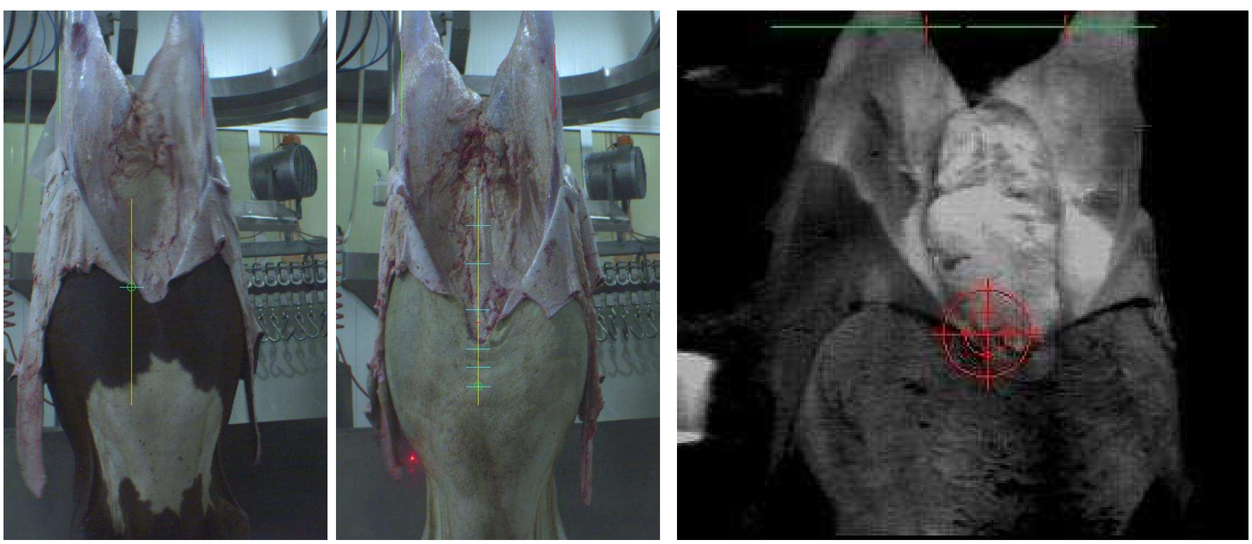
The sensing system was demonstrated on an indexed beef production line operating at a cycle time of between 40 and 50 seconds to an MLA representative on July 10th 2006. During this demonstration approximately 25 animals were successfully scanned and an explanation of the system and its adjustments was provided to the satisfaction of the MLA representative. A video of the program operating is included as part of this report.

The sensing system was integrated to the ABB4400 robot and facilities at Food Science Australia at Cannon Hill. The integrated system was successfully demonstrated to an MLA representative in July 11th 2006 using a single carcass conveyed to the sensing station. The robot was utilised to trace the cutting path on the carcass after it had been scanned by the sensing system. The carcass was moved several times to simulate different animals arriving at an automated work station. A video of the demonstration is included as part of this report.

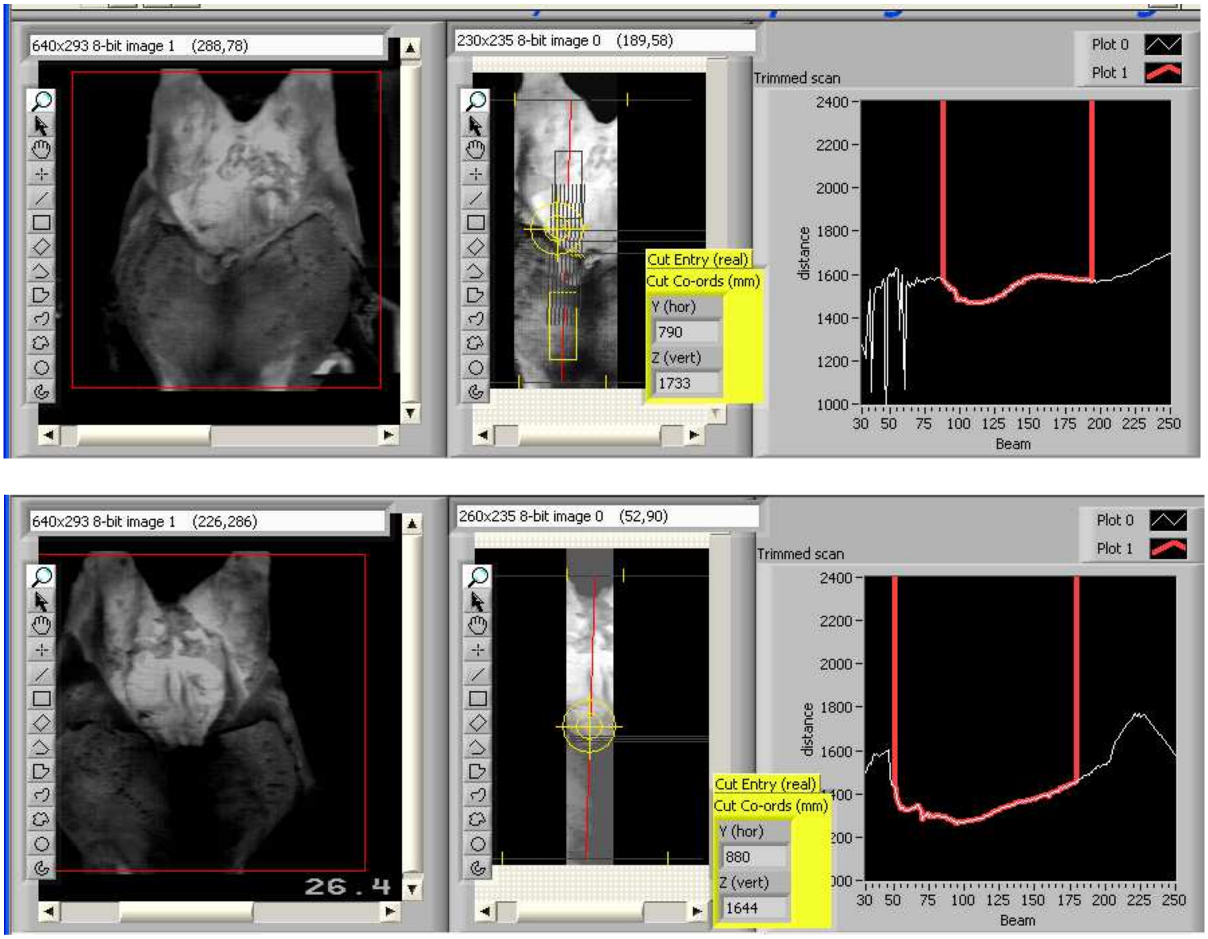
It was concluded that the thermal imaging combined with the stronger laser used (LMS400-1000) can provide a robust sensing system for the automation abdominal-thoracic hide opening process.



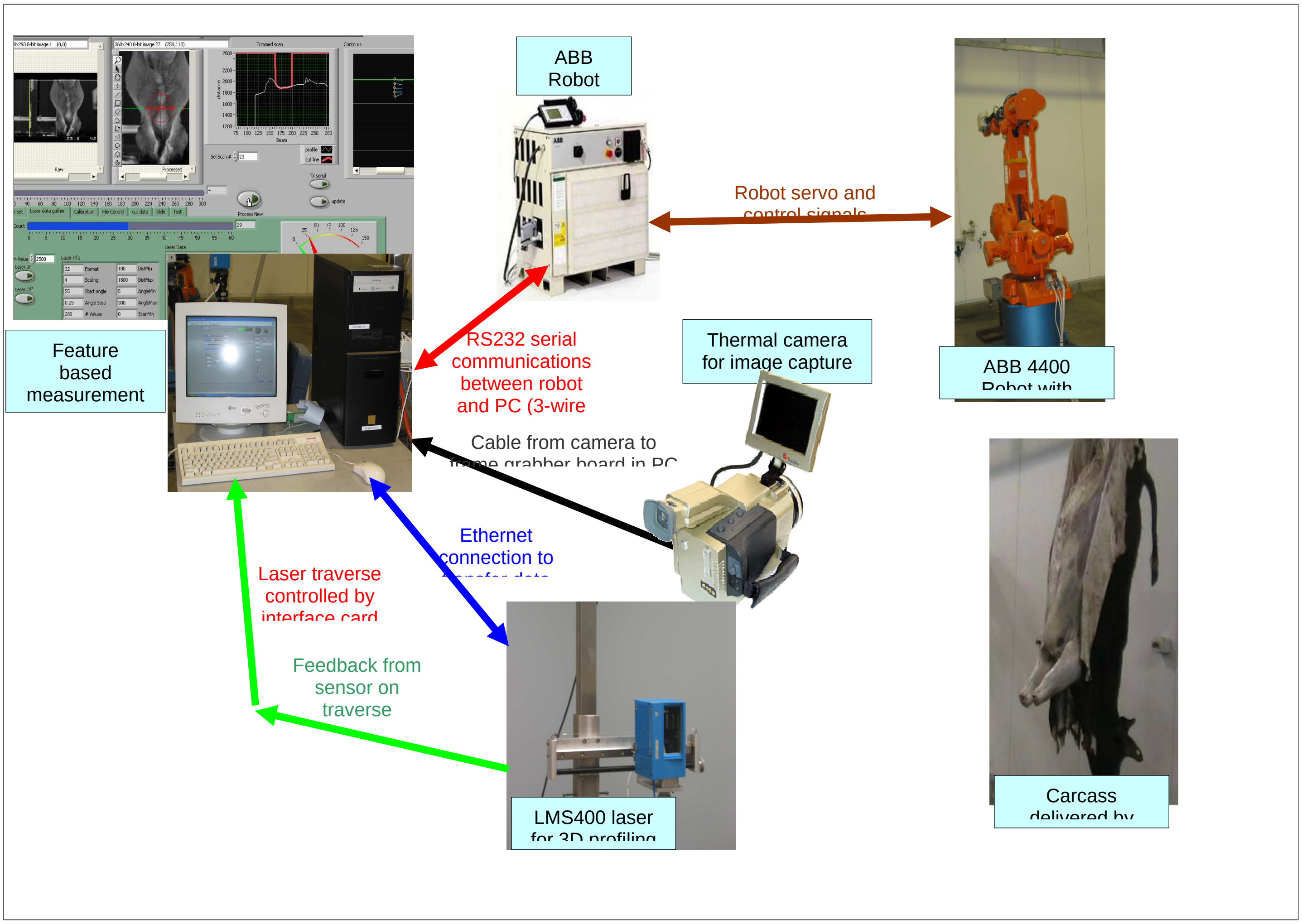
Comparative results of the early and late model lasers on a dark surface



Carcass colour has no bearing on the results from thermal imaging



Typical good analysis results from thermal imaging and laser scanning



Fully integrated system used in demonstration of abdominal-thoracic hide opening at Food Science Australia

MILESTONE 1: SHEEP – FRONT Y-CUT VACSAN

The sheep task selected for sensing for milestone 1 of PRTEC.042 was for the automation of a VacSan unit for the front Y-cut region with the two fore legs suspended.

The manual operation of the VacSan unit over the Y-cut region was studied at several plants with results showing that – although the VacSan was used to meet sanitising requirements – the paths used for the units varied between operators. Each individual operator also varied the operation between carcasses. An automated VacSan system could guarantee a consistent sanitising path across all carcasses.

The processing times across sheep processing plants in Australia were also studied with results showing a carcass processed every 5.8 to 7.5 seconds. A period of 6 seconds total sensing time was set as a reasonable target. Separating the sensing station from the operation station allows a further 6 seconds for the automated VacSan operation.

Some plants specify that the VacSan operator targets any visual contamination. The sensing system developed as part of this project is only used to provide a fixed VacSan path and any searching for contaminants would require additional sensing mechanisms.

Differing requirements for the VacSan task between plants also means that a final specification for the VacSan will be determined when a plant has been selected for installation testing and trials.

The shape and variation of the carcasses scanned has been studied and it has been found that the height of the neck has the greatest variation and must be measured for proper tool placement. Other features, including the locations on the legs and chest regions have a smaller variation. All of these features can be determined by either the vision system or the laser system, or a combination of both. The laser profile data gives an accurate distance measurement from the sensing systems to the surface of the carcass, which is not provided by image analysis alone.

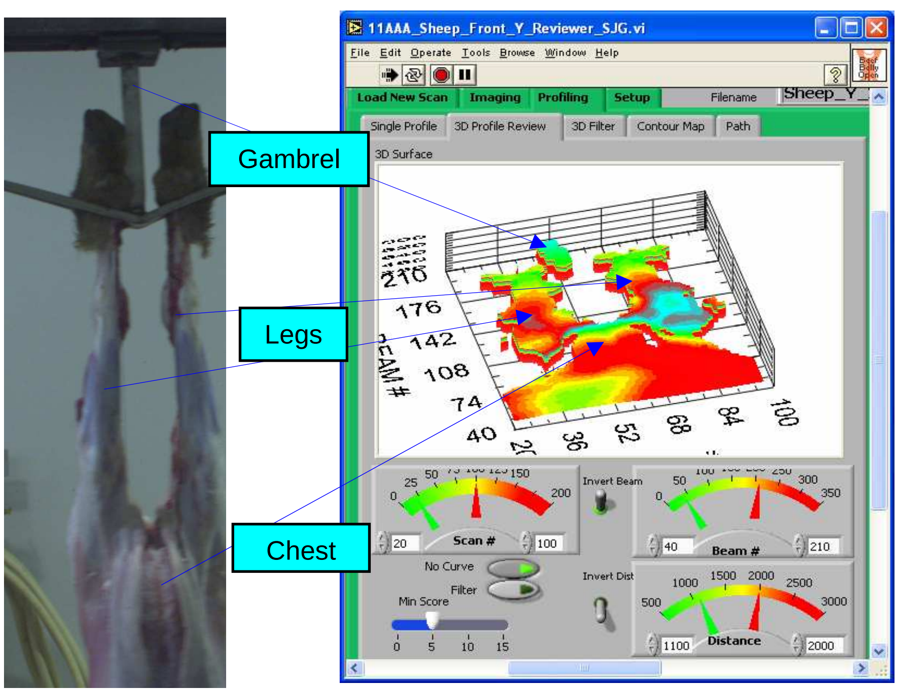
A requirement of the project was to test the sensing system in a commercial operating plant with no interference to normal production. To correctly implement 3D laser scanning, individual 2D scans should be evenly spaced by a known distance. Testing did not allow the laser to be integrated into a production line so the image analysis and the laser sensing have been combined to provide a basic calibration method for laser scanning.

The sensing system integrating both vision and laser data analysis was demonstrated to an MLA representative on the eighth of March, 2006 in a typical sheep production plant. Approximately 170 carcasses were successfully analysed at production speeds during the demonstration.

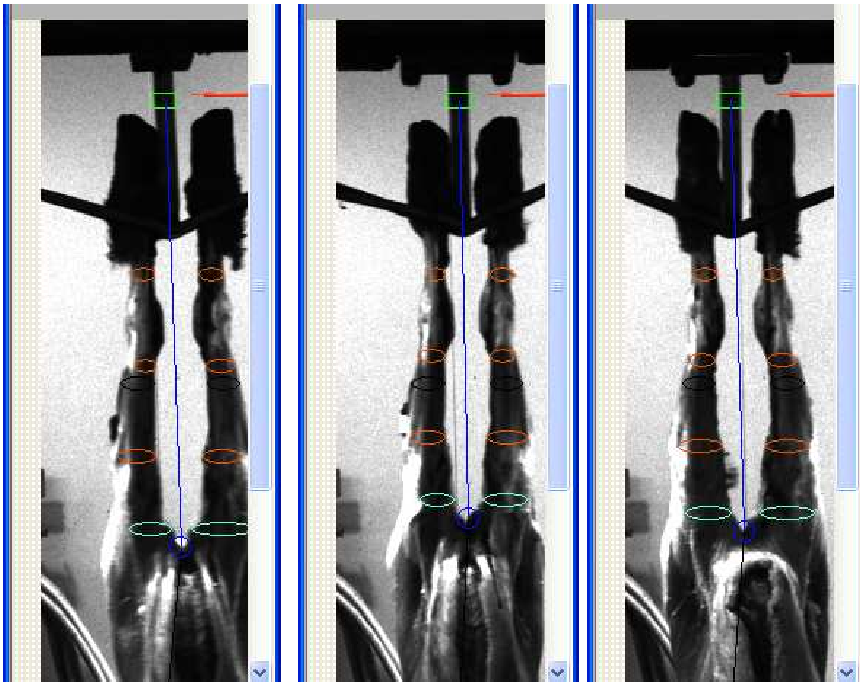
Future development of a modified VacSan tool and the application of that tool will determine if vision or laser sensing can be used individually, or if a combination of laser and imaging is required to automate a VacSan task.

A basic automated VacSan system was demonstrated for this process as part of Milestone 2 of PRTEC.042.

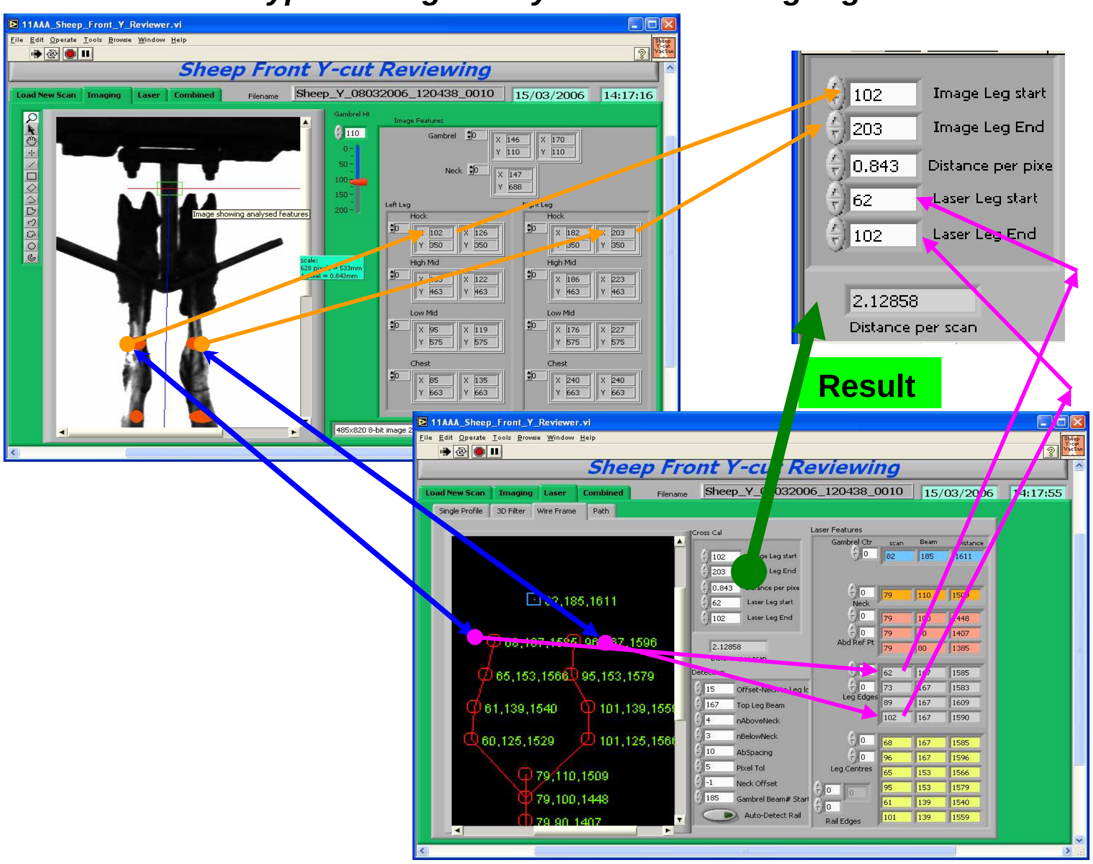
Manual Y-cut VacSan process and sensing system being demonstrated in a typical sheep plant



Typical laser profiling results of a carcass for Y-cut VacSan



Typical image analysis results of leg regions



Combining the image and laser profile data produces the data for an automated VacSan path

MILESTONE 2: REVIEW OF BEEF AND SHEEP TASKS

Determining Further Tasks

Milestone 2 of the project PRTEC.042 “Development of Vision and Laser Systems suitable for Beef and Slaughter Tasks”, evaluated the category one slaughter floor tasks from a previous MLA/AMPC funded project PRTEC.032 “Investigation and Evaluation of Sensors for Adaptation to the Meat Industry”.

The category one tasks were short listed, and in consultation with MLA, a list of three beef and three sheep category one tasks were selected for development as part of Milestones 3, 4 and 5 of PRTEC.042.

The tasks chosen for beef were:

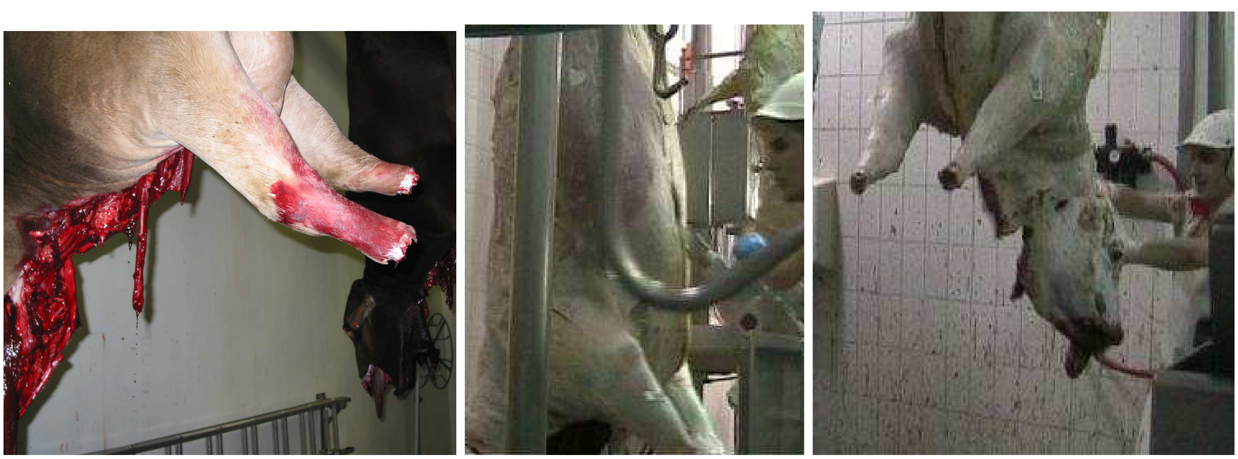
1. Remove front hoof
2. Brisket Cut
3. Horn Removal

The tasks chosen for sheep were:

1. Leg Reposition
2. VacSan – Rump
3. Neck Tipping

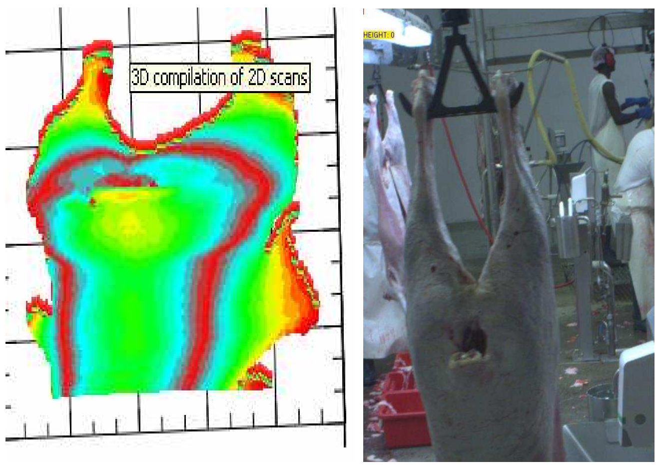
Each of the selected tasks was detailed and a set of suggested features and technologies for sensing those features were outlined in detail.

A gantt chart outlining the time management of the project and each milestone was developed in consultation with MLA to provide deliverable dates for PRTEC.042.

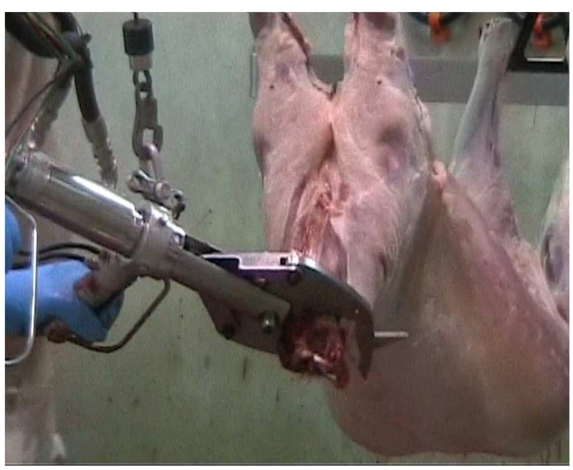


Beef sensing tasks for hoof removal, brisket opening and horn removal

Sheep leg reposition



Sheep rear VacSan



Sheep neck tipping

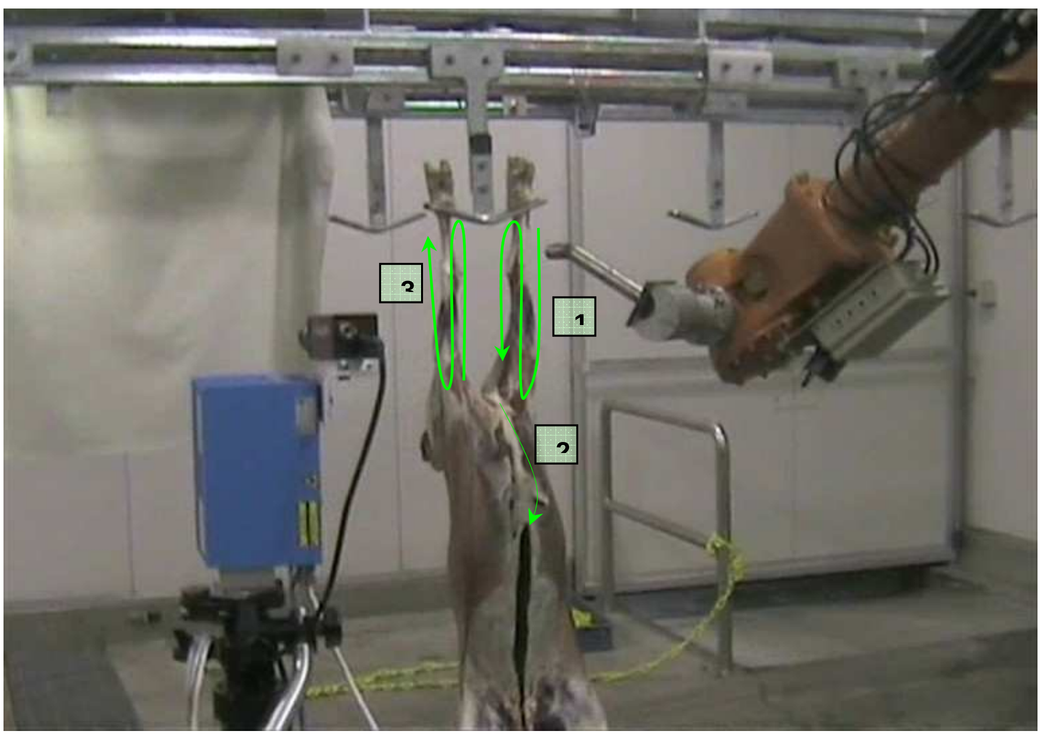
Robotic Demonstration Paths for Tasks in Milestone 1

The sensing system developed for the first beef task as part of Milestone 1 - the abdominal thoracic hide opening - was determined in consultation with MLA not to be robust; therefore it was not demonstrated as part of milestone 2. This task was further developed as part of milestone 3 of PRTEC.042 using alternate image and laser technology (being thermal imaging and a later model laser scanning unit.)

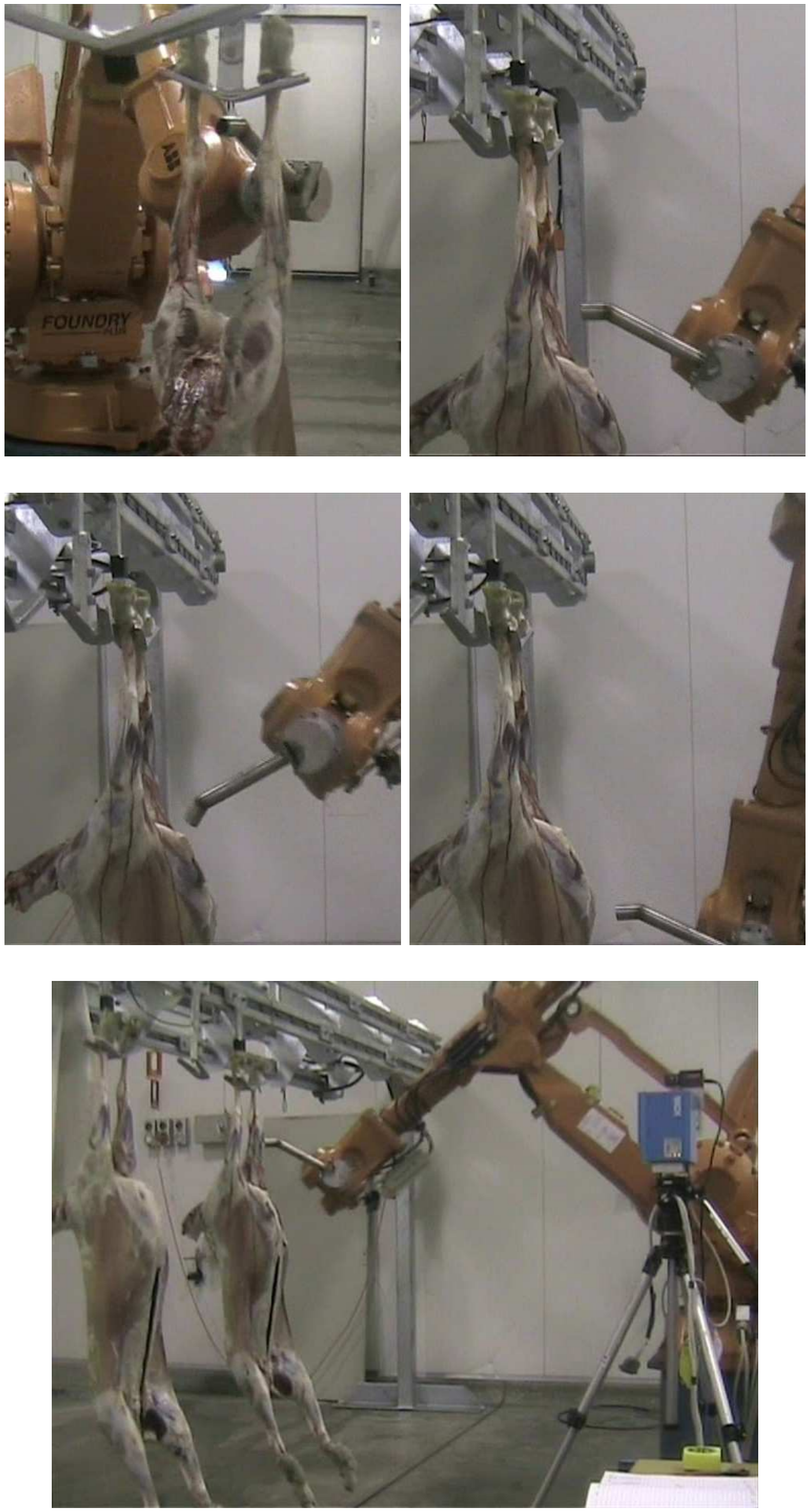
The sensing system for the first sheep task - VacSan of Y-cut - was successfully demonstrated on March 27, 2006 to MLA in the Food Science Australia slaughter and processing facilities at Cannon Hill.

The sensing system was integrated with an ABB4400 robot and incorporated a demonstration VacSan tool. Two carcases were presented to the system and each was scanned and a path was generated using the analysed data to demonstrate an automated robotic VacSan path.

Although the sensing system has been proven to work in 6 seconds, each carcase was processed in 8 seconds, which is comparable to the plant selected to demonstrate the sensing system. A video of the automated process was also produced and submitted to MLA.



Sensing system generates the co-ordinates for automated Y-cut VacSan path



The sensing system is integrated to demonstrate a fully automated VacSan system (the tool is held 30mm off the carcass during the demonstration)

MILESTONE 3: BEEF – FRONT HOOF REMOVAL

The beef task selected for sensing for milestone 3 of PRTEC.042 was for the automation of front hoof removal.

The manual process was studied and the process was found to have an indeterminate speciation that varied widely between plants. The common elements found between plants was that the “dirty” (through the hide) cut location was not an exact location, and a secondary “clean” cut was performed to remove the leg with a knife at the carpus after the hide had been removed.

A set of features was chosen to define the each leg and provide a reference location to determine a cutting point. These features include the hoof tip, leg angle, hoof-to-hide line and dew claw location.

It was proposed that the location of the hoof need only be determined in two dimensions – that is, image analysis will suffice – and the location of the hoof in the third dimension can be determined by a proximity sensor on the cutting tool.

The problems associated with using a colour image for analysis - including distinguishing the colour of hooves and different hide colours – was considered and it was determined that a thermal camera would provide the best solution to analyse carcass images.

Software was developed to analyse carcasses and provision was made to allow operators to adjust settings in the software to customise the cutting position for different plants.

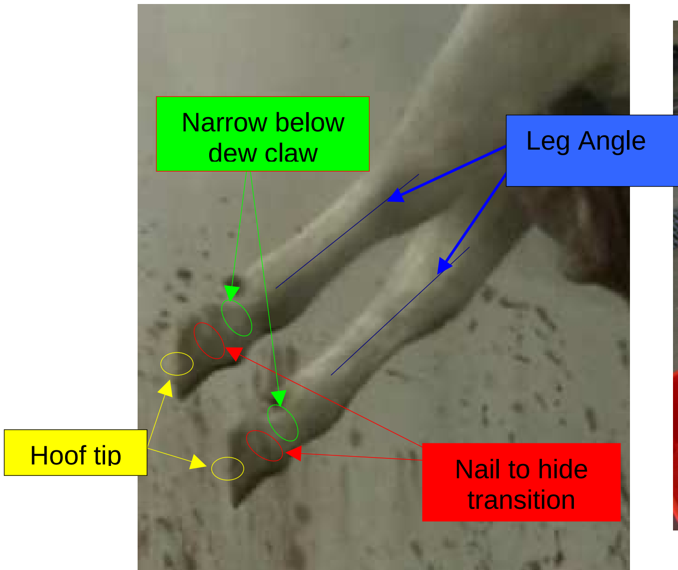
Carcasses could be analysed and features identified within 300 milliseconds of capturing an image. Should an error occur in the carcass analysis, i.e. two carcass images in one capture or an operator in the vision field, up to 10 attempts to correct the analysis would be undertaken by the software before an analysis failure is registered.

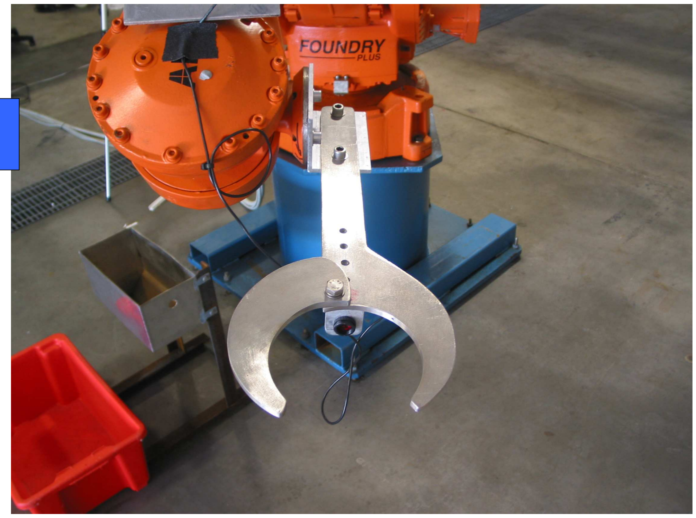
The sensing system was successfully demonstrated to an MLA representative in an operating plant, demonstrating the system working in real time.

The sensing system was successfully integrated to robot fitted with a mock hock cutting tool. Rudimentary cutting, disposal and sterilising process paths were developed to show the automated hock cutting process as a combined system. The total time require for the simulated cutting process was restricted to less than 15 seconds, including one second for the cutting shear to close and 0.5 second for the cutters to open for each leg.

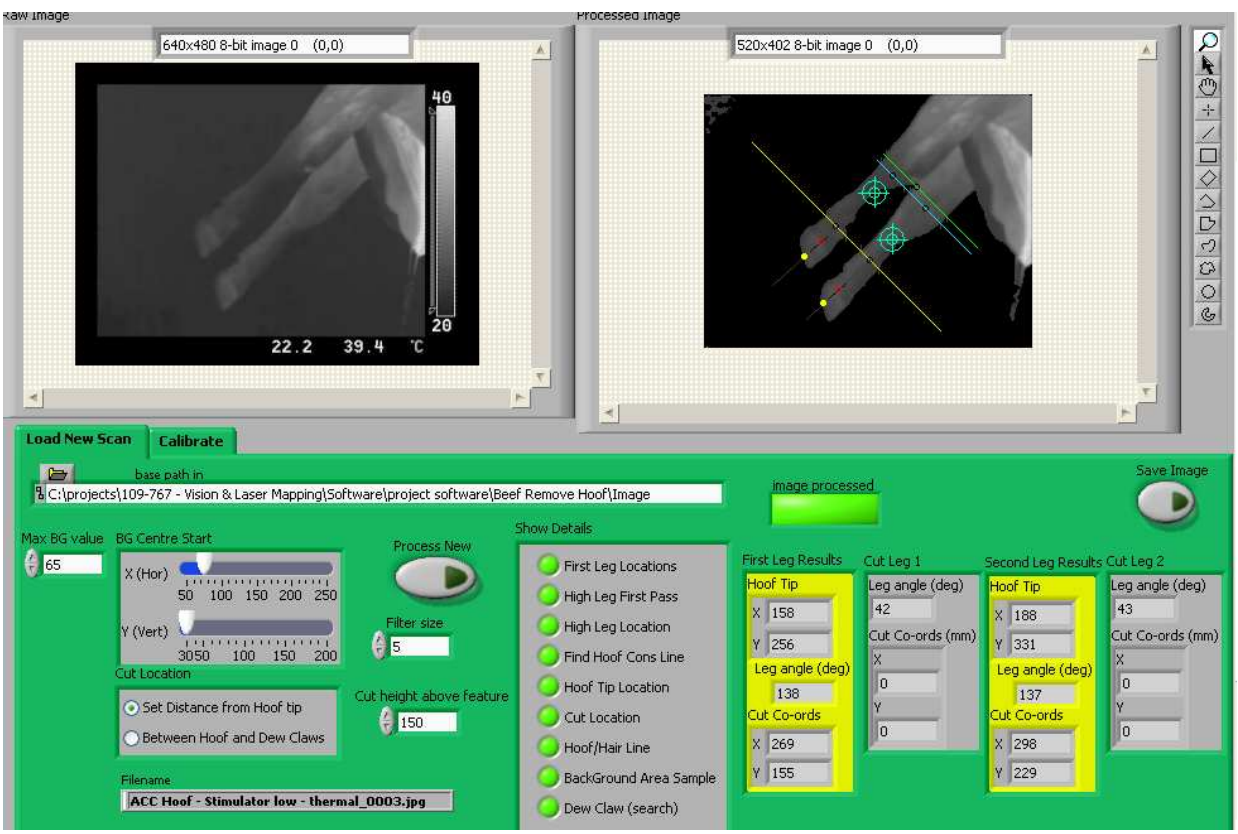
The hock cutters recommended for modification in this process would be the type that combines cutters with gripping jaws that would assist in stabilising and disposing of the hoof as it is cut from the leg.

The combined robotic system was demonstrated to an MLA representative on June 8, 2006 using one carcass that was moved to simulate the delivery of different carcasses. The calibration of the sensing system to the robot tool system was also successfully demonstrated to be robust and easy to implement.

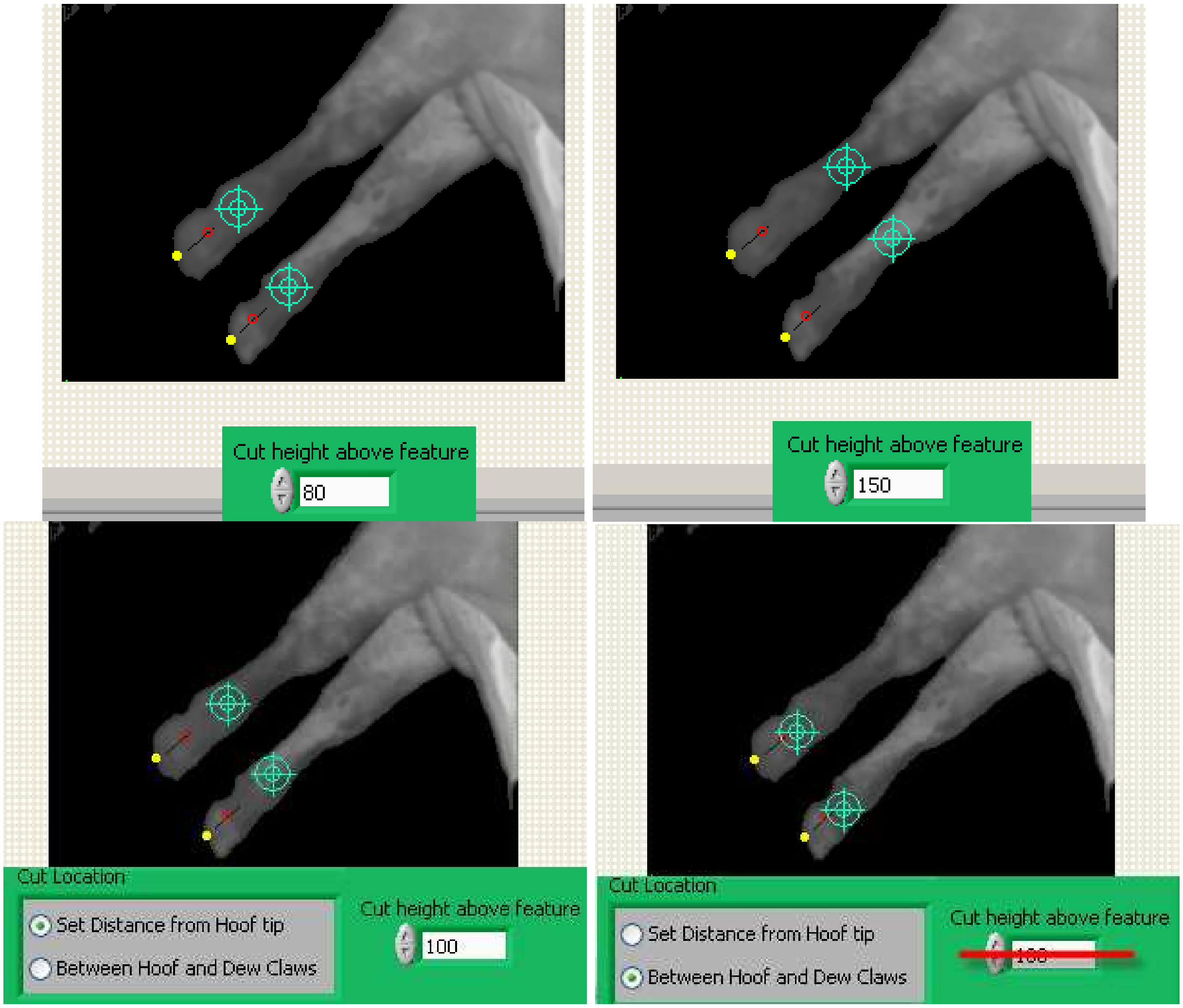




Hoof features and hock cutting tool used for demonstration purposed



Sensing system screen capture during plant demonstration



Available operator settings allow for the final hock cut location to be varied

The sensing system is integrated to a robot to demonstrate a fully automated beef hock cutting system

MILESTONE 3: SHEEP – FRONT LEG REPOSITION

The sheep task selected for sensing for milestone 3 of PRTEC.042 was for the automation of the task of sheep fore leg repositioning,

The task is outlined in PRTEC.032 [1] as “lift left fore leg out of the ankle spreader shackle and place in the double flat shackle below the ankle; then remove and replace right fore leg below the ankle on the same side of the double flat shackle, while supporting carcass weight”.

The aim of this project was to produce a sensing and automation system that is capable of not only repositioning the sheep legs, but detecting and correcting placement errors that may have occurred in prior processing steps. As a result, the overall position of the carcass will be more consistent and simplify later stages in the process.

The carcass legs are held steady in one dimension by the gambrels (or shackles) before repositioning is required. This reduced the complexity of sensing equipment required. For this reason it was not considered necessary to measure features of the legs in all three dimensions, and software was developed to analyse two dimensional images captured from a digital camera.

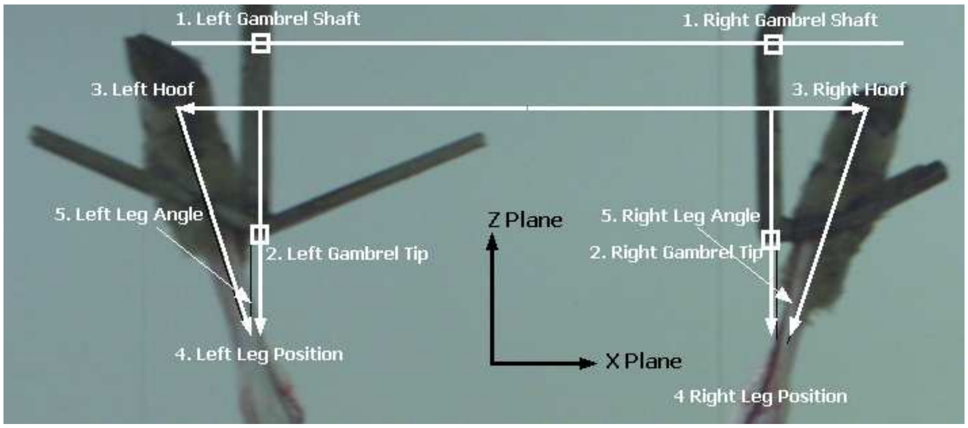
It is possible that the carcass could be presented with a number of different of hoof and leg positions. For example, if the hooves are presented low, it is necessary to pick up the hoof from below the gambrel and deliver the leg above the gambrel. If both legs are already in the right gambrel, it is only necessary to reposition the legs if one or both hooves are too low, and must be repositioned above the gambrel.

Following analysis of the current manual leg repositioning process and a review of video data captured during site visits to a selected sheep abattoir, a list of features that must located by the image analysis sensing system to determine the leg presentation was developed.

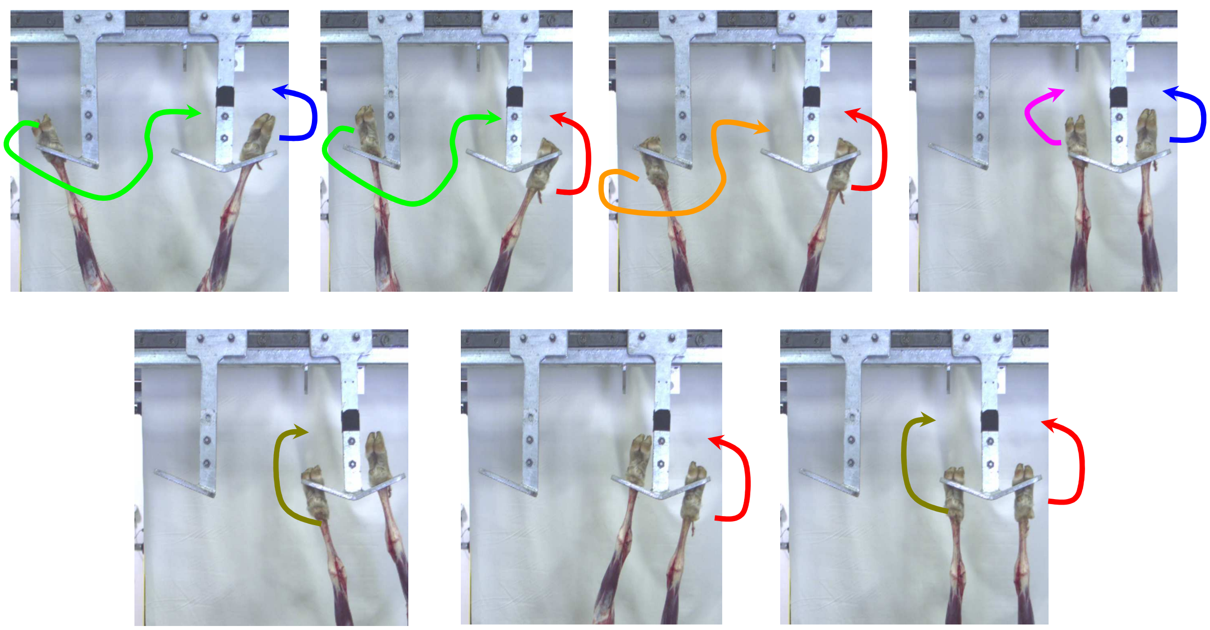
The image analysis programs that detected these features were developed and tested using Labview. Other components of the system included a digital Firewire camera to acquire the images, and a light box to provide silhouette images of the carcasses and simplify the image analysis techniques applied in the software.

For the demonstration of the image analysis sensing system in the plant, an MLA representative observed carcasses being processed. During this time carcasses were processed, and the features were displayed on a computer monitor for each carcass in real time

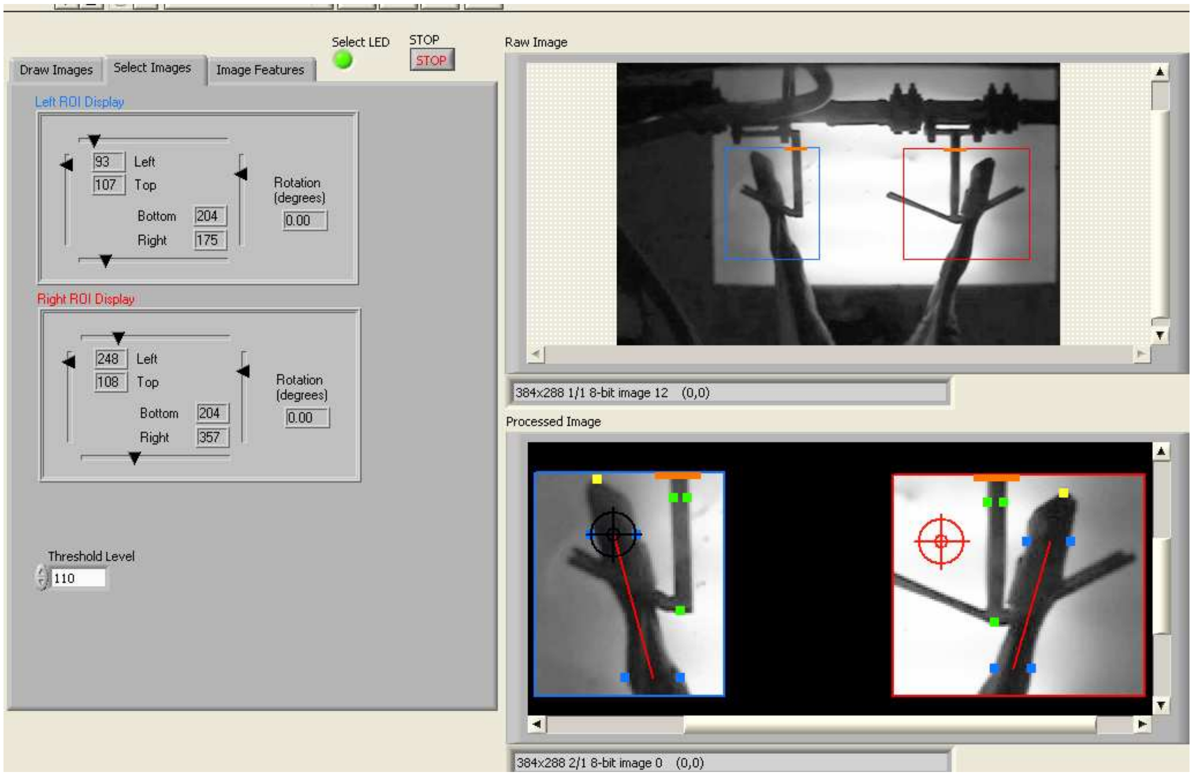
To demonstrate the effectiveness of image analysis as a sensing system for the automation of the leg repositioning task, the image analysis software developed for demonstration in a plant was expanded to select and generate robot paths based on measurements and calculations performed by the software. The paths were transmitted to a robot that moved through each path as a sheep carcass was transported along a conveyor system. This system was successfully demonstrated to a MLA representative at the FSA facilities.



Features to be identified for sheep hoof repositioning



Typical carcass leg repositioning moves required for an automated system



Screen capture of sensing system during plant demonstration of sheep leg repositioning

MILESTONE 4: BEEF - BRISKET CUT

The beef task selected for sensing for milestone 4 of PRTEC.042 was the brisket opening cut process.

The manual brisket task has been documented and studied and found to be made up of two basic tasks: the marking cut over the brisket and the brisket cut.

Previous attempts at automated brisket cutting were studied and were found to be limited by the amount sensing available at the time. This project was aimed at providing an alternative sensing solution for an automated brisket task.

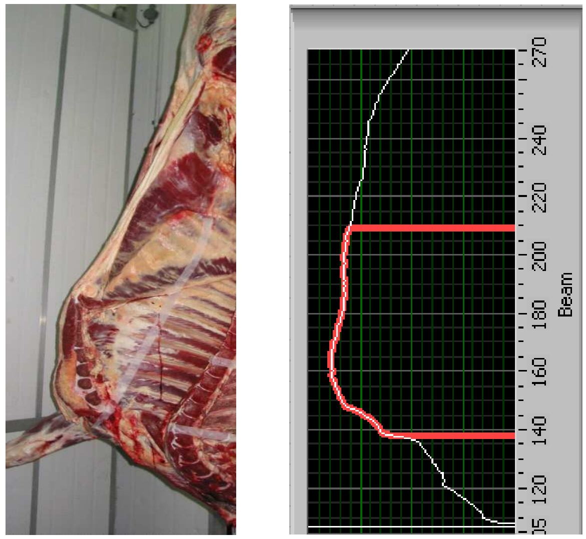
The sensing system developed incorporated an IRB928+ thermal camera to determine the position of the carcass on the production line, and a SICK LMS400-1000 laser device to establish the profile of the centre of the carcass. The profile of the carcass provided information to identify the carcass brisket and then to develop a suggested cutting path.

The total time required to scan and analyse each carcass was under 3.5 seconds, with 3 seconds of this time being required to traverse the laser unit over 300mm of travel.

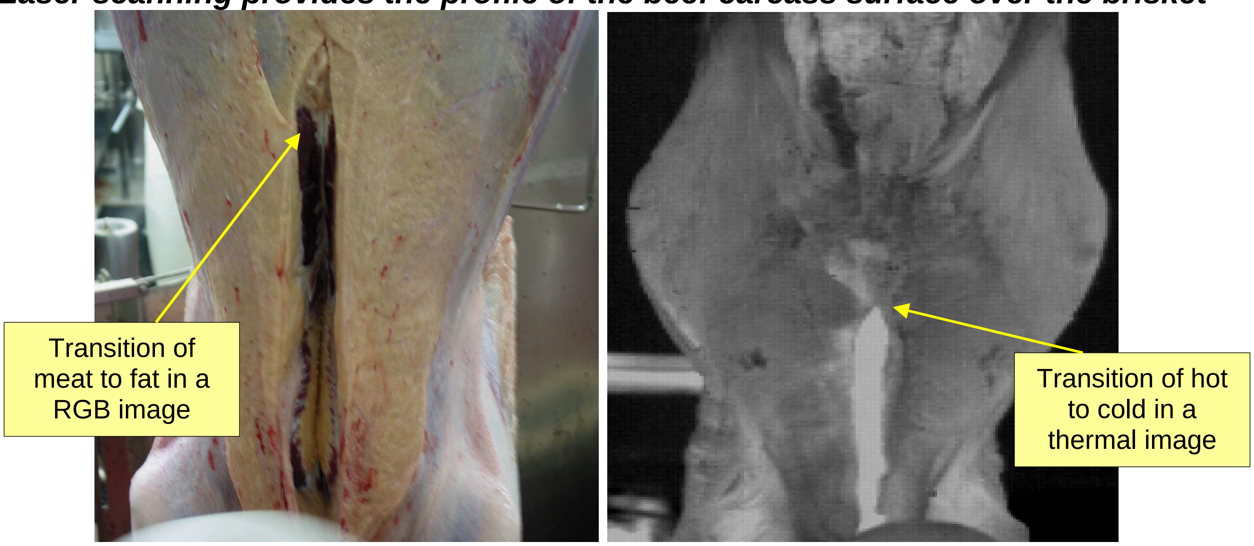
The sensing system was successfully demonstrated to an MLA representative in an operating abattoir with a cycle time of 40 to 50 seconds for approximately 80 carcasses.

The sensing system was integrated to the test facility at FSA in Cannon Hill including the use of an ABB4400 robot fitted with a mock cutting tool. This automated system was successfully demonstrated to an MLA representative in a single carcass moved into several different positions, and a video showing this demonstration was released.

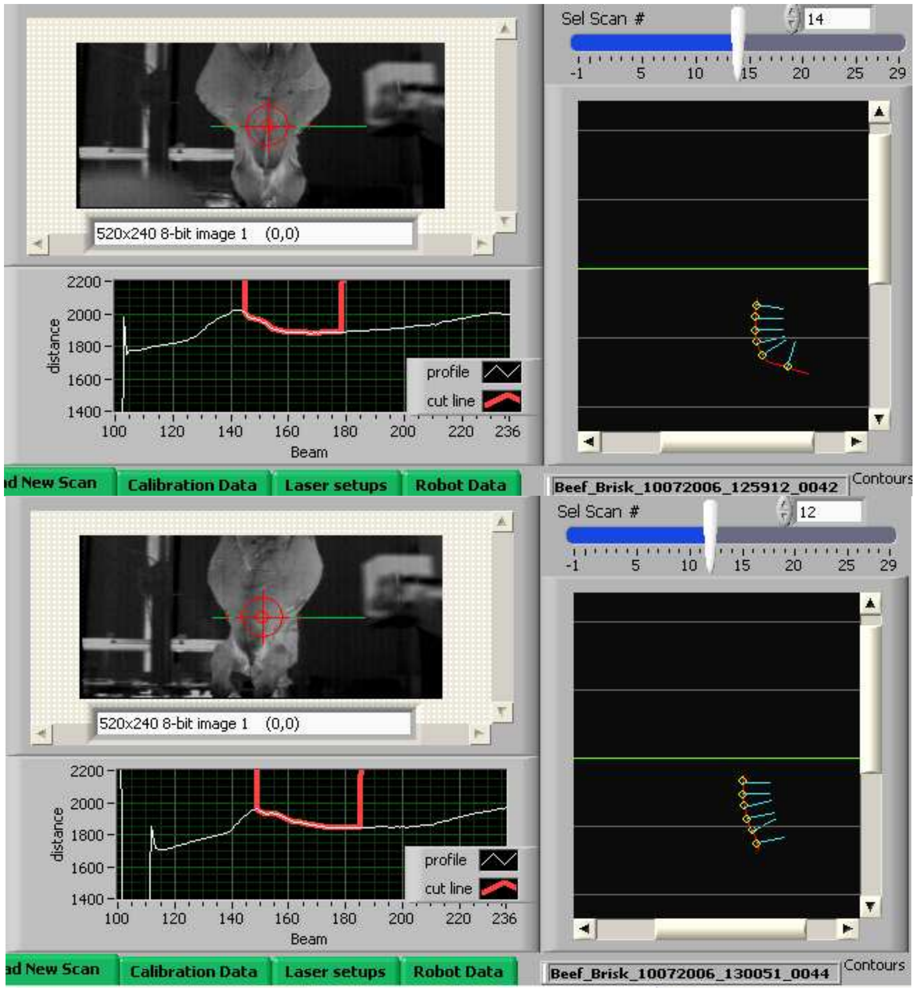
It has been concluded that the sensing system is reliable, but how that data is used is very reliant on the tool and cutting system that is used. Further tool research is required before this system would be suitable for a production environment.



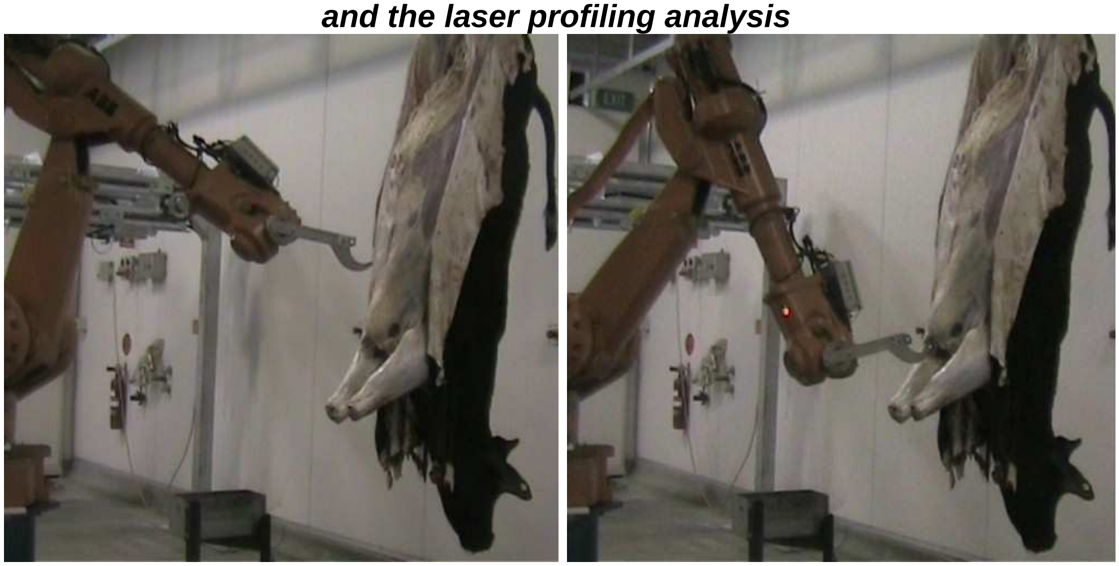
Laser scanning provides the profile of the beef carcass surface over the brisket



Comparing the imaging of the marking cut using RGB imaging and thermal imaging



Typical results of the cutting path after the combination of the thermal image analysis and the laser profiling analysis



The sensing system is combined with the robot to demonstrate a fully automated brisket cutting system

MILESTONE 4: SHEEP – VACSAN RUMP REGION

The sheep task selected for sensing for milestone 4 of PRTEC.042 was for the automation of the rear VacSan process.

Manual operation of the VacSan tool was observed and recorded under production conditions. Further investigation identified advantages in the manual operator being able to seek and concentrate on surface contamination, but also inconsistencies in routine application.

Based on observations of the manual rear VacSan operation:

- A rudimentary robot path was specified.
- It was established that routine data acquisition, analysis and transmission from the sensing system was to be completed in less than six seconds, as required for a production rate of ten carcases per minute.
- It was determined that, to test the sensing system for automation, the test plant need only be able to present the rear of the carcase, that is a plant utilising the manual process was not required.

The sensing equipment selected consisted of an Oscar 510 FireWire (IEEE 1394) camera to obtain reference images and a SICK LMS400 laser-measuring device to profile the carcase surface.

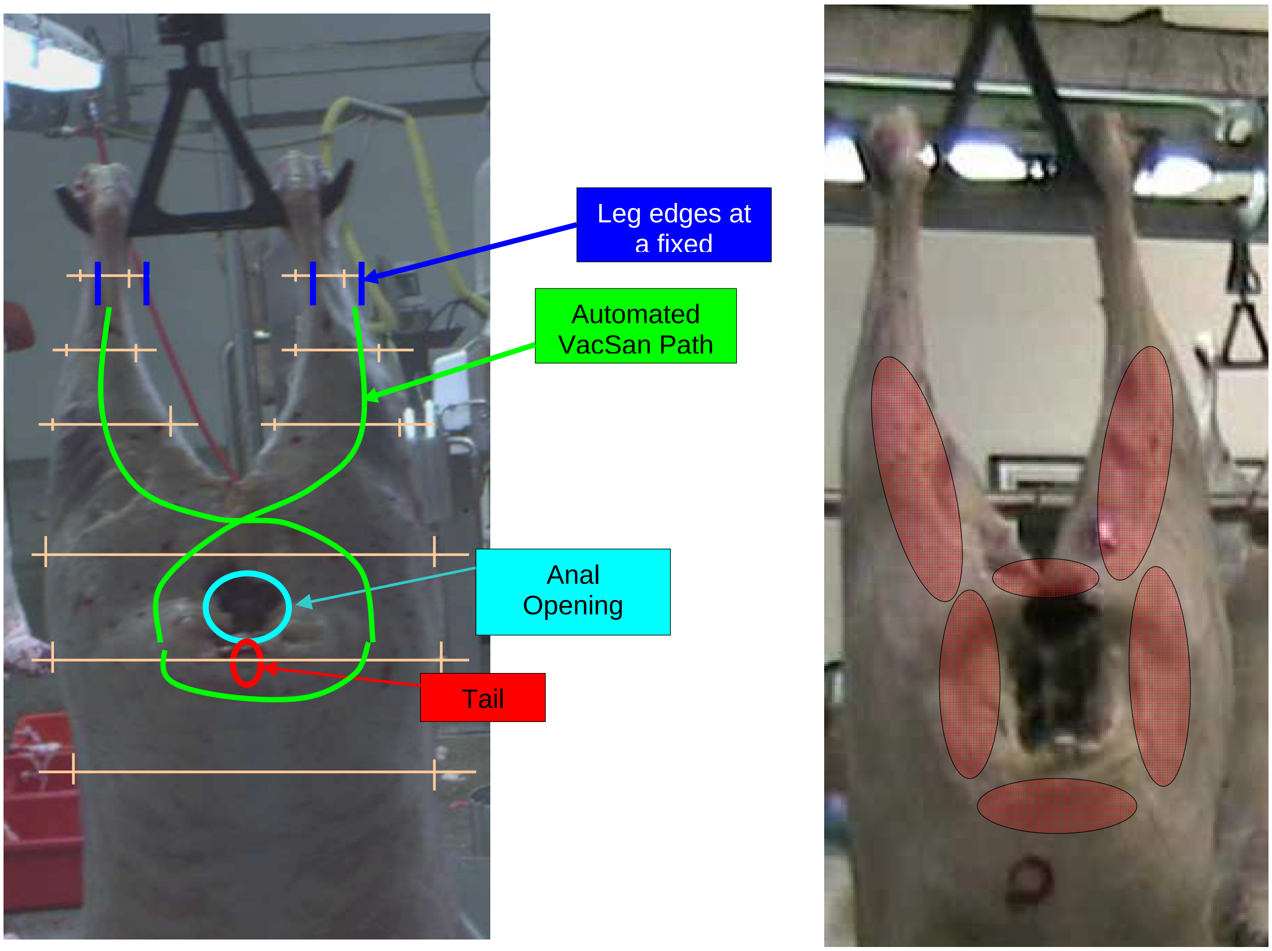
Software was developed to interface with the sensing equipment, acquire and analyse the laser data, then generate and transmit the rudimentary rear VacSan path to an ABB4400 industrial robot.

The software was designed to manage reasonable variation in carcase dimensions and with operator accessible controls to accommodate variation in plant conditions and robot path requirements. The robot path was generated using fixed (operator selected) and, detected, reference points. These points include leg positions and the locations of the tail stub and anal cavity, determined from analysis of the laser surface profile of the carcase. A mock VacSan tool was developed and mounted on the ABB4400 robot at the Food Science Australia (FSA) facility at Cannon Hill for testing and demonstrations.

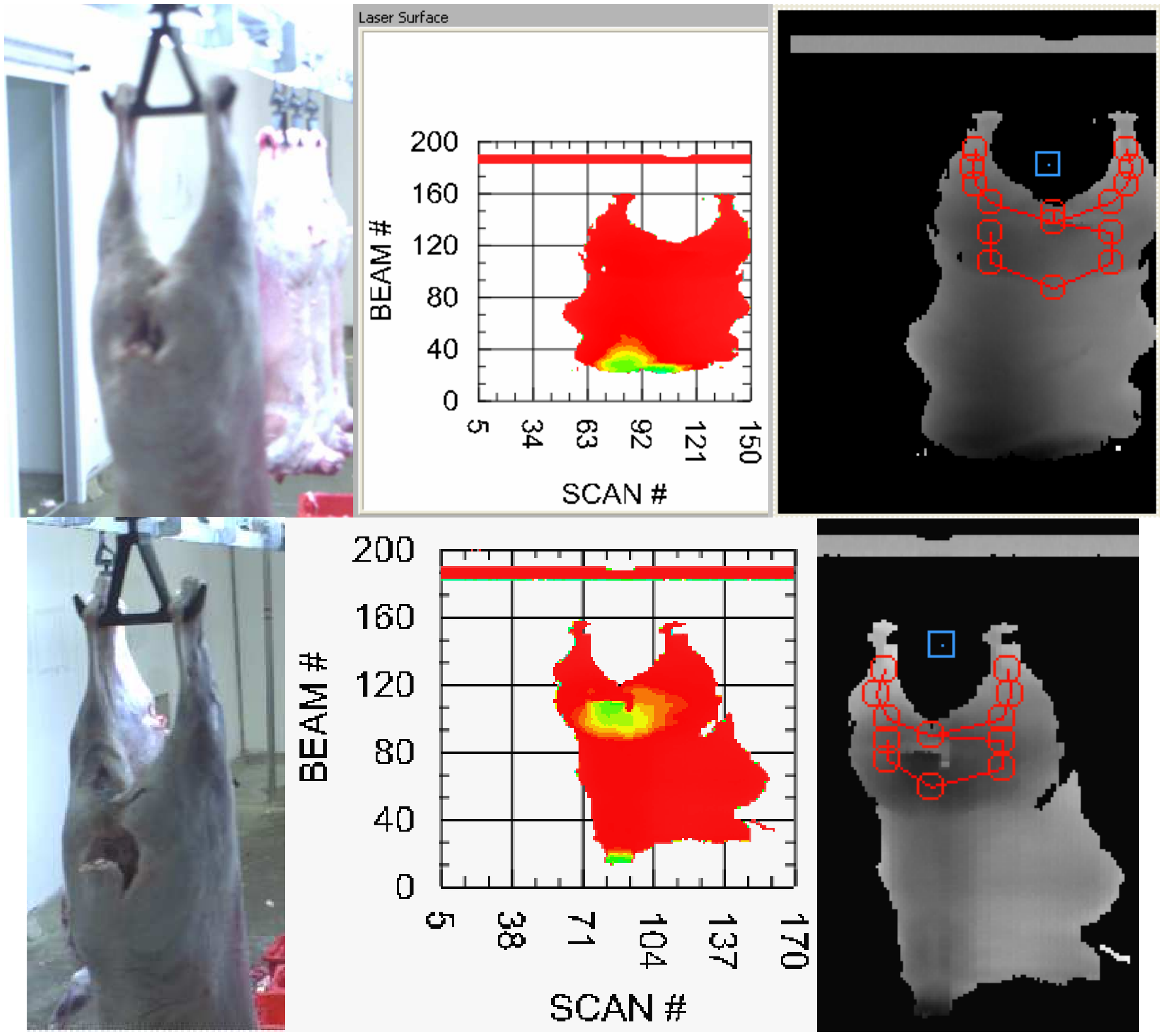
During development, the sensing system was successfully tested in a plant at production speed continuously for several hours, before demonstration to an MLA representative for approximately 60 consecutive carcases.

Subsequently, robot functionality was implemented and the combined system, incorporating the robot with mock tool and the specially installed sheep rail, was successfully demonstrated to an MLA representative at the FSA facility. Two sheep were used on the rail during all demonstrations to illustrate the ability of the system to contend with the production (or continual processing) environment within the specified time frame.

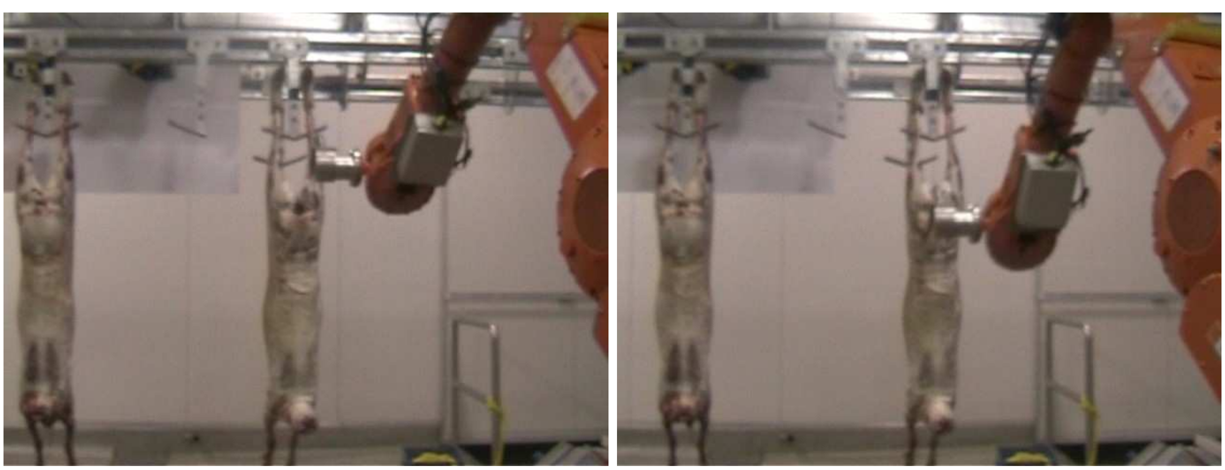
The system could successfully be adapted for use in a plant processing up to ten carcasses per minute as long as the sensing system station and the operation station are separated.



Features and path required for an automated rear sheep VacSan system



Typical results of carcass profile analysis to produce the desired rear VacSan path



The sensing system is integrated to a robot and the complete automated system is demonstrated

MILESTONE 5: BEEF – HORN REMOVAL

Previous CSIRO research into the automation of beef slaughtering processes has concluded that improved methods of sensing the location of horns (and the position of the head) regardless of their shape and appearance are necessary to increase the reliability of automated horn removal. The aim of this project was to investigate and test image analysis technologies for this application.

To achieve this aim, 3 plant visits were organised to allow statistical data about the presence and size of horns on carcasses to be gathered, and digital images of carcasses immediately prior to dehorning to be acquired.

Following the analysis of digital images acquired during the first plant visit, it was noted that due to the variety of colour and appearance of both horns and the hide of carcasses, it would be necessary to detect and locate horns using thermal rather than visual image analysis.

Through analysis of statistics gathered during plant visits, it was also discovered that although the management at each plant indicated that they processed very few carcasses with horns, between 20 and 35 percent of the carcasses observed during plant visits had short stubs that were manually removed either with shears or with a knife.

During the second and third plant visits, thermal images were recorded at a variety of angles, to determine an optimal method of detecting and locating horns using image analysis techniques. Through the analysis of these images, software was developed to detect and locate the cooler tips of horns contrasted against the warmer background of the carcass. The reliability of this technique was most successful when the temperature levels of the thermal camera were adjusted to increase the contrast between these areas in the image and the carcass was viewed through the thermal camera from the side of the head.

The curved shape of bars on the stimulator at one plant made carcasses roll into a consistent orientation regardless of how the carcass approached. This factor, added to the layout and relatively slow speed of the conveyor system in the plant, made it the best plant to demonstrate this system.

Two plant demonstrations to a MLA representative were arranged for this project at the selected beef processing plant. At the first demonstration image analysis software was successfully used to reliably detect the cooler tips of horns in thermal images acquired from the side of the carcass at the stimulator. Profile data from a SICK LMS 400 laser was used to measure the distance to the tip of the head (adjacent to the base of the horn or horns) and when combined with the image analysis results, provided a 3 dimensional location of the horns.

Feedback from the MLA representative was that, although this system was successful with short stubs, the curvature of larger horns could mean the cooler tips of the horns would be offset from the base of the horns where they are cut. The MLA representative also requested that the design of the software be enhanced to provide more information to explain how the distance to the horns was calculated.

For a second plant demonstration the software was modified to detect and locate horns in images acquired with the camera perpendicular to the head of the carcass. When the images acquired from this angle were analysed, the software was designed to detect the horizontal positions of the warmer bases of the horns contrast against the slightly cooler surface of the carcass in the background.

The main problem identified at the first demonstration was overcome by detecting the base of the horn, rather than the tip. Through the use of this method, any curvature of the cooler tip of the horn can not affect the results. Graphs were also displayed on the user interface of the software showing the distance and height measurement of the horns, and the laser profile data used to calculate these values. Cursors were also placed on these graphs to indicate how the distance and height of the tip of the head selected from the laser, related to the horizontal position of the horns detected through image analysis.

This system did not operate reliably at the second plant demonstration. The subsequent analysis of images acquired during this demonstration revealed that this was caused by the limited field of view of the thermal camera. Limitations in the space available in the section of the plant prevented the camera being placed far enough away from the carcasses to allow for the variation of carcass length and height of the head when vertically suspended.

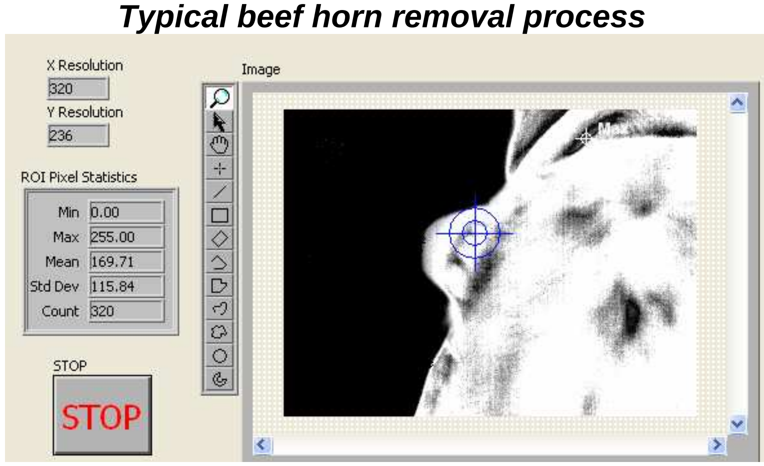
If the whole head of each carcass could have been reliably included in the field of view of each thermal image, it would have been possible to use discernable features in the thermal image of each carcass (such as the eyes and nose) to locate regions of interest in the image where the horns are most likely to be detected. This would have increased the reliability of the system by allowing the system to detect horns regardless of the length of the carcass, and the position of the head in the image.

The method used to calculate the distance and height of the tip of the head (adjacent to the bases of the horns) and the side of the head (between the ears and horns) using laser profile data from the LMS 400 was found to be accurate and repeatable on all carcasses observed during both demonstrations. This was concluded through the observation of the data and results displayed in real time and through the subsequent analysis of the data collected during the demonstrations.

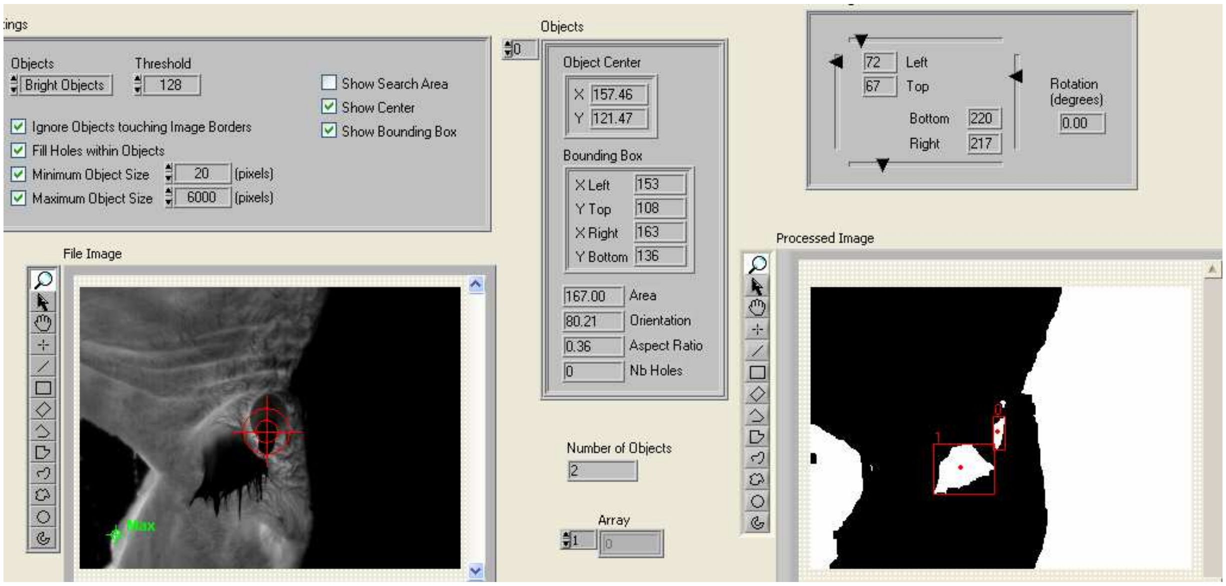
The recommended approach to developing a robust sensing system to detect and locate horns on carcasses would utilise the features of the systems that were successful in all demonstrations. The development of a sensing system must also avoid the factors that prevented image analysis functioning reliably in the final demonstration by incorporating the improvements that have been described in this report.

The feasibility of further developing such a system must also consider the statistics relating to the percentage of carcasses that require horn removal, and whether this will change with future trends in cattle breeding and rearing. A continuing decrease in the prevalence of horns in the Australian herd would cast doubts on whether further development of sensing for automated horn removal can be justified.

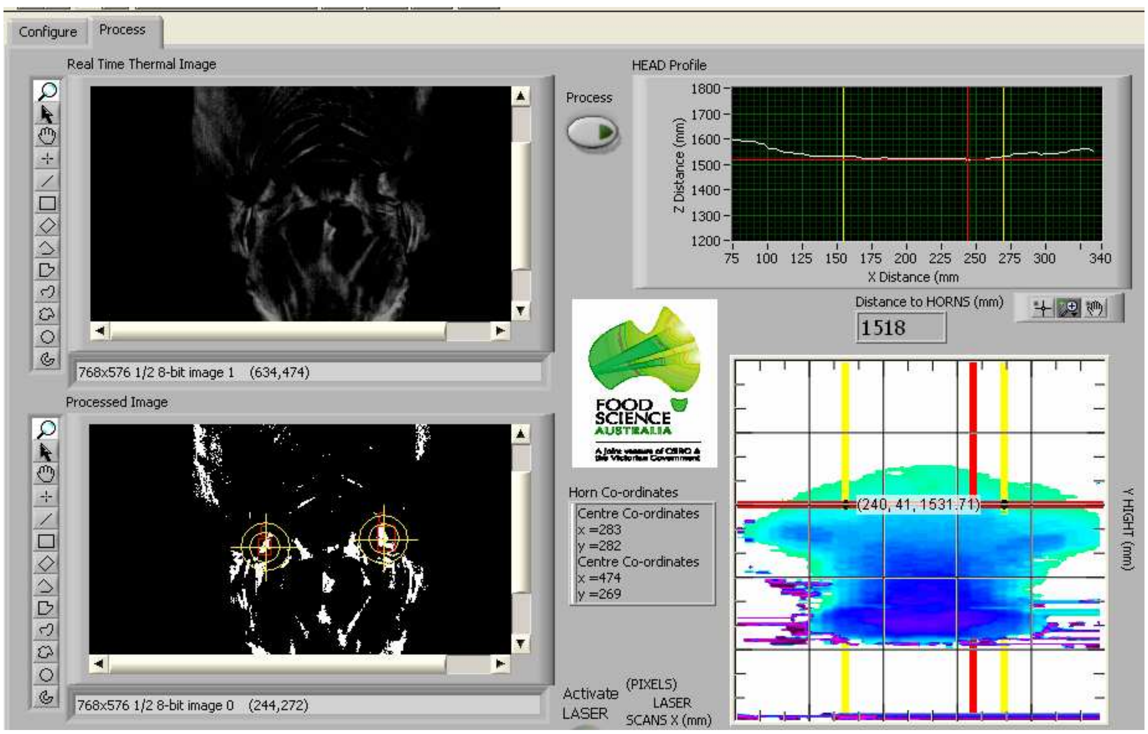
Typical beef horn removal process



Thermal analysis of the horn using an angled image capture



Thermal analysis using the "cooler" horns and ears to contrast on the "hotter" body, imaged from the side



Thermal and laser analysis combined to locate the horn location in 3 dimensions perpendicular to the head

MILESTONE 5: SHEEP – NECK TIPPING

The sheep task selected for sensing for milestone 5 of PRTEC.042 was for the automation of the sheep neck tipping operation.

This project separated the neck tipping from the hock cutting process. No sensing of contamination beyond the end of the neck was included as part of this project.

The study of the manual neck tipping operation showed that the angle of the cut was more related to the angle the operator held the tool comfortably, than to the orientation of the carcass. The amount of product removed manually from the neck varied widely, with different operators producing different consistencies.

A specification of sheep neck tipping is outlined as part of PRTEC.032 "Investigation and Evaluation of Sensors for Adaptation to the Meat Industry ". A specification for the requirements of sensing for automation was determined by combining the specific outline of PRTEC.032 with the general requirements of the plants studied. This specification outlined the operator adjustments that should be available to allow plant adjustments.

The sensing system was developed using vision sensing only, incorporating an Oscar 510 firewire camera with a 25mm lens positioned approximately 2500mm from the carcass. The prototype software to perform the vision analysis was written using Labview operating on a 1.6GHz laptop with 1Gb RAM running under MS Windows XP.

The image analysis provides a cut location on the neck and co-ordinates are available in two dimensions as a real-world location. The information about the cut is shown graphically on the computer screen to give feed back to the operator about the neck analysis. The total analysis time taken for each carcass ranged from 380msec to 430msec.

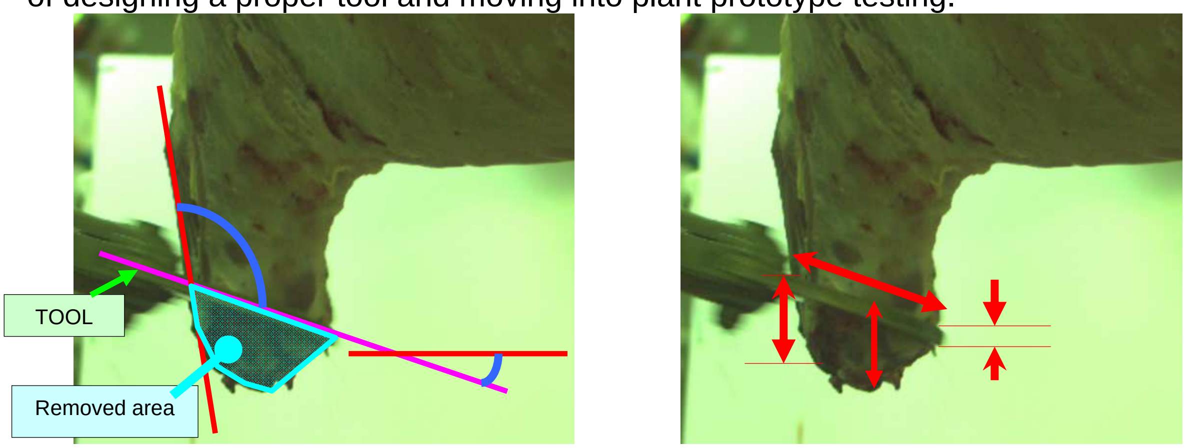
The sensing system was demonstrated to an MLA representative on September 8th, 2006, with the demonstration sensing approximately 300 carcasses. The demonstration included the procedures required to set the system up in the plant and the effect of altering some of the operator available options to change the results of sensing. A video showing a screen capture of this demonstration has been released to MLA.

The results from the MLA demonstration were compared to the manual cutting operation. Over the sample taken, it was found that an automated system and a manual operation would have removed similar amounts of product from end of the neck. It was also concluded that the automated system would have performed a more consistent cut, with less product being removed from the front of the neck, and a more accurate cut level at the back of the neck to guarantee that the specification of PRTEC.032 could be met. Overall, the automated sensing system would have provided a more consistent cut across the carcass neck.

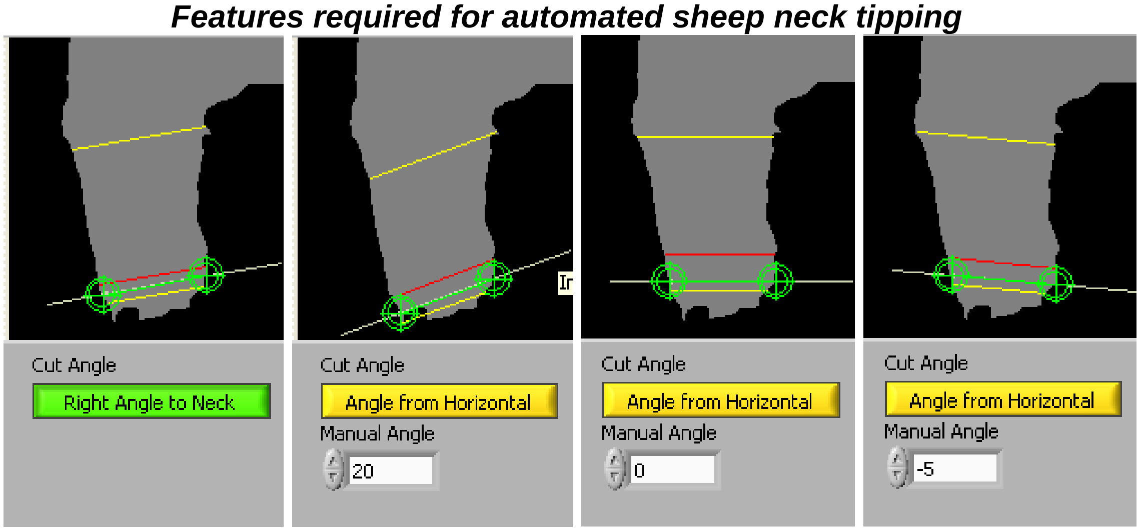
The sensing system can transmit user selected information using the computer's serial interface. This information allowed the sensing system to be integrated to an ABB4400 robot fitted with a mock tool at the Food Science Australia export accredited facility at Cannon Hill. The integrated automated sheep neck tipping system was demonstrated to an MLA representative on September 20th, 2006 using two carcasses being placed on the sheep rail in different orientations. The fully automated neck tipping system completed the cycle, including delivery to a steriliser, in times ranging from 3.8 to 4.2 seconds, which was well under the 5.8 seconds of a fast Australian sheep processing plant. A video showing this demonstration has been released to MLA.

It has been concluded that the automated neck tipping operation can be completed in the time allowed in a typical sheep processing plant and the operation guarantees that tool is sterilised between carcasses. The time remaining after the automated neck tipping operation allows for the possibility of including another simple operation within the same cycle time using the same robot and tool.

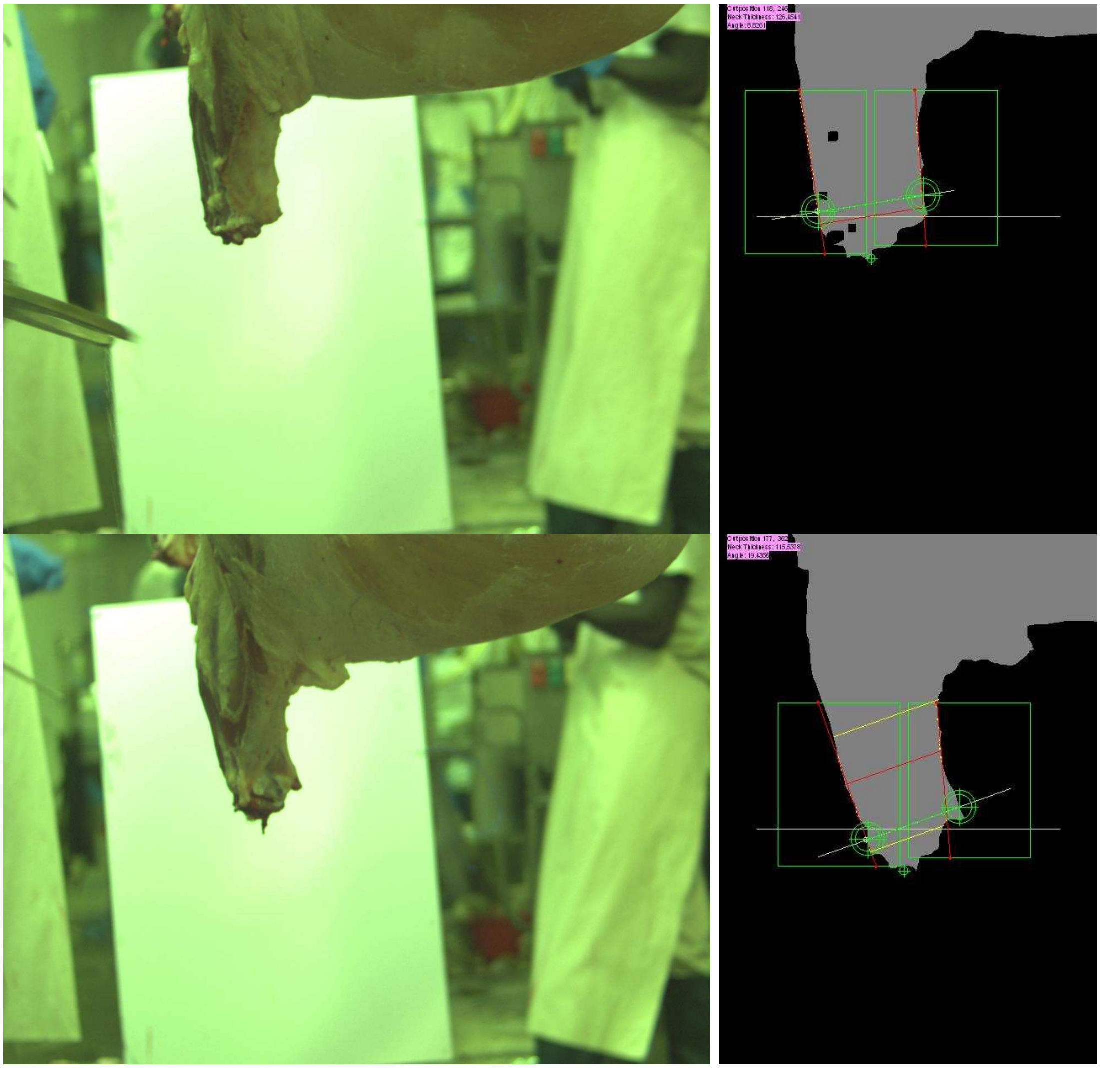
It is recommended that the automated neck tipping task now be advanced to the next steps of designing a proper tool and moving into plant prototype testing.



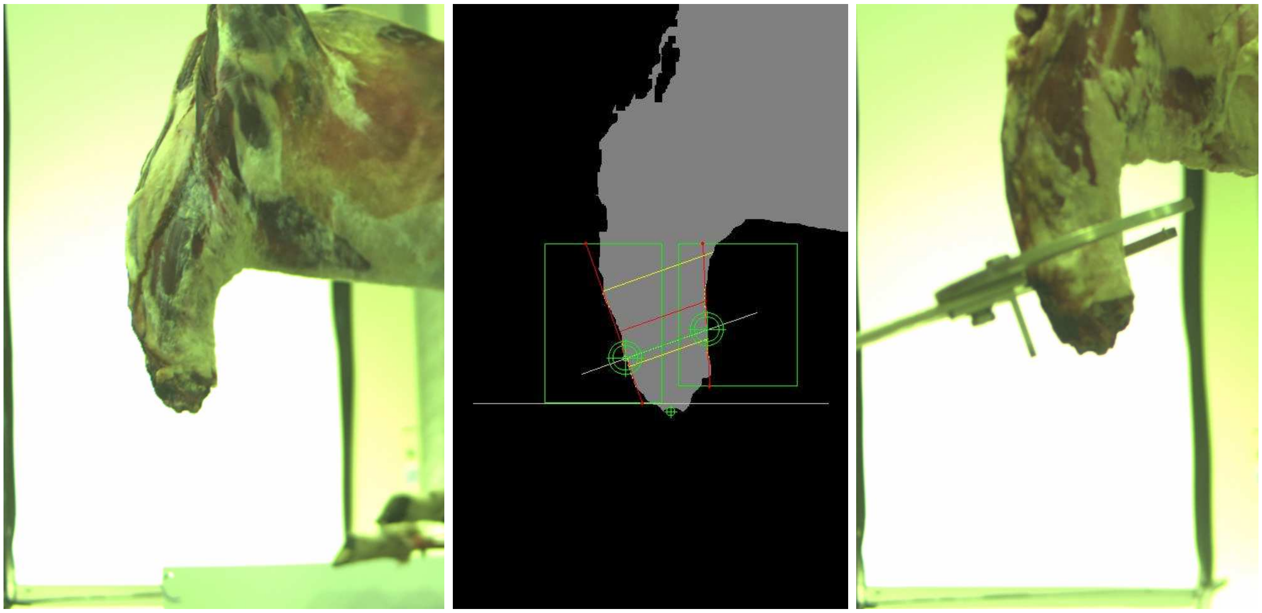
Features required for automated sheep neck tipping



Operator settings determine how the final cut should be made



Typical analysis for automated neck tipping during the on-site demonstration to MLA



Carcass cut analysis and tool placement by fully automated sheep neck tipping system during MLA demonstration

The sensing for the sheep neck tipping was integrated to a robot and a fully automated neck tipping system was demonstrated at the Food Science Australia facility