final report

Project Code: P.PSH.619

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Date published: Oct 2012

PUBLISHED BY
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Beef Carcass 3D camera motion sensing trials

This is an MLA Donor Company funded project.

Meat & Livestock Australia and the MLA Donor Company acknowledge the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

These Beef carcass 3D camera motion sensing trials are being conducted to provide valuable learning's for use of a low cost 3D camera (Microsoft Kinect) in Beef and Lamb Processing automation. The aim of the trials is to assess sensor and software performance in terms of resolution, measurement, quality and effects of motion blur with a view to determining whether the sensor trialled would be suitable to replace existing more expensive laser distance measuring sensors in Red Meat Robotic systems.

Executive Summary

These Beef carcass 3D camera motion sensing trials are being conducted to provide valuable learning's for use of a low cost 3D camera (Microsoft Kinect) in Beef Processing automation. The aim of the trials is to assess sensor and software performance in terms of resolution, measurement, quality and effects of motion blur with a view to determining whether the sensor trialled would be suitable to replace existing more expensive laser distance measuring sensors in Red Meat Robotic systems.

Trials were conducted on Beef and Lamb carcasses with the following Robotic systems in mind:

- Beef Spinal Cord Removal.
- Beef Hygiene Trim.
- Beef Vac San
- Lamb Bung Cutting.
- Lamb Kidney Fat Removal.
- Lamb Brisket Saw.
- Lamb Sani Vac.

The results proved that the camera could provide data on carcases range as well as 2D information at suitable resolution and quality that could lead to the replacement of two, more expensive, laser distance measuring sensors and hence reduce the overall cost of the current and potential robotic systems mentioned above.

The obvious impact of the Kinect Camera on the meat industry, now and in the future is that these cameras signify an advance in technology accompanied with a reduction in cost. These cameras help reduce the complexity of robotic systems by eliminating multiple sensors and replacing with a single unit capable of achieving the same results. This reduces the installation and maintenance costs making the robotic systems more attractive and viable to more processors.

Contents

1 Background

Sensing solutions utilised outside red meat processing sectors are continually improving and offer opportunities to improve processing practices within the Red Meat Industry. Utilising cost efficient sensing technologies will reduce cost and complexity of automated solutions making the automation available to a wider range of processors throughout. Identifying sensing technologies able to improve current processing and/or provide a platform for automation is a key focus for automation RD&E suppliers such as MAR and the industry as a whole. A key sensing technology that would benefit the Red Meat Industry is 3d scanning/imaging, the main issue with 3D scanning systems is that they are costly in both equipment cost and in integration time. Microsoft has recently launched a 3D camera to be used in a wide array of 3D sensing applications, including robot control. The goal of this trial is to determine whether this sensor can be used to add 3D capabilities to Red Meat applications at a price that would enable MAR to be more competitive in the marketplace.

2 Project Objectives

During May 2012, MAR performed X-Ray sensing trials as part of the project P.PIP.0288 – Beef

Rib Cutting Stage 2. These X-Ray trials were performed on-site at Swift Australia Brooklyn and effectively tested x-ray sensing under continuous moving carcass/beef sides conditions.

Setup and performing these trials incurred significant effort and cost and would be difficult to replicate without similar efforts in the future. In order to maximise the value from the effort required to setup the equipment on-site, MAR saw an opportunity to gather new sensing data, not just x-ray, that can simulate the effects of constant carcass motion on the sensing.

MAR aimed to utilise the test conditions, equipment and apparatus setup for the trials to perform additional sensing trials specifically focussed on how low cost high function 3D cameras could offer opportunities when fully developed to assist adoption of automation in Beef Processing.

The trials will aim to provide the following outcomes:

- Valuable Learning's for use of low cost 3D sensing in Beef Processing automation, particularly in the areas of:

- Beef Spinal Cord Removal.
- Beef Hygiene Trim.
- Beef Vac San
- Lamb Bung Cutting.
- Lamb Kidney Fat Removal.
- Lamb Brisket Saw.
- Lamb Sani Vac.

- Identify sensor and software performance in terms of resolution, measurement quality, effects of motion blur etc.
- Detailed report to outline findings and possible uses for Beef Process automation.

3 Methodology

Trials are to include;

- Setup Low Cost 3D camera (on X-Ray Test rig at Swift Brooklyn)
- Obtain and setup new Microsoft vision software and libraries for testing camera
- Perform and collect data for a series of low and high speed 3D camera scans on Beef sides.
- Offline data analysis of 3D Camera scans to identify sensor and software performance in terms of resolution, measurement quality, effects of motion blur etc.
- Detailed report to outline findings and possible uses for Beef Process automation.

The following Milestones will be achieved during the project

Milestone 1

Setup Low Cost 3D camera on (X-Ray Test rig at Swift Brooklyn)

Miles tone 2

Obtain and setup new Microsoft vision software and libraries for testing camera

Milestone 3

Perform and collect data for a series of low and high speed 3D camera scans on Beef sides.

Milestone 4

Offline data analysis of 3D Camera scans to identify sensor and software performance in terms of resolution, measurement quality, effects of motion blur etc.

Milestone 5

Detailed report to outline findings and possible uses for Beef Process automation.

4 Results and Discussion

In order to test the Kinect cameras suitability for the applications listed above a Kinect Camera was sourced.

Fig. 1 Kinect 3D camera

In order to acquire and store data from the sensor test software was written. This software utilized the Microsoft Kinect software development kit provided by Microsoft. A screenshot of this software is shown in Figure 2; this software displays both a colour image and 3D range data. Range data is displayed in red for close objects, green for moderately distanced objects, and blue for objects spaced further away from the camera. Black is used to show objects past the working range of the sensor and white is used for objects that are too close to the sensor, or for data that could not be reliably determined.

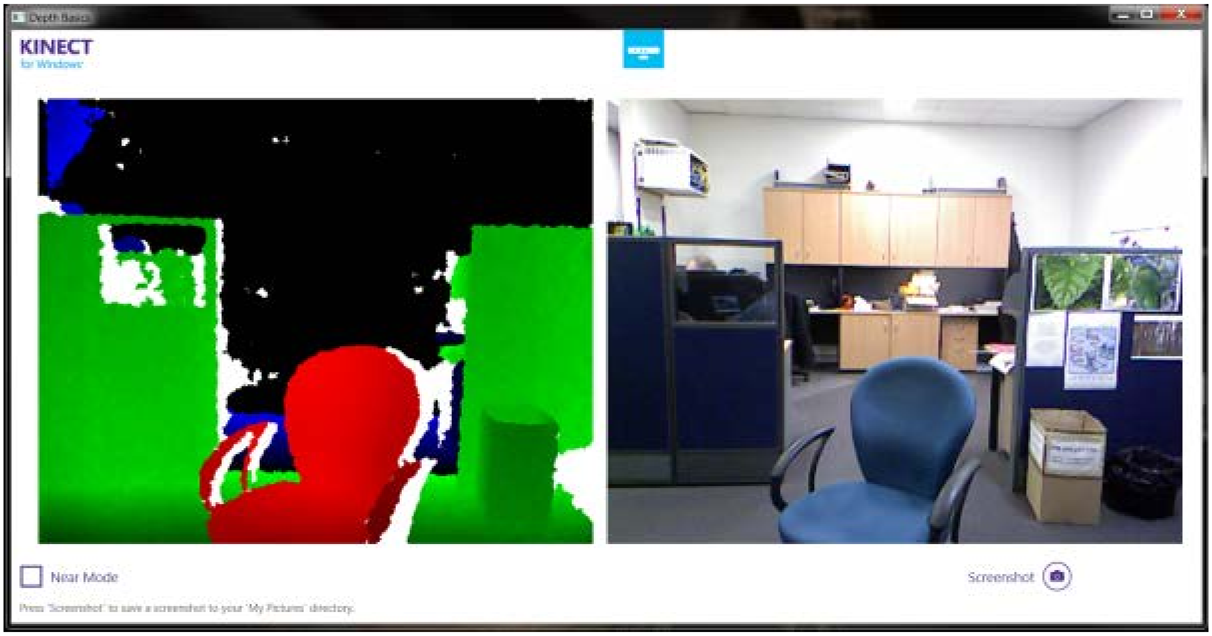

Figure 1 Test Software showing Image and 3D data

The images below show the Low Cost camera system setup at JBS Brooklyn while the X Ray trials for project P.PIP.0288 were taking place, approximately 180 images of beef sides were taken during the trials. The images obtained by the Kinect camera are taken as a single ‘snap shot’ as the carcass passed the centre point of the field of view. This is in contrast to the Sick LMS Laser scanner which takes a ‘line scan’ with a laser as the carcasses passes. The data gathered from this is then used to ‘build’ a 3D image.

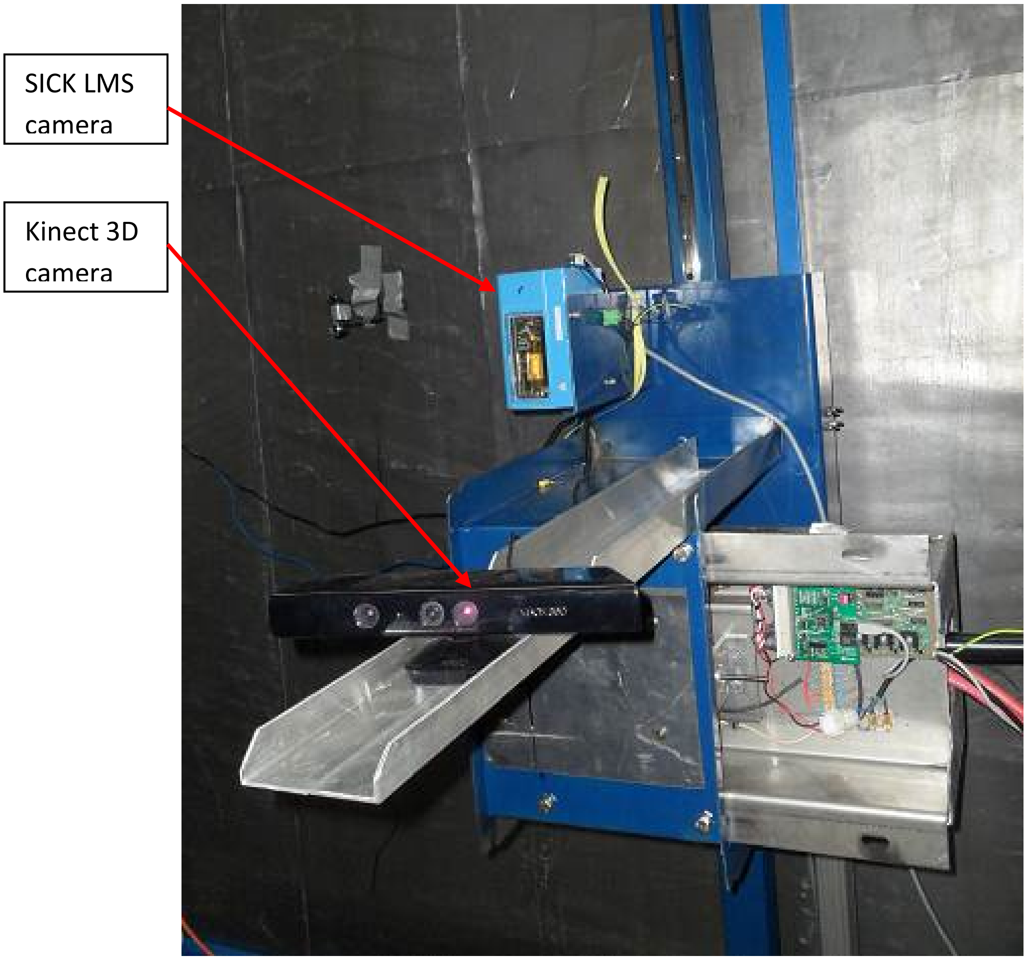

Fig. 3 Kinect 3D camera setup at JBS Brooklyn

Fig. 4 Kinect 3D camera setup in X Ray cell at JBS Brooklyn

An example of the images gathered from the Kinect and Sick cameras are shown below, the first image shows the raw image received by the cameras, the second image is the 3D data as seen by both cameras,

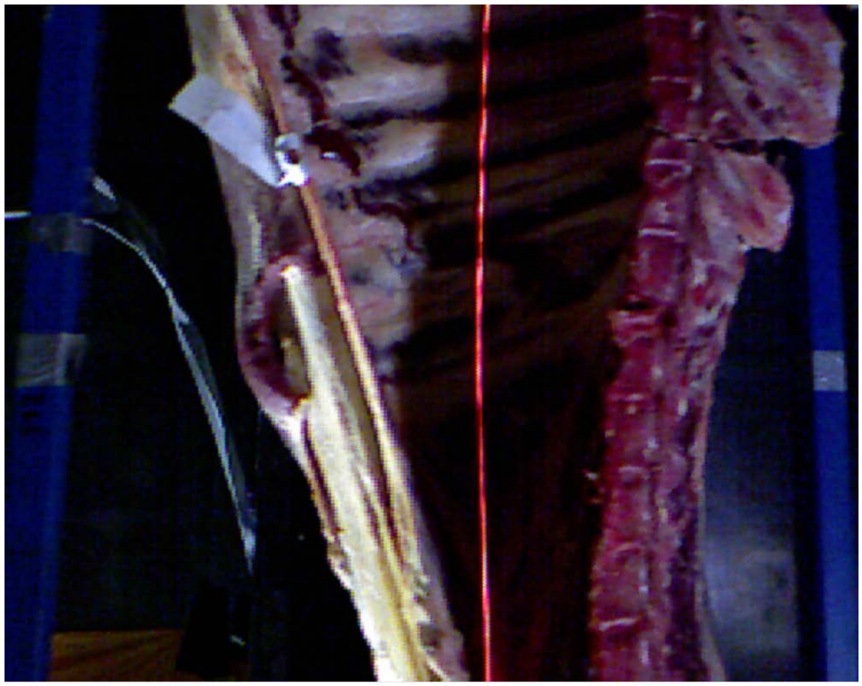

Fig. 5 Raw image received from Kinect 3D camera

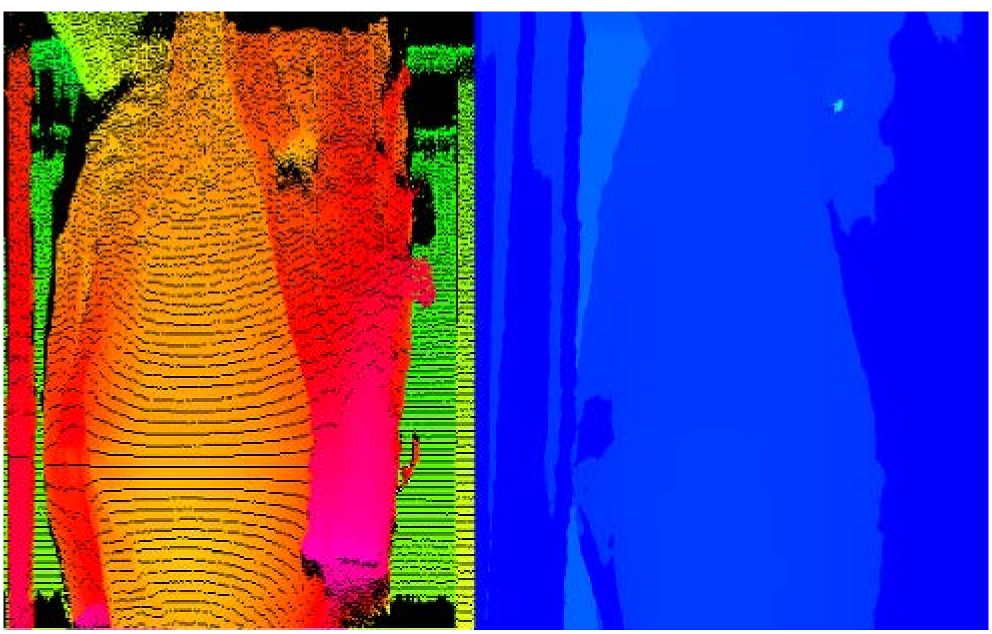

Fig. 6 3D image received from Kinect 3D camera

As can be seen in Fig.6 above the data from the LMS camera (image on the left) has been used to build an image of varying colours indicating various depths from the camera as described above. However the data received from the Kinect camera has not given this depth variation in the form of varying colours and it is believed that during the trails a setting in the camera setup was incorrect and hence incorrect data was received. This data was not analysed until the XRay trails were complete and hence by the time it was realised the data was incorrect the trial cell had been dismantled. Hence a second set of trials were conducted at Hawkesbury Valley meat Processors in Wilberforce NSW. Out of necessity at HVMP images were acquired in a chiller with the camera mounted on a tripod and a laptop used to acquire and store the data from the camera. Processing of the final images was undertaken using the Halcon image processing package. Some images were also taken of swinging carcasses and of carcasses while moving the camera to simulate carcass movement in reality.

As a comparison, images were also taken at HVMP with a SICK Ruler 3D camera and the data acquired with this is compared with that acquired with the Kinect Camera in discussion at the end of this report.

4.1 Spinal Cord Removal

The desire for Spinal cord Removal would be to accurately determine the location of the spinal cord within the spinal cord canal. This has been shown to be particularly difficult using other more expensive 3D cameras in a concurrently running project looking at Spinal Cord Removal. This is due to the fact that there is very little difference in height between the top of spinal cord when it is laying in the canal and the surrounding bone structure. Indeed as can be seen in the 3D images below, there is no detectable change in the colour of the red in the area of the spinal cord canal. An alternative that is considered here is using the edge of the vertebrae as a guide and then using an offset from this to locate the spinal cord canal.

Results from the trials at HVMP show the Kinect camera could find the edge of the vertebrae within the beef side reliably for approximately half of its length. An example of the results is shown below.

Fig. 7 Colour image of the carcasses at HVMP

Fig. 8 3D image received from the Kinect camera

In this image the carcass under inspection is shown as red as it is relatively close whilst carcasses in green are located behind. The variation's in the intensity of the red colour in this image shows the variation in depth across the carcass.

Below is an image that has been produced by processing the Kinect Camera data with the Halcon software to remove the objects in the background. The Halcon software was then used to locate the edge of the vertebrae this was found relatively easily and as can be seen from the values on the image below, a step change in the depth at the line of the vertebrae can be determined. Although not noted on the image below, as well as depth data, the 2D information ie the length and breadth of the carcass can also be derived from this Halcon processed image.

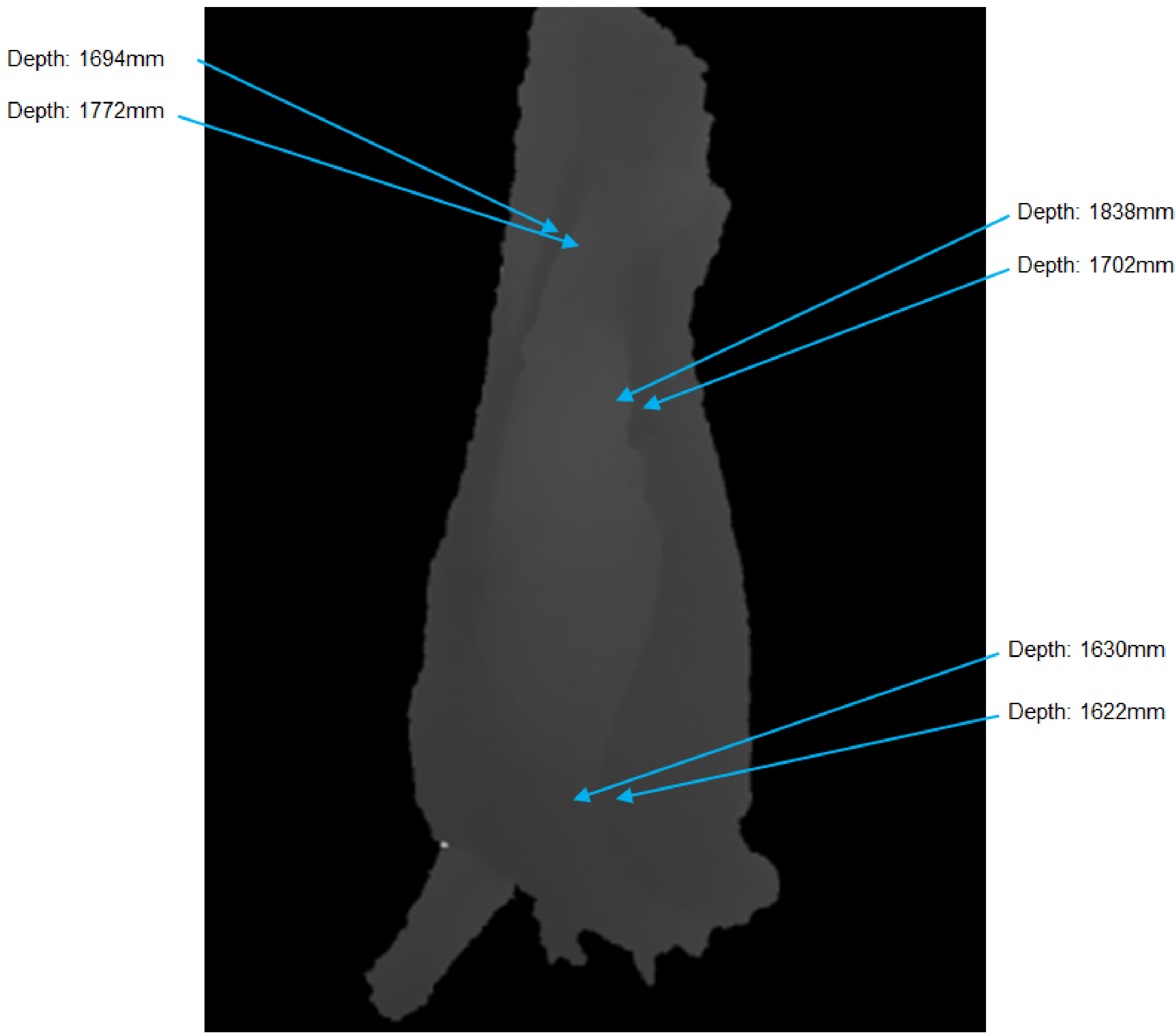

Fig. 9 3D image processed by the Halcon software, with depth data shown

4.2 Hygiene Trim

The Hygiene trim system relies on accurately locating the cavity of the carcass so that trimming may be performed by a robot. Typical robot paths for Hygiene trim are shown in the image below and as can be seen from the results achieved in the spinal cord section above the depth information as well as the 2D information required can be determined from the data from the Kinect Camera and processing of the data by the Halcon software.

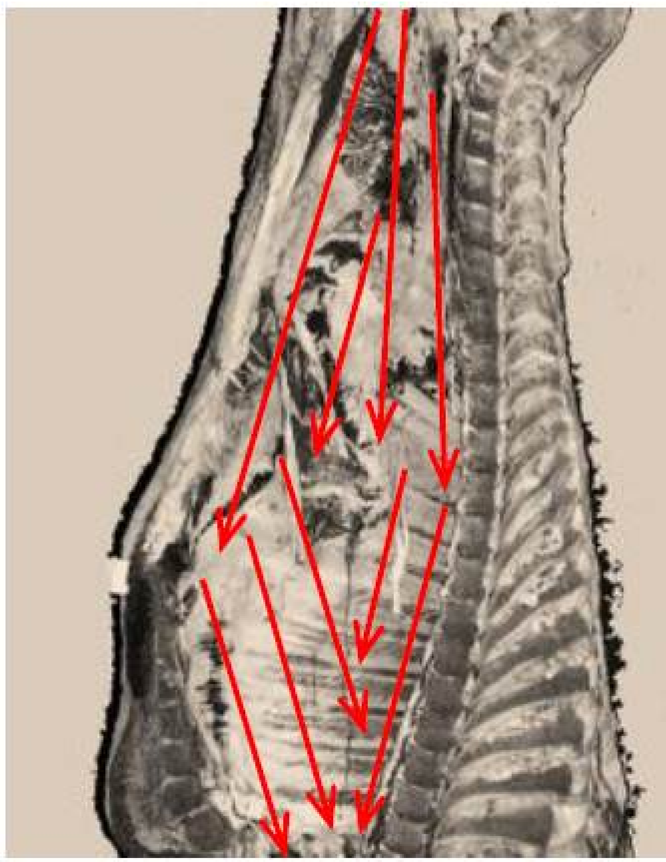

Fig. 10 Hygiene Trim paths

4.3 Beef Vac San

Below are images of the paths required to achieve Beef Vac Saning. It is evident from Fig.9 and the previous discussion that an image similar to that produced in Fig.9 could be used to determine the depth and 2D data required to achieve the robot paths in Fig.11 below.

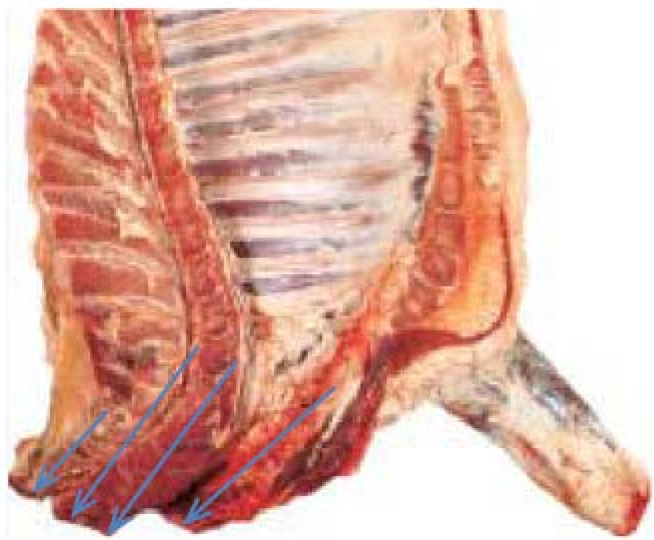

Fig. 11 Beef Vac San Paths

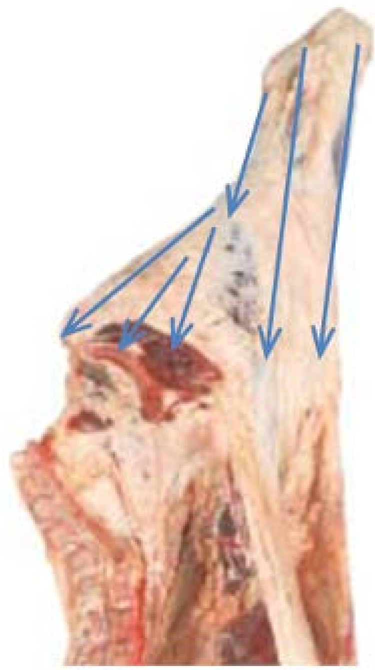

Fig. 12 Beef Vac San Paths

The images below show the colour image, the data received from the Kinect Camera and the Halcon processed image. From previous discussion it is evident that the depth and 2D data for these hind legs could be determined and used to direct the robot along the paths required.

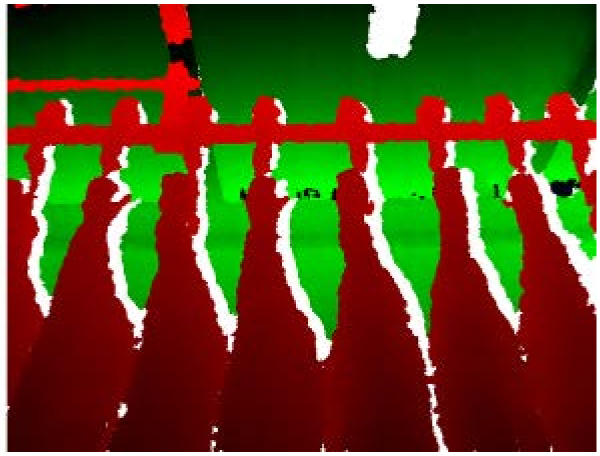

Fig. 13 Images of beef hind legs at HVMP and the data that could be used to determine the leg bosition for Beef Vac Saning

4.4 Bung Cutting

Bung Cutting relies on finding the rear legs and the hindquarters but also ideally would detect the depression in the carcass in the bung area. The images below show half of a sheep carcass hanging from a rack. Unfortunately there were no sheep being processed during the visit to HVMP so images of sheep are limited to the carcasses that had already been de-bunged hanging in the chiller.

Fig. 14 Lamb carcasses hanging in the chiller at HVMP

Fig. 15 3D Data from the Kinect camera

As can be seen from the image above created from the data from the Kinect Camera the legs and hind quarters can easily be identified. In addition the image below, which shows the range data processed by the Halcon software, shows the closest carcass isolated form the background and also the range of some key points on the image. The range of such points is currently determined using a laser distance sensor which, on sensor cost alone, is a magnitude of four times the price of the Kinect sensor. In addition, from the Kinect Sensor data the crotch height, relative to the rail height, can be determined as shown, again this is currently determined using the more expensive laser distance sensor.

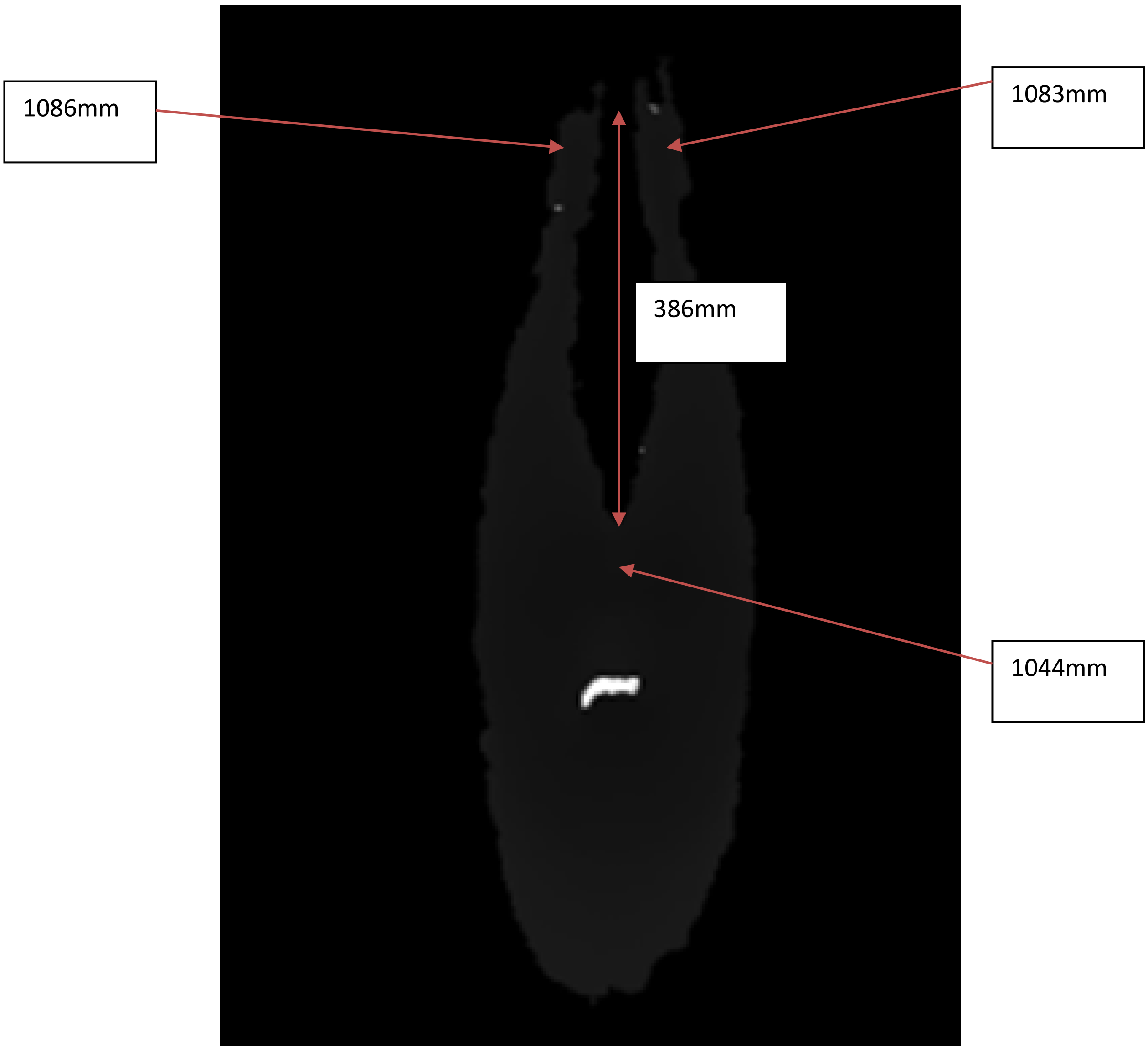

Fig.16 3D Data from the Kinect camera processed by the Halcon Software

4.5 Kidney Fat Removal, Brisket Saw, Sani Vac

Similarly to the results for the Bung Cutter, the Brisket Saw, Sani Vac and Kidney Fat Removal cells could all benefit from the use of the Kinect Camera by utilising the data shown in Fig. 11 to determine the distance the carcass is away from the robot as well as the crotch height/brisket height. Thus replacing two sensors in the system and creating a cost saving for each of these systems.

4.6 Carcass Movement

To simulate carcass movement (carcasses travelling along a chain at production speed) the camera was moved while the image was being taken in the chillers at HVMP. This can be seen by the blurred image in the colour image below.

Fig.16 Blurred image to simulate moving carcasses

The data received form the camera along with range data is shown below. The change in depths at these points are similar , allowing for caracss variation toi those achieved on the stationary carcasses above and hence we would say that the movement of carcasses has has no marked affect on the data received from the camera.

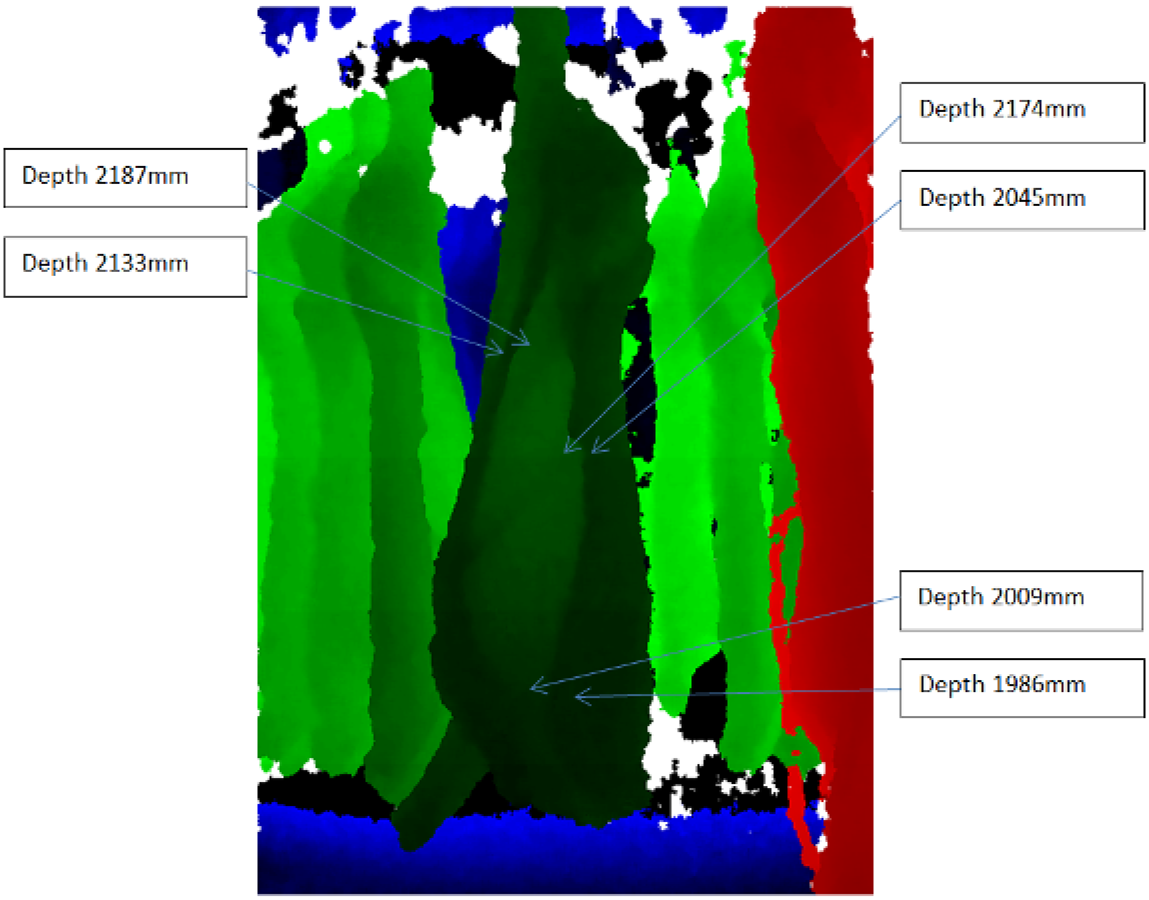

Fig.16 Data from Kinect Camera of blurred image

5 Success in Achieving Objectives

The project has achieved its objectives, it has shown that the Kinect camera is capable of providing depth and 2D information at an acceptable resolution (1mm) and quality on both beef and lamb carcasses which would be beneficial in providing more cost effective sensor solutions to the current commercial / development projects of:

- Bung Cutting.
- Kidney Fat Removal.
- Brisket Saw.
- Sani Vac.

As well as the potential future projects of:

- Spinal Cord Removal.
- Hygiene Trim.
- Beef Vac San

The trials conducted included simulating the effect of carcass movement (ie along a chain in production) and this did not create any issues in gathering data.

A Sick Ruler camera that was used as a comparison provided similar results to the results provided by the Microsoft Kinect camera. The main difference was that the Ruler provided more resolution, however this resolution came at the price of the field of view. Hence imaging a whole beef or lamb carcass would require moving the camera on a linear slide or robot or multiple cameras. This in reality would not be financially viable due to the high cost of the Sick Ruler (in the order of twenty thousand dollars). In comparison multiple Kinect cameras with their low cost (low hundreds of dollars) may be an option if a larger field of view is required. In reality however as can be seen from the images above a single Kinect camera is suitable for scanning a whole carcass at an appropriate resolution.

6 Impact on Meat and Livestock Industry – now & in five years time

The obvious impact of the Kinect Camera on the meat industry, now and in the future is that these cameras signify an advance in technology accompanied with a reduction in cost. These cameras help reduce the complexity of robotic systems by eliminating multiple sensors and replacing with a single unit capable of achieving the same results. This reduces the installation and maintenance costs making the robotic systems more attractive and viable to more processors.

7 Conclusions and Recommendations

From the results achieved it is evident that the Kinect Camera is able with, suitable resolution and quality to provide range data as well as 2D data that could be used in a range of current and proposed red meat projects. The camera allows elimination of two more expensive laser distance measuring sensors which helps reduce the cost of the robotic systems. There is obvious initial setup/programming costs for the camera but once this code is programmed it is then transferable to subsequent projects. The camera will also need to be housed in a suitable enclosure however the cost of this combined with the cost of the camera will still be far less than the cost of the two laser sensors. MAR will look to implement a Kinect sensor in an upcoming Brisket Cutting system.