AMPC

FINAL REPORT

A Dynamic Re-Poseable 3D Skeletal Model of the Carcass

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1.0 EXECUTIVE SUMMARY

This final report describes the completion and findings of the research stage into whether the X-ray image(s) of an animal carcass that is currently available from a parallel MLA/AMPC X-ray scanning project is suitable as input into our general Re-Posable 3D Skeletal Model so adapting it to become a Re-Posable 3D Skeletal Model of a specific animal.

This final research stage follows Milestones 1, 2 & 3 wherein

- Milestone 1 showed that it is feasible to create a re-posable 3D Skeletal Model of an animal carcass in software, and
- Milestone 2 showed that this 3D Skeletal Model can be posed as required to match the disposition of an actual carcass.
- Milestone 3 showed that X-ray images per se do have the necessary clarity and thus the information to support the extraction of bone dimensions for use as input to our 3D Skeletal Model of an animal carcass.

This Final Report will address the suitability of using the existing X-ray data available from the current MLA/AMPC X-ray scanning projects, and if so, where the Re-Posed 3D skeletal Model of a particular animal, may be used in practice in an automated Boning Line.

2.0 INTRODUCTION

This R&D Project is to explore the feasibility to extend the usefulness of the X-ray scanning of a carcass to further downstream carcass break-up operations by the use of the carcass's geometric predictability in its bone structure.

In other words, it is believed that an expensive X-ray Scanner System installed at the start of the Boning Line to measure the bone structure of each incoming carcass, can share this scanned data with downstream automation stations through the use of a 3D Dynamic Re-Poseable Skeletal Model .

This is done by populating a general Skeletal Model with the specific data for each carcass to make that general 3D Skeletal Model *specific* to a particular carcass which is then associated with that carcass as it moves down the Boning Line, and futhermore, the 3D Skeletal Model is dynamically re-posed as required to mimick the actual disposition of the carcass at each downstream Boning Line station.

For the Re-posing of the Skeletal Model, at each downstream workstation a 3D Laser Scanner is used to measure the position and outer shape of the carcass (or part thereof) as currently disposed, so the scanned 3D outer shape can be used to re-pose the Skeletal Model so that it represents the skeleton inside the scanned shape. This re-posed 3D Skeletal Model can then be used to predict the disposition of the skeleton within the scanned shape at that workstation. As such, this specific 3D Skeletal Model can then be used to support any automation operation that requires the knowledge of the position of the carcass bones, at that workstation.

Such an ability to "piggy-back" a machine concept on an expensively and cumbersomely obtained X-ray data set from an upstream scanning module will make it possible to accurately locate the bone structure at a downstream workstation without the further use of specific dedicated expensive X-ray scanning there.

This capability could be one of the missing technology elements that can be used to make feasible new or nascent downstream automation applications.

The overall Project will examine the feasibility in three areas of technology that are needed to underpin this concept:

1. that a Dynamic 3D Skeletal Model can be created, that it can be readily made specific to each carcass, and that it can be dynamically re-posed in real time, and
2. that X-ray bone measurement data can be obtained and used to adapt the general 3D Skeletal Model to that of each specific carcass.
3. that it is feasible to re-pose this 3D Model at each downstream station by using simpler sensors to ascertain the positions of salient features of the carcass.

Milestone 1 reported on the result of the research on the feasibility of the first technology element that a Dynamic 3D Skeletal Model can be created. The Milestone 1 Report established that it can be readily created levering on established computer modeling methods for 3D linkages, that it can be made specific to each carcass, and that it can be dynamically re-posed in real time. The Milestone 1 feasibility was established as positive.

The Milestone 2 reported on the result of the research on the feasibility of the third technology element, that it is feasible to employ simpler and less expensive sensors/scanners to read the disposition of the carcass at a downstream workstation, so enabling the automatic fitting of the 3D skeletal model to this scanned shape, so as to accurately representing the carcass skeletal disposition for automation purposes. The Milestone 2 Report established that feasibility was established as positive.

The Milestone 3 Report examined the feasibility that x-ray images can in general provide the necessary input data to make a ***general*** 3D skeletal model into a ***specific*** 3D skeletal model of a particular carcass (or part thereof). The Milestone 3 Report established that feasibility was established as positive.

In this Final Report, an assessment will be made that whether or not existing available X-ray data from MLA/AMPC projects can be used as input to our 3D Skeletal Model, and some examples of automation applications where this capability will be useful will be discussed.

3.0 PROJECT OBJECTIVES

Specifically, as stated above, this final report research will establish that whether or not existing available X-ray data from parallel MLA/AMPC projects can be used as input to our 3D Skeletal Model, and some examples of automation applications where this capability will be useful will be discussed.

3.1 X-RAY SCANS IN GENERAL DO HAVE THE REQUIRED RESOLUTION FOR OUR APPLICATION.

In the following, we will shows that existing technology X-ray scans are capable of extracting bone dimensions to the accuracy that is required for our 3D Skeletal Model to be useful on a Boning Line.

For example, Figs 1 & 2 show an existing x-ray scan on a human lower body. It also indicates the level of measurement accuracy that is available. Fig 3 shows the scans of a dog's pelvis geometry.

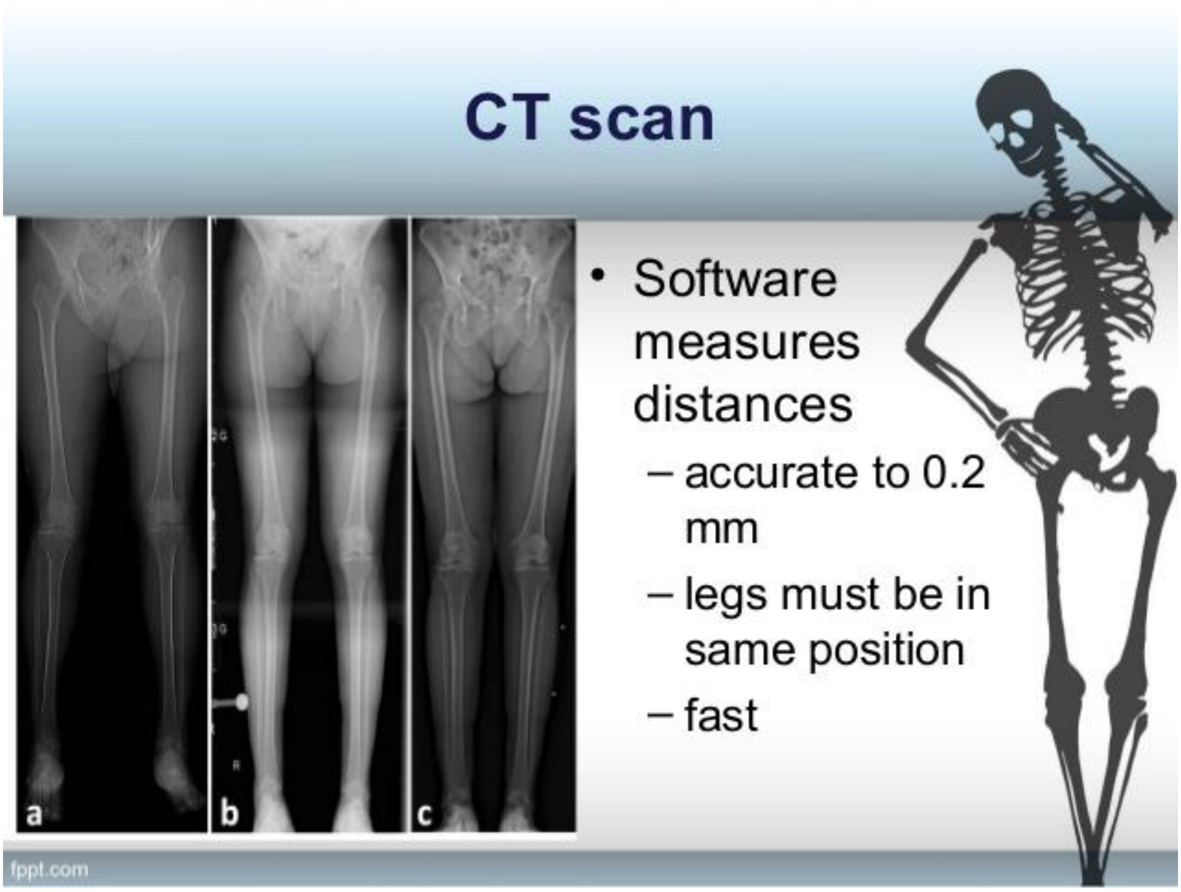


Fig. 1 Typical CT scan of human leg and the measurement accuracy available.

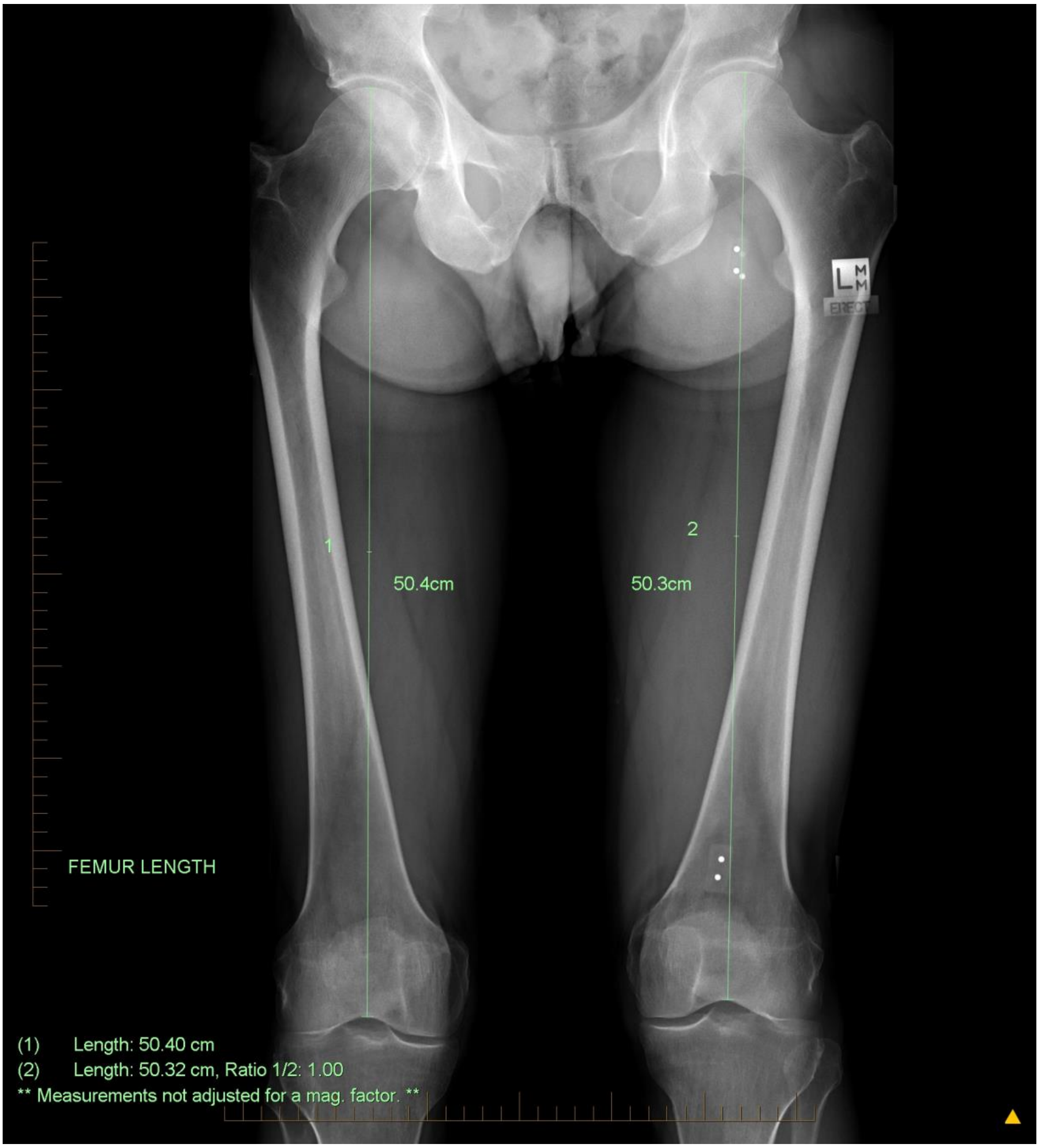
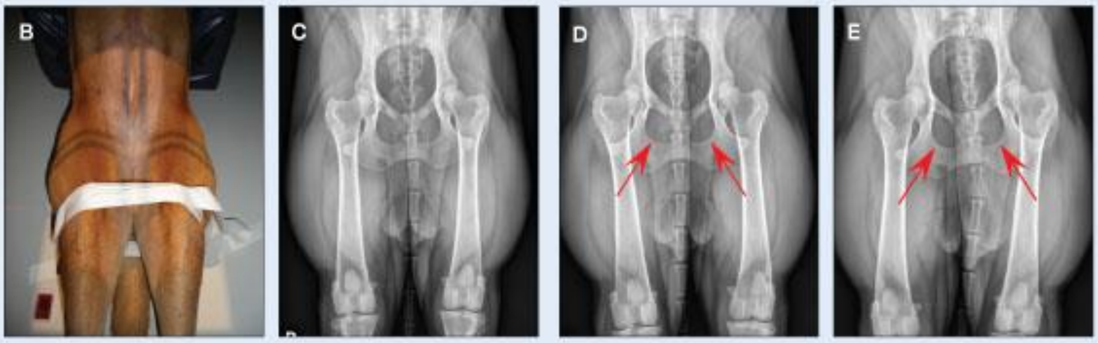


Fig. 2 shows the detailed dimensional measurement of the human upper leg.



(B) Another view of dog positioned for an extended-leg ventrodorsal radiograph. (C) Routine radiograph of the pelvis from the dog in A and B. Note the symmetry of the size and shape of the obturator foramina. (D and E) Obliqued or rotated radiographs where the pelvis was positioned incorrectly; note the asymmetry of the obturator foramina (arrows). For D, the right side of the dog's pelvis should pulled up (away from the table slightly) to correct this positioning abnormality. For E, the left side of the dog's pelvis should be pulled up (away from the table slightly) to correct this positioning abnormality.

Fig. 3 shows the X-ray scans of a dog's pelvis.

Therefore, Figs 1, 2 & 3 show that in general x-ray scans can have the resolution to support the extraction of bone lengths. Since each x-ray scan is a 2D image, to obtain the true length of a bone, it is necessary to use at least two x-ray scans from near orthogonal viewing directions (and the trigonometry to calculate the bone's true length, see below).

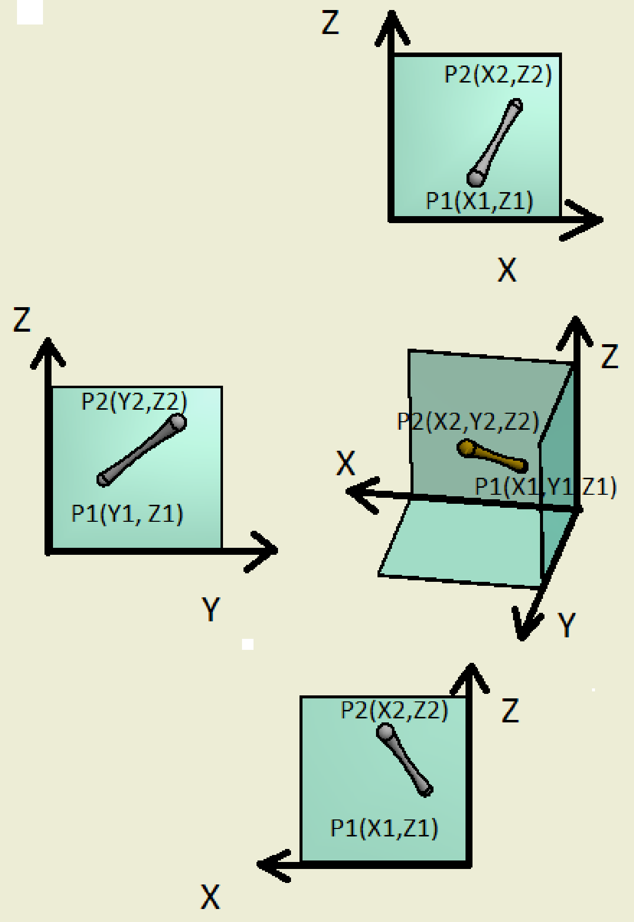
3.2 OBTAINING BONE DIMENSIONAL DATA FROM A X-RAY SCAN (FROM FIRST PRINCIPLES)

Basically, we need the dimensional data – such as bone lengths – as input to our 3D Skeletal Model; to calculate the length of a bone we will need to know the positions in 3D space of the two ends of the bone, P1 and P2, respectively, in Fig 4.

In other words, within a frame of reference (in this case an X/Y/Z co-ordinate system) in which the bone has been imaged, we will need the positional co-ordinates of one end of the bone - P1 defined as X1, Y1, Z1, and the other end of the bone - P2 defined as X2, Y2, Z2. Using the values of X1, Y1, Z1 and X2, Y2, Z2 we are than able to calculate the real length of the bone (simply using Pythagoras' Theorem, for example).

Fig 4 shows the projection of the bone onto the XY, XZ and YZ orthogonal planes.

Fig 4 Projections in the XY, XZ & YZ Orthognal Planes



In Fig 4, the bone length, LB, can then be calculated as

$$LB = SQR((X2 - X1)x(X2 - X1) + (Y2 - Y1)x(Y2 - Y1) + (Z2 - Z1)x(Z2 - Z1))$$

3.3 OBTAINING BONE DIMENSIONAL DATA FROM CURRENTLY AVAILABLE MLA/AMPC X-RAY SCANNING PROJECTS

Fig. 5 shows a typical existing X-ray scan available from the current MLA/AMPC projects as provided by Murdoch University.

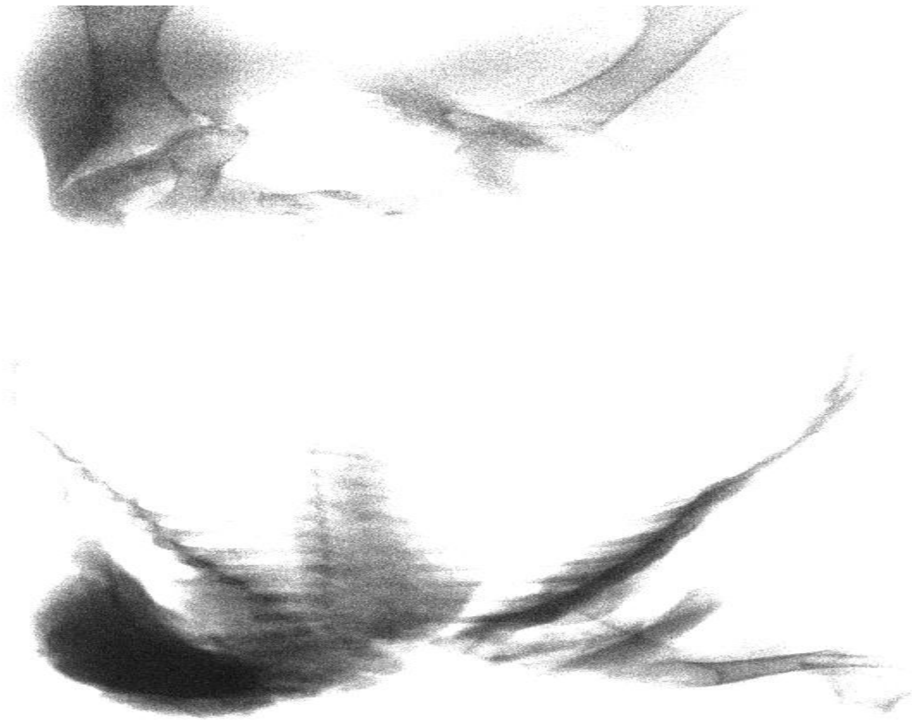


Fig. 5 Example of Murdoch University X-ray Scan

The above available X-ray scans of the mid-section of a carcass have been optimized for the purposes of the current MLA/AMPC projects, and as such they differ significantly from that which is required for our purposes. In other words, they are essentially 2D scans – not from near 90 degree scanning directions, but from scanning directions only about 20 degrees apart. Therefore, they do not avail themselves to the accurate extraction of bone lengths (by the methodology described) for our 3D Modeling requirements), although they are eminently adequate for its designed purpose for the

MLA/AMPC existing projects of guided 2D cutting of a carcass mid-section.

The MLA has foreshadowed that in future X-ray scanning projects, they are contemplating to obtain real 3D X-ray scan data to support 3D robotic cutting in the guided sub-division of the carcass mid-section into smaller primal cuts (from MLA discussions, Nov 2017).

This future X-ray work is likely to involve CT or MRI type technologies, at which time X-ray scan similar to those shown in Figs 2 & 3 above will be obtained. When this happens, we will be in a position to "piggy-back" onto this X-ray scan data, so to advance our Re-Posable 3D Skeletal Model concepts.

3.4 LIKELY "PIGGY-BACK" APPLICATIONS

Some examples for downstream automatic boning applications that can benefit from "piggy-backing" onto appropriate upstream 3D X-ray scan data.

3.4.1 Featherbone Removal

In an earlier AMPC project (2014/1005 - Concepts Creation & Review for the Automated Meat Recovery off Featherbones) which examined, among other applications, the removal of the featherbone efficiently with the minimum of attached meat, it was found that simple sensing methods (such as sensors, Vision Systems, etc.) was unable to reliably detect the size and position of each featherbone, but that X-ray data was necessary. The employment of a dedicated 3D X-ray scanning system for this application is not economically or practically feasible, however, the availability of the necessary 3D X-ray scan data from an existing upstream task, may enable this ask to be automated economically.

3.4.2 Lamb Rib Racks Frenching

In our current AMPC project (2017-1052 – Automated French Dressing of Lamb Rib Rack), we are proposing to use a 2D Vision System (supported with smart software implementing noise abatement techniques and algorithms) to detect the position of each rib bone in the rack by viewing the non-meaty side of the rib rack and the end view of the freshly cut-to-length rib bones. The availability of X-ray data from an up-stream X-ray scan will simplify this function and reduce the amount of data processing, reduce the processing time and the required processing capability.

4.0 PROJECT OUTCOMES

This Project examined and established the in-principle feasibility in three areas of technology that are needed to underpin this concept:

1. that a Dynamic 3D Skeletal Model can be created, that it can be readily made specific to each carcass, and that it can be dynamically re-posed in real time, and

2. that X-ray bone measurement data can be obtained and used to adapt the general 3D Skeletal Model to that of each specific carcass.

3. that it is feasible to re-pose this 3D Model at each downstream station by using simpler sensors to ascertain the positions of salient features of the carcass.

Thus this scoping research project has indicated that it is indeed conceptually feasible to "piggy-back" and utilize the scan data from an upstream 3D X -ray scan, provided that the X-ray scan is of sufficient high-resolution and is able to yield data to extract 3D measurements.

However, at this time, the first generation of X-ray scans in use in existing abattoir applications is of insufficient resolution and “3D-ness” for our application.

It is foreshadowed that the second generation of X-ray scans currently envisaged for more sophisticated future boning applications will be of sufficient resolution and “3D-ness” for us the “piggy-back” onto, and use our concept to extend their usage for down-stream boning automation.

A recommendation is that our “piggy-back” concept is borne in mind when this second generation X-ray scanning is being developed so that its results can be directly suitable also for our application.

5.0 METHODOLOGY

This Project is a preliminary examination of whether or not a concept can be released by an existing set of technologies. As such the methodology was desk research, data-base research and discussions with engineers and project managers now involved in AMPC/MLA X-ray scanning projects.

6.0 CONCLUSIONS/RECOMMENDATIONS

The research has indicated that it is indeed conceptually feasible to “piggy-back” and utilize the scan data from an upstream 3D X -ray scan, provided that the X-ray scan is of sufficient high-resolution and is able to yield data to extract 3D measurements. Such X-ray data can be manipulated either by first principle methods (familiar to those skilled in the art as described in our Milestone 2 & 3 Reports), or by the adaptation of existing methodologies already developed for the x-ray 3D guidance of robotic cutting.

However, at this time, the first generation of X-ray scans in use in existing abattoir applications is of insufficient resolution and “3D-ness” for our application. It is foreshadowed that the second generation of X-ray scans currently envisaged for more sophisticated future boning applications will be of sufficient resolution and “3D-ness” for us the “piggy-back” onto, and use our concept to extend their usage for down-stream boning automation.

A recommendation is that our “piggy-back” concept is borne in mind when this second generation X-ray scanning is being developed so that its results can be directly suitable also for our application.