Three-Dimensional Modelling of Carcass and Meat Cut Shape

R. D. Clarke[1], H.L. Zhang[1] and A. Pullan[2]
1. The Meat Industry Research Institute of New Zealand, Inc.
2. Department of Engineering Science, University of Auckland

INTRODUCTION

Three-dimensional information on carcass shape and form is currently utilised in meat processing applications from stock selection and grading to meat cut and product presentation. However, because of the difficulties associated with measuring, storing and interpreting three dimensional shape information, shape has generally been evaluated subjectively and described loosely in terms of a conformation, or muscling score. Objective measures of three dimensional shape and structure are not used when processing and assessing potential value. While attempts to utilise three dimensional carcass and bone shape information have been investigated[1,2,3,4], a complete parametric description of three dimensional structure has yet to be attempted.

The immediate advantages of describing 3-D carcass and meat cut shape mathematically are twofold. By describing the fundamental form in terms of one or more three-dimensional mathematical surfaces, the large amount of empirical data can be expressed as useful information using a small amount of parametric information. A small number of physical measurements could then be used to deform these surfaces to approximate the overall meat cut or carcass shape, based on a generic 3-D parametric model.

3-D DATA ACQUISITION

Three dimensional mathematical models of surface shape are derived from three dimensional surface data. There exist many ways of measuring the three-dimensional surface of carcasses ranging from manual measurement systems through to automatic topographical and tomographical techniques such as full body laser scanners, Computer Aided Tomography (CAT) and Magnetic Resonance Imaging (MRI). We are currently using a three dimensional digitising arm and plan to use three dimensional surface information obtained from CAT scans of meat cuts and carcasses. The digitising arm can access a hemisphere of approximately 1.2 metres in diameter.

Using the digitising arm, individual ovine shoulder bones and lamb carcasses were digitised and saved as sets of three-dimensional surface points in world coordinates. Information regarding point connectivity was also retained. A lower spatial sampling frequency was used when digitising meat cuts due to the lower surface curvature of a carcass compared to a bone. The operating reach of the digitising arm was insufficient to allow a whole lamb carcass to be digitised intact. Lamb carcasses were therefore halved and cut into their constituent primal cuts (five rib fore, chump off long loin and long cut leg). Each primal cut was digitised and the individual cuts combined to generate the surface model of the entire carcass.

After an object had been digitised, a surface mesh was generated by interpolating between points (using a complex hull surface interpolating technique within the digitising software) to form a surface mesh over the digitised points. This surface could then be rendered to produce a visualisation of the three-dimensional object. The digitised surface mesh of a lamb carcass is shown in Figure 1. While digitisation artefacts have been introduced by the digitisation and mesh generation process (due to under-sampling in areas of high curvature, operator bias, surface interpolation), the macro structure of the carcass is nonetheless accurately reconstructed.

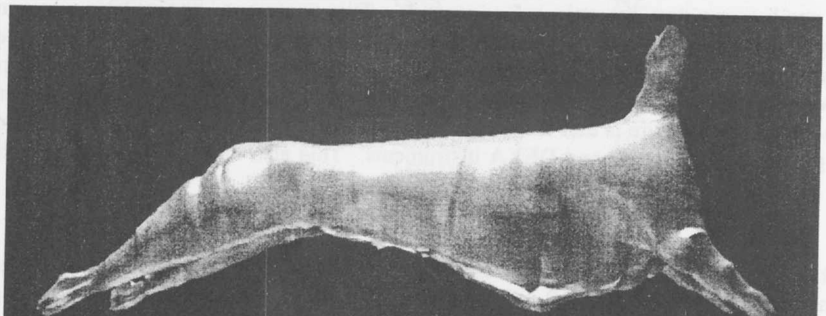

Figure 1.
Three-Dimensional lamb carcass model created by combining individual primal cuts.

3-D MODELLING

Based on our experience with modelling bones and carcasses in two dimensions[5,6] we have extended our work to three-dimensional modelling. There are several ways to construct a mathematical representation of the measurement data, one of which was discussed above. Since our aim is to produce a deformable full carcass model that can not only simulate passive shape variation, but also model possible shape changes under muscle movement, a computational model (rather than a pure graphical model) has been investigated.

Developing a mathematical representation of a carcass based on real-world data involves fitting a mathematical surface to an actual points in a way that minimises the error between the actual data and the corresponding point on the surface, in three-dimensional space. A number of different modelling techniques have been investigated, using a variety of linear and non-linear techniques to minimise these errors. Traditional finite-element type models involve interpolating between every data point using linear functions. The approach used in (7) is to use higher-order C1 interpolating functions (cubic Hermites) and use a nonlinear fitting procedure to minimise the distance between the parametric cubic Hermite elements and the data set. This results in an accurate representation of the surface with substantially fewer degrees of freedom than data points.

An example of a digitised humerus bone is shown in Figure 2a. While this data set is representative of the actual bone, the digitisation and mesh generation process has introduced a number of artefacts which do not exist in the actual bone surface. The causes of these errors include under-sampling in areas of high curvature, deficiencies in the complex hull surface generation algorithm and operator bias. Figure 2b shows the original

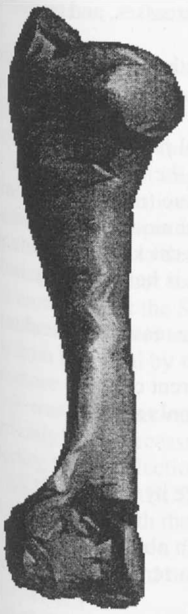

Figure 2a.
3-D surface of humerus using triangular patches between digitised surface points.

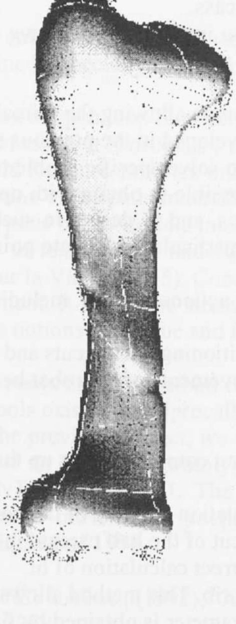

Figure 2b.
Original three-dimensional Cubic Hermite mesh of a humerus bone showing original data points

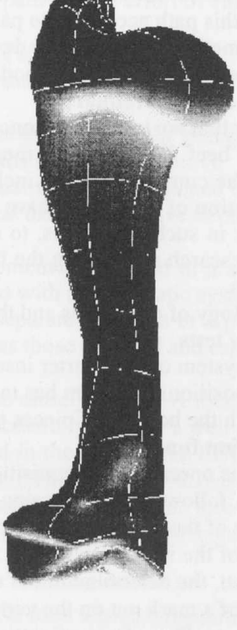

Figure 2c.
Three Dimensional Cubic Hermite model of a humerus bone with the underlying model mesh overlaid.

data points and the initial cubic hermite mesh prior to optimisation. The final surface model is shown in Figure 2c. While some artefacts have been introduced into the fitted 3-D surface due to under-sampling, the surface is nonetheless representative of a humerus bone and the mathematical model has accurately reproduced the major surface features of the bone surface, particularly around the surfaces at the top of the bone where it joins the scapula. In Figure 2a where 4747 data points were used to represent the humerus. The final model surface (Figure 2c) contains only 241 degrees of freedom and has a Root Meat Squared error of less than 0.6mm.

FUTURE WORK

We are currently in the process of developing and refining our three-dimensional surface models of the ovine humerus bone and a lamb carcass. Once developed, we will investigate techniques for deforming these models to represent the three-dimensional shape of particular objects. For this task it will be important to have an efficient representation of the three dimensional surface.

POTENTIAL APPLICATIONS

Our ultimate objective is to predict the shape of a particular carcass or meat cut using only a few physical measurements. These measurements will cause an anatomically correct, three dimensional carcass model of the carcass to deform and approximate the three dimensional shape of the particular carcass being measured, within predetermined limits of accuracy and resolution. Anatomically correct models can then be used to predict actual structure and form from only a small number of physical measurements. In this way these models will effectively form part of a model based control reference, whereby the model, deformed to fit a particular carcass, is able to estimate attributes of each carcass in areas that have not been measured.

ACKNOWLEDGEMENTS

This work forms part of a multi-year programme funded by the New Zealand Foundation of Research, Science and Technology with assistance from the New Zealand Meat Research and Development Council (NZMRDC).

REFERENCES

1. Madsen, N.T. *et al,* BCC-2 for Objective Beef Carcass Classification and Prediction of Carcass Composition, Proc. 42nd ICOMST, 1996..
2. Gigli, S. *et al,* Video Image Analysis (VIA) in Evaluation of Pig Fresh Thigh for Cured Ham Production, Proc. 42nd ICOMST, 1996.
3. Horgan, G.W. *et al,* Automatic Assessment of Sheep Carcasses by Image Analysis, Animal Science **60**, 1995.
4. Wadie, I,.H.C. and Khodabandehloo, K. Modelling Primal Cuts on Pork Carcasses for Automatic Butchery, IEE Colloquium on Intelligent Automation for Processing Non-rigid Products, 1994.
5. Zhang, H.L. and Clarke, R.D., Application of the Point Distribution Model to the Ovine Humerus Bone, Proc. IVCNZ '95, Lincoln, Aug. 1995.
6. Zhang, H.L., Clarke, R.D. and Pullan, A.J., Two-Dimensional Shape Modelling of the Ovine Scapula Bone, Proc. IVCNZ '96, Lower Hutt, 29-30 August, 1996.
7. Bradley, C.P., Pullan, A.J. and Hunter, P.J., Geometric Modelling of the Human Torso using Cubic Hermite Elements, Ann. Biomed. Eng, 27:1, 96-111, 1997.