<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>New Applications Of Three-dimensional Data Acquisition, Modelling, And Printing In Animal Sciences: A Case Report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Author(s)</strong></td>
<td>Viana, Joao Henrique Moreira; Bartolo, Paulo Jorge Da Silva</td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td>2016</td>
</tr>
<tr>
<td><strong>URL</strong></td>
<td><a href="http://hdl.handle.net/10220/41843">http://hdl.handle.net/10220/41843</a></td>
</tr>
<tr>
<td><strong>Rights</strong></td>
<td>© 2016 by Pro-AM 2016 Organizers. Published by Research Publishing, Singapore</td>
</tr>
</tbody>
</table>
NEW APPLICATIONS OF THREE-DIMENSIONAL DATA ACQUISITION, MODELLING, AND PRINTING IN ANIMAL SCIENCES: A CASE REPORT

JOAO HENRIQUE MOREIRA VIANA
Embrapa, UPqEB, Av. W5N
Brasília, DF, 70770-917, Brazil

PAULO JORGE DA SILVA BARTOLO
Manchester Institute of Biotecnology, 131 Princess St,
Manchester, M1 7DN, UK

ABSTRACT: Precision phenotyping is a new approach to improve the selection and management of farm animals, and consequently livestock production, productivity, and wellbeing. It requires new tools to obtain large amounts of biometric data. This work aims to investigate the feasibility of the rapid generation of 3D models for the recovery, analysis, and storage of biometric information in cattle. Structured infrared light scanning was used to obtain 3D data of dairy cows, and digital models were created using a real-time 3D scanning software and edited with a software for processing triangular meshes. Measurements and comparisons were performed using a 3D inspection and metrology software. Physical models were generated by additive manufacturing and laser scanned to evaluate differences to the original 3D models. Animal movement limited the quality of whole body scans as expected, though useful partial body scans were obtained from areas of interest, such as the thurl and udder. Biometric measurements in 3D models presented slight differences compared to the ones made in live animals, and were consistent with results of other works, such as subjective scoring or ultrasonography. Comparing 3D models from different animals by superposition was useful to demonstrate the pattern of deposition or mobilization of subcutaneous fat. Finally, the 3D printed models showed minor differences when re-digitalized and compared to the original 3D models. Results show that 3D data acquisition, modelling, and printing techniques can be used to obtain biometric information from cattle, as well producing physical models for research and educational purposes.

Key words: Biometry, cattle, 3D technologies

INTRODUCTION

Additive manufacturing is an emerging technology applied to a wide range of fields such as aerospace, aeronautics, and medicine. However, its use in animal sciences and livestock production is not fully explored. In this domain, 3D acquisition, modelling, and printing of geometrical body shape information can be highly relevant, for example, to improve both the quality and the quantity of biometric data, allowing the precise and high-throughput phenotyping of farm animals. This phenotypic data is critical to animal breeding programs, and its demand was boosted by the huge advances in genomics, as well by the increasing pressure on meat and dairy industries to improve productivity, while reducing the use of natural resources (Houle et al. 2010). New methods to measure animal characteristics are especially important in large animals, due to current measuring limitations, e.g., data inconsistencies, high maintenance costs, and increasing concerns with animal wellbeing.
The combination of advanced scanning technologies and additive manufacturing systems are critical tools in the emerging area of precision farming, providing feedback information for management decision. These technologies can be also relevant for educational and training programs in animal sciences. The preliminary results reported in this work are part of a major research program focusing in the use of these technologies for both precision farming and education.

METHODOLOGY

Image acquisition

Adult, lactating dairy cows were used in this trial. The acquisition of three-dimensional data of the animals was performed by structured infrared light scanning, using a motion sensor equipped with built-in infrared projector and infrared and RGB video cameras (Kinect, Microsoft Studios, USA). The sensor was connected to a computer equipped with a real time scanning software (ReconstructMe 2.0, Profactor GmBH, Austria). The scanning box area was previously set in the software to fit data from large objects. The points-cloud data was transformed in a geometric surface and stored as OBJ files. Whole body scanning was performed by freely moving the sensor around the animals, while for partial body scans restraining devices were used to avoid animal movement (Figure 1).

Figure 1: Cow at the restraining device and corresponding image, as captured by the Kinect sensor.

3D Data processing and modelling

The 3D data was edited using the open-source software MeshLab (SourceForge, USA) for processing 3D triangular meshes. Minor mesh defects were corrected; and fragments or unspecific scan objects (as parts of the restraining device) were deleted from the models. Biometric measurements were made in the 3D models using a 3D modelling software (Rhinoceros 3D 5.0, McNeel North America, USA). Specific body areas, such as clearly visible prominences of bones, were used as reference marks for the measurements and to align different models, when necessary. Comparisons between models were performed using the 3D inspection, and metrology software Geomagic Control (3D Systems, USA).

3D printing
Three-dimensional physical models of the animals were produced using the binder-jetting technology (ProJet 160, 3D Systems). The original 3D models were re-scaled to fit in the printing area, and the corresponding SLI files were built using the printer software (3DPrint, 3D Systems).

Reverse engineering was used to validate the physical models generated by additive manufacturing. To ensure a higher accuracy, the 3D prints were laser scanned using a portable device (HandyScan ExaScan, Creaform, Costa Mesa, CA, USA), after calibration, and generated models saved as STL files. These models were then compared with those obtained from the live cows.

**Data analysis**

Data from the measurements performed in the 3D models were compared to biometric data of the cows, which was previously obtained by conventional farm animal evaluation procedures, such as by the use of a hyprometer, visual scoring, and ultrasound subcutaneous fat measurements. Relations between variables were calculated through the Pearson’s correlation method.

**RESULTS AND DISCUSSION**

Structured infrared light scanning allowed successful 3D data recover from cattle (Figure 2A). There was no detectable interference of fur length or color, as occur with other scanning technologies such as time-flight cameras (Salau et al. 2015). However, direct sunlight disrupted the scanning process, resulting in missing parts in the final 3D models. As expected, because of cow size, whole body scans were difficult to obtain and the inability to keep cows standing still was a major limitation for the quality of the 3D models. Distortions and changes in body shape caused by movements are a major challenge to full body scanning. Nevertheless, in the current study, partial body scans were performed using conventional restraining devices.

The pelvis is one area of particular importance in cattle management. It can be easily visualized in different perspectives during animal feeding or milking, pelvis morphology is correlated to calving ease (Nahkur et al. 2011), and it is an area most frequently used to inspect body condition (Edmonson, 1989). As the pelvis is delimited by a set of bones (ilium, ischium, pubis, and sacral vertebra) that are joined but nor articulated, it is also less prone to changes in shape due to pose. Thus, in the current report we decided to use scans of the pelvis to explore some of the potential uses of 3D modelling in cattle.

The resulting 3D models showed minor mesh defects, but were useful for the evaluation the pelvis. As observed from Figure 2B, the image of the tessellated surface did not affect the visual perception of the main morphological features (Viana et al., 2016). Measurements of the distances between the ischia and ilia prominences, obtained directly in the cows or from the 3D models, showed overall differences of less than 2% (Figure 2C). Comparisons of cows showing contrasting body conditions were made by superposition of their 3D models, and differences displayed as a color-coded map, allowing a straightforward visualization of the main regions were fat tissue was accumulated or mobilized during weigh changes (Figure 2D). When differences were quantitatively evaluated among cows with a range of body conditions (from very thin to emaciated), the amount of energy (fat) reserves estimated using the 3D models was positively...
correlated to those predicted either by visual scoring (Figure 3) or by measurement of subcutaneous fat thickness ($R=0.96$ and $0.77$, respectively, $P<0.05$).

Figure 2A-E: Three-dimensional (3D) modelling of biometric data from the lumbar and pelvic regions of a lactating dairy cow with poor body condition. The geometric data acquisition was performed by scanning with structured infrared light (Kinect sensor, A). Data was used to create a point cloud data, and to reconstruct the partial 3D model (B). These models were then used to recover biometric data (C), make comparisons with reference models and map fat tissue mobilization (in blue, D), and generate physical models by additive manufacturing (binder jet in powder bed, E).
Figure 3: Association of values of energy reserves, as predicted in 3D models by superposition and measurement of differences from a template, and values of subjective visual scoring of the body condition in cattle.

Finally, the 3D data was used to generate physical models by additive manufacturing (Figure 2E), which were then validated using reverse engineering. 3D physical models were compared to the original 3D scan models, and only minor differences (-0.96 to +1.25 mm) were observed, mostly in the edges.

These results suggest that printed models could be used to physically store biometric data of farm animals, as well to construct realistic phantoms for educational and training usage. The characterization of phenotypic traits in cattle is particularly challenging, as it requires the description of complex and irregular shapes. However, such traits are important both to animal breeding programs, and to characterize biodiversity and preserve endangered breeds. Additive manufacturing of animal models could be used to produce reference standards for the evaluation of type traits. These models could also be used to reproduce the tactile information of body shapes, which can be used, for instance, in some body scoring systems (Isensee et al. 2014).

CONCLUSIONS

The rapid generation of three-dimensional (3D) models together with the Kinect sensor can be used for the recovery, analysis, and storage of biometric information in cattle.
In the livestock industry, the approach presented in this work can be an interesting alternative to recover precision data for specific purposes, for instance, teat measurements for the design of robotic milking devices. The proposed approach allowed to obtain reasonable quality data for biometric purposes. A further integration of different image technologies will allow the creation of large phenotypic database of livestock animals.

ACKNOWLEDGMENTS

This study was supported by the Minas Gerais State Research Foundation (FAPEMIG) and by the Brazilian Agricultural research Corporation – Embrapa.

REFERENCES


