Automated data capture using laser technology to enhance live cattle assessment and description

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Abstract

This paper describes the development of an automated technique using laser technology to estimate hip height of cattle. Body dimensions of cattle are very useful as basic descriptors, but can also be used to predict animal performance and carcass characteristics. Descriptive data used for trading needs to be objective and low cost to encourage value based transactions and assist producers to meet market specifications. Height at the hips relative to age (referred to in the industry as frame score) provides an assessment of ‘maturity type’, which determines the varying rates and sites of deposition of fat and lean tissue as an animal grows and approaches its mature size. Body dimensions such as hip height and stifle width can be easily measured manually but are labour and time consuming. An automated electronic system would make the capture of such data objective and more cost efficient. The system developed can be incorporated into typical cattle handling facilities to measure body dimensions and generate useful descriptive parameters. The principle has subsequently been extended to explore the capability of 3D camera technology to improve and expand data capture for descriptive and predictive applications.

Keywords: cattle, conformation, live assessment, frame, hip height, laser, RGBD, imaging

Introduction

The ‘Phenotypic Prediction’ project, within the research program of the Cooperative Research Centre for Beef Genetic Technologies (Beef CRC; see Griffith et al. 2006) examined cattle industry issues at all stages of the supply chain. The value of animals at the level of commercial producers is determined primarily by liveweight, but also varies according to criteria that are subjectively assessed such as fatness and muscularity (McKiernan 2002; Griffith et al. 2013). However, there is rarely any accounting for potential future performance. Profit made during the finishing stage (increasingly through feedlot management) is determined by growth rate, feed efficiency and the characteristics that affect the value of the carcass produced. Efficiency and profitability at the processing stage is affected primarily by carcass weight and meat yield, but quality traits (such as marbling) are assuming increasing attention.

Prediction of quality traits currently relies largely on the experience of the operators, who buffer their purchase costs against uncertain returns. The processor needs end product that is consistent and directed to specific markets, requiring nominated carcass specifications, while maintaining sufficient supply. The ability to meet these goals is dependent on the numbers and the body composition of the animals presented for slaughter. The industry therefore needs reliable methods of predicting the outcome at various stages in the chain, so that all operators can be fairly rewarded for their component of production.

The use of modelling to predict body composition during growth is a valuable aid to managing beef production to ensure success in meeting targeted end points (Walmsley et al. 2014).

This paper describes a technique developed to capture body measurements of the live animal, objectively and automatically using laser technology (updating preliminary results reported in Wilkins et al. 2014). Such measurements have both descriptive and predictive applications, but were initially directed at refining inputs to a decision aid tool that predicts fat deposition using a growth model (‘BeefSpecs’- McKiernan et al. 2008), to improve the accuracy of the output.

Industry significance/application

The immediate relevance of the laser technique is to facilitate the use of prediction tools, such as 'BeefSpecs' as described by Walmsley et al. (2010), by the estimation of frame score which is one of the inputs required. The equations used by 'BeefSpecs' to predict fat deposition are described by Walmsley et al. (2014), showing the importance of an accurate assessment of frame score, as well as the other inputs, to the accuracy of the prediction. Apart from their use in predictive tools, objective measurements enable easily interpretable and accessible descriptors for saleyard or other live transactions and market reporting. This also allows more precise market signals to facilitate and encourage value based trading (VBT). When objective measurements are used in feedlot induction or saleyard scenarios, automation provides greater efficiency and accuracy.

Rates of non-compliance have been shown to be quite high in some cases, which can severely affect value of product (Slack-Smith et al. 2009). Accurate definition of current phenotype will enable management decisions to improve compliance to specifications for live transactions, feedlot entry or slaughter by prediction of body composition at a later point in the supply chain.

Methodology and results

Measuring hip height

Height at the hips relative to age (referred to in the industry as frame score) provides an assessment of 'maturity type', which determines the varying rates and sites of deposition of fat and lean tissue as an animal grows and approaches its mature size (Walmsley et al. 2010). Frame score is determined from a height/age matrix (McKiernan 2005). Height at the hips can be measured by several techniques including visual estimates made by reference to a scale on the side of a crush or race, or by using a device with a horizontal arm which is placed over the hip area. However a common, and relatively simple, method is to use a tape that is lowered from a fixed point above the animal to the hip region and this measurement is subtracted from the reference distance of the fixed point to the ground, as illustrated in Figure 1. The tape method is typically used while the animal is standing in a crush or other holding station. Whatever method is used, the height obtained is affected by the stance of the animal. Thus, the stance of the animal should be as 'natural' as possible to minimise the variation in the height measurement in determining the allocation of frame score.

Prior to developing the laser technique, we assessed the repeatability of height measurements with the tape method as this was used for comparison with the laser estimates. Repeatability between and within 2 experienced operators was determined for the tape method using 51 adult Angus cows, ranging in height from 114-132 cm. Observations were made on 2 or 3 occasions by each operator over 2 days. Data were analysed for correlation between all possible combinations of repeated measurements. Those results are shown in Table 1. Estimates of repeatability (assessed by correlations) were all highly significant ($P < 0.001$) and ranged from 0.89 to 0.94 within operators, while those between operators ranged from 0.86 to 0.93.

Repeatability of tape measurements made by another experienced operator on mature cows taken 4 months apart was 0.87 ($n = 235$; $P < 0.001$). Measurements taken by the same operator on the same group of cows 12 months apart gave a repeatability of 0.85 ($n = 238$; $P < 0.001$). Thus the tape estimate of height was shown to be fairly robust in animals that were fully grown.

Measurements made using the tape method should be around 85 - 90% repeatable when taken by experienced operators. However, any particular measurement will be affected by the stance and behavior of the animal which may be influenced by a number of factors including the handling facilities, familiarity (both animal and operator) and genotype (temperament). This inherent variability of the measurement is unavoidable noise and must be taken into account when assessing repeatability or when comparing different techniques. However, the measurement by tape was used as the only valid comparison in subsequent evaluation of the estimations by the laser system during development.

Development of laser measurement systems

The development of the laser measurement system was based on the manual technique described above and involved applying an electronic (laser) technology to complete the task automatically. The system was developed by staff of the Department of Primary Industries (DPI), using the contracted services of Mr Tim Driver (CAWD Engineering, Dubbo, NSW) for the hardware development, who sub-contracted Crossmuller Technology (Blacktown, NSW) in the co-development of the software ('Cow Auto Frame Scorer'). Experiments were conducted at the DPI Agricultural Research Centres at Trangie and Grafton, NSW, and some testing of the systems was carried out at a commercial feedlot.

The electronic measurement is made using the SICK LMS 400 laser unit (SICK AG - Auto Ident, Reute, Germany – further details appended below). Similar laser units are commonly used in a variety of industrial scenarios to detect, identify, measure and record inanimate objects – typically for product flow and quality control, robotic, logistic and other applications. The transmission of a laser beam and the receival of a return signal after striking the target enables the distance to an object to be measured which is the function used for our purpose. The primary aim of the current project was to capture animal height, but also to explore the possibility of measuring other dimensions that may be useful for description, or for prediction of carcass traits like meat yield. Estimates of muscularity, using a visual (thus subjective) scoring system, are well correlated with yield when assessed by an experienced operator just prior to slaughter (r ~ 0.7, Perry et al. 1993), and even moderately correlated to muscle score at weaning or feedlot entry, when estimated many months before slaughter (r ~ 0.4 – 0.5, Wilkins and McKiernan, unpublished data). An objective estimate of muscularity can be made by measuring hip and stifle width (McKiernan, pers. comm.). However, initial attempts to capture such measurements by varying the angle of the laser beam revealed that this would be a difficult task and further attempts at this approach were abandoned due to the successful examination of a much more promising technique using 3D imaging (RGB-D camera technology - see Henry et al. 2012). RGB-D sensors combine RGB color information with per-pixel depth information.

Laser measurement procedures

Two configurations of the system were developed, each having the laser unit sending the signal from above the animal, either with the animal moving and the laser held stationary or the animal held and the laser moving. The primary components of the system consist of the laser unit and a software program installed on a computer to accept and process data sent from the laser unit. Animal identification can be incorporated automatically from a radio frequency identification (RFID) reader or can be entered manually to the software by user interface. The laser scan is activated by either light sensors or manually as described below. The software program has algorithms that filter the data to eliminate those extraneous to the animal and also to correct for noise, such as the cyclical variation in the height measurements caused by the gait of the animal, or from various contaminations on the back of the animal (e.g. dung, mud, backline treatment etc.).

System 1 - Stationary laser unit – animal scanned while passing under scanner.

The stationary laser unit has the laser located in a fixed position, centrally above a race, through which the animal moves while scanned (Figure 2). This is an easily achieved placement in typical cattle handling facilities (farm or saleyard). In the stationary configuration the timing of the laser scan is controlled by sensors on the side of the race. The scan is activated when the rear of the animal has moved past the entry sensor and is deactivated when it has moved past the exit sensor (Figure 2). The laser beam is projected in a vertical plane toward the animal and is refreshed every 5 milliseconds to produce many 'slices' of a horizontal pass perpendicular to the backline of the animal as it moves forward. A large amount of data is delivered to the software (10,000 – 50,000 distance readings) for processing and generation of the height estimate. Scan data are collected from a region starting behind the shoulder and extending to just behind the hip. Although the tape method gives a measurement at the hip specifically, rather than along the backline, the estimate generated by the scan data correlates well with the height at the hip. A scan could be taken at the same point as the tape measurement but this would require the animal to be held stationary while the laser was manually positioned to the correct spot, which would defeat the aim of having an automatic system.

System 2 - Moving laser unit – animal stationary while scanned.
A moving laser system was also developed since it may be suitable to hold the animal stationary while scanned if also involved in other measurements, like liveweight and fatness (Figure 3). It was also reasoned that noise due to the gait effect mentioned above would not be an issue if the animal was stationary.

The moving laser system uses a laser unit mounted on a cradle which is placed above the scanning station. The cradle has a moving carriage driven by a pneumatic ram which moves the laser unit along a path over the backline of the animal (Figure 3), and thus also generates many 'slices' as described for the system above. The moving carriage and scan is activated manually when the animal is standing suitably still.

Accuracy of laser estimates – correlation with manual measurements

As mentioned above, there is unavoidable noise in estimating an animal's height by any method, and this should be taken into consideration when assessing correlations/repeatabilities. The following describes the correlations between laser height estimates and those from tape measurements for the 2 systems as they were developed.

System 1 - Stationary laser unit.
The stationary laser unit was the initial system developed at the DPI research centre at Trangie. Various configurations altered the section of the backline scanned. The results obtained in these runs using mature cows are shown in Table 2.

Table 2 shows correlations ranging from 0.50 to 0.91. Runs 1 and 2 had identifiable problems that were rectified. Thus the mean correlation for the remaining runs was 0.825. The mean absolute divergence of 1.7 cm between the tape measurement and laser estimate for each animal represents less than half the difference required to alter a frame score estimation by one unit (5 cm/score - McKiernan 2005), and is thus considered acceptable. When first used under less ideal conditions at a commercial feedlot the correlations were much lower (0.44 to 0.66), but served to highlight a problem with the tape measurement in the crush, which was later rectified.

System 2 - Moving laser unit
The results obtained from the initial development of the moving laser setup are shown in Table 3. In this case we had 2 estimates of the height of mature cows for comparison against the laser predictions. One was the standard method of the tape in the crush, and the other was the visual alignment of the backline of the animal with a scale on the side of the race in which the animal was held stationary (but unrestrained) while being scanned with the moving laser.

Table 3 shows that the laser estimates appeared better correlated with the visual scale reference than the tape measurements, likely due to the identical stance of the animal at the time of scan and when visual estimates were taken. The mean of all correlations in Table 3 was 0.85. A further validation experiment was conducted on another group of cows with these results shown in Table 4.

System 2 appeared to give more reliable results but the hardware to operate the moving carriage is more complex, and therefore System 1 may be the preferred option.

Conclusions

- Systems using laser technology are capable of delivering acceptable estimates of hip height for use in frame score determinations. Similarly high accuracy was shown in several different groups of animals, demonstrating the robustness of the technique. This provides an efficient, low cost and reliable input of frame score to improve the accuracy of prediction tools like 'BeefSpecs'.

- System 2 with the moving laser unit was considered more accurate as assessed by higher and more consistent correlations with manual measurements. Correlations of 0.8 to 0.9 can be expected between laser estimates and 'actual' height, given the inherent noise in this parameter. The estimates of error for individual animals are acceptable in relation to the height differences for increments in frame scores.

- The ability of laser technology to capture dimensions to describe hindquarter conformation was not resolved by the preliminary investigations here but they provided the guidelines and impetus for subsequent work on alternative imaging techniques. This led to the involvement of a research group from the University of Technology Sydney (UTS) – Centre for Autonomous Systems, and the development of collaborative experiments using 3D camera (RGB-D; Henry et al. 2012) technology as mentioned above. A small scale pilot trial established that the hardware could be easily incorporated into typical cattle handling facilities and that the images obtained would be suitable to extract useful descriptors (Wilkins and Alempijevic, unpublished data). Subsequent work has produced encouraging results (McPhee et al. 2014) and will be at least complimentary but considered likely to supersede the laser technique in many situations as it offers far greater capability in description and prediction of body traits (including fatness and muscularity).

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The study was approved by the NSW Dept of Primary Industries Animal Ethics Committee, Orange (Approval : ORA 09/007 – 'Automatic measurement of frame size of cattle'), and was compliant with the Animal Research Act 1985 (as amended) in accordance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes (NHMRC, 2004).

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Appendices

Technical details of the SICK - LMS400-200 laser unit:- wavelength 650-670 nm, pulse duration < 130 µs, response time 2-2.8 ms, resolution 1 mm, range 3 m. The beam is transmitted from a point source in the unit and covers a 70° span angle using a rotating mirror. The beam is refreshed every 5 milliseconds = 200 'slices'/ sec, and produces 160 data points / 'slice'. Thus many thousands of data points are processed by the computer software to generate the hip height estimate – typically 10,000 – 50,000 data / scan (depending on duration of scan; set by sensor spacing or predetermined for moving carriage).

System input/output and further details. Inputs to the software include the data from the laser unit which is transferred by Ethernet cable to the computer, and the ID data – either by serial port to the computer from an RFID reader or as a manual input via user entry screen. The software ('Cow Auto Frame Scorer') generates individual .csv format files for each animal scanned which contains all the data recording distance from the laser, filtered and processed to produce an estimate of animal height. Files often have about 50,000 data points. The other output from the software is a session summary file that accumulates just the ID and height data for each animal scanned in that session.

Table 1. Repeatability of measurements of hip height of cows, using a tape, by 2 experienced operators – correlation (r) values for various estimates within and between operators (51 pairs of observations per cell). All correlations P < 0.001

	Op 1 - A	Op 1 - B	Op 1 - C	Op 2 - D
Op 1 – B	0.94			
Op 1 – C	0.92	0.89		
Op 2 – D	0.93	0.91	0.86	
Op 2 – E	0.92	0.92	0.88	0.90

Table 2. Correlation (r) of laser estimated height of cows with tape measurements for System 1 across 8 runs. Absolute errors shown are the mean divergences between estimates using tape or laser for each animal. All correlations P < 0.05

Run	n	r	Absolute error (cm)
1	35	0.50	± 2.2
2	37	0.79	± 1.6
3	51	0.76	± 1.7
4	50	0.81	± 1.6
5	50	0.88	± 1.6
6	50	0.88	± 1.6
7	50	0.91	± 1.4
8	37	0.71	± 2.3

Table 3. Correlation (r) of laser estimated height (laser) of cows using System 2 with either tape measurements (tape) or reference to a visual scale (visual). Absolute errors shown are the mean divergences between estimates by laser v visual or laser v tape for each animal. All correlations P < 0.05

Run	n	r	error (cm)	Comparison
1	114	0.91	± 1.1	Laser v visual
2	114	0.95	± 0.9	Laser v visual
3	114	0.81	± 1.9	Laser v tape
4	114	0.74	± 1.9	Laser v tape

Table 4. Correlation (r) of laser estimated height of cows using System 2 with tape measurements for a herd across 3 runs. Absolute errors shown are the mean divergences between estimates by laser or tape for each animal. All correlations P < 0.01

Run	n	r	Absolute error (cm)
1	250	0.85	± 1.9
2	210	0.83	± 1.8
3	230	0.86	± 1.8

Figure 1. Manual method of measuring hip height using a tape

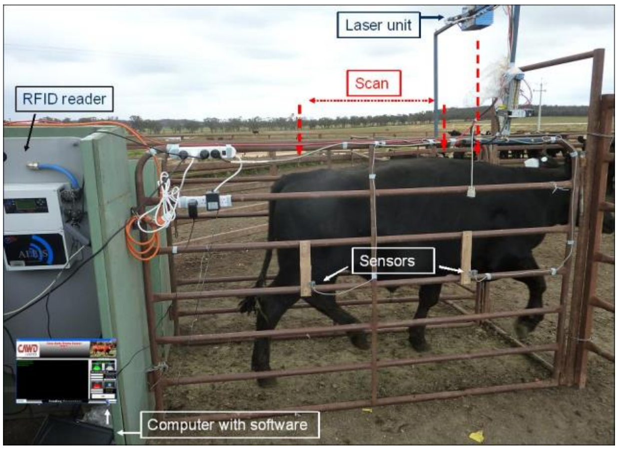

Figure 2. Stationary laser setup showing positioning of laser unit, activating sensors and associated equipment

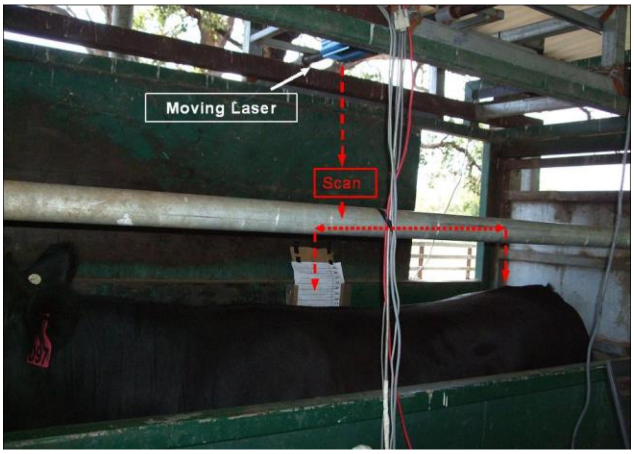

Figure 3. Moving laser setup showing positioning of laser unit on the movable carriage