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Development of an automatic cow body condition scoring using body shape signature and Fourier descriptors

A. Bercovich,* Y. Edan,* V. Alchanatis,† U. Moallem,‡ Y. Parmet,* H. Honig,‡ E. Maltz,† A. Antler,† and I. Halachmi†[1]
*Department of Industrial Engineering and Management, Faculty of Engineering Sciences, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel
†Institute of Agricultural Engineering, and
‡Institute of Animal Science, ARO, The Volcani Center, PO Box 6, Bet Dagan 50250, Israel

ABSTRACT

Body condition evaluation is a common tool to assess energy reserves of dairy cows and to estimate their fatness or thinness. This study presents a computer-vision tool that automatically estimates cow's body condition score. Top-view images of 151 cows were collected on an Israeli research dairy farm using a digital still camera located at the entrance to the milking parlor. The cow's tailhead area and its contour were segmented and extracted automatically. Two types of features of the tailhead contour were extracted: (1) the angles and distances between 5 anatomical points; and (2) the cow signature, which is a 1-dimensional vector of the Euclidean distances from each point in the normalized tailhead contour to the shape center. Two methods were applied to describe the cow's signature and to reduce its dimension: (1) partial least squares regression, and (2) Fourier descriptors of the cow signature. Three prediction models were compared with manual scores of an expert. Results suggest that (1) it is possible to automatically extract and predict body condition from color images without any manual interference; and (2) Fourier descriptors of the cow's signature result in improved performance ($R^2 = 0.77$).
Key words: dairy cow, cow body condition scoring sensor, computer vision, Fourier descriptor

INTRODUCTION

Body condition scoring estimates a cow's energy reserves and thus fatness or thinness (Hady et al., 1994). Evaluation of BCS is an important management tool for analyzing health problems, feed intake, and optimal time interval between calving and first insemination (Heinrichs and Ishler, 1989). The most popular method for evaluating BSC is the 5-point scale (Ferguson et al., 2006: 1 representing emaciated cows and 5 representing obese cows). Currently, BCS is determined manually (Roche et al., 2009). This is a time-consuming task that requires a trained technician. Furthermore, the scores are subjective and may be influenced by previously observed cows (Halachmi et al., 2008). Subjectively assigned scores may not be a perfect indicator of subcutaneous energy reserves.

Despite several attempts to automate body condition scoring of dairy cows (Coffey et al., 2003; Ferguson et al., 2006; Bewley et al., 2008; Halachmi et al., 2008; Azzaro et al., 2011), it is still handled manually with no commercial applications for an automated process. Halachmi et al. (2008) extracted the cow's contour from thermal images. The curvature of the tailhead contour reflected BCS, and this score could be predicted by calculating the mean absolute error between a fitted polynomial and the cow's contour. However, implementation of a thermal camera is relatively expensive and might be problematic in warm environments (Halachmi et al., 2008). Bewley et al. (2008) manually labeled 23 anatomical points on the cow's contour and used the angles created from those points as features for linear regression prediction. Azzaro et al. (2011) used the same 23 points as features for principal component analysis (**PCA**). However, both of those studies required manual labeling of the 23 anatomical points, which requires time and training and is also not consistent.

Shape signatures such as centroid-contour distances, complex coordinates, or cumulative angle are often used for automatic representations of shapes. These methods do not involve manual labeling, and they are scale-invariant (Zhang and Lu, 2004). Zion et al. (2006) described a fish's contours with a polar coordinate signature (distance and angle from each point in the contour to the centroid of the shape) followed by partial least squares (**PLS**) to compress the data and produce a small number of features for fish type classification. Partial least squares involves selection of

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[1]Corresponding author: halachmi@volcani.agri.gov.il

several latent variables that minimizes the root mean square error in a cross validation scheme, using the "leave-one-out method" (**LOOM**), a cross-validation statistical estimator of prediction model performance that is frequently used for model selection. The R^2 of LOOM is obtained by performing N sample predictions based on the model evaluated from $N - 1$ samples (Stone, 1974).

Zhang and Lu (2004) concluded that Fourier descriptors are an effective tool to describe the variances between signatures of 1-dimensional (**1D**) centroid-contour distances. Fourier transformation converts any mathematical function to the frequency domain. For N sampling points, the discrete Fourier transform (**DFT**) yields N Fourier coefficients known as Fourier descriptors (**FD**). Zhang and Lu (2004) showed that FD are an efficient tool to overcome sensitivity to noise and difficulties in normalizations. Transformation FD have been successfully applied in the quality inspection of food products, such as potato grading, classification of broccoli heads, and analysis of apple shapes (Brosnan and Sun, 2004). In many cases, only 1% of the FD are sufficient to describe the essence of a shape's boundary. In addition, FD have physical meaning, they are easy to compute, and they capture both local and global features.

This research builds upon previous studies (Bewley et al., 2008; Halachmi et al., 2008; Azzaro et al., 2011) that aimed to develop an automated computer-vision tool to predict cow BCS using a low-cost digital camera without the need for manual labeling.

MATERIALS AND METHODS

The main research steps are illustrated in Figure 1.

Image Acquisition

Data were collected at the Volcani Center ARO experimental farm in Bet Dagan, Israel, between October 2011 and February 2012. The procedures used were approved by the Volcani Center Animal Care Committee. A Nikon D7000 DSLR camera (Nikon Inc., Tokyo, Japan) was located at the milking parlor entrance gate, 2.5 m above ground and aimed downward. All images were taken before the noon milking. The camera was activated from a personal computer (Camera Control pro 2 software, Nikon Inc.) each time a cow entered through the milking parlor gate and acquired 6 consecutive images with a 1,632 × 2,464 resolution. All images were downloaded to the computer and processed offline. Images for processing were selected using the following criteria: (1) the cow's entire tailhead area was included in the frame; (2) the tailhead area was not touching any iron construction objects or another cow; and (3) the tail and legs were straight. Figure 2 demonstrates 2 selected images (top) and 2 rejected images (bottom).

Training and Testing Sets

Two data sets were collected separately. A training data set containing 87 different images of 71 Holstein cows was collected between October and December 2011 and was used for the model development. A testing data set containing 64 different images of 41 Holstein

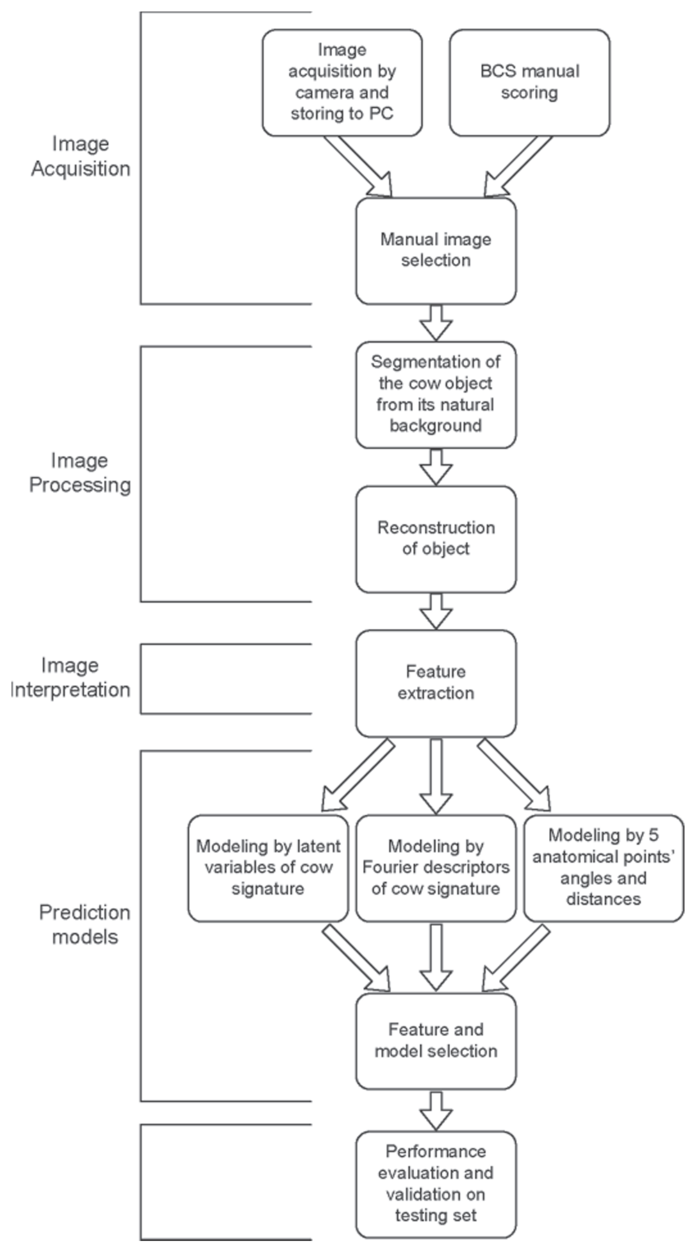

Figure 1. The main research steps.