J. Dairy Sci. 94:2126–2137
doi:10.3168/jds.2010-3467

Objective estimation of body condition score by modeling cow body shape from digital images

G. Azzaro,* M. Caccamo,*[1] J. D. Ferguson,† S. Battiato,‡ G. M. Farinella,‡ G. C. Guarnera,‡ G. Puglisi,‡ R. Petriglieri,* and G. Licitra*§
*Consorzio Ricerca Filiera Lattiero-Casearia (CoRFiLaC), Regione Siciliana, 97100 Ragusa, Italy
†University of Pennsylvania, School of Veterinary Medicine, Kennett Square 19348
‡Image Processing Laboratory, University of Catania, 95125 Catania, Italy
§Dipartimento di Scienze Agronomiche, Agrochimiche e di Produzioni Animali (D.A.C.P.A.), Agriculture Faculty, University of Catania, 95123 Catania, Italy

ABSTRACT

Body condition score (BCS) is considered an important tool for management of dairy cattle. The feasibility of estimating the BCS from digital images has been demonstrated in recent work. Regression machines have been successfully employed for automatic BCS estimation, taking into account information of the overall shape or information extracted on anatomical points of the shape. Despite the progress in this research area, such studies have not addressed the problem of modeling the shape of cows to build a robust descriptor for automatic BCS estimation. Moreover, a benchmark data set of images meant as a point of reference for quantitative evaluation and comparison of different automatic estimation methods for BCS is lacking. The main objective of this study was to develop a technique that was able to describe the body shape of cows in a reconstructive way. Images, used to build a benchmark data set for developing an automatic system for BCS, were taken using a camera placed above an exit gate from the milking robot. The camera was positioned at 3 m from the ground and in such a position to capture images of the rear, dorsal pelvic, and loin area of cows. The BCS of each cow was estimated on site by 2 technicians and associated to the cow images. The benchmark data set contained 286 images with associated BCS, anatomical points, and shapes. It was used for quantitative evaluation. A set of example cow body shapes was created. Linear and polynomial kernel principal component analysis was used to reconstruct shapes of cows using a linear combination of basic shapes constructed from the example database. In this manner, a cow's body shape was described by considering her variability from the average shape. The method produced a compact description of the shape to be used for automatic estimation of BCS. Model validation showed that the polynomial model proposed in this study performs better (error = 0.31) than other state-of-the-art methods in estimating BCS even at the extreme values of BCS scale.

Key words: body condition score, digital imaging, body shape

INTRODUCTION

Body condition score is widely considered an important tool for management of dairy cattle because it is a simple and repeatable system used to evaluate body fat stores and changes in BCS can be used to estimate cumulative energy balance (Otto et al., 1991; Ferguson et al., 1994). Visual and tactile methods have been used to estimate BCS. Generally, the score range used by dairy management advisors applies a numerical scale, with thin animals receiving lower scores and fat animals receiving higher scores. The system described by Wildman et al. (1982), later modified by Edmonson et al. (1989) and Ferguson et al. (1994) was based on a scale from 1 to 5, with 1 representing emaciated cows and 5 representing obese cows, without palpating the animal. According to Ferguson et al. (1994), it is possible to separate BCS into 0.25-point increments between scores of 2 to 4; however, this degree of resolution may not be possible with BCS of <2 and >4. It is generally considered that cows with a BCS of >3.5 are too fat and that cows having a BCS of <2.5 are too thin (Domecq et al., 1997a,b).

Despite the consensus of dairy producers, nutritionists, consultants, and herd managers, on the benefits of the BCS evaluation, less than 5% of US dairy farms have adopted this practice as an on-farm routine practice (J. D. Ferguson, unpublished data). Many reasons discourage the use of the traditional BCS evaluation techniques: among them is the lack of computerized reports (Ward, 2003), the subjectivity in the judgment that can lead to different scores for the same cow under

Received May 24, 2010.
Accepted January 5, 2011.
[1]Corresponding author: caccamo@corfilac.it

consideration, and the complex as well as time consuming on-farm training of technicians. Furthermore, measurements on a cow must be collected every 30 d throughout the lactation cycle to have valuable information (Hady et al., 1994), thus increasing the cost and complexity of BCS data.

Interest in collecting information on body condition is increasing for use in selection indices, because selection for production traits has increased reliance of cows on body reserves in early lactation to support milk production (Agnew and Yan, 2000; Coffey et al., 2003). Furthermore, BCS is highly related to reproductive performance: thinner cows experience more reproductive difficulties (Pryce et al., 2000), whereas increasing BCS has positive associations with days to first heat, interval to first service, and conception rate at first service, and negative associations with calving interval and number of services per cow (Agnew and Yan, 2000; Pryce et al., 2000; Dechow et al., 2002; Pryce et al., 2002; Berry et al., 2003; Wall et al. 2003). For this reason, genetic variation in BCS could be included in genetic indexes as an indirect trait for more balanced selection strategies aimed at simultaneously increasing milk production and improving reproductive performance and health (Bastin et al., 2010). The ability to automatically record BCS would increase its use in farm management and enable large volumes of data to be collected for use in national evaluations.

Recent studies have addressed the problem of BCS estimation directly from digital images. Ferguson et al. (2006) assessed the ability to assign a BCS to a dairy cow from digital photographs. In that study, BCS could be assessed by observers from digital photographs or a video taken from the rear of a cow at a 0 to 20° angle relative to the tail head. A sample size of 30% was adequate to estimate the mean BCS of a group of cows. Bewley et al. (2008) assessed the feasibility of using digital images to determine BCS using a semiautomatic estimation technique from digital images. They considered a single image of the dorsal view of the cow captured automatically as cows passed through a weigh station and used 23 anatomical points to define the shape of the body of the cow. These points, selected in a manual way, were used to compute 15 angles around the hooks, pins, and tailhead. All identifiable points were used to define and formulate measures describing the cow's contour. Halachmi et al. (2008) tested the hypothesis that the body shape of a fatter cow is rounder than that of a thin cow and, therefore, may better fit a parabolic shape. Images were acquired by means of a thermal camera that allowed a very simple and straightforward shape extraction. The posterior part of the cow was considered and a parabolic fitting was performed. The absolute difference between the real body shape and the fitted parabola was used to estimate BCS for a cow.

Despite the progress in this research area, such studies have not adequately addressed the problem of modeling the shape of a cow's body to build a robust descriptor for automatic BCS estimation. Among the visual cues used by humans, shape provides important information to distinguish between objects of different categories (Belongie et al., 2002) as well as information that is relevant to understand the differences in the appearance of an object within a specific class (Cootes et al., 2001). In computer vision literature, several shape descriptors have been proposed (Persoon and Fu, 1977; Cootes et al., 1992, 2001; Belongie et al., 2002; Di Fabio et al., 2009). More specifically, shape descriptors based on principal component analysis (**PCA**; Cootes et al., 1992, 2001) are used to consider the different variability of anatomical landmarks with respect to the average shape.

The aim of the present study was to develop a technique to model the body shape of a cow from which learned parameters could be used in BCS estimation. A further objective was to build a benchmark data set useful for dairy cattle research purposes, available through the Internet.

MATERIALS AND METHODS

System Overview

A general scheme of the system for semiautomatic evaluation of the BCS from digital images is shown in Figure 1. The system consists of 2 different blocks: training (**TB**) and employing (**EB**). The TB is used to learn the parameters of the model exploited to infer the BCS from features extracted on digital images. The parameters are learned by using a set of labeled examples. Once the training is completed, the learned parameters are used in the model to infer the BCS of new samples during the employing phase. Both TB and EB use the same hardware infrastructure (e.g., parameters of digital camera, position of the digital camera).

Each block is composed of different modules organized in a sequential pipeline. The TB is composed of 3 modules as follows: acquisition of training examples, labeling of anatomical features, and learning the BCS model parameters. The acquisition module (**AM**) is used to acquire images to be used as examples in learning the model parameters. The example cow images generated to be used in the AM should include the range of the number and variety of samples to be acquired. This set of acquired images should be representative of the possible BCS values. During the AM, technicians should evaluate BCS on site of the involved cows to build a