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Automatic monitoring of the body condition score of dairy cows

The commonly used methods to estimate fat reserves of cows are body condition score (BCS) and backfat thickness (BFT). But these methods are subjected to restrictions regarding objectivity of results and amount of work. Therefore, a visual three-dimensional sensor system has been developed for the automatic determination of body condition of cows during lactation. The designed software evaluates recorded images for further processing. In the next step characteristics for body condition were extracted of suitable images. These characteristics are integrated in a linear model, which estimates the body condition score. The correlation between manual recorded BCS and estimated BCS is 0.8 ($p < 0.0001$).

Keywords
BCS, TOF-sensor, image processing

Abstract
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The determination of body condition of dairy cows is very important regarding the fertility, health and production of the animal [1]. Commonly used methods to estimate fat reserves of cows are body condition score and backfat thickness. BCS can be applied without any devices only depending on breed specifications. A more objective method than BCS is the measurement of the backfat thickness [2]. But also with this method a large variability of results depending on measuring point is possible [3].

In line with the program of the Ministry of Food, Agriculture and Consumer Protection in Germany for promotion of innovations a joint project was carried out. The development of a three-dimensional sensor system for automatic determination of body condition of dairy cows during lactation was the scope of the project. In the case of deviations of optimal body condition regulatory interventions can be made soon.

The project was carried out in cooperation with the Institute for Animal Breeding and Husbandry of the Christian-Albrechts-University (CAU), GEA Farm Technologies GmbH (GEA), the Institute for Animal Nutrition and Feed Management (ITE) and the Institute for Agricultural Engineering and Animal Husbandry (ILT) of the Bavarian State Research Center for Agriculture (LfL).

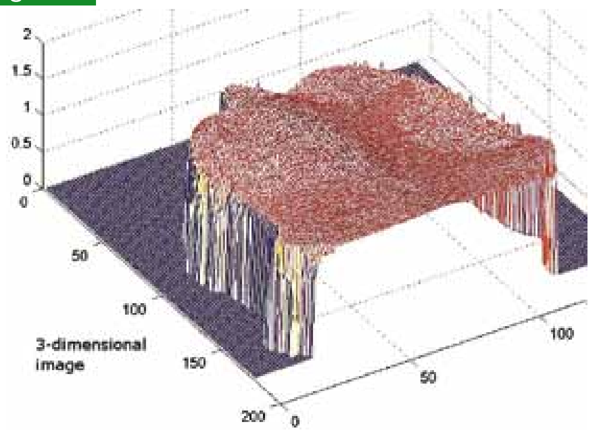
Used technique

A time-of-flight sensor was used to record three-dimensional information of dairy cows. This sensor emits infrared modulated light at a frequency of 30 MHz, which is reflected by the object. The distance between object and sensor is calculated on the base of the phase shifts of emitted and reflected light. The imager of the sensor has a size of 176 x 144. For each pixel the distance is calculated by the sensor. The sensor computes a three-dimensional point cloud of the field of view, e.g. a back of a cow (**Figure 1**). Dependent on the integration time the sensor can produce up to 54 frames per second. The calibrated range of the sensor is 0.8 to 5.0 m.

Data collection

To collect information for different breeds two research farms have been involved. One farm with Holstein-Friesian cows is located in Karkendamm. The second farm with Simmental cows belongs to the LfL in Grub. The software to control the sensor was developed by the CAU. In Karkendamm long-term records

Fig. 1



Three-dimensional exposure of the back of a cow (up to two weeks) were carried out periodically. The sensor was installed above the concentrate feed station. A RFID based animal identification system was used to assign animal IDs to matching recorded animals. Furthermore, CAU developed software to classify and evaluate sensor data to estimate the body condition. To adjust the three-dimensional information with the body condition of the recorded cows in Karkendamm, the backfat thickness was measured weekly and the BCS was determined monthly by a skilled person.

A second sensor was installed above a weighing box for cows in Grub. During the trials the cows were driven through the box once a week. The time of record was different depending on the trial. The backfat thickness and the BCS were determined by a skilled person on the same day as the sensor records have been taken place.

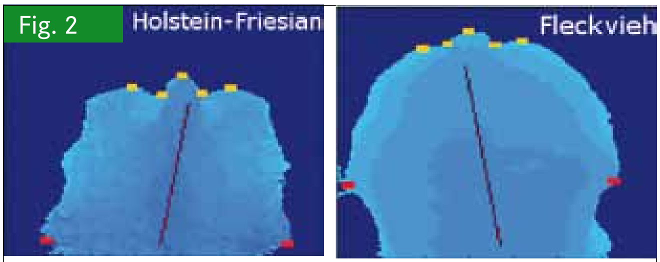
In Grub another main aspect was the examination of development and regulation of body condition of Simmental cows. Therefore different feeding trials were carried out to get a broad range of different body conditions for investigation. To examine the relation between BCS and body fat content 30 Simmental cows were slaughtered and the whole bodies were analysed to determine the composition. Furthermore, two other methods of determination of body condition were investigated of their suitability: the skinfold calliper and the bioelectrical impedance analysis. The results of the body condition estimations refer to a trial, where 30 animals (20 cows, 10 heifers) were examined for 17 weeks (2 weeks antepartum to 15 weeks postpartum).

Results

Software

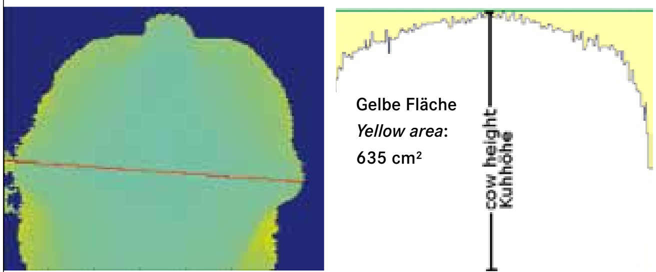
The Software developed by CAU detects during recording images with a complete posterior back that are suited for estimation of body condition. Only these images are saved for further processing. At the end of processing a list with cow-ID, timestamp and characteristics of body condition (extracted from the images) is generated for each recording day. The first step of processing is the multi-step analyse of the suitability of images for automatic detection of remarkable body parts and for determination of body condition. Therefore, the contour and the position of the cow within the image are controlled. Clear shapes and images are favoured, on which cows do not lean against the wall of the concentrate feed station. The software automatically determines the tail, backbone, ischial tuberosities and hip bones of cows. These determined regions of interest are used to achieve the information concerning body condition. The regions are shown in **Figure 2** for both breeds investigated in the project. In a further step, the identified feature points are connected. Distance information are extracted between these points (e.g. hip to hip, **Figure 3**). The calculation of areas and depths depending on the three-dimensional information results in 13 parameters per image, e.g. the area between cow and tangent as shown in **Figure 3** on the right. In a last step outliers of the parameters of one day are eliminated

Fig. 2



Identified parts left Holstein Friesian, right Simmental

Fig. 3



Connecting line hip to hip (left), profile of cow and size of area (right)

and a list is generated with characteristics, cow-ID and date. Depending on cow-ID and timestamp the parameters can be connected with management data.

Evaluation of body condition

The correlation between BCS and fat content (%) of Simmental cows was r = 0.84 ($p < 0.0001$) [5]. The relation between BFT and fat content (%) was less than with BCS (r = 0.65, p = 0.0001) [5]. Following results show the relation between BCS and parameters computed with the help of three-dimensional information.

The repeatabilities of determined characteristics lay between 26 and 83 % (repeatability of BCS = 74 %). The range of the absolute correlations of the characteristics is shown in **Table 1**. A linear correlation to BCS was found by seven of the 13 parameters. The correlation values reach from 0.13 up to 0.47. For six characteristics no significant correlation ($p > 0.05$) could be determined.

Table 1

Absolute correlations between characteristics and body condition score

Anzahl Kennwerte *Number of characteristics*	Spannweite absoluter Korrelationen zwischen Kennzahlen und BCS *Range of absolute correlation between characteristics and BCS*	p-Wert *p-value*
7	0.13–0.47	p < 0.01
6	0.02–0.07	p > 0.05

Table 2

Range of correlation between estimated BCS and BCS for individual cows

Anzahl Kühe *Number of cows*	Spannweite der Korrelationen zwischen geschätztem BCS und BCS für die einzelnen Kühe *Range of correlation between estimated BCS and BCS for individual cows*	p-Wert *p-value*
16	0.57–0.87	$p < 0.05$
14	0.09–0.50	$p > 0.05$

A linear model was estimated with BCS (recorded manually) as dependent variable for the determination of body condition. Additional to the variables

- Cow
- Week of year
- Number of lactation
- Week of lactation

two of the computed characteristics were used as independent variables. The correlation of estimated BCS and manually recorded BCS in the trial (30 cows, 17 weeks) was 0.8 ($p < 0.0001$). Regarding the individual cows, only for 16 cows a significant correlation of estimated BCS and manually recorded BCS could be found (**Table 2**). The correlations lay in a range of 0.57 up to 0.87 (**Table 2**).

Figure 4 shows the development of manually recorded BCS and estimated BCS for the cow 384 ($r = 0.84$). For both, the typical decrease after calving depending on mobilisation of body fat is obvious.

Discussion

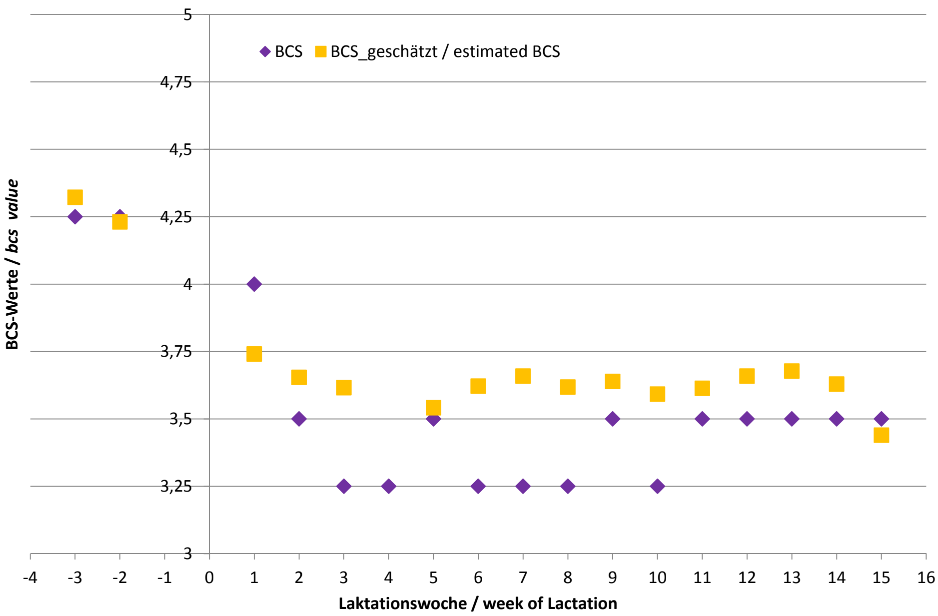
A high correlation between estimated and manually recorded BCS could be determined. However, further investigations should be conducted to clarify the reason of the differences in correlation between individual cows. One possible reason could be the different anatomical shape and the individual retention and mobilisation of body fat at different body parts of cows. Another reason could be the individual movement of cows during the recording of the 3D-information. The quality of images is influenced by the cow motion and consequently the computed parameters. In a further step the improvement in computed parameters should be investigated, if only images with less cow motion are used for calculation.

Additional to animal specific inaccuracies, the image quality is limited due to the principle of time of flight. The influences of motion artefacts on image quality stated in literature [6] were much higher then expected, especially by shifts of coat colour. Furthermore the high advertised frame rate could not be reached in practice. For the evaluation of body condition high-quality images are necessary, therefore a high exposure time is essential. But this results in a lower frame rate, which was not sufficient for recording enough usable images for cows in motion. Technical improvements have to be made for example with additional light emitting diodes. Furthermore, sunlight, flies, dust and condensed breath of animals influence the image quality.

Conclusion

An automatic evaluation of body condition of dairy cows is basically practicable with the developed sensor system. Nevertheless further investigation regarding individual differences between

Fig. 4



Developing of BCS-values estimated and determined manually for cow 384 cows has to be conducted. To what extend it will be possible to evaluate BCS automatically without teaching with manually recorded BCS, has to be clarified until the end of the project. Furthermore, technical improvements are necessary to achieve high-quality images of cows in motion with less motion artefacts.

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