CFIT – Cattle Feed InTake – a 3D camera based system to measure individual feed intake and predict body weight in commercial farms

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Abstract

A 3D camera technology to measure feed intake and body weight on individual cows in commercial farms has been developed. The camera based method for feed intake measurements is validated using scale measures in a commercial farm. In this study the squared correlation between camera data and scale measures on daily intake was 0.90. Body weight is predicted based on images of back couvertures and corresponding scale measures in three dairy breeds: Jersey (301 cows), Holstein (398 cows) and Red dairy cows (103 cows). Root mean square error between observed and predicted weight was 23.5, 31.0 and 22.7 kilos and the repeatabilites were 0.86, 0.83 and 0.90 for Jersey, Red dairy cattle and Holstein respectively. Several management tools continue to be developed based on the data for the farmers that have the equipment installed and more traits are expected to be developed based on the 3D methodology in the future.

Introduction

Feed intake (FI) is the highest variable cost in the dairy farm. Therefore even marginal improvements in the amount of feed that is used to produce an amount of milk and meat will have a huge effect on the turnover for a farmer. Milk and meat production has been core traits in most breeding systems for several decades, but not until recently feed efficiency has been a trait that has been evaluated. This is not due to lack of value of the trait, but more due to lack of data on the trait at an individual level. Individual FI measures has only been available on cows from research farms, and often only for limited parts of lactation and in few lactations per cow. FI is a main driver for cow health and welfare. Most diseases occur in early lactation so if data is not available in this period it is very difficult to provide information that possibly could prevent diseases from developing. The system is currently installed in 20 dairy herds in Denmark where more than 10000 cows are providing data.

FI measures historically has been done using scale based measures. These systems are relatively expensive and labour intensive. Therefore they are also impractical for measurements in commercial herds. Over the recent years both 3D cameras, hardware such as graphic cards and algorithms around image analysis has been under drastic improvements. This includes among others Artificial Intelligence (AI) algorithms such as the convoluted neural network method called MASK-CNN (He et al., 2018). Combining all these developments into a working system is very difficult.

Since 2016 a 3D camera system has been developed to measure individual FI records and make body weight (BW) prediction at an individual cow level. In this paper the methodology as well as the system will be described and discussed.

Materials & Methods

System and data description. In order to make individual FI and BW measures 3D cameras was used in a top down position (Microsoft Kinect). Each camera is placed 2.5 meter apart and 4.5 meter from the empty feeding table in order to cover the entire feeding table. Also, in the exit corridor of the milking system an ear tag reader and a 3D camera was placed. Three type of images were recorded from the 3D camera: normal pictures, infrared (IR) pictures and depth pictures. These images were indicating the distance from the camera to the object that can be seen by the camera. When cows left the milking system their electronic ear tag was read and at the same time a 3D picture was taken of the back of the cow. For BW prediction as well as a reference to predict the same cow these pictures were stored and used. The identification was done based on the contours, colour and patterns of the back of the cow, when eating at the feeding table. The MASK-CNN algorithm based on instance segmentation prediction was used for this (He et al., 2018) and this approach was validated in an earlier study (Thomasen et al., 2018; WO 2017/001538). When a cow entered the head to the feeding table the last image of the feeding pile before she put in her head and began eating was stored from virtual boxes defined in the feeding table. When the cow had finalized the meal and took the head out again the first new image of the feeding pile was stored. In the next step the height in each pixel from two stored images were now subtracted from each other and the removed feed was quantified on pixel level. Five variables were stored from each specific visit: the ID of the cow, the placement in the barn, time when the meal was initiated and finalized and the amount of feed eaten. During a visit feed would be allocated to a specific cow from a total of 5 virtual boxes - the virtual box right below the cow as well as the two virtual boxes to the left and the right respectively. If a virtual box was shared during a feeding visit cows would also share the feed taken from this box during the two cow specific visits.

Feed intake trial. FI was measured both with cameras and on a scale in an area of the herd where only one cow could attend the feed. Daily intake was estimated with the camera based FI algorithm as well as with the scale data as the difference between provided feed and residual feed for a day. Six different cows was used in the trial and each cow was measured for 4 days. Correlations between these measures where estimated.

Body weight prediction. Weight data of the cows has been recorded in 6 weeks periods in 4 herds: 2 Jersey (JER), 1 Red Dairy Cow (RDC) and 1 Holstein (HOL) after every milking. Using the partial least square approach (PLS) where the 12 variables that described the most of the variance where chosen to predict BW (SAS software version 9.4). In a 10-fold crossvalidation the root mean square error (RSME) was estimated. Variance components for BW was analysed using the following model:

Weight = mean + herd + week of year + lactation number + week of lactation + animal + residual

Where herd, week of year, lactation number and week of lactation was fixed effects and animal and residual was random effects. The repeatability was estimated as the random animal variance divided by the total variance.

Results

Mean daily FI based on scales in the feeding trial was 55.4 kg of feed and the squared correlation between observed FI from the scales and the predicted FI from the cameras was 0.90. Descriptive statistics from scales as well as RMSE, variance components and repeatabilities for camera based BW in JER, HOL and RDC cows are presented in Table 1.

Table 1. Breed, mean observed weight, RMSE in kg and in % of mean, animal variance, residual variance, repeatabilities and number of animals used in the study.

Breed	Mean obs weight	STD	RMSE kg/%	Var animal	Var Res	Repeatability	Number of animals
JER	508	48.8	23.5/4.60	950	153	0.86	300
HOL	678	84.2	31/5,38	2,527	512	0.83	398
RDC	624	59.6	22.7/3.60	2,216	233	0.90	101

The mean BW was 678 kg for Holstein, 508 kg for Jersey and 624 kg for RDC. The RMSE were 23.5 kg (4.6% of mean), 31.0 kg (5.38% of mean) and 22.7 kg (3.60% of mean) for JER, HOL and RDC respectively. Repeatabilities were 0.86, 0.83 and 0.90 for JER, HOL and RDC respectively.

Discussion

The validation trial of the FI algorithm showed a squared correlation between FI measured from scales and cameras of 0.90. This indicates a strong relationship between the two methods. We are currently not aware of any other studies that have made such a comparison. BW based on 3D image analysis was predicted based on scale measures with RMSE between 22.7 and 31 kg. This is lower or in the same range as other studies (Song et al., 2018). Several parameters can influence these results including camera and scales, information used from images, software and statistical model.

A major priority for developing this system was to obtain data throughout lactation. In relation to genetic analysis several studies have shown that genetic correlation change during lactation between FI, milk yield and BW (Manzanilla-Pech et al., 2014; Li et al., 2017). Estimates for the genetic correlation between FI and milk yield varies from -0.80 in early lactation up to 0.8 in mid and late lactation (Manzanilla-Pech et al., 2014). Selection for improved efficiency in early lactation where FI and BW changes specifically needs to be improved based on records obtained in mid lactation then might lead to even lower FI in early lactation. From a management perspective also FI records and BW are interesting throughout lactation. In early lactation the absolute majority of health problems occurs both related to mastitis, BW changes, reproduction and nutrition. In mid lactation the farmer wants to know which cow are most efficient to optimize culling strategy and in late lactation the FI is interesting in order to optimize strategies in relation to drying off cows. With this system all information will be available for the farmer. Heritability estimates for FI and BW is presented in another abstract in this conference (Manzanilla-Pech et al., 2022). Also the data is used for national prediction of saved feed which consist of a maintenance part and a physiological part described as residual feed intake (NAV 2020; Stephansen et al., 2021). The identification algorithm was validated in an earlier study where more than 6000 cow visits were annotated and in over 99% of the visits the right ID was predicted (Thomasen et al., 2018; WO 2017/001538). This system opens up for working with phenotypes such as body condition score and lameness.

Conclusions

FI and BW can be predicted based on image analysis using a 3D camera system. The squared correlation between FI measured with scales and cameras was 0.90. Repeatability was between 0.86 and 0.90 for BW.

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