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A MODEL TO PREDICT CALVES' LYING TIME WITH WIRELESS 3-DIMENSIONAL ACCELEROMETER COLLAR

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ABSTRACT Accelerometers have been developed for measuring lying time of cows, but they have not been applied to calves. The aim of this project was to develop a system of small wireless accelerometer to measure the lying time of calves. We developed a wireless 3 D accelerometer device, weighing 19 g. The device included an accelerometer, microcontroller and a 869 MHz transceiver. We programmed the devices to measure and transmit acceleration data with the range of ±2 g at 25 Hz. The accelerometers were attached to collars of six calves under the age of six weeks. The calves were kept in a group pen. The behavior of the calves was filmed for 24 hours and the lying behavior was coded from the video continuously. We analysed the mean and variance to extract features from the acceleration data in 20 s epochs and used a Support Vector Machine Classifier for predicting the lying time. Leave-one-out cross-validation was used to develop and validate the model. The daily time spent lying was calculated from the observed and predicted behaviors. The model was able to distinguish (mean ± SE) 90 ± 4.7% of the total lying time. We were able to measure the lying time of calves with a high accuracy without disturbing the animal. This is potentially useful data for automatically detecting health problems and studying different production systems.

Keywords: Calf, accelerometer, lying time, animal welfare.

INTRODUCTION Changes in lying time can be an indicator of calves' health, but methods for automatically measure the lying time have been lacking. Accelerometers are a non-invasive method for measuring animal activities and they have been reported to be able to give valuable data about behavior and welfare issues, such as lameness. Cornou and Cristensen (2008) have used accelerometers in classifying sows' activities, both Martiskainen et al. (2009) and Robert et al. (2009) aimed at classifying cattle behavior patterns using data from accelerometers. Also Pastell et al. (2009) have used accelerometers with cattle to asses lameness. Both Pastell et al. (2009) and Robert et al. (2009) attached the sensors in cow's limb, Martiskainen et al. (2009) mounted sensors in collars.

We have developed a wireless accelerometer device to monitor the behavior of dairy calves. The aim of this study was to develop a model to predict lying time of the calves based on the accelerometer data. Sensors were mounted in calves' collars. We recorded acceleration data for 24 hours and recorded video simultaneously.

Support Vector Machines (SVM) are robust nonlinear classifiers that need only a few parameters and produce stable and reproducible results (Bennett & Campbell 2000). SVM is commonly used in machine learning applications, such as pattern recognition in machine vision applications (Davies 2005). SVM classifier tries to fit two separating hyperplanes between the classes in teaching data. If datasets can not be separated linearly they will be transformed to a higher dimensional feature space. More dimensions often means better classification with training data but worse generalization.

MATERIALS AND METHODS

The measurement system We developed a wireless 3-dimensional accelerometer. The device included an accelerometer, microcontroller and a 869 MHz transceiver. The radio channel permitted the transmission of 330 messages per second (four 8-bit bytes: x, y and z acceleration, and sensor ID) from a single transmitter. We programmed the devices to measure and transmit with the range of ± 2 g at 25 Hz and a simple listen-before-transmit protocol. The sensor is described in more detail in Pastell et al. (2009).

Data collection The accelerometers were attached to collars of six calves under the age of the six weeks. The calves of West Finland Cattle were kept in a straw-bedded group pen in a commercial dairy farm in Kangasniemi. Simultaneously, we filmed calves behavior for 24 hours, and calculated the daily duration for lying and standing. In average about 13 hours of the original 24 hours was used for this study. The behavior codes were recorded with CowLog (Hänninen & Pastell 2009) and analyzed with R 2.9.2 (R Development Core Team 2008) using package Animal (Hänninen & Pastell 2009). Figures 1 and 2 show acceleration and variance during 20 s epochs. Figure 1 visualizes the behavior codes and normalized mean acceleration in X-axis. Normalized variance of acceleration in X-axis is shown in Figure 2 together with behavior codes.

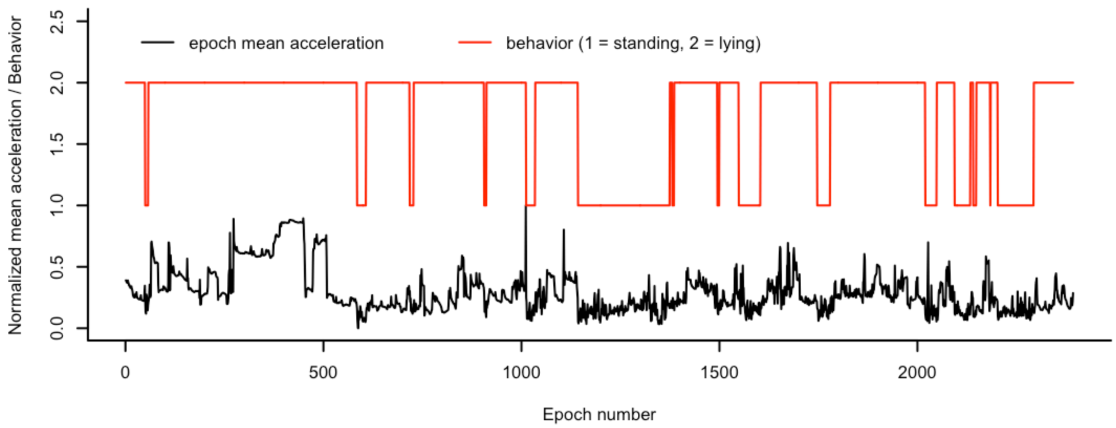

Figure 1. Observed (true) behavior and normalized acceleration in X-axis during 20 s epochs.

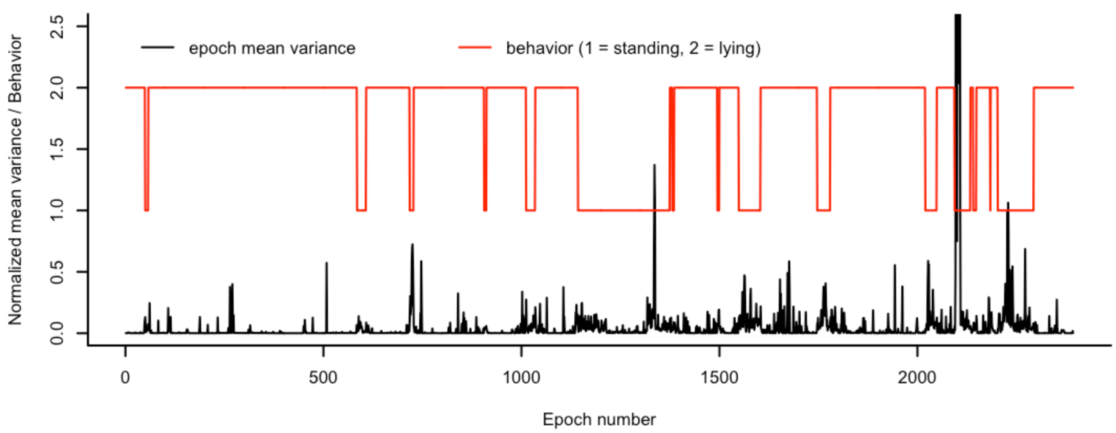

Figure 2. Observed (true) behavior and variance of normalized mean acceleration in X-axis duting 20 s epochs.

Modeling The model for predicting lying time based on the acceleration data and behavior codes. The data was first split in epochs of 20 seconds. Then we calculated the mean and the variance in acceleration on each epoch. We used an SVM with a radial basis kernel to classify the behaviours.

We used Leave-one-out cross-validation to teach and develop the model. This means that the data from five calves was used to develop the model and data from one calf was used top validate the model. Teaching the model and predicting was then repeated totally six times so that each time one calf was used for validation and the rest of the calves were used for teaching. The mean accuracy of the six runs was used as the accuracy of the model and the standard error of the mean of the different runs as an error estimate.

Since we calculated the mean acceleration and variance in acceleration for all three axis, totally six variables where used for creating the SVM model. Figure 3 shows how the normalized epoch mean acceleration and variance values are divided between standing and lying. Mean acceleration in X-axis seems to be the most separating variable.

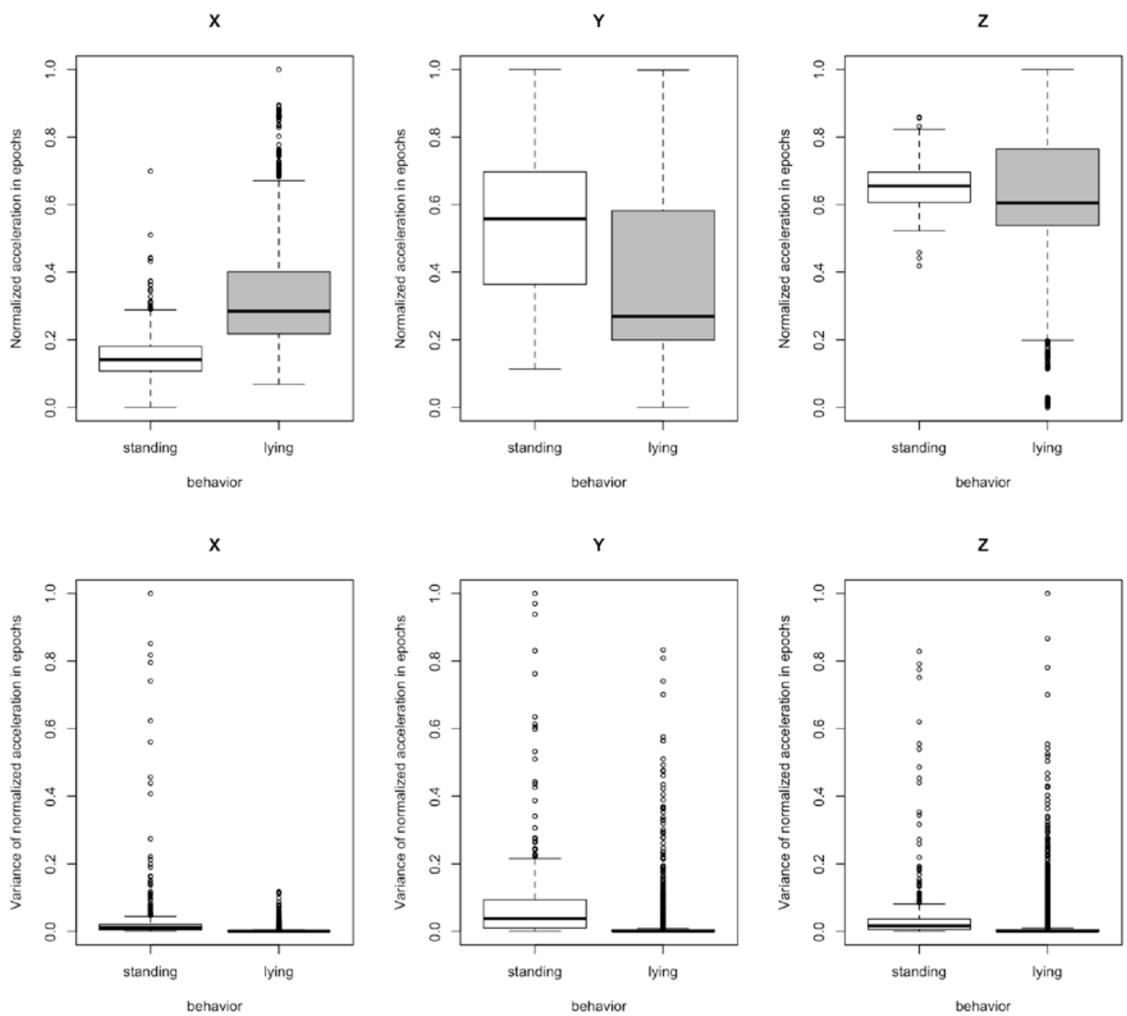

Figure 3. Normalized mean acceleration and normalized mean variance during 20 s epochs grouped by observed behavioral codes. The boxplots show the median (centre line), quartiles (box) and 1.5 times interquartile range from the box (whiskers). Remaining dots are outliers.

The modeling was conducted with R 2.92 and package e1071 (Dimitriadou et al 2009), which has an interface to C++ library LIBSVM (Meyer 2009).

RESULTS

In order to estimate the performance of the model we compared the predicted values from the model and the observed (true) values. Summary Table 1. Shows an example of the true cases versus predicted cases for one calf. The observed (true) cases are in the columns and predicted cases are in the rows. Crossing points show the number of successful cases. In this table the calf was predicted to be standing totally 580 times and 544 predictions of those were correct. Correspondingly when predicting lying, 1862 cases were correct and 44 wrong.

Table 1. An example of comparing table: Predicted and observed (true) behavior of a calf no 5 in 20 s epochs. Predicted true cases are shown in bold font.

Observed	Predicted	
	standing	lying
standing	**544**	36
lying	44	**1862**

The model was able to predict the lying periods (20 s epochs) with average accuracy of 90%. Predicting the standing periods succeeded with average accuracy of 85%. The difference between the accuracies is because of greater lying time compared to standing time. The average error in lying time prediction was -30 minutes of the 649 minutes total The results for predicting lying time are shown in Table 2 .

Table 2. Predicted and observed (true) lying times of the all six calves used in the experiment. (SE = standard error)

	Predicted lying time (min)	True lying time (min)	Total time measured (min)	Error (min)	Relative error (%)
Calf no 1	537	618	828	81	13.1
Calf no 2	723	689	862	-35	5.0
Calf no 3	798	608	798	-190	31.2
Calf no 4	712	664	929	-48	7.2
Calf no 5	635	633	829	-3	0.4
Calf no 6	668	681	842	12	1.8
Average	679	649	848	-30	10
SE	36.2	13.8	18.3	36.8	4.7

CONCLUSION

We developed a new wireless system for measuring acceleration from a collar of dairy calves and used it to collect data reliably over the 24 hour test period. We were able to relate the mean inclination of the device and the variance of acceleration during 20 s epochs to lying and standing. Furthermore we were able to predict the lying time of calves with a good mean accuracy using a SVM classifier.

However the accuracy varied a lot between the calves. The prediction and it is possible that the prediction could be improved by changing the length of the epoch and incorporating frequency domain measures into the model.

Wireless acceleration sensors and modeling with SVM offers a new tool for non-disturbing calf health monitoring. Wireless accelerometers such as the ones we used could offer valuable data about animal behavior and welfare.

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