Prediction of Milking Robot Utilization

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SUMMARY

For the planning of the barn layout, cow traffic and facility locations (such as: cubicles, forage lane, etc.), the farmer has to know the milking robot utilization of his production herd. Therefore, prediction of the milking robot utilization has to be done. The milking robot utilization depends on the cow's visiting pattern and capacity of the milking robot. The models used for prediction were generalized multiple regression models. Behavioural data were obtained by video observations and electronic measurements. For eleven behavioural variables used in the model from all three experiments, only two (number of cows and sum of milk yields per hour in kilograms) were statistically significant ($p \leq 0.05$) and measurable on a commercial farm. A part from the milking capacity, forage feeding routine influenced utilization of the robot. Combined cow traffic used in experiments appeared to be feasible.

KEY WORDS

milking robot, cow, behaviour, milk yield, cow traffic

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IZVORNI ZNANSTVENI RAD

Predviđanje iskorištenja robota za strojnu mužnju

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SAŽETAK

Izgled staje, kretanje krava, te raspored pojedinih dijelova staje (npr. ležišta, "krmna zabrana"...) ovisi o stupnju iskorištenja robota za strojnu mužnju u postojećem stadu krava. Zbog toga je važno predvidjeti stupanj iskorištenja robota za strojnu mužnju. On ovisi o redoslijedu posjeta krava robotu i kapacitetu robota za strojnu mužnju. Statistički modeli korišteni za predviđanje su općeniti modeli multiple regresije. Opisni podaci o kravama su prikupljeni pomoću video opreme i elektronskih mjerenja. Od jedanaest varijabli korištenih u statističkom modelu od tri eksperimenta, samo dvije (broj krava i ukupna količina izmuzenog mlijeka (kg/h)) su bile statistički signifikantne ($p \leq 0.05$) i mjerljive na komercijalnoj farmi. Osim kapaciteta strojne mužnje na stupanj iskorištenja robota za strojnu mužnju utjecao je i vremenski raspored hranjenja na "krmnoj zabrani".

Kombinirani način kretanja krava u staji se pokazao izvediv.

KLJUČNE RIJEČI

robot za strojnu mužnju, krava, ponašanje, količina mlijeka, kretanje krava u staji

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INTRODUCTION

Advances in robotics, automation and milking have allowed the introduction of milking robots to dairy farming. Rasmussen and Lind (1999) reported that in the middle of 1999 there were around 300 installations in use on commercial farms. Numerous ways to integrate a milking robot into the dairy farm have been developed (Rossing et al., 1998; Rossing et al., 1997; Ipema, 1997). The milking robot capacity required is an important part of the integration process. Automatic milking systems are developed for low hourly capacity, but for milking 24 hours a day (Rossing et al., 1998). In such a system, the number of cows can be at least 20% higher than the number of cubicles and even 50% higher than the number of feeding places (Halachmi et al., 2000b). The basic assumption of an automatic milking system is that the cows are expected to visit the milking box voluntarily. There are various solutions for control of visiting frequency to the milking robot area with different barn layouts (Rossing et al., 1997). To justify the sizable investment in the milking robot, its capacity must be as high as possible, while minimizing its influence on cow welfare. Sonck et al. (1995) developed a formula for calculation of milking robot capacity. Because it is not enough for a farmer to know only the milking robot capacity, it is important to develop an optimal layout of the robotic milking barn with various facilities and herd sizes (Halachmi et al., 2000a). In order to plan the barn layout, cow traffic and facility locations (such as: cubicles, forage lane, etc.) the farmer must know the utilization of the milking robot for the production herd. Ipema et al. (1997) showed that in robotic milking, intervals between milkings and the duration of the cows' visiting time to the robotic milking area are variable. The utilization of the milking robot depends on the cows' visiting pattern and the capacity of the milking robot. For purposes of economic rentability, there is a need to determine the utilization level of a milking robot in a given barn or a barn yet to be built. This is also important for farmers using milking parlours, if they would like to switch to robotic milking. The model that is derived in this research calculates the utilization level of the milking robot for new or existing barn facilities and will give valid information to aid in the farmer's decision. The intention of this model is to predict milking robot utilization before the barn is built. This prediction will be based only on those variables that are measurable on a commercial farm.

MATERIALS AND METHODS

The research involved three experiments (experiment I, II and III), with 10, 20 and 29 lactating crossbred Holstein-Friesian dairy cows respectively. The cows were held as a group in 'De Vijf Roeden,' Duiven, in the experimental farm of the Agricultural and Environmental Engineering institute (IMAG-DLO). The cows were kept in a loose housing system with concrete floor. The cows were kept in a cowshed which consisted of 30 cubicles, 2 watering places, one concentrate self feeder (CSF), a concentrate waiting area, a robot waiting area, a free passage between the cubicles and the forage lane, a milk tank, 12 forage lane places and 2 robotic milking boxes. The cowshed was placed in a tent, 20 metres in length and 13.6 metres in width as shown by Halachmi et al. (2001). The cow traffic, concentrate and forage distribution as well as milking robot (Prolion, The Netherlands) setup and frequency are described in detail by Halachmi et al. (2001). In each of the three experiments, the cow routine was the same. Each experiment consisted of one preparation and two measuring weeks. In experiments I and II two milking boxes were used, while in experiment III only one was used. All three experiments were conducted using the same feeding, farm and milking routine. Video observations were made by three video cameras, which covered the entire cowshed area. During the all three experiments, the number of cows in all cowshed facilities was registered at sampling time (every 10 minutes). Standing or lying in the cubicle was registered if the cow had all four legs in the cubicle. Standing in the forage lane was registered if the head of the cow had passed through the forage lane gate. Cows were registered if they were in the concentrate waiting area, but not in the CSF. Cows were registered as being in the robot waiting area if their heads were oriented toward the milking robot entrance gate. All cows that were passing were not registered. Electronic measurements for milking and CSF were obtained by the computer described by Devir et al. (1996). The data used from the milking robot were as follows: milk yield per cow per visit in kilograms, entrance and exit time per cow per visit and presence of the cow in the milking robot during video sampling time. The data used from the CSF were as follows: amount of concentrate dispensed per visit, entrance and exit time per cow per visit and presence of the cow in the CSF during video sampling time. The last electronically measured data were passing times. These were obtained by sensors that work using principle of light beams. There were six sensors present. The first was placed between the robot waiting area and the entrance of the milking robot. The second was placed between the exit of the milking robot and the concentrate waiting area. The third was placed at the entrance of the passage from the forage lane side and the fourth was placed at the exit of the passage toward the cubicles. The fifth and sixth sensor were placed in milking box one and two respectively. The time and the number of each cow was recorded with every electronic measurement. Electronic measurements were collected continuously during the experiments. The descriptive statistics were calculated for the CSF (histogram) and the milking robot (average and standard deviation per experiment, histogram) using the SPSS statistical package (SPSS 7.5, 1997).

The utilization equation used was defined as follows by Halachmi et al. (2000a):

$$\eta = \frac{\lambda \times s}{c}$$

where

η = milking robot utilization (%)
λ = arrival rates (number of visits per hour)
s = service time (average milking time per visit)
c = number of milking boxes

The statistical analysis was done using Genstat 3.2 (Genstat 5, 1993) and the SPSS 7.5 program. The behavioural variables were adjusted to the hour values either as an average or a sum. The generalized multiple regression model was used, because the dependent variable Y was expressed as a percentage. It was assumed that Y is binomially distributed (n,pi) and therefore a logistic link function was used. The measurement of the quality of fit was calculated from the logarithm of a ratio of likelihood, which is called deviance (McCullagh and Nelder, 1989).

The following logistic regression model for the forecasting of the milking robot utilization was used:

$$\ln(Y_i/(100 - Y_i)) = \alpha + \sum_{j=1}^{9} \beta_j X_j + e_{ij}$$

where

The dependent variable is:

Yj = robot utilization measurement
α = intercept
βj = regression coefficients (j =1, …,9)

And the independent variables are:
Xj = predictors of the model, where:
X1 = number of cows in concentrate waiting area per hour
X2 = sum of amount of conc. given per hour in grams
X3 = number of cows in CSF per hour
X4 = number of cows in cubicle per hour
X5 = number of cows in forage lane per hour
X6 = number of cows in robot per hour
X7 = time
X8 = sum of milk yields per hour in kilograms
X9 = number of cows in experiment
eij = residual error term

In modelling all three experiments together, variables X1 to X9 were used. A stepwise forward regression procedure with a tolerance criterion F-value belonging to $p \leq 0.05$ was used for independent variables to enter into the model.

RESULTS

Fig. 1 presents the queue in front of the CSF during experiment III with 29 cows. In experiment III during 8% of the sampling time there were 2 cows in the queue. A queue of one cow was present 30% of the sampling time. For the rest of the time (62%) there was no queue. In the 14 experimental days there were 55% rewarded visits (defined as visits when concentrate was given) to the CSF. The average duration of successful visits is 7:48 minutes, with a standard deviation of 5:17 minutes. Fig. 2 indicates that the duration of visits mainly fell within the range between 2:31 minutes and 13:05 minutes. A 9.6% fraction of visits had a longer duration than 13:05 minutes. Fig. 3 shows that with 29 cows in the experiment during one day, for 31% of sampled time there were no cows in the queue, for 50% of the sampled time there was 1 cow in the queue and for 19% of the sampled time there were 2 cows in the queue in front of the milking robot.

The average milking stall occupation time was 8:18 minutes, while the standard deviation was 2:46 minutes. Fig. 4 shows the occupation time per milking and that is 87.8% of cases this was under 11:00 minutes. The maximum occupation time was 27 minutes. Table 1 contains data indicating a decrease in the number of milking robot visits per day, and increased milk yield standard deviation per visit, with an increasing number of cows. The amount of milk per visit was highest with 10 cows and lowest with 20 cows. The generalized multiple regression model A was obtained by a stepwise forward procedure (Fig. 5). It contained the following variables: the sum of milk yields in kilograms per hour, the number of cows, the average number of cows in the concentrate waiting area and the average number of cows in the milking robot per hour. Among these variables,

Table 1. Milk yield and number of visits to the robot

Number of cows	Average milk yield per visit	Standard deviation	Average number of visits per day
10	11.78	2.45	2.88
20	11.18	4.42	2.88
29	11.40	4.73	2.76

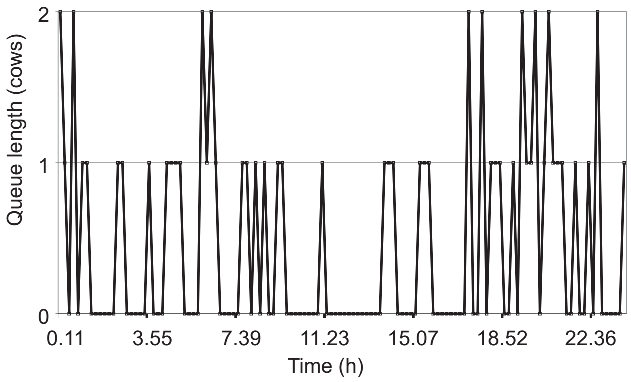

Figure 1. Daily time pattern of CSF waiting area for experiment III

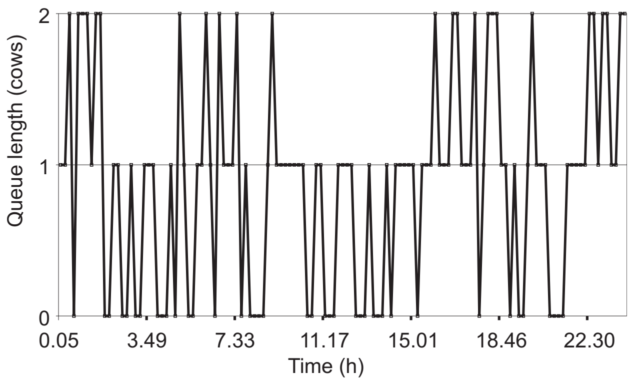

Figure 3. Daily time pattern of robot waiting area in experiment III

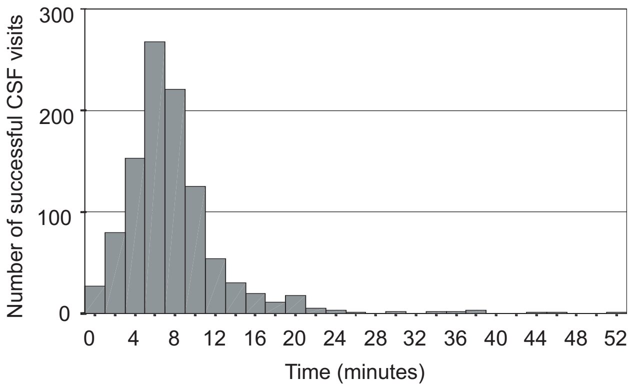

Figure 2. CSF time distribution of 14 days (1030 visits) for all three experiments

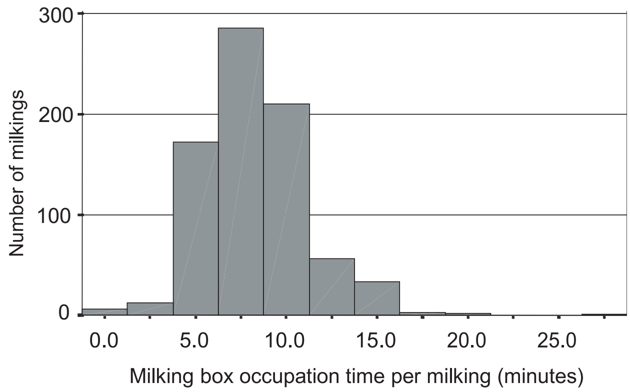

Figure 4. Milking box occupation time distribution for 14 days (781 milkings) for all three experiments

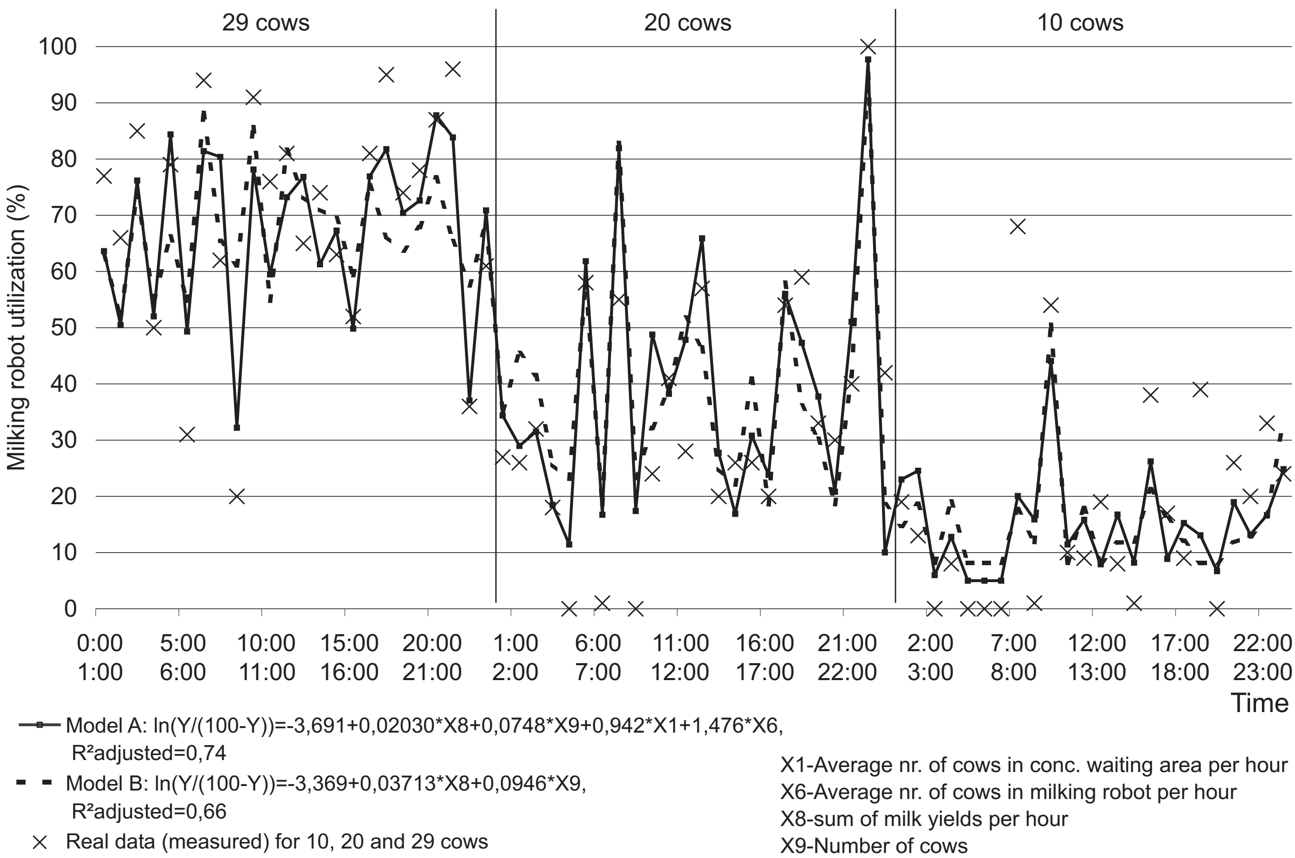

Figure 5. Measured and predicted milking robot utilization for all three experiments

Table 2. Standard errors and p-values of the variables in model A of all three experiments

Variable	Standard error	p-value
Constant	0.334	0.000
Sum of milk yields kg h^{-1}	0.00852	0.027
Number of cows	0.0154	0.000
Average number of cows in concentrate waiting area per hour	0.289	0.004
Average number of cows in milking robot per hour	0.565	0.016

two variables were measurable on commercial farm (the number of cows and the sum of milk yields in kilograms per hour). These were chosen and a new model was fitted (model B). Model A explained 74% of variation about the mean, adjusted for degrees of freedom, and model B, 66%. The maximum differences between the model A and measured data were 18.37% (for 29 cows), 31.98% (for 20 cows) and 25.92% (for 10 cows). The maximum difference between model B and the measured data were 41.09% (for 29 cows), 27.85% (for 20 cows) and 50.22% (for 10 cows). Table 2 shows that the number of cows and the average number of cows in the concentrate waiting area per hour were highly significant ($p<0.01$), while the variables of the sum of milk yields in kilograms per hour and the average number of cows in the milking robot per hour were significant ($p<0.05$).

DISCUSSION

The data for the cubicle, forage, CSF and milking robot utilization are shown by Halachmi et al. (2001). Ketelaar-de Lauwere et al. (1998) concluded that a concentrate self feeder which can only be reached by passing trough the milking robot is a good stimulus to attract cows to the milking robot at regular intervals. In our all three experiments, a sufficient number of visits to the milking robot was found ranging from 2.76 to 2.88 on average per day. Almost the same milking robot capacity (8:18 minutes) was found as that already reported by Ipema and Benders (1992) with three milkings per day. This indicates that the milking robot in the barn design used in the three experiments satisfied the need of a cow to be milked and also did not cause additional milking work for the farmer. A high percentage of milkings had durations of up to 11 minutes, which indicates that the milking procedure was done properly. Longer idle times were found during the nighttime cleaning and with smaller number of cows, showing that cow traffic was lower. Only the measurable variables that could feasibly be used became a part of the model: the number of cows (X9) and the sum of milk yields (X8). Apart from those, there are two other highly significant variables which are not measurable on a commercial farm: the average number of cows in the concentrate waiting area per hour (X1) and the average number of cows in the milking robot per hour (X6). In the future, it is recommended that the model be calibrated on more days (this was done on only one day per experiment) and that the model be validated on a greater number of days, different farms, cows and farm routines.

CONCLUSIONS

The combined cow traffic used in the three experiments did not cause long queues in the robot and concentrate waiting areas, therefore it seems that the barn layout used is a feasible one. The high percentage of unrewarded visits to the CSF and sufficient milking frequency indicated by the one-way traffic reflected a sufficient number of visits to the CSF and the milking robot. The multiple generalized regression model was developed with the behavioural variables measurable on a commercial farm. The variables were the number of cows in the experiment and the sum of milk yields per hour in kilograms. However, better calibration with the representative sample and a larger amount of data from a commercial farm are needed. The number of cows is a highly significant variable in the model. This was due to the difference in the variables present in the models between the three experiments performed. Therefore, more experiments with a number of cows close to the maximum milking robot capacity are needed.

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