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Effects of A Simulated Power Cut in AMS on Milk Yield Valued by Statistics Model

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SUMMARY
A statistics model was developed in order to be able to determine the effects of a simulated power cut of an Automatic Milking System on the milk output.Measurable and relevant factors, such as power cuts, milk yield, lactation days, average two days digestion and rumination and time were considered in the calculation tool.
Key words: Automatic milking system, milk yield, ruminant activities, statistics model

I. INTRODUCTION

A vast number of factors, such as less physical work, higher flexibility and cow specific milking, have led to an increase in the number ofautomatic milking systems throughout Bavaria. In the past years, the number of farms equipped with automatic milking systems has risen considerably, to nearly 1,200 agricultural holdings (Sprengel and Korndörfer, 2014).

Applying automatic milking systems leadsnot only to organizational adjustments but alsorequires adapting energy supplies. The energy required must be available for24 hrs/day.

Though surveys have shown that Europe provides quite a stable power network, there have been diverse irregularities in supply in different countries of the EU (Roon and Buber, 2013). The last significant power cut, on November 25th 2005 in North Rhine-Westphalia, Germany, left 250,000people without power for up to four days; on November 4th 2006 10 million people in vast parts of Europe were without power for two hours.

In this paper we will present one of the effects of a simulated power cut in four Bavarian farms on the frequency of use of the Automatic Milking System, on the ruminant activities, the immediate, intermediate and long term reaction of the cows and possible effects on their milk output.

In order to simulate a power cut, twelverandom cows were not admitted to the Automatic Milking System for twohours on three consecutivedays.

Furthermore, stress reactions were examined closely via video analysis, heart rate, pedometer and measurements of cortisolmetabolites.

MATERIAL AND METHODS

In order to be able to determine the feasibility of milking by automatic systems, a plant independent calculating method was developed. Measurable and relevant factors, such as power cuts, milk yield, lactation days, average two days digestion and rumination and time were considered in the calculation tool. Parameters induced by stress such as heart rate and cortisol content may be included any time.

The model generalises Cauchy-Link and binomial distribution based on probability. Hence, the result and its tendency may be influenced by the choice and the interpretation of the variables.

The data used in this study were generated in four different south Bavarian farms with an average herd size of 60 milking cows in the time from 3.3. - 24.8.2014. The data gave 34,203 random samples. Some data were deliberately not included in the model, as they would have distorted the results. For this reason, the parameter “minimal milking interval not achieved” was eliminated.

The reduced data set of 19,232 was not transformed, all data were of equal value. These are realistic and as such closely related to practical experience.

In order to restrict complexity, only one target variable was applied together with five variables. The target variable is X_6 = milking outcome (yes/no) and the five chosen co-variables (X_1 = simulated power cut (yes/no); X_2 = milk output, rounded; X_3 = lactation days; X_4 = average two hrs activity/two hrs rumination; X_5 = time). Adding further variables merely leads to collinearity and increases the complexity of problematic instances. The developed GLM (Generalised Linear Model) does not include any random effects and hence can analysed easily. Due to the low rate of error in the sample the model proves to be very easily predictable. It satisfies imitation of conditions, prediction and the significance of explanatory variables.

The model was calculated using the statistics software R. The following formula was defined through stepwise backward reduction considering the AIC Criterion:

```
y ~ x1 + x2 + x3 + x4 + x5 + x1:x3 + x1:x4 + x1:x5 + x2:x3 +
x2:x4 + x2:x5 + x3:x4 + x3:x5 + x4:x5 + x1:x3:x4 + x1:x3:x5 +
x1:x4:x5 + x2:x3:x4 + x2:x3:x5 + x2:x4:x5 + x3:x4:x5 + x1:x3:x4:x5 +
x2:x3:x4:x5
```

RESULTS

The following tables show the calculation of the coefficients (estimates) and the approximation quality (deviance residuals) of the above model:

```
Deviance Residuals:
Min       1Q   Median       3Q      Max
-3.4296  -0.1582   0.0854   0.1111   3.1227

Coefficients:
Estimate Std. Error z value Pr(>|z|)
(Intercept)  2.832e+00  2.463e+01   0.115   0.9085
x1          -4.593e+07  8.783e+10  -0.001   0.9996
x2          -1.637e-01  8.123e+00  -0.020   0.9839
x3          -1.088e-01  1.014e-01  -1.073   0.2834
x4          -9.929e-01  5.702e-01  -1.741   0.0816 .
x5          -6.979e-01  1.576e+00  -0.443   0.6579
x1:x3        1.088e-01  8.315e+08   0.000   1.0000
x1:x4        9.929e-01  2.315e+09   0.000   1.0000
x1:x5        6.980e-01  6.758e+09   0.000   1.0000
x2:x3        3.983e-02  3.294e-02   1.209   0.2265
x2:x4        3.173e-01  1.869e-01   1.697   0.0897 .
x2:x5        3.668e-01  5.002e-01   0.733   0.4633
x3:x4        3.649e-03  2.042e-03   1.787   0.0740 .
x3:x5        3.810e-03  6.382e-03   0.597   0.5504
x4:x5        3.637e-02  3.677e-02   0.989   0.3226
x1:x3:x4    -3.649e-03  2.177e+07   0.000   1.0000
x1:x3:x5    -3.812e-03  5.579e+07   0.000   1.0000
x1:x4:x5    -3.637e-02  1.782e+08   0.000   1.0000
x2:x3:x4    -1.307e-03  6.566e-04  -1.991   0.0465 *
x2:x3:x5    -1.609e-03  2.019e-03  -0.797   0.4254
x2:x4:x5    -1.595e-02  1.137e-02  -1.404   0.1605
x3:x4:x5    -1.307e-04  1.300e-04  -1.005   0.3150
x1:x3:x4:x5  1.307e-04  1.522e+06   0.000   1.0000
x2:x3:x4:x5  5.449e-05  4.012e-05   1.358   0.1745

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 25957.3  on 19231  degrees of freedom
Residual deviance:  2002.8  on 19208  degrees of freedom
AIC: 2050.8

Number of Fisher Scoring iterations: 25
```

In addition the statistical influence (Pr(>Chi)) of the coefficients is identified by the milk output.

Analysis of Deviance Table

Model: binomial, link: cauchit

Response: y

Terms added sequentially (first to last)

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)	
NULL			19231	25957.3		
x1	1	1000.2	19230	24957.1	< 2.2e-16	***
x2	1	22917.8	19229	2039.3	< 2.2e-16	***
x3	1	0.3	19228	2039.0	0.5942626	
x4	1	15.0	19227	2024.1	0.0001095	***
x5	1	0.6	19226	2023.4	0.4208560	
x1:x3	1	0.0	19225	2023.4	1.0000000	
x1:x4	1	0.0	19224	2023.4	0.9987861	
x1:x5	1	0.0	19223	2023.4	1.0000000	
x2:x3	1	0.6	19222	2022.8	0.4410557	
x2:x4	1	4.9	19221	2017.9	0.0262460	*
x2:x5	1	3.2	19220	2014.7	0.0737422	.
x3:x4	1	2.0	19219	2012.7	0.1556413	
x3:x5	1	0.5	19218	2012.2	0.4755629	
x4:x5	1	1.7	19217	2010.4	0.1872985	
x1:x3:x4	1	0.0	19216	2010.4	1.0000000	
x1:x3:x5	1	0.0	19215	2010.4	1.0000000	
x1:x4:x5	1	0.0	19214	2010.4	0.9999309	
x2:x3:x4	1	0.7	19213	2009.7	0.4024740	
x2:x3:x5	1	3.7	19212	2006.0	0.0549941	.
x2:x4:x5	1	0.1	19211	2005.9	0.7357760	
x3:x4:x5	1	1.2	19210	2004.7	0.2763516	
x1:x3:x4:x5	1	0.0	19209	2004.7	0.9999034	
x2:x3:x4:x5	1	1.9	19208	2002.8	0.1646522	

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

It should be mentioned that, if the null hypothesis is not rejected it is not true to say that the corresponding coefficients do not have any influence on the milk output. As expected, the power cut (x1, p-value < 2.2e-16), the milk output (x2, p-value < 2.2e-16), the average two hrs activity/two hrs rumination (x4, p-value = 0.0001095) and the interactions milk output:average, two hrs activity/two hrs rumination (x2:x4, p-value = 0.0262460), milk output:time (x2:x5, p-value = 0.0737422) and milk output:lactation:time (x2:x3:x5, p-value = 0.0549941) are obvious to the significance niveau 0.1. The interactions could be expressed by the linear predictor parts.

Now the error classification matrix and rate is calculated:

y	0	1
0	7621	161
1	35	11415

It is obvious that in 7621 cases with "no milking" and in 11415 cases with "milking" the data has been classified in the correct way. As there is a miss-classification in 196 cases we will have aerror-classification rate of 1.019135 %.

The influence of anAMS power cut on the milk output in a certain time interval is analyzedby using the standard k-nearest-neighbor regression (knn-regression) method. As explained above, the power cut and the milk output variables are modeled by a 0-1 sequence. All other variables are directly taken to the knn-regression by using the R functions knn.reg:

knn.reg(train, test, y, k = 1, algorithm=c("kd_tree", "cover_tree", "brute"))

Arguments:

train	matrix or data frame of training set cases.
test	Matrix or data frame of test set cases. A vector will be interpreted as a row vector for a single case. If not supplied, cross-validataion will be done.
y	reponse of each observation in the training set.
k	number of neighbours considered.
algorithmm	nearest neighbor search algorithm.

With theFNN-package and the plot function, the following three examples are observed:

Example 1

Power cut: 0, 0, 0, 0, 1, 1, 1, 0, 1, 0

Milk output in [l]: 9, 17, 11, 15, 0, 0, 0, 14, 0, 16 (assumed by the authors of the paper)

Lactation in [days]: 116, 79, 75, 115, 170, 170, 24, 61, 170, 52

Average two hrs activity/two hrs rumination: 38, 32, 35, 45, 32, 32, 31, 49, 32, 23

Time in [hrs]: 4.15, 4.37, 4.44, 4.54, 4.54, 4.58, 5.01, 5.07, 5.08, 5.37

Milk result: 1, 1, 1, 1, 0, 0, 0, 1, 0, 1

The knn-regression graph indicates the relationship between time and the milk output.

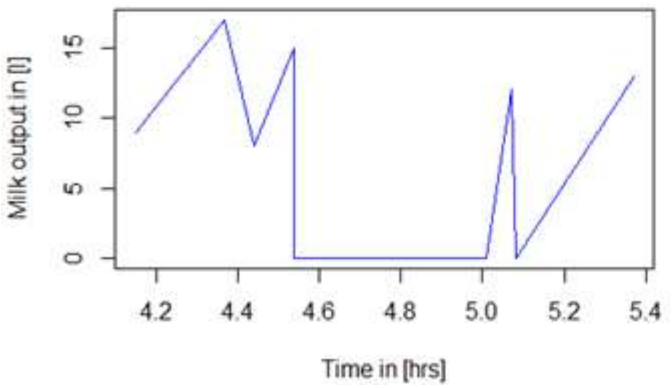

Figure 1: Relationship between time and milk output for example 1.

It should be noted that this first example is trivial, because it is using the origin data pool with the 19232 random samples.The knn-regression with k = 1 has been able to reconstruct the origin data by 100 percent.

Example 2

Power cut: 0, 0, 0, 1, 1, 1, 1, 0, 0, 0

Milk output in [l]: 11, 21, 9, 0, 0, 0, 24, 22, 13 (expected by the authors of the paper)

Lactation in [days]: 42, 61, 220, 100, 100, 100, 100, 55, 190, 82

Average two hrs activity/two hrs rumination: 38, 32, 35, 45, 32, 32, 31, 49, , 32, 23

Time in [hrs]: 6.15, 6.17, 6.24, 6.5, 6.51, 6.55, 7, 7.1, 7.18, 7.21

Milk result: 1, 1, 1, 0, 0, 0, 0, 1, 1, 1

The following correlation therefore exists between the milk output and the time:

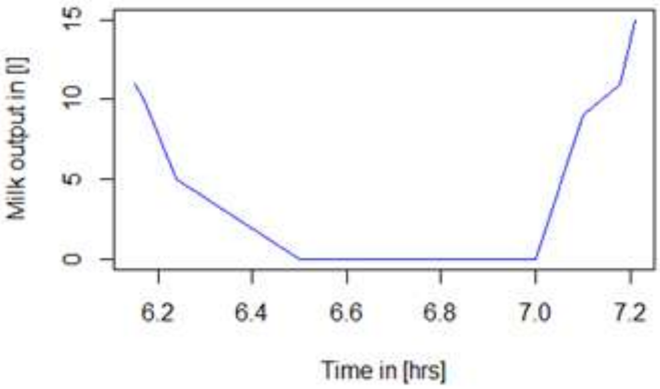

Figure 2: Relationship between time and milk output for example 2.

With the knn-regression method and k = 1 the following milk output in [l] was gained: 11, 10, 5, 0, 0, 0, 0, 9, 11, 15. The above milk output graph shows that the milk output after a short power cut behaves as expected by the authors: The milk output shows a sharp increase.

Example 3

Power cut: 0, 1, 1, 1, 0, 0, 0, 0, 0, 0

Milk output in [l]: 25, 0, 0, 0, 29, 5, 20, 9, 13, 15 (expected by the authors of the paper)

Lactation in [days]: 50, 50, 56, 56, 56, 111, 73, 245, 36, 101

Average two hrs activity/two hrs rumination: 41, 41, 41, 38, 44, 39, 40, 15, 23, 28

Time in [hrs]: 15.03, 16.45, 16.48, 16.54, 17.09, 17.28, 17.41, 17.57, 18.08, 18.37

Milkresult: 1, 0, 0, 0, 1, 1, 1, 1, 1, 1

The following correlation therefore exists between the time and the milk output:

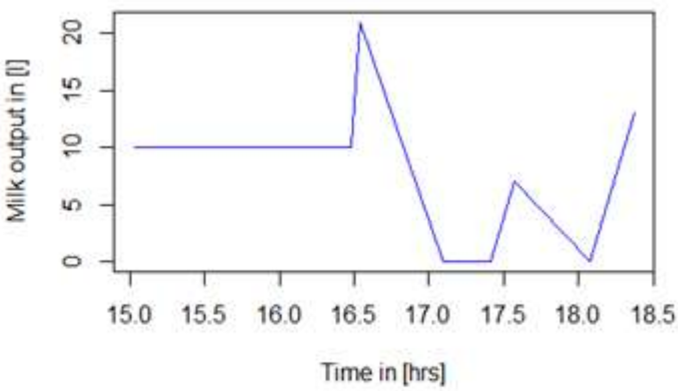

Figure 3: Relationship between time and milk output for example 3.

The estimated milk output obtained by the knn-regression with k = 1in [l] was the following: 10, 10, 10, 21, 0, 0, 0, 7, 0, 13. It can be seen that the milk output assumed by the authors (increasing) does not behave as the milk output graph obtained by knn-regression. Probably the reason therefore could be that the cows usually visit the AMS in the morning or in the evening times, and so there are not enough random samples available for this time stamp. In this case, the knn-regression fails.

II. DISCUSSION AND CONCLUSION

Generalising the model allowed its adaption and application to any method of observation. The advantage is that the model can be applied to any dairy farm using an automatic milking system, regardless of its size, the cattle race and the herds output. The model works via probability and not with exact data. Therefore, direct consequences of simulated core times or power cuts cannot be analysed directly. However, due to the large amount of data, the low rate of error classification, and the high quality of the model, the results are so precise that it is impossible to identify individual probabilities.

Even though the statistical methodology was of high quality and has a very low rate of error, when considering good practice and interpretation of data, one must be aware that the concept is based on simulation. The power cut was simulated for 12 cows from four dairy farms. Not much data needed to be considered because only 12 animals were effected. The consequence of a real power cut would be a lot worse, as this would effect all animals of the herd and not only a dozen focussed cows. Thereby, also see the failure of the knn-regression. To improve the knn-regresion, the random samples can be scaled and weights of the knn-regression can be adjusted by a genetic algorithm. But the problem, where no data are available, is not eliminated.

Parameters such as cortisol content, heart rate variability and paces may be included into the model by significant additional work in order to record individual animal reaction regarding health and stress.

In summary the model proves to be very good for statistical surveys, the evaluation and interpretation of possible effects of simulated power cuts of the milking robot on milk yield. Precise observation and examination, especially taking into account individual animal behaviour, would require further data and parameters.

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