Imprecise Classification of the Gram Status of the Causal Pathogen of Clinical Mastitis

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Introduction

Clinical Mastitis (CM) – a type of udder infection – is one of the most frequent and costly diseases in a dairy herd. Its main characteristics are:
• reduction in a cow’s milk production and overall yield;
• painful for the infected cows;
• can be transmitted between cows.

An effective and quick CM treatment is of economic importance.

Treatment
Appropriate treatment is selected based on the gram status of the causal pathogen.
• Bacteriological culturing is ineffective due to long waiting times.
• Classifiers help farmers to determine the gram status of the causal pathogen, allowing them to select an appropriate treatment.

Motivation for imprecision
• If a single gram status of the causal pathogen is convincingly established, a narrow-spectrum antibiotic is better.
• If the gram status of the causal pathogen cannot be convincingly established, a broad-spectrum antibiotic is more appropriate.

Data Setting

For constructing classifiers, a set of 3534 clinical mastitis cases was used. This data was kindly provided by Van der Gaag and Renooij (Steeneveld et al., 2009), for which we would like to thank them.

Models

Imprecise model We use the Naive Credal Classifier (NCC) (Marco Zaffalon, 2001) as the imprecise model. Let \( g \) and \( \hat{g} \) denote the classes of gram-positive and gram-negative, \((f_1, \ldots, f_l) = f \) is a vector of \( l \) feature variables in this case. For any \( c \in \{g, \hat{g}\} \), the conditional lower and upper probabilities of \( c \) given \( f \) are:

\[
\begin{align*}
p_l(f|c) &= \frac{\sum_{\omega_k \in \omega_k|c} n_f(\omega_k)}{N} \\
p_u(f|c) &= \frac{\sum_{\omega_k \in \omega_k|c} n_f(\omega_k) + s}{N + s}
\end{align*}
\]

where \( N = \sum_{c \in \{g, \hat{g}\}} n_f(\omega_k) \), and where

\[
\begin{align*}
p_l(f|c) &= \frac{n_f(\omega_k)}{N} \quad \text{and} \quad p_u(f|c) = \frac{n_f(\omega_k) + s}{N + s}
\end{align*}
\]

where \( N \) is the total number of training units, \( n(c) \) and \( n(f|c) \) are the observed frequencies of class \( c \) and of \((f_1, \ldots, f_l)\) in the \( N \) observations. We choose \( s \) equal to 1.

Precise model We use the Naive Bayes Classifier (NBC), which is well known in classification, as the precise model.

Model measurement TP and FP denote the number of true and false positive cases, TN and FN denote the number of true and false negative cases. UP and UN is the number of positive and negative cases for which the model gives a result of ‘I don’t know’.

Accuracy and Precision are used to analyse the performance of the NCC and NBC classifiers.

\[
\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}
\]

\[
\text{Precision} = \frac{TP}{TP + TN + FP + FN}
\]

Decision rules In the NBC, we select the class with the largest probability as the output. In the NCC, the decision rule is shown in following table:

| Condition | Output | \( p(c|f) \) | \( p(\hat{g}|f) \) | Class \( g \) |
|-----------|--------|-------------|----------------|-----------|
| \( p(g|f) > p(\hat{g}|f) \) | \emph{Up} | \( \text{I don't know} \) |
| \( p(\hat{g}|f) > p(g|f) \) | \emph{Down} | \( \text{I don't know} \) |

Conclusion and Future Work

Conclusion
• In the NCC, the precision depends strongly on the training set, whereas the accuracy seems more stable across different training sets. In the NBC, the precision is always 1, but the accuracy varies greatly across different training sets.
• The imprecise model has a better accuracy than the precise one, at the cost of a loss of precision.
• For small training sets, the imprecise model has a lower variance than the precise one.

Future work
• Investigate and compare several imprecise classification methods by applying them to our case study on clinical mastitis.
• Compare the obtained results with other precise methods.
• Study the effect of the parameter \( s \) on the performance of the NCC model.

Results for Different Sizes of Training Sets

For every size of training set, 1000 precise and imprecise classifiers were constructed for random datasets of that size. For the NCC (blue) and NBC (red), the results are depicted in graphs (a) – (f). The x-axis depicts the Accuracy and the y-axis depicts the Precision. Graph (g) and (h) compare the average and variance of the accuracy between both models.