Exploring explainability formats to aid decision-making in dairy farming systems

A small case study using the example of mastitis infection

Mengisti Berihu Girmay[1], Felix Möhrle[1] and Jens Henningsen[2]

Abstract: In this paper, we examine different approaches to explaining decision support in herd management systems for their effects on comprehensibility and trust. To this end, we present a hypothetical system for assessing the risk of mastitis, a common infectious disease in dairy cattle. For this system, we design four explanation formats to present risk assessments to farmers. We collect their feedback in a survey to get suggestions for designing systems that are well accepted. In our work, it was not possible to identify one explanation format that is preferable to all others. Rather, a finding was that herd management systems should optimally support multiple explanation formats and allow switching between them depending on the situation.

Keywords: explainability, decision support, dairy farming, trust

1 Introduction

Dairy farming is an important sector of agriculture dedicated to the rearing and milking of cattle. It has evolved over time from small family farms to large commercial operations. In 2021, Germany held the position of largest EU milk producer with an estimated 31.9 million tons of milk [De23]. However, profit margin is still a big challenge for many dairy farmers, who face unstable prices, high capital investments, regulatory burdens and growing societal demands for greater sustainability and animal welfare.

Digitalization is a promising means for addressing these challenges. Modern systems such as feeding or milking machines enable the automation of formerly manual processes. By collecting and correlating animal data, it is also possible to draw conclusions about animal welfare or susceptibility to disease [Sh20]. However, besides the potential benefits, the introduction of digital systems also brings along new challenges. Their acquisition often involves high costs and training efforts, which can be a burden for small farms with limited resources [AW11]. In addition, trust in new technologies and the perceived loss of control can be barriers [TKT19]. Ultimately, the low adoption rate of many systems, as shown for

[1] RPTU Kaiserslautern-Landau, Digital Farming, Erwin-Schrödinger-Str., 67663 Kaiserslautern, mengisti.berihu@rptu.de, felix.moehrle@cs.rptu.de
[2] Fraunhofer-Institut für Experimentelles Software Engineering IESE, Fraunhofer-Platz 1, 67663 Kaiserslautern, jens.henningsen@iese.fraunhofer.de

example by [Ba19], suggests that current systems are not optimally adapted to the needs of farmers.

Many researchers are investigating possible reasons for the low level of adoption, such as a lack of explainability [BRT21], which is also the focus of our work. While recent research in explainability is focused predominantly on AI, many features of herd management systems rely on traditional programming methods. For this reason, we widen the definition to include any form of decision support offered by digital systems. We borrow from the following definitions:

- The process of generating a description of how an outcome was reached [Br21]
- The degree to which a human observer can understand the reason behind a decision [DTG18]

In short, the term implies that results or suggestions are not presented in isolation, but with additional reasoning that makes it easier to understand the underlying rationale.

The aim of this work is to contribute to improving user acceptance of herd management systems. To this end, we examine (1) how explainability influences comprehensibility and trust and (2) how well different explanation formats are accepted by farmers.

2 Methodology

We introduce a hypothetical herd management system for the detection of mastitis. Mastitis is a commonly encountered infectious disease among dairy cattle and is a leading cause for the administration of antimicrobial agents [Mi12]. Signs of infection include an increased number of somatic cells in the milk, increased body temperature, and a change in the pH value of the milk. In designing the hypothetical system, we assume that the dairy farms in question are equipped with milking machines that record these parameters during the milking process. The system presents assessments of mastitis infection based on these parameters in four different explanation formats that we will introduce in the following.

2.1 Explanation Formats

When designing the hypothetical herd management system, we followed the classification of Valone et al. [VL21]. The authors classify techniques from the field of explainable AI (XAI), among others, by their scope (local, global) and their output format (numerical, rule-based, textual, visual). Although our hypothetical system is not necessarily based on AI, we found this classification useful in selecting potential explanation formats and corresponding representations. We adopted the classes textual (F1), rule-based (F2), global (F3), and local (F4) that can be readily applied to our use case. The global class (F3) refers to explanations involving multiple animals in the herd, while the local class (F4) concerns only a single animal. We did not explicitly include the classes numerical

and visual, since all explanation formats include numbers and visualizations in some form. In designing the explanation formats, we examined existing herd management systems to get a realistic picture of how systems currently present assessments. For each adopted class, we designed an exemplary representation of the evaluation of mastitis infection.

2.2 Data Collection and Analysis

We presented the explanation formats to dairy farmers in an online survey which was completed by 14 participants. Participants were asked to rate with a 5-point Likert scale:

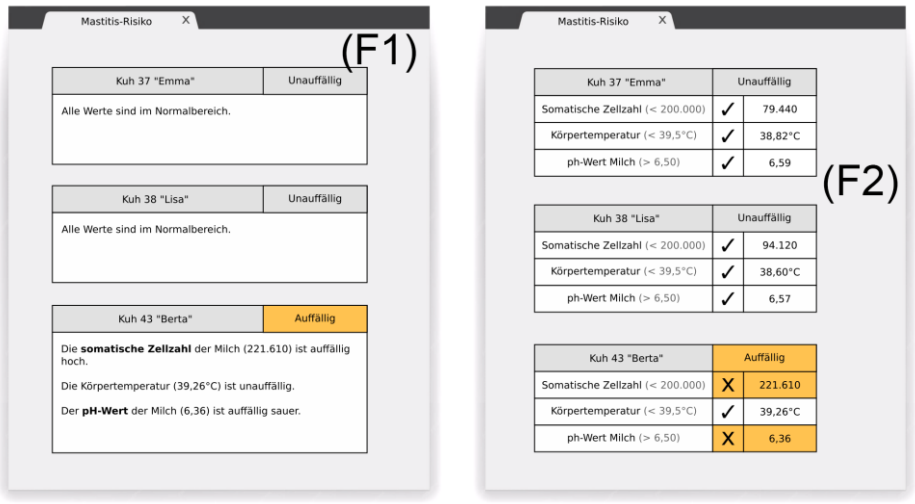
1. How comprehensible they consider each format to be
2. How much they would trust a system using each format

Furthermore, the participants were asked:

3. Which of the four alternative formats they ultimately prefer (single choice)
4. What the rationale for their choice is (free text input)

3 Survey: Explaining Mastitis Risk in Dairy Farming

The four explanation formats are presented in Figure 1. The textual format (F1) provides the user with explanations based on natural language. The rule-based format (F2) evaluates and highlights three conditions. The herd comparison (F3) relates the values of multiple cows. The time series (F4) shows the values of a single animal over time.



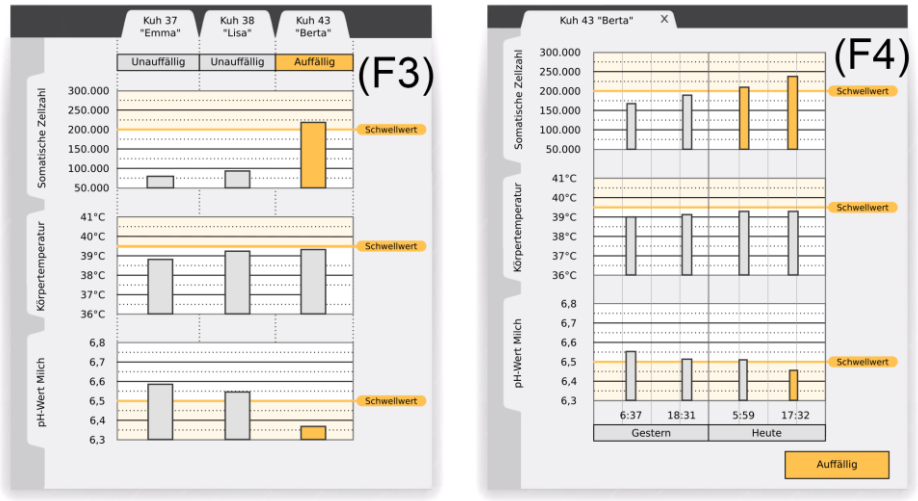


Fig. 1: Formats: textual (F1), rule-based (F2), herd comparison (F3), time series (F4)

4 Results

4.1 Quantitative Analysis

The numerical results are shown in Table 1. It contains the ratings (1: low, 5: high) for comprehensibility and trust, and the number of farmers favoring each format.

	Comprehensibility	Trust	Favored
(F1) Textual	5,2,4,1,5,5,3,1,1,5,5,5,5,3	4,1,5,4,5,4,3,5,2,4,5,3,3,3	1
(F2) Rule-based	5,5,5,1,5,5,4,1,1,2,5,5,5,5	4,5,5,2,5,4,3,2,1,2,4,4,3,5	5
(F3) Herd comparison	4,5,4,1,5,4,5,1,2,3,5,5,5,3	3,5,5,1,5,4,4,1,1,2,5,4,3,2	2
(F4) Time series	5,5,4,1,5,4,5,1,1,5,5,5,1,3	3,5,5,1,5,4,4,1,1,2,2,4,2,2	6

Tab. 1: Survey results (N=14)

We calculated the median, minimum, maximum, and the first and third quartile for each format for both comprehensibility and trust. The results are illustrated in Figure 2.

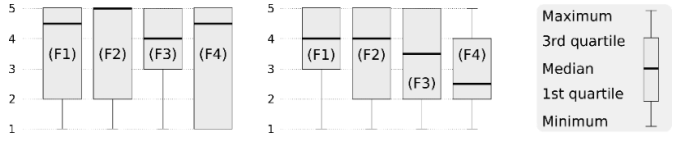


Fig. 2: Quantitative analysis results for comprehensibility (left) and trust (right)

The results did not reveal any clear differences regarding comprehensibility. Farmers trusted the textual (F1) and rule-based (F2) formats slightly more, while the time series (F4) received the lowest trust. Ratings varied widely with each format receiving both the lowest (1) and the highest (5) rating at least once. The time series (F4) was the most frequently favored format with 6 votes, followed by the rule-based format (F2) with 5 votes. The herd comparison (F3) and the textual format (F1) received 2 and 1 vote, respectively. Overall, no format emerged as generally superior and opinions varied widely.

4.2 Qualitative Analysis

The text feedback is summarized in Table 2. The textual format (F1) was found to be inferior to the more expressive time series (F4) by one farmer. The rule-based format (F2) was generally rated as clear and self-explanatory. The herd comparison (F3) was valued for its efficient and time-saving overview of affected animals in large herds, although one farmer found F3 unclear. The time series (F4) was valued for showing all relevant information such as changes in individual animals over time, facilitating decision making, and providing insight into potential treatments. Some farmers added that combining F3 and F4 is beneficial to enable comparisons between animals with a historical perspective.

Textual (F1)	Rule-based (F2)
- Unnecessary as F4 contains all information and more (1)	+ Shows problems most clearly (4) + Easy to understand and self-explanatory (1) - Not clear (1)
Herd comparison (F3)	**Time series (F4)**
+ Shows at a glance which animals are affected (2) + Useful as each herd is unique (2) + Complements well with F4 (2) - Not clear (1)	+ Changes in an individual animal are most relevant for decision making (5) + Useful as each animal is unique (1) + Shows relevant information at a glance (1) + Complements well with F3 (2)

Tab. 2: Statements from the text feedback (with the number of occurrences)

In summary, all formats (except F1) were considered useful at least once in the text feedback. The results do not suggest that any explanation format is generally superior to all others. Some farmers recommended a combination of F3 and F4.

5 Conclusion

Our work examined how different explanation formats in a hypothetical herd management system are perceived by farmers. The findings suggest that perceptions are very subjective. Even in our small test group, responses varied widely, and no format stood out significantly. It is conceivable that a larger sample group could help reveal tendencies. The time series (F4) was rated by many farmers as helpful for decision-making and

treatment selection. The herd comparison (F3) was appreciated for its concise overview. A good user interface could therefore combine both and allow switching depending on the situation. The participants saw value in all four formats. A conclusion for promoting user acceptance is that herd management systems should ideally support multiple explanation formats. Our study did not allow us to identify a format that is superior to all others.

Acknowledgements: The research was conducted within the scope of Sustainable Embedded AI and funded by Carl Zeiss.

Bibliography

[AW11] Allen, J.; Wolfert, J.: Farming for the Future: towards better information-based decision-making and communication-Phase I: Australasian stocktake of Farm management tools used by farmers and rural professionals. AgFirst Consultancy/Wageningen University and Research Centre, Palmerston North, 2011.

[Ba19] Barnes, A. P. et al.: Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers. Land use policy 80, S. 163-174, 2019.

[Br21] Broniatowski, David A. et al.: Psychological foundations of explainability and interpretability in artificial intelligence. NIST, Tech. Rep, 2021.

[BRT21] Ben David, D.; Resheff, Y. S.; Tron, T.: Explainable AI and adoption of financial algorithmic advisors: an experimental study: Proceedings of the 2021 AAAI/ACM Conference on AI, Ethics, and Society, S. 390–400, 2021.

[DE23] Deutschland EU-weit größter Kuhmilcherzeuger, Statistisches Bundesamt, https://www.destatis.de/Europa/DE/Thema/Land-Forstwirtschaft-Fischerei/Milchquote.html, last accessed: 13.07.2023.

[DTG18] Dam, H. K.; Tran, T.; Ghose, A.: Explainable software analytics: Proceedings of the 40th int. conf. on software engineering: New ideas and Emerging results, S. 53-56, 2018.

[Mi12] Minst, K. et al.: Streptococcus species isolated from mastitis milk samples in Germany and their resistance to antimicrobial agents. Journal of dairy science 95(12), S. 6957-6962, 2012.

[Sh20] Sharma, A. et al.: Machine learning applications for precision agriculture: A comprehensive review. In: IEEE Access 9, S. 4843-4873, 2020.

[TKT19] Tummers, J.; Kassahun, A.; Tekinerdogan, B.: Obstacles and features of Farm Management Information Systems: A systematic literature review. Computers and electronics in agriculture 157, S. 189-204, 2019.

[VL21] Vilone, G.; Longo, L.: Classification of explainable artificial intelligence methods through their output formats. Machine Learning and Knowledge Extraction, 3(3), S. 615-661, 2021.