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Time series data analysis to predict the status of mastitis in dairy cows by applying machine learning models to automated milking systems data

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Introduction

- Mastitis is a significant disease affecting dairy cows, leading to economic losses and welfare concerns
- Early detection and management of mastitis are crucial for:

  > minimizing the risks to animal health & welfare > maximizing economic gains
- Traditional detection methods rely on manual inspections, which are labor-intensive
- Automated Milking Systems (AMS) generate large datasets that can be leveraged using Machine Learning (ML) for early mastitis prediction
- The aims of this study were to apply ML techniques to AMS data to predict mastitis occurrence:
  - one day prior to its observation and
  - on the day of mastitis observation.

Materials & methods

Dataset:

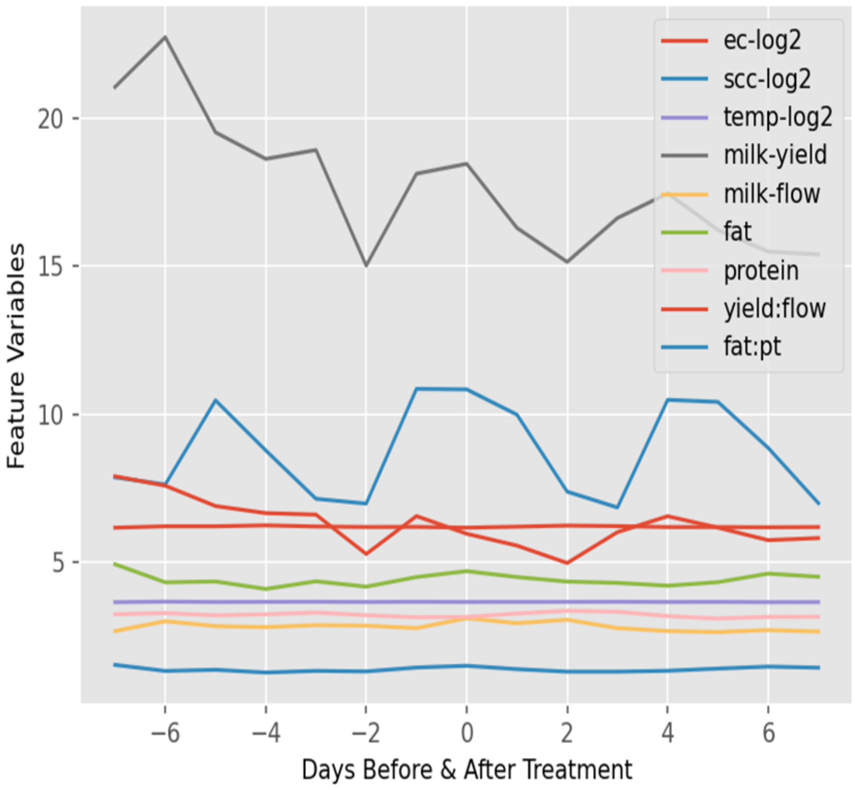
- Original data: AMS milk records 3-4 times per day per cow: 2.73 million observations
- Number of Individual Cows: 1790
- Number of Farms: 2
- Time Duration: 2019-2022 (4 years)
- X variables 7 (details on next slide…)
- Y variable 1
- Time resolution adjusted to one time (average value per day per cow)
- Total Observations 953,270
- Total negative obs. 942290 (days without treatment)
- Total Positive obs. 2250 (days with treatment)

Data format tranformation (auto-regressive order)

Seven predictor (X) variables

1. E-conductivity
2. Somatic cell count
3. Milk temperature
4. Milk yield
5. Milk flow
6. Fat content
7. Protein content

Individual pattern over time



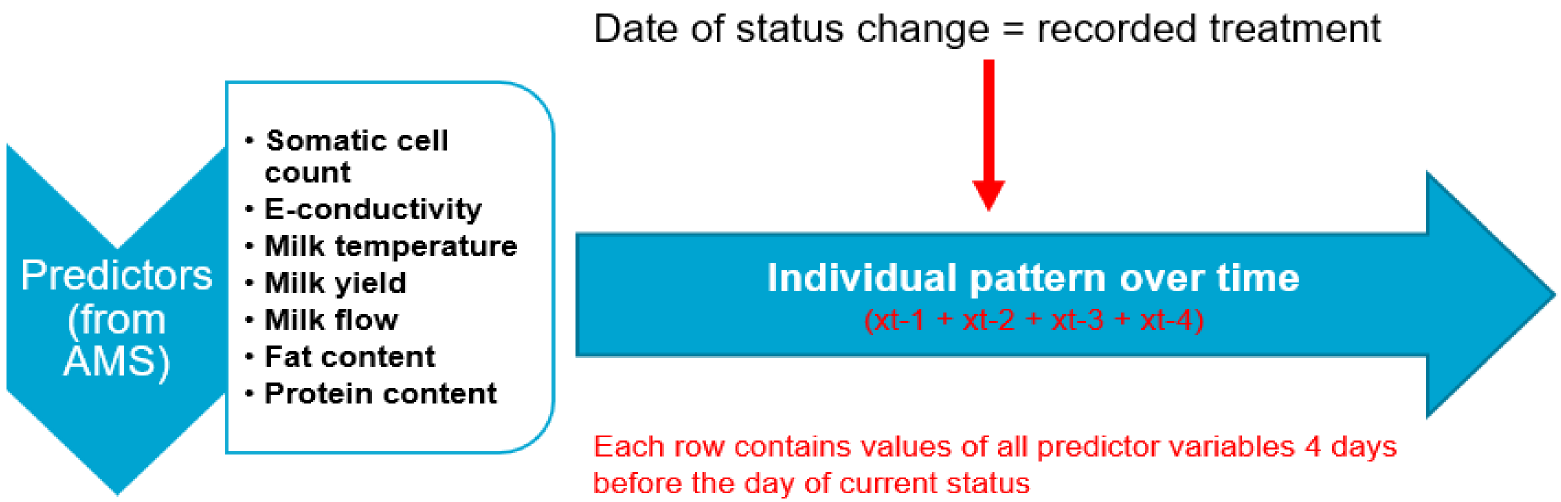
Auto-regressive data format

e-conduct	econd-1	econd-2	econd-3	econd-4
70.33	72.75	72.00	73.00	74.25
69.67	70.33	72.75	72.00	73.00
71.00	69.67	70.33	72.75	72.00
73.67	71.00	69.67	70.33	72.75
70.33	73.67	71.00	69.67	70.33

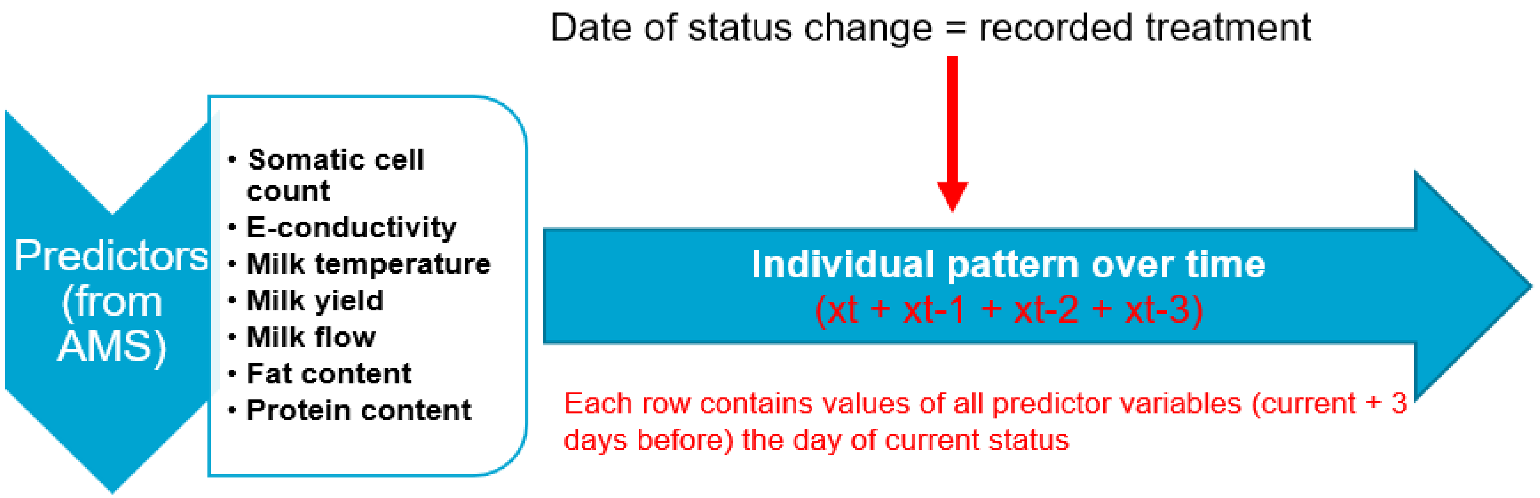
xt + xt-1 + xt-2 + xt-3 + xt-4

Model Formats

Format-1: Mastitis prediction one day prior



Format-2: Mastitis prediction on same day of observation



Training and testing of ML models

- Dataset was split into: >training (75%) and >testing (25%)
- Training dataset (highly class imbalance) >Negative = 722662 >Positive = 1800
- Synthetic minority oversampling technique (SMOTE)
  - After oversampling >Negative = 722662 >Positive = 722662
- Testing dataset (No oversampling) >Negative = 208299 >Positive = 450
- Six ML models applied:

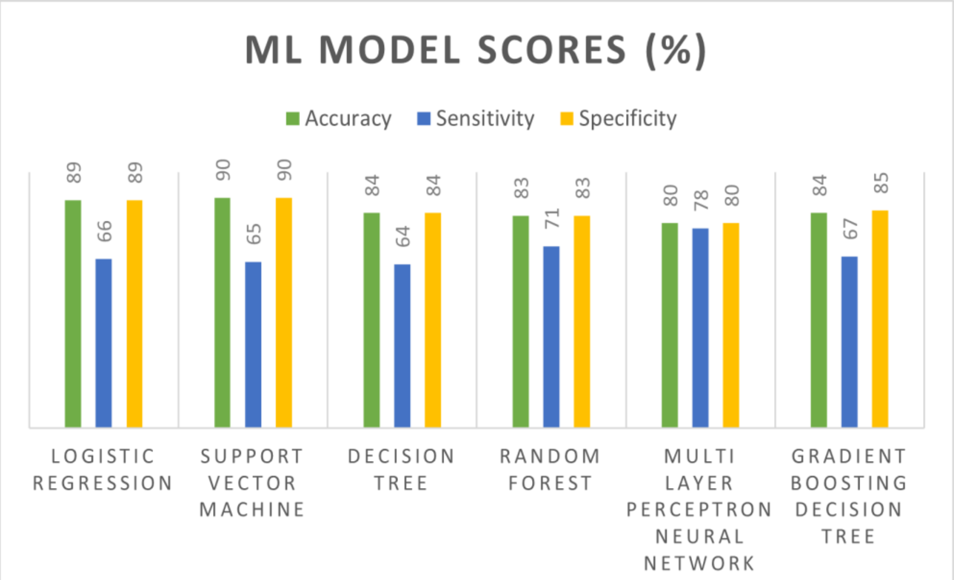
  > Logistic regression (LR) > Support vector machines (SVM) > Decision tree (DT)

  > Random forest (RF) > Gradient boosting decision tree (GBDT)

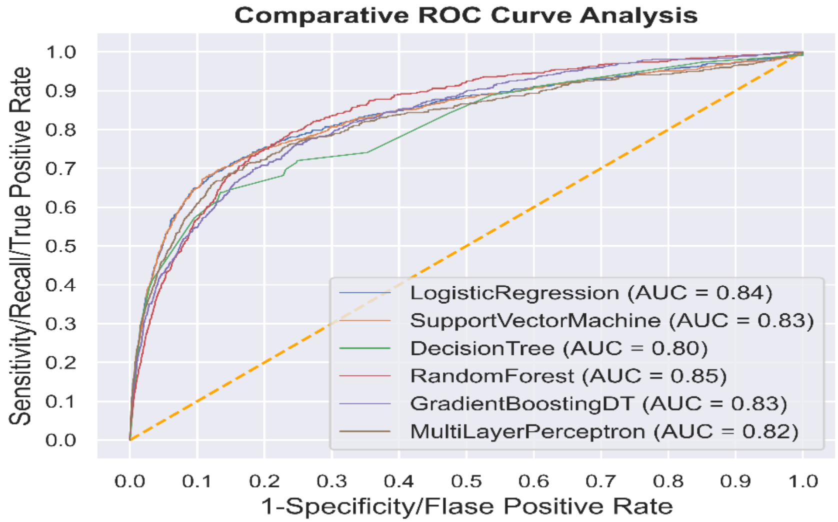
  > Multi-layer perceptron neural network (MLP-NN)
- GridSearchCV: > Hyper-parameter tuning > 5-fold cross validation

Results part-1 (mastitis prediction one day before)

- Over all
  - Accuracy 80-90%
  - Sensitivity 64-78%
  - Specificity 80-90%
- Highest accuracy and specificity > support vector machine
- Highest sensitivity > multi layer perceptron

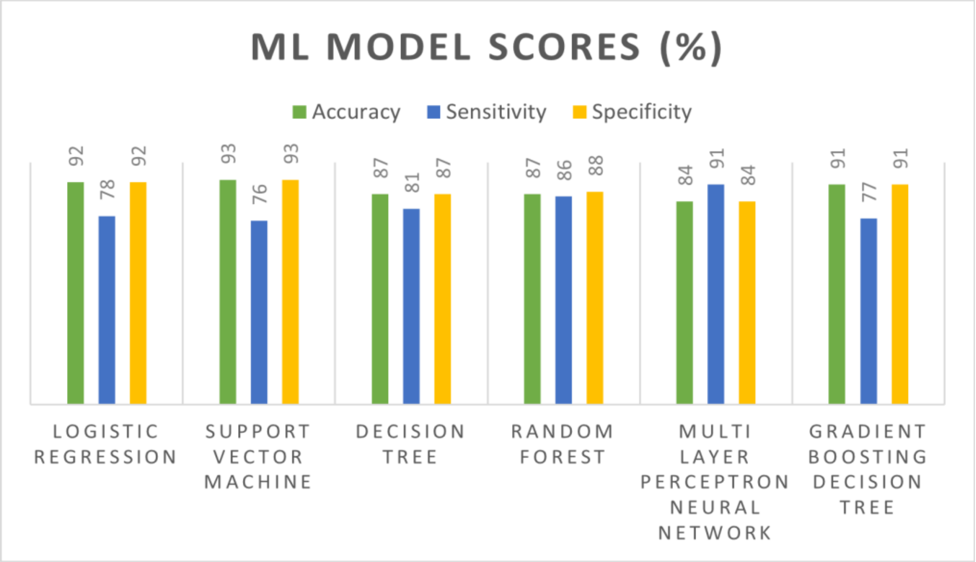


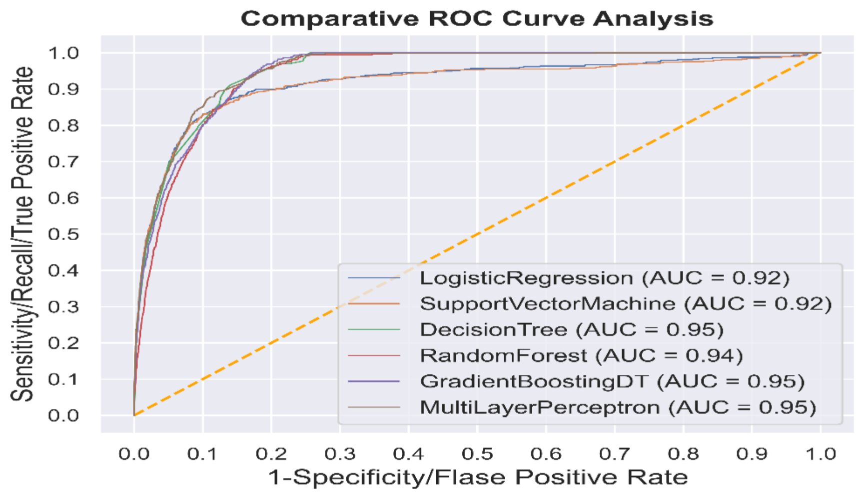
- Overall moderate predictive accuracy
- Area under curve (AUC) score 0.8-0.85
- Random forest classifier had greatest AUC
- Decision tree scored lowest



Results part-2 (mastitis prediction on the day of observation)

- Over all
  - Accuracy 84-93%
  - Sensitivity 76-91%
  - Specificity 84-93%
- Highest accuracy and specificity > support vector machine
- Highest sensitivity > multi layer perceptron
- Overall all models scored an area under curve (AUC) greater than 0.9 (high accuracy)
- Decision tree, gradient boosting and multi layer perceptron had greatest AUC
- Logistic regression and support vector machine scored lowest AUC





Discussion

- This study developed a framework of ML models for mastitis prediction on a time series dataset generated by AMS
- Since this is an ongoing area of research, a targeted level of sensitivity and specificity for prediction models on AMS data is not yet decisively defined.
- Some studies have suggested that Mastitis detection models should have Sensitivity of ≥80% (Hillerton, 2000; Hogeveen et al., 2010, 2021)
- International Standard Organization (ISO, 2007) recommends that Sensitivity be >70% with an Specificity level of 99%.
- However, the requirements mentioned above have rarely been met to date (Khatun et al., 2018; Anglart et al., 2021; Hogeveen et al., 2021).

Conclusion

- Our findings indicated moderate to high accuracy of ML models to predict mastitis
- Study also demonstrated the robustness of time series AMS data to predict mastitis events in future
- However, as each model had its own strengths and weaknesses, therefore these findings have certain limitations.
- We propose inclusion of additional variables from AMS records and integration of other sensorial data for further improvement of ML models in future studies.

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