Identifying Sick Cows Using Rumen Temperature

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1. Introduction

Background:

- Zalliant, an agriculture technology company based in Amsterdam, NY has designed and produced a temperature sensor capsule that a cow swallows.
- Capsule stays in the rumen, the first of four stomach compartments of a cow.
- The rumen temperature differs from the body temperature as it is measured inside the stomach where it is impacted by what the cow consumes.
- Increases in the rumen temperature can be caused by food digestion or light fevers
- The rumen temperature can decrease dramatically if a cow drinks cold water or because of a serious illness. [1][2]

Methods:

- Predict internal temperature from rumen temperature using vaginal readings
- Get rid of temperature drops caused by cow drinking cold water
- Detect low-temperature events associated with illnesses using past averages
- Complete the project using Python Jupyter Notebooks and Google Collab

2. Data Overview

Three types of time series data was made available to us:

1. Rumen temperature every 10 minutes for 3 adult cows with labeled extreme temperature events.
   i. 1 month of data (4,674 data points) with 7 high- and 3 low- temperature events
   ii. 1 week of data (1,068 data points) with 3 low-temperature events
   iii. 2 months of data (10,002 data points) with 1 low-temperature event
2. Paired rumen temperature and internal body temperature (via vaginal measurement) every 5 minutes for 1 cow (the "ground truth" temperature to predict real temperature from rumen temperature)
   i. 1 month of data (10,068 data points)
3. Rumen temperature every 5 minutes for 11 calves
   i. Daily updates starting from 3/1/23 (over 120,000 data points)

3. Data Imputation

- The data is collected via radio waves, sending "packets" of thirty-minute stretches of data with varying timestamps
- If the radio signal is interrupted, the entire packet goes unreceived, resulting in 30+ minutes of missing data depending on when the next signal is received.
- This missing data is not represented by NAs; instead, there are jumps from one timestamp to the next.
- To get around this, the missing rows were created with NA values in place of data.
- To create NA values, a dataframe consisting entirely of NAs is created, with a row for every five minutes during the timeframe analyzed
- Then, the live data is forced onto this full NA dataframe, replacing NAs at the timestamp closest to the real timestamp
- This results in a dataframe with NA values, allowing us to perform data imputation
- Pandas' interpolate function is used to replace the missing data with appropriate values for the time series

	deviceId	temp	timestamp	NA_dataframe	index	interp_temp
28	281B040000200229	39.22	2023-03-01T07:20:32.552Z	2023-03-01 07:20:00+00:00	28	39.22
29	281B040000200229	39.24	2023-03-01T07:25:32.552Z	2023-03-01 07:25:00+00:00	29	39.24
30	281B040000200229	NaN	NaN	2023-03-01 07:30:00+00:00	NaN	39.24
31	281B040000200229	NaN	NaN	2023-03-01 07:35:00+00:00	NaN	39.24
…	…	…	…	…	…	…
41	281B040000200229	NaN	NaN	2023-03-01 08:25:00+00:00	NaN	39.24
42	281B040000200229	39.24	2023-03-01T08:30:41.192Z	2023-03-01 08:30:00+00:00	30	39.24
43	281B040000200229	39.30	2023-03-01T08:35:41.192Z	2023-03-01 08:35:00+00:00	31	39.30

Figure 1. Original index, temperature and timestamp values are matched to the closest rigid timestamp values in NA_dataframe, where the index values are readjusted and missing temperature values are interpolated

4. Drink Removal Algorithm

- Vast majority of temperature drops are caused by the cow drinking water, so the real internal temperature had to be inferred from the rumen temperature.
- Using a 10-minute differencing, the beginning of the drink is identified, and the following hour of temperature readings is ignored.
- After the differencing value returns to near 0, the missing values are linearly interpolated from the last reliable reading and the most recent one.
- The rumen temperature is consistently about 0.5°C higher than the real internal temperature, so half a degree is subtracted to get the prediction.
- The resulting time series is the predicted internal temperature from rumen temperature

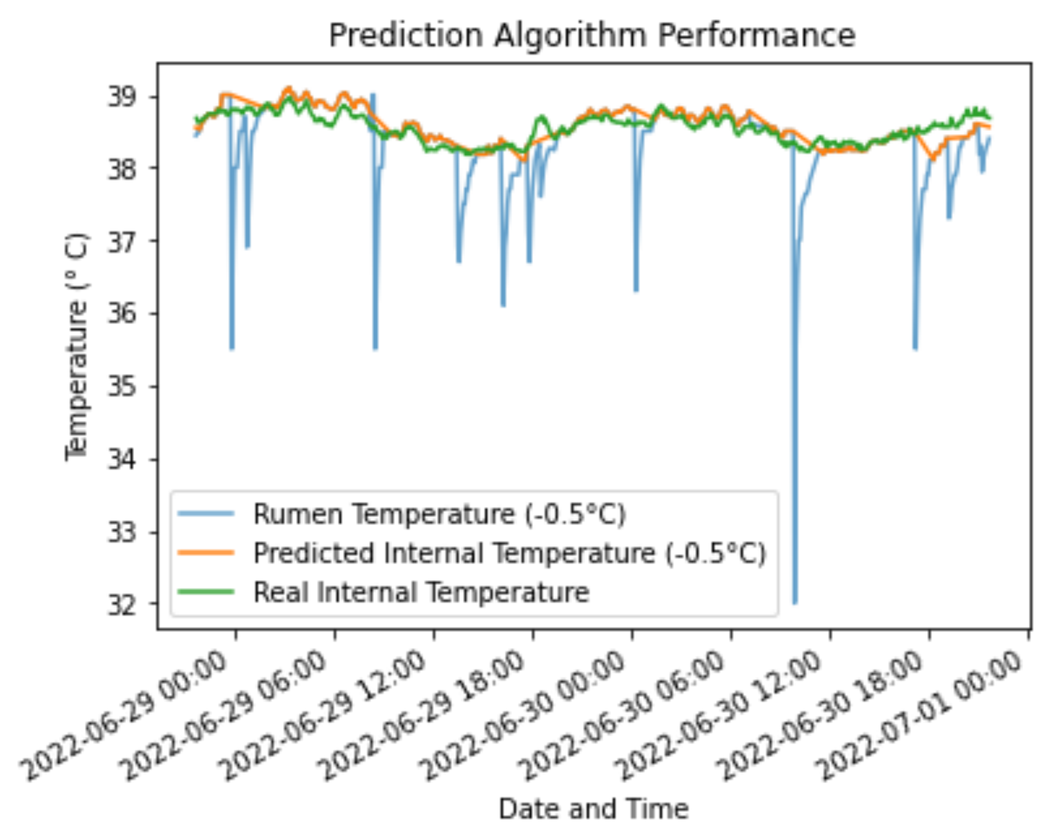

Figure 2. The temperature drops are eliminated, and the predicted internal temperature closely matches the real internal (vaginal) temperature.

5. Feature Engineering

- Following the analysis of labeled data and guidance from the Zalliant team, these two new features were created:
- Median difference from temperatures taken within 30 minutes of the current time in the past 7 days
- Median difference from temperatures taken within 30 minutes of the current time yesterday
- This allows for cow-specific detection of abnormal temperature fluctuations
- If the temperature is more than 0.9°C lower than the 7-day median at that time and is 0.5°C lower than the median from the day before, a low-temperature alert is issued.
- Similar process was completed for high-temperature detection upon successful testing
- The model is adapted to work in real time, with the averages updating as data comes in

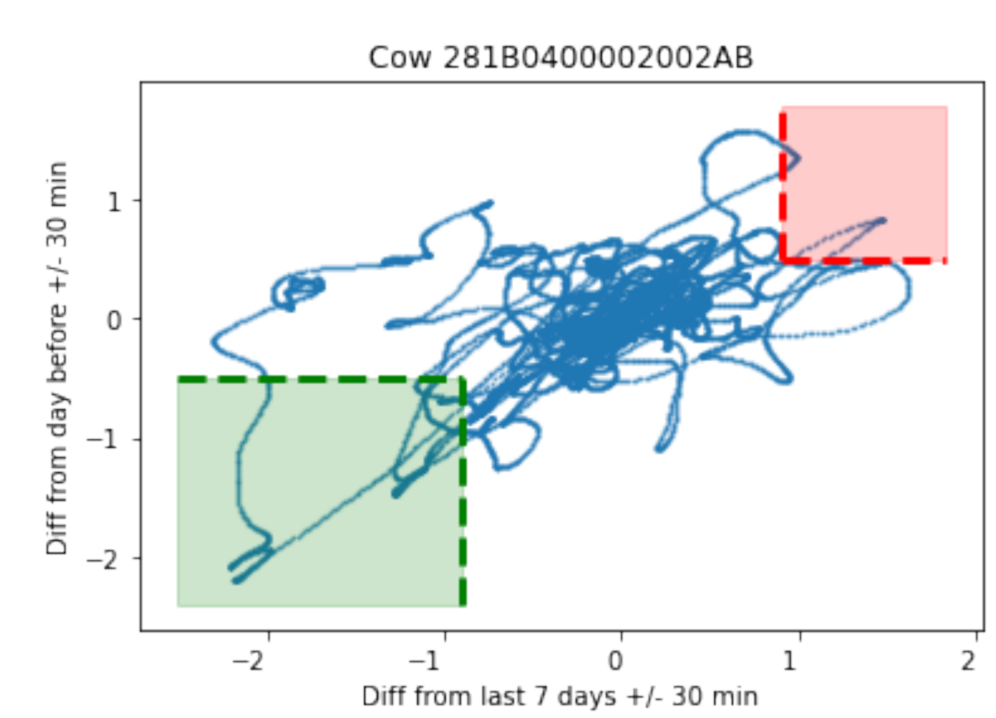

Figure 3. The two engineered features are graphed against each other with every data point plotted accordingly. If a point lies in the bottom-left or upper right corner, a low- or high-temperature alert, respectively, is issued.

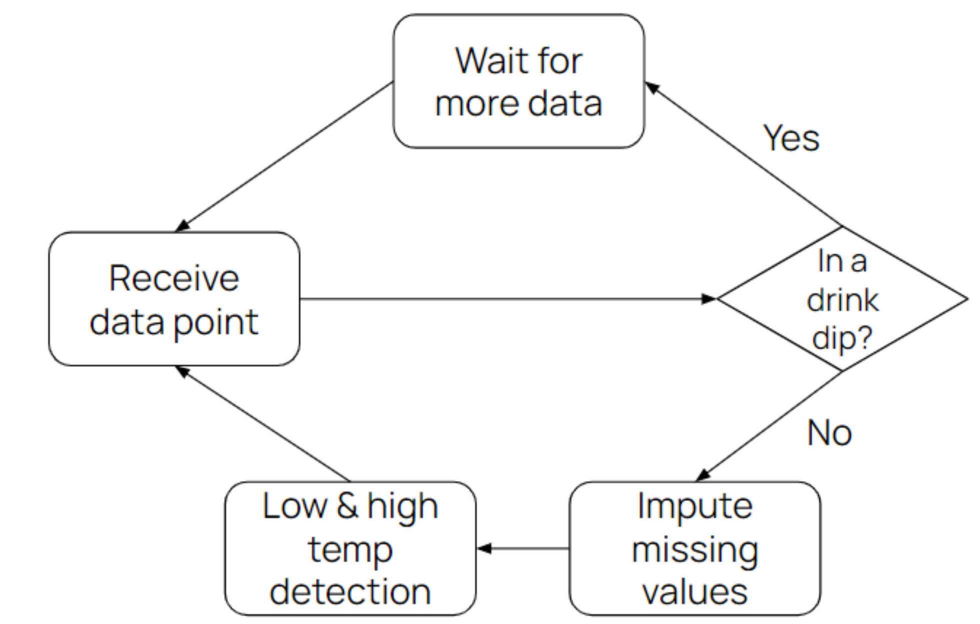

Figure 4. A flow chart of the final live model.

6. Results

- The model was able to correctly identify all 6 labeled low-temperature events in the 3 adult cow temperature data sets with no false positives
- 11 low-temperature events have been identified in the unlabeled calf temperature data, all of which have been confirmed as correct by the Zalliant team
- High temperature alert results are to be confirmed by the Zalliant team
- The predicted internal temperature (without drops due to drinking or missing values) is stored permanently; in case a farmer needs to reference it in the future

7. Acknowledgements

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8. References

1. Rose-DyeBurciaga-Robles LO;Krehbiel CR;Step DL;Fulton RW;Confer AW;Richards CJ;, T. K., et al. "Rumen Temperature Change Monitored with Remote Rumen Temperature Boluses after Challenges with Bovine Viral Diarrhea Virus and Mannheimia Haemolytica." *Journal of Animal Science*, U.S. National Library of Medicine, 4 Dec. 2014, https://pubmed.ncbi.nlm.nih.gov/21169514/.

2. Costa, J. B. G., et al. "Reticulo-Rumen Temperature as a Predictor of Calving Time in Primiparous and Parous Holstein Females." *Journal of Dairy Science*, U.S. National Library of Medicine, June 2016, https://pubmed.ncbi.nlm.nih.gov/27060819/.