Application of Bayesian Updating for Anomaly Detection during the Decommissioning of Fukushima Daiichi Nuclear Power Plant

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This paper proposes an easily updated and rational framework for the treatment of measurement data using Bayesian updating for fast and proper quantification of uncertainty. The approach is demonstrated to be robust and responsive in detecting anomalies.

Keywords: Bayesian updating, Fukushima Daiichi NPP Decommissioning, uncertainty, risk management

1. Introduction and Theory

Sparse and conflicting measurement data can be expected during the decommissioning of Fukushima Daiichi nuclear power plant. When an increase in temperature is measured, it is important to know if it is due to measurement noise or if it is actually indicative of an anomaly. Bayesian updating using Bayes' Theorem [1] allows us to treat measured data in a way that preserves more information regarding the uncertainty, and easily updated in real time. Quantitative estimates of the noise/anomaly scenario can also be obtained.

2. Methodology and results

A set of 10 temperature measurements following a Normal distribution N(μ_T=20°C, σ_T =1°C), and then a steady increase of 0.5°C per timestep from t=11 to t=30 was simulated (Figure 1a). This was fed into a Bayesian updating algorithm sequentially, using a Normal-Gamma Distribution NG(μ=0, k=0, α=-0.5, β=100) as an initial prior. Three-dimensional surface plots were generated at each timestep that encapsulate the epistemic uncertainty in the form of the probability density function for the unknowns μ_T and σ_T (Figure 1b). The posterior predictive is obtained from this, and used to calculate the probability that newly measured temperature data is anomalous. If anomalous, a subroutine examines future data points to confirm if the temperature is indeed changing (Figure 1c).

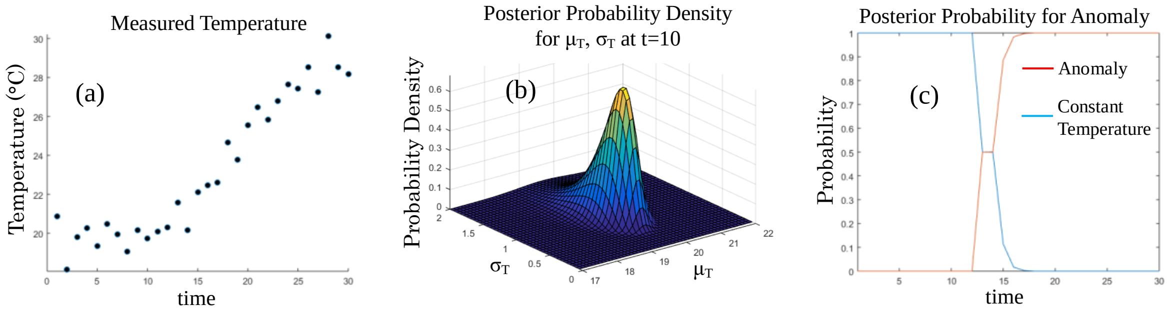

Figure 1: Example of results obtained using Bayesian Treatment. (a) shows the raw temperature data, (b) shows an example of the Normal-Gamma Posterior probability density obtained at each time step, and (c) shows calculated probability of an anomaly being in progress at each time step.

3. Conclusion

The Bayesian approach was demonstrated to be effective in encapsulating uncertainty in the treatment of data. It also allows for easy updating when relevant information is available. Quantitative estimates of a data point being indicative of an anomaly or noise can be obtained which can be used as an aid for decision-making.

References

[1] P. M. Lee, "Bayesian Statistics: an introduction," 2004.