System Reliability Estimation under Prior-Data Conflict

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In reliability engineering, data about failure events is often scarce. To arrive at meaningful estimates for the reliability of a system, it is therefore often necessary to also include expert information in the analysis, which can be dealt with straightforwardly via a Bayesian approach using an informative prior distribution.

A problem that then can arise is called prior-data conflict, see, e.g., [3]: from the viewpoint of the expert, the observed data seem surprising, i.e., the information derived from observed data is in conflict with prior assumptions. Models based on conjugate priors can be insensitive to prior-data conflict, in the sense that the spread of the posterior distribution does not increase in case of such a conflict [see 4, §A.1.2 for two examples], thus conveying a false sense of certainty by communicating that we know the reliability of a system quite precisely when in fact we do not.

As was shown in [5], models using sets of conjugate priors (generated through sets of canonical parameters) can mitigate this issue, by leading to larger sets of posteriors, and thus to more cautious inferences, in case of a prior-data conflict. [See 4, §§3.1, 3.2 for the general framework and its comparison with other models based on sets of priors.]

Building on previous work about reliability estimation for a simplified parallel system using sets of priors [6], we generalize the approach presented in [1] by considering sets of conjugate priors for expressing prior knowledge on component lifetimes. Through use of the recently developed survival signature [2], we obtain lower and upper bounds for the system reliability function. These posterior predictive bounds adequately represent our knowledge on the system reliability, giving more precise probability statements as data accumulate, and appropriately reflecting prior-data conflict by wider bounds.

As an example, we consider the problem of forecasting the reliability of a currently running new one of a kind system, where we have vague prior information on the lifetimes of the components the system is made of, where the only available data consists of observed behaviour of the system components so far, that is, the failure times of the components that have already failed, and the fact that the remaining components still function, whose failure time is thus right-censored. We present a method for taking into account surprisingly early or late component failures in the system reliability prediction, and analyse its effect on decisions about replacements of failed components.

Keywords. System reliability, survival signature, imprecise probability, generalized Bayesian Inference.

References

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