Mechanical Engineering Doctoral Defense

Bayesian-Entropy method for Probabilistic Diagnostics and Prognostics in Engineering Systems

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Abstract

Information exists in various forms and the better utilization of the available information can benefit the system awareness and response predictions. The focus of this dissertation is on the fusion of different types of information using Bayesian-Entropy method. The Maximum Entropy method in information theory introduces a unique way of handling information in the form of constraints. The Bayesian-Entropy (BE) principle is proposed to hybrid the Bayes' theorem and Maximum Entropy method to encode extra information. The posterior distribution in Bayesian-Entropy method has a Bayesian part to handle point observation data, and an Entropy part that encodes constraints, such as statistical moment information, range information and general function between variables. The method is then extended to its network format as Bayesian Entropy Network (BEN), which serves as a generalized information fusion tool for diagnostics, prognostics, and surrogate modeling.The proposed BEN is demonstrated and validated with extensive engineering application. The BEN method is first demonstrated for diagnostics of gas pipelines and metal/composite plates for damage diagnostics. Both empirical knowledge and physics model are integrated with direct observations to improve the accuracy for diagnostics and to reduce the training samples. Next, the BEN is demonstrated in prognostics and safety assessment in air traffic management system. Various information types, such as human concepts, variable correlation functions, physical constraints and tendency data, are fused in BEN to enhance the safety assessment and risk prediction in the National Airspace System. Following this, the BE principle is applied in surrogate modeling for general simulation purpose. Multiple algorithms are proposed based on different type of information encoding methodology, such as Bayesian-Entropy Linear Regression (BELR), Bayesian-Entropy Semiparametric Gaussian Process (BESGP), Bayesian-Entropy Gaussian Process (BEGP) are demonstrated with numerical toy problems and practical engineering analysis. The results show that the major benefits are the extraordinary prediction performance and significant reduction of training samples by using additional physics/knowledge as constraints. This is not surprising due to the additional information included in the analysis and the proposed BEN offers a systematic and rigorous way to incorporate various information sources. Several major conclusions are drawn based on the proposed study.

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