

Briefing of Bayes nets for processing sensor data

by G. B. Baecher

A central issue in statistically processing the data resulting from a sensor network is how to combine the complex fragments of information into a set of probabilistically described engineering parameters that can be used as input to the prognosis model. We propose to use well-established Bayesian Network (BN) methodology to do this.^[1] The BN methodology allows real-time, complex measurement data to be processed to draw logically consistent parameter inferences, which in turn can serve as input to prognosis models.

A Bayesian network, is a directed acyclic graphical that is structured to represent a set of random variables and their conditional independencies. In the present case, a Bayesian network can be used to represent the probabilistic relationships between sensor measurement observations, and engineering properties of the infrastructure, and then parametric input to other models, such as prognosis. Given the sensor measurements, the network can be used to compute the probabilities of future performance.

Within the Bayesian network, nodes represent variables or states of nature, and the vectors between nodes encode conditional independencies between the corresponding variables (i.e., Likelihood functions in a statistical sense). Nodes may be observable quantities (sensor data), latent variables, unknown parameters or hypotheses. The Likelihood functions can be based on modeling, statistics, or expert judgment. Efficient algorithms exist to perform inference and learning in Bayesian networks. Bayesian networks that model time sequences of variables are called dynamic Bayesian networks, and are likely to be the type used in this research. Generalizations of Bayesian networks that can represent and solve decision problems under uncertainty are sometimes called influence diagrams.

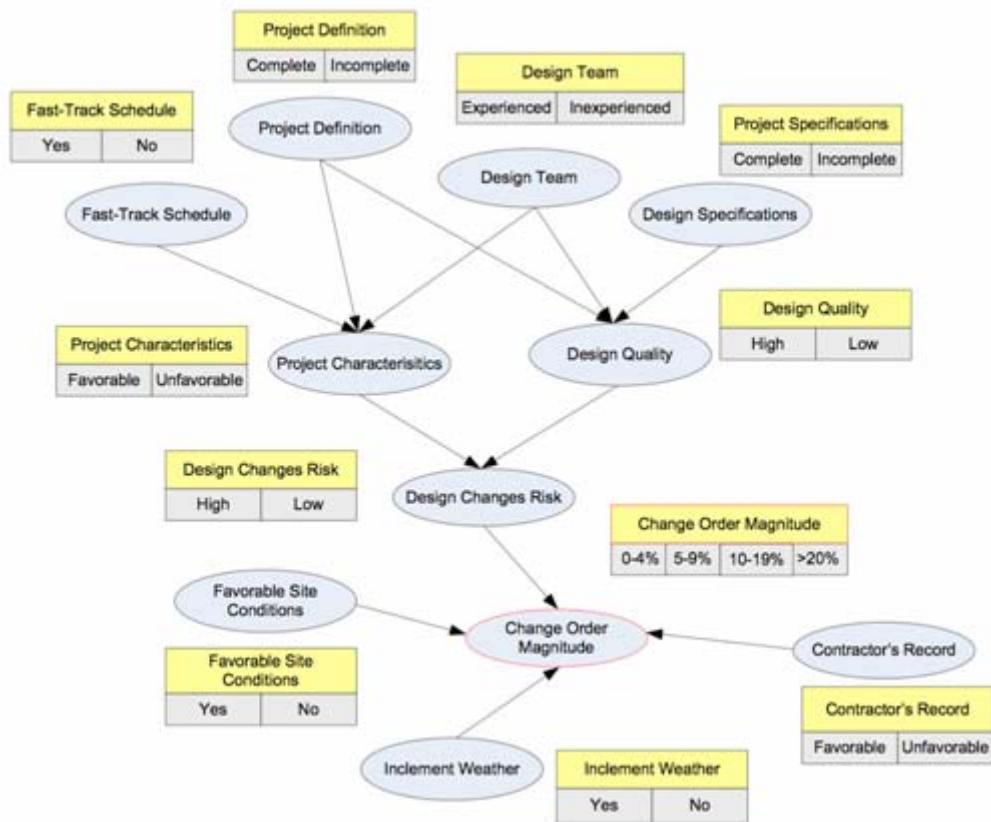
An example of a Bayesian net for the question of predicting construction claims based on observed properties of the project is shown in Figure 1. The principle underlying this net is the same as for interpreting sensor data, but in the case of predicting claims, the input observations are typically categorical.

A strength of Bayesian networks is that they are reasonably complete inferential models for the variables and their relationships, and so can be used to answer probabilistic questions about the variables and their implications. For example, the network can be used to find out updated knowledge of the state of a subset of variables when other variables (e.g., sensor data) are observed. The posterior probability distributions is sufficient for detection applications in which one wants to choose values for the variable

or some implication of the variable that minimize a loss function, for instance the probability of future life of the infrastructure. A Bayesian network can thus be considered a mechanism for automatically applying Bayes's Rule to complex problems. The Bayes net can also be used as a structure for learning more about the process being modeled, as new data become available, and the links between nodes (represented by Likelihood functions) are updated.

Figure 1. Example Bayesian net for construction claims inferences

(Source: Ordóñez-Arígaga, Javier F., "A Methodology For Project Risk Analysis Using Bayesian Belief Networks Within A Monte Carlo Simulation Environment," Thesis submitted in partial fulfillment of the requirements for the degree Doctor of Philosophy, University of Maryland, College Park, 2007).



¹¹ Pearl, J. (1988). *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference*, Morgan Kaufmann, 552pp.