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Modelling the Degradations and Dependencies of CNC Machines using Dynamic Bayesian Networks

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Abstract

There are many complex multi-component systems with partial observations in production facilities. When an unexpected failure occurs, it can cause serious profit losses. For this reason, it holds significant importance to determine and implement efficient maintenance strategies. Nevertheless, the interactions and interdependencies among components pose challenges in obtaining effective maintenance policies for these systems. Therefore, it is crucial to accurately model the relationships in complex systems. Bayesian networks (BNs) hold the advantage of representing and modelling such complex relations by using conditional probabilities. Moreover, dynamic Bayesian networks (DBNs) extend the BNs to be applied in dynamic environments by adding a temporal dimension to the network.

In this study, we tackle the maintenance problem of the CNC machines in a pump production facility. The operation of the CNC machines is automatically controlled with the help of computer support and this enables mass production possible. CNC machines are complex systems having many interacting and partially observable components. We analyze the different types of CNC machines by realizing many site visits to the production facility. Out of them, we first consider the CNC Vertical Machining Centre (CNC-VMC), which is the most frequently used one in the facility, as a complete system. Then, we divide the CNC-VMC system into subsystems by using the HAZOP methodology and asking critical questions to the experts working in the facility. Among these subsystems, the axis system, which is the most critical one for the operation of the system, is chosen for modelling the maintenance problem in this study. We represent and model the interactions, dependencies and depreciations of the system using DBNs. The maintenance of the axis system is simulated with the help of the DBN model under corrective maintenance strategy. We verify and validate the model by replicating it many times and compare the policy outputs with the real-life data. The results justify the validation of the DBN model under corrective maintenance.

Keywords
Maintenance, Multi-component systems, Dynamic Bayesian networks, CNC machines, Stochastic dependency

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