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A Fault Prediction Approach Based on Bayesian Network for System

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CONTENTS

1.INTRODUCTION

- Due to the development of science and technology, the engineered products are getting more and more complexity, it is very important to assess their state and predict their fault and lifetime.
- Bayesian network (BN) is one of the best mathematical model that can handle uncertainty knowledge expression and reference especially suitable for complex systems. It has been successfully applied in fault diagnosis, data mining, reliability analysis, security analysis, and information fusion. Besides, BN also has great potential in fault prediction.
- In our paper, we discussed a Bayesian network-based fault prediction approach, mathematically model and layer the system, and calculate its mean time to failure time (MTTF) and other reliability parameter of the system.
- At last, an active vehicle suspension (AVS) system will be used as an example to explain this method. This fault prediction approach will lay an important foundation for the development of fault prediction technology for complex system.

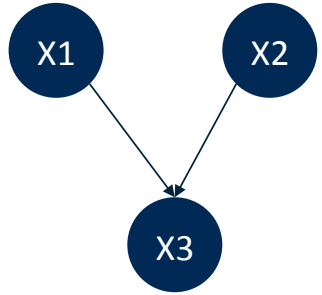
2.BAYESIAN NETWORK

- The Bayesian network is a graphical model that describes the relationship between data variables and perform probabilistic inference, which can reflect the dependencies between variables. It provides a structural framework that can clearly express causation and complete inference on uncertainty issues in a more clear, more logical, and more understandable way.
- It uses a directed acyclic graph to construct the system structure, uses the conditional probability table to construct the system parameters, and then performs probabilistic inference according to Bayes' theorem.
- In Bayesian network, the state of the current moment of any node depends on the state of all its parent nodes at the current moment.

$$\mathrm{P}(X_1, X_2, \cdots, X_N) = \prod_{i=1}^{n} P(X_i | Pa(X_i))$$

2.BAYESIAN NETWORK

X1=1	X1=2
0.8	0.2



X2=1	X2=2
0.95	0.05

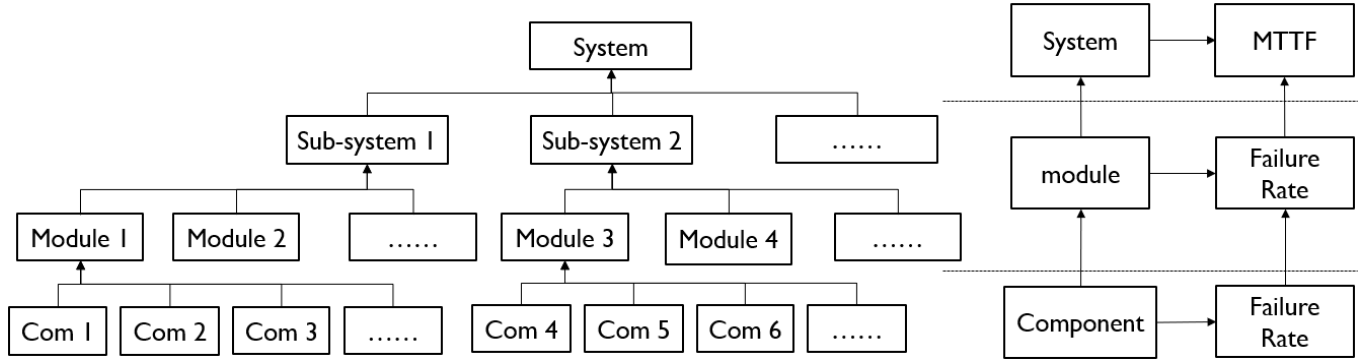
X1	X2	X3=1	X3=2
1	1	1	0
1	2	0.6	0.4
2	1	0.8	0.2
2	2	0	1

$$\mathrm{P}(X_3) = P(X_3|P(X_1), P(X_2))$$

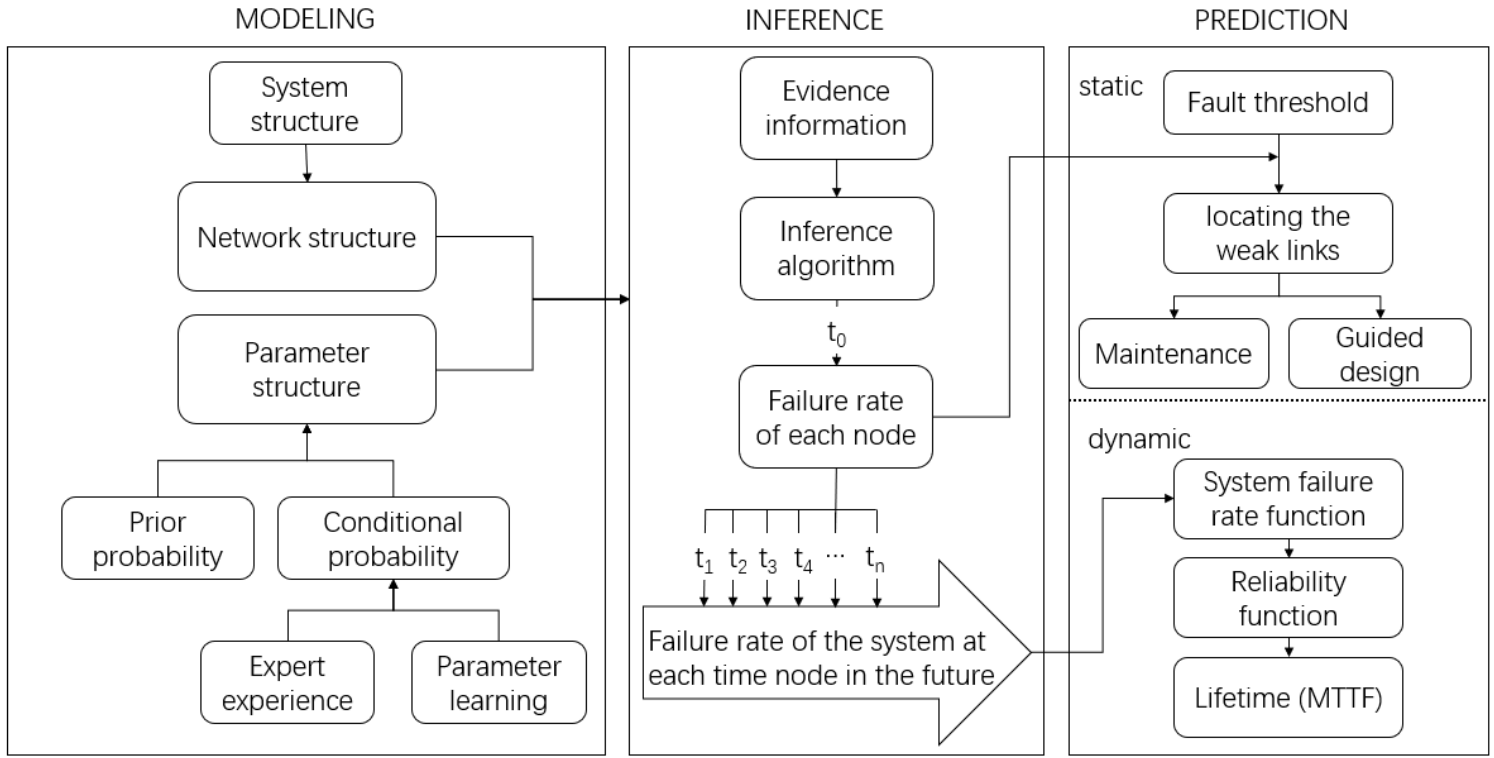
$$\begin{aligned}\mathrm{P}(X_3 = 1) = {} & P(X_3 = 1|P(X_1 = 1), P(X_2 = 1)) + \\ & P(X_3 = 1|P(X_1 = 1), P(X_2 = 2)) + \\ & P(X_3 = 1|P(X_1 = 2), P(X_2 = 1)) + \\ & P(X_3 = 1|P(X_1 = 2), P(X_2 = 2)) \\ = {} & 0.8 \times 0.95 \times 1 + 0.8 \times 0.05 \times 0.6 + \\ & 0.2 \times 0.95 \times 0.8 + 0.2 \times 0.05 \times 0 \\ = {} & 0.946\end{aligned}$$

3. BAYESIAN NETWORK-BASED FAULT PREDICTION

- In the fault prediction, we use the Bayesian network to layer the system and establish a mathematical model, so that the failure rate of the system can be derived from the failure rate of the underlying device.
- Its most prominent advantage is that it can deal with uncertainty issues very well. For example, to compare with fault tree (FT) approach, BN can quantitative the uncertain relationship between each node through conditional probabilities, instead of deterministic “AND” and “OR”. The Bayesian network also has advantages in computing power and speed, which makes it more suitable for complex large-scale systems.
- The two-way inference ability of Bayesian network also enables us to not only calculate the system failure rate in the forward direction, but also locate the system weak link in the backward direction.

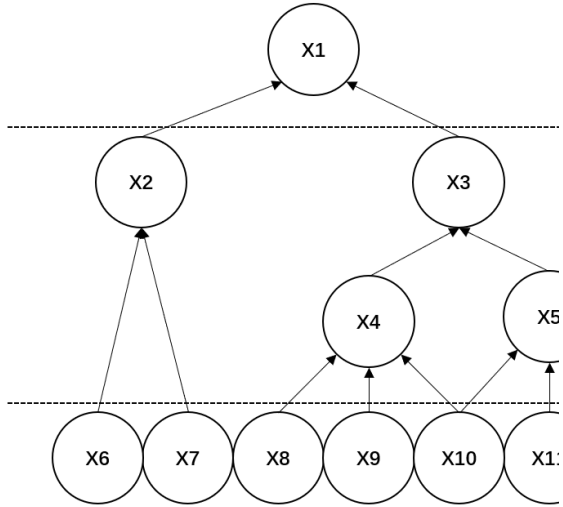


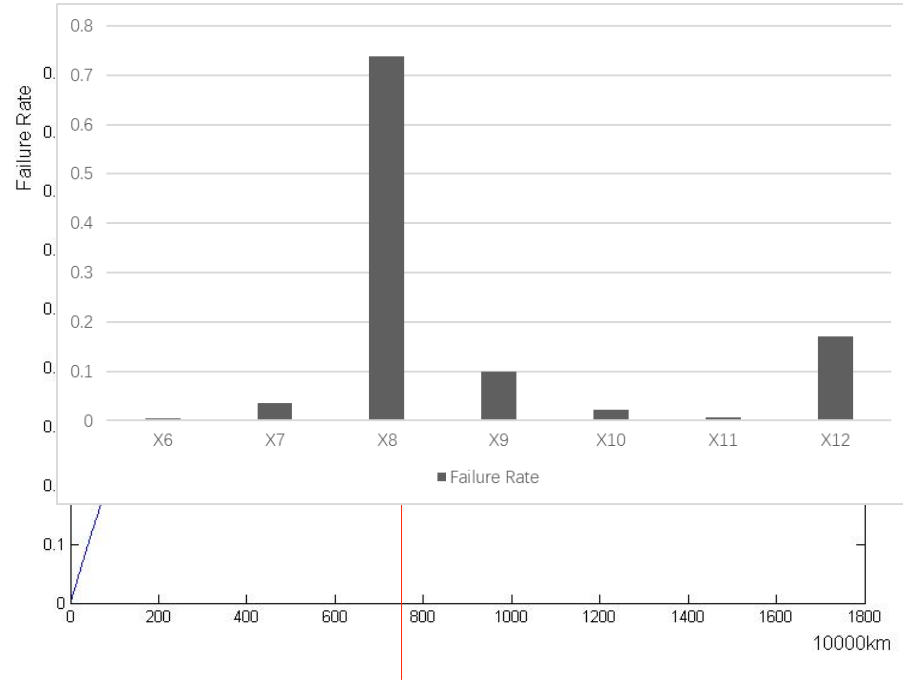
3. BAYESIAN NETWORK-BASED FAULT PREDICTION



4. CASE STUDY

1.AVS
2.Passive device
3.Actuator
4.Mechanical device
5.Electronic device
6.Spring
7.Damper
8.Pump and piston
9.Servo valve
10.Power
11.Sensors
12.Controller





$$R(t) = e^{-\int_0^t \lambda(t)dt} \qquad MTTF = \int_0^\infty R(t)\,dt \qquad MTTF = 7.78434 \times 10^6\,(km)$$

4.CONCLUSION

- Bayesian networks have unique advantages and great potential in the field of reliability modeling and fault prediction for complex systems. However, there are many deficiencies in this study. Future work will start from the following points:

The case in this paper approximates a linear system, but most of the actual systems are nonlinear. The application of this approach in nonlinear systems still requires practical testing.

We have considered three parts of the system, but for the lifetime of products, environment condition is very important. So, we need to add the environment information as the lowest level nodes to the network.

Conditional probability is not always changeless in a complex system. Bayesian network can also realize conditional probability changes over time.

Bayesian network as a powerful fusion tool should also incorporate more information from different levels.

Thanks!

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