Diagnosis (04)
Bayesian Networks

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Model

Knowledge about “how the world works”

[Russel and Norvig, 2003]

Mathematical representation of the behavior of the environment that enables to simulate it.

[Grastien, 2005]
“There will always be things about the device that the model does not capture. The good news is that the things the model fails to capture may have no pragmatic consequence. A schematic for a digital circuit will not indicate the color, smell or coefficient of friction of the plastic used to package the chips, but this typically doesn’t matter. In theory, the model is always incomplete, and hence incorrect, in some respects, but it is a demonstration of the power and utility of engineering approximations that models are often pragmatically good enough.”
1. Bayesien Networks

2. Diagnosis by Bayesien Networks

3. Extensions
1. Bayesien Networks

2. Diagnosis by Bayesien Networks

3. Extensions
What a Bayesian Network is

A directed acyclic graph:
- a node is a variable + a domain of values
- an arc between two nodes is a conditional dependency between the assignments of the variables on the nodes.

In a causal Bayesian network, the arcs represent causal relations.
→ Causal Graph
State of the System

State

A state of the system is a valuation of all the variables.

<table>
<thead>
<tr>
<th>$v_0$</th>
<th>$v_1$</th>
<th>$v_2$</th>
<th>$v_3$</th>
<th>$v_4$</th>
<th>$v_5$</th>
<th>$v_6$</th>
<th>$v_7$</th>
<th>$v_8$</th>
<th>$v_9$</th>
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<tbody>
<tr>
<td>R</td>
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<td>G</td>
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Probability

\[
P(G_0) \times P(T_1) \times P(R_2) \times \\
P(H_3 \mid G_0) \times P(B_4 \mid G_0) \times P(O_5 \mid T_1 \land R_2) \times P(W_6 \mid T_1 \land R_2) \times \\
P(R_7 \mid H_3 \land B_4) \times P(C_8 \mid B_4 \land O_5) \times P(S_9 \mid O_5 \land W_6) = \\
\frac{1,285,956}{10^8} \approx 1.3\%\
\]
Can You Compute...

- $P(R_7 \mid G_0 \land T_1 \land R_2)$?
- $P(G_0 \mid H_3 \land B_4)$?
- $P(R_0 \mid R_7 \land G_8 \land N_9)$?

The most probable value of $v_7$ given $G_0 \land T_1 \land R_2$?
The most probable value of $v_0$ given $C_3 \land F_4$?
The most probable value of $v_0$ given $R_7 \land G_8 \land N_9$?
Bayesian Networks

Diagnosis by Bayesian Networks

Extensions
System Model

Faults

Observations

\[ \begin{align*}
\nu_0 &\rightarrow R \quad 0.4, \quad G \quad 0.5, \quad B \quad 0.1 \\

\nu_1 &\rightarrow T \quad 0.7, \quad F \quad 0.3 \\

\nu_2 &\rightarrow L \quad 0.1, \quad R \quad 0.9 \\

\nu_3 &\rightarrow C \quad 0, \quad H \quad 1, \quad R \quad 0, \quad G \quad 0.4, \quad B \quad 0.6 \\

\nu_4 &\rightarrow F \quad 0.8, \quad B \quad 0.2, \quad R \quad 0, \quad G \quad 0.1, \quad B \quad 0.3, \quad 0.7 \\

\nu_5 &\rightarrow O \quad 0, \quad T \quad 1, \quad L \quad 0.7, \quad T \quad 1, \quad R \quad 0.7, \quad 0.3, \quad F \quad 0.1, \quad L \quad 0.8, \quad F \quad 0.2, \quad R \quad 0.1, \quad F \quad 0.1, \quad 0.9 \\

\nu_6 &\rightarrow K \quad 0, \quad W \quad 1, \quad T \quad 1, \quad L \quad 0.6, \quad T \quad 1, \quad R \quad 0.4, \quad F \quad 0.7, \quad L \quad 0.1, \quad F \quad 0.2, \quad 0.8, \quad F \quad 0.1, \quad R \quad 0.6, \quad 0.4 \\

\nu_7 &\rightarrow C \quad 0, \quad R \quad 0.6, \quad C \quad 0, \quad F \quad 0.4, \quad C \quad 0, \quad B \quad 0.5, \quad B \quad 0.5, \quad 0.5, \quad H \quad 0.2, \quad F \quad 0.8, \quad H \quad 0.7, \quad 0.3 \\

\nu_8 &\rightarrow C \quad 0, \quad G \quad 0.2, \quad 0.8, \quad F \quad 0, \quad T \quad 1, \quad F \quad 0, \quad T \quad 0, \quad B \quad 0.4, \quad 0.6, \quad B \quad 0.8, \quad T \quad 0.8, \quad 0.2 \\

\nu_9 &\rightarrow N \quad 0, \quad S \quad 1, \quad O \quad 0, \quad K \quad 1, \quad O \quad 0, \quad W \quad 0, \quad T \quad 0, \quad K \quad 1, \quad T \quad 0, \quad W \quad 0, \quad 1 \\
\end{align*} \]
Diagnosis

### Diagnosis State

A diagnosis state is a valuation of the fault variables.

### Diagnosis

Given a distribution of probabilities (usually 0s and 1s) over the valuation of the observation variables

- Determine the most probable diagnosis states
- Compute the distribution of probabilities over the diagnosis states
Example
1. Bayesien Networks
2. Diagnosis by Bayesien Networks
3. Extensions
Temporal Behavior

In some domain, there is a delay before a cause generates an effect.
Example: a high temperature can damage a device after several minutes.