Diagnosis (06)
Diagnosis by Chronicles

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1 Systems to Diagnose
2 Chronicle
3 Chronicle Recognition
4 Generation of Chronicles
1 Systems to Diagnose

2 Chronicle

3 Chronicle Recognition

4 Generation of Chronicles
Notion of Event

Definition (erk.)
An event is *something that happens at some time.*

Example
- “The button is switched on.”
- “A mail is received.”
- “An alarm is emitted.”
- “The temperature increases.” (but not “The temperature is increasing”)
- “The temperature starts increasing.”, “The temperature ends increasing.”
- “The temperature reaches a high value.”
Formal Definition of an Event

Beware!

event occurrence $\neq$ event type

An event (occurrence) is defined by:
- Event type (what happened)
- Parameters (more precisely what happened)
- Time of occurrence (when it happened)
- Unique identifier (to distinguish from other similar events)
Diagnosis

Dynamic system

Observations
The observations generated by the system are events.
- Alarm emitted by a component
- Log entry from a software
- Observation of a sensor at a given time
- Sound at a given time
- Etc.

Diagnosis
Determine what happened...
Examples

- Power Supply Networks
- Telecommunication Networks
- Factory
- Web Services
- Mail Servers
- Airplanes
- etc.
1 Systems to Diagnose
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Unformal Definition

Principle

- A chronicle is a *pattern* of events with time constraints
- A chronicle is a signature of a behaviour (normal or faulty) $\rightarrow$ diagnosis

Examples

- The pattern that corresponds to the fact that a light was switched on by mistake is:
  - Light $l_i$ is switched on at time $t$
  - Light $l_i$ is switched off at time $t'$ where $t' < t + 1s$
Formally

**Chronicle [Dousson 1996]**

- A set of events occurrence – an event is
  - An event type
  - A set of parameters
  - A time occurrence
- A set of time constraints between the events

**Example**

Switch([?\(i\),on],\(t_1\))
Switch([?\(i\),off],\(t_2\))
\(t_2 - t_1 \in [0, 1]\)
1. Systems to Diagnose
2. Chronicle
3. Chronicle Recognition
4. Generation of Chronicles
Chronicle Recognition

Switch([l₁,on],0.2)
Switch([l₂,on],0.3)
Switch([l₁,off],0.5)
Switch([l₃,on],0.6)
Switch([l₄,on],1.1)
Switch([l₂,off],1.4)
Switch([l₄,off],1.5)
Switch([l₄,off],1.7)
Switch([l₅,on],1.8)
Switch([l₃,off],1.9)
Switch([l₄,off],2.0)

etc.
Chronicle Recognition

Switch([l1,on],0.2) Chronicle 1
Switch([l2,on],0.3)
Switch([l1,off],0.5) Chronicle 1
Switch([l3,on],0.6)
Switch([l4,on],1.1)
Switch([l2,off],1.4)
Switch([l4,off],1.5)
Switch([l4,on],1.7)
Switch([l5,on],1.8)
Switch([l3,off],1.9)
Switch([l4,off],2.0)
etc.
<table>
<thead>
<tr>
<th>Switch([l1,on],0.2) Chronicle 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch([l2,on],0.3)</td>
</tr>
<tr>
<td>Switch([l1,off],0.5) Chronicle 1</td>
</tr>
<tr>
<td>Switch([l3,on],0.6)</td>
</tr>
<tr>
<td>Switch([l4,on],1.1) Chronicle 2</td>
</tr>
<tr>
<td>Switch([l2,off],1.4)</td>
</tr>
<tr>
<td>Switch([l4,off],1.5) Chronicle 2</td>
</tr>
<tr>
<td>Switch([l5,on],1.7)</td>
</tr>
<tr>
<td>Switch([l5,on],1.8)</td>
</tr>
<tr>
<td>Switch([l3,off],1.9)</td>
</tr>
<tr>
<td>Switch([l4,off],2.0)</td>
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<tr>
<td>etc.</td>
</tr>
</tbody>
</table>
Chronicle Recognition

Switch([l_1, on], 0.2) Chronicle 1
Switch([l_2, on], 0.3)
Switch([l_1, off], 0.5) Chronicle 1
Switch([l_3, on], 0.6)
Switch([l_4, on], 1.1) Chronicle 2
Switch([l_2, off], 1.4)
Switch([l_4, off], 1.5) Chronicle 2
Switch([l_4, on], 1.7) Chronicle 3
Switch([l_5, on], 1.8)
Switch([l_3, off], 1.9)
Switch([l_4, off], 2.0) Chronicle 3
etc.
Chronicle Recognition

Switch([l₁, on], 0.2) Chronicle 1
Switch([l₂, on], 0.3)
Switch([l₁, off], 0.5) Chronicle 1
Switch([l₃, on], 0.6)
Switch([l₄, on], 1.1) Chronicle 2 Chronicle 4
Switch([l₂, off], 1.4)
Switch([l₄, off], 1.5) Chronicle 2
Switch([l₄, on], 1.7) Chronicle 3
Switch([l₅, on], 1.8)
Switch([l₃, off], 1.9)
Switch([l₄, off], 2.0) Chronicle 3 Chronicle 4 etc.
### Hypothesis

The observations are processed in the order they are received.

### Principle

Maintain a list of partial recognised chronicles

When a new observation is received

- Add new chronicles corresponding to the extension of existing chronicles with this event
- Remove the chronicles that can no longer be recognised (because of time constraints)

### Chronicle Recognition System (CRS)

http://crs.elibel.tm.fr/index.html
Example

Switch \([?l,\text{on}]\) \([0, \infty]\) \rightarrow \text{Switch} \([?l,\text{off}]\) \([0, \infty]\)
Observation 1: Switch([I₁, on], 0.2)
Observation 1: $\text{Switch}([l_1,\text{on}], 0.2)$

- $\text{Switch}([?l,\text{on}], [0, \infty])$ \(\rightarrow\) $\text{Switch}([?l,\text{off}], [0, \infty])$
- $\text{Switch}([l_1,\text{on}], 0.2)$ \(\rightarrow\) $\text{Switch}([l_1,\text{off}], [0.2, 1.2])$
Observation 2: Switch([l_2, on], 0.3)
Example

Observation 2: \(\text{Switch}([l_2,\text{on}], 0.3)\)

- \(\text{Switch} \ [?l,\text{on}] \ [0, \infty]\) \(\rightarrow\) \(\text{Switch} \ [?l,\text{off}] \ [0, \infty]\) 
- \(\text{Switch} \ [l_1,\text{on}] \ 0.2 \rightarrow \text{Switch} \ [l_1,\text{off}] \ [0.2, 1.2]\)
- \(\text{Switch} \ [l_2,\text{on}] \ 0.3 \rightarrow \text{Switch} \ [l_2,\text{off}] \ [0.3, 1.3]\)
Observation 3: Switch(\([l_1,\text{off}], 0.5\))

- Switch \([?l,\text{on}]\)
  \([0, \infty]\)

- Switch \([?l,\text{off}]\)
  \([0, \infty]\)

- Switch \([l_1,\text{on}]\)
  \([0.2, 1.2]\)

- Switch \([l_1,\text{off}]\)
  \([0.2, 1.2]\)

- Switch \([l_2,\text{on}]\)
  \([0.3, 1.3]\)

- Switch \([l_2,\text{off}]\)
  \([0.3, 1.3]\)
Example

Observation 3: \( \text{Switch}([l_1, \text{off}], 0.5) \)

- Switch \([?l, \text{on}] [0, \infty]\)
- Switch \([?l, \text{off}] [0, \infty]\)
Example

Observation 4: Switch([l_3, on], 0.6)

Switch \([?l, on]\)
\([0, \infty]\) → Switch \([?l, off]\)
\([0, \infty]\)

Switch \([l_1, on]\)
0.2 → Switch \([l_1, off]\)
\([0.2, 1.2]\)

Switch \([l_2, on]\)
0.3 → Switch \([l_2, off]\)
\([0.3, 1.3]\)
Example

Observation 4: Switch([/3,on],0.6)

Switch
[?l,on]
[0, ∞]

Switch
[?l,off]
[0, ∞]

Switch
[l1,on]
0.2

Switch
[l1,off]
[0.2,1.2]

Switch
[l2,on]
0.3

Switch
[l2,off]
[0.3,1.3]

Switch
[l3,on]
0.6

Switch
[l3,off]
[0.6,1.6]
Example

Observation 5: Switch([l_{4},on],1.1)

Switch [?l,on] [0, ∞] \rightarrow Switch [?l,off] [0, ∞] \rightarrow Switch [l_{1},on] 0.2 \rightarrow Switch [l_{1},off] [0.2,1.2]

Switch [l_{2},on] 0.3 \rightarrow Switch [l_{2},off] [0.3,1.3] \rightarrow Switch [l_{3},on] 0.6 \rightarrow Switch [l_{3},off] [0.6,1.6]
Observation 5: $\text{Switch}([l_4,\text{on}], 1.1)$

- **Switch $[?l, \text{on}]$**
  - $[0, \infty]$
- **Switch $[?l, \text{off}]$**
  - $[0, \infty]$

- **Switch $[l_2, \text{on}]$**
  - $0.3$
- **Switch $[l_2, \text{off}]$**
  - $[0.3, 1.3]$

- **Switch $[l_4, \text{on}]$**
  - $1.1$
- **Switch $[l_4, \text{off}]$**
  - $[1.1, 2.1]$

- **Switch $[l_1, \text{on}]$**
  - $0.2$
- **Switch $[l_1, \text{off}]$**
  - $[0.2, 1.2]$

- **Switch $[l_3, \text{on}]$**
  - $0.6$
- **Switch $[l_3, \text{off}]$**
  - $[0.6, 1.6]$
Example

Observation 6: \( \text{Switch}([l_2,\text{off}],1.4) \)
**Example**

**Observation 6:** \( \text{Switch}([l_2, \text{off}], 1.4) \)

<table>
<thead>
<tr>
<th>Switch ([?l, \text{on}])</th>
<th>[0, 1]</th>
<th>Switch ([?l, \text{off}])</th>
<th>[0, 1]</th>
<th>Switch ([l_3, \text{on}])</th>
<th>0.6</th>
<th>Switch ([l_3, \text{off}])</th>
<th>[0.6, 1.6]</th>
</tr>
</thead>
<tbody>
<tr>
<td>([0, \infty])</td>
<td></td>
<td>([0, \infty])</td>
<td></td>
<td>([0, 1])</td>
<td></td>
<td>([0.6, 1.6])</td>
<td></td>
</tr>
<tr>
<td>([l_4, \text{on}])</td>
<td>[0, 1]</td>
<td>([l_4, \text{off}])</td>
<td>[1.1,2.1]</td>
<td>([l_3, \text{on}])</td>
<td>0.6</td>
<td>([l_3, \text{off}])</td>
<td>[0.6, 1.6]</td>
</tr>
</tbody>
</table>
Observation 7: \( \text{Switch}([l_4, \text{off}], 1.5) \)

<table>
<thead>
<tr>
<th>Switch</th>
<th></th>
<th>Switch</th>
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<th>Switch</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>([0, 1])</td>
<td></td>
<td>([0, 0, \infty])</td>
<td></td>
<td>([0, 1])</td>
<td></td>
</tr>
<tr>
<td>Switch</td>
<td></td>
<td>([0, \infty])</td>
<td></td>
<td>([0, 0, 1])</td>
<td></td>
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<td></td>
<td>([1.1, 2.1])</td>
<td></td>
</tr>
<tr>
<td>([0, 1])</td>
<td></td>
<td>([0, 0, \infty])</td>
<td></td>
<td>([0.6, 1.6])</td>
<td></td>
</tr>
</tbody>
</table>
Example

Observation 7: Switch([l₄,off],1.5)

Switch [?l,on] [0, ∞] \[0, 1]\ Switch [?l,off] [0, ∞]

Switch [l₄,on] 1.1 \[0, 1]\ Switch [l₄,off] [1.1, 2.1]

Switch [l₃,on] 0.6 \[0, 1]\ Switch [l₃,off] [0.6, 1.6]

Switch [l₄,on] 1.1 \[0, 1]\ Switch [l₄,off] 1.5
Example

Observation 8: $\text{Switch}([l_4, \text{on}], 1.7)$

$$
\begin{align*}
\text{Switch} & \quad \text{[0, 1]} \\
[l_4, \text{on}] & \quad [0, \infty] \\
\text{Switch} & \quad \text{[0, 1]} \\
[l_3, \text{off}] & \quad [0, \infty] \\
\text{Switch} & \quad \text{[0, 1]} \\
[l_3, \text{off}] & \quad [0.6, 1.6] \\
\text{Switch} & \quad \text{[0, 1]} \\
[l_4, \text{on}] & \quad 1.1 \\
\text{Switch} & \quad \text{[0, 1]} \\
[l_4, \text{off}] & \quad [1.1, 2.1]
\end{align*}
$$
Example

Observation 8: Switch([\(I_4,\text{on}\], 1.7)

- Switch \([?I,\text{on}] [0, \infty]\)
- Switch \([?I,\text{off}] [0, \infty]\)
- Switch \([I_4,\text{on}] 1.1\)
- Switch \([I_4,\text{off}] [1.1, 2.1]\)

\[0, 1\]
Example

Observation 9: Switch([l_5, on], 1.8)

Switch [l, on] [0, ∞] \rightarrow Switch [l, off] [0, ∞] \rightarrow Switch [l, on] 1.7 \rightarrow Switch [l, off] [1.7, 2.7] \rightarrow Switch [l, on] [0, 1] \rightarrow Switch [l, off] [1.1, 2.1]
Example

Observation 9: Switch([l₅, on], 1.8)

Switch [l₄, on] [1.7, 2.7] → Switch [l₅, on] [1.8, 2.8]

Switch [l₄, off] [1.7, 2.7] → Switch [l₅, off] [1.8, 2.8]
Observation 10: Switch([l₃, off], 1.9)

Switch [l₄, off]
[0, ∞]

Switch [l₄, on]
[0, ∞]

Switch [l₅, on]
[1.1, 2.1]

Switch [l₅, off]
[1.7, 2.7]

Switch [l₄, off]
[1.1, 2.1]

Switch [l₄, off]
[1.7, 2.7]

Switch [l₄, off]
[1.8, 2.8]
Example

Observation 10: Switch([l₃, off], 1.9)

Switch
{l₃, on
[0, ∞]

Switch
{l₄, off
[0, ∞]

Switch
{l₄, on
[0, 1]

Switch
{l₄, off
[0, 1]

Switch
{l₅, on
[1.1, 2.1]

Switch
{l₅, off
[1.8, 2.8]
Observation 11: Switch([l4,off],2.0)
Observation 11: Switch([l4,off],2.0)

Switch [l4,off] [0,∞]
Switch [l5,off] [0,∞]
Switch [l4,off] [1.1,2.1]
Switch [l5,off] [1.1,2.1]

Switch [l4,on] [0,1]
Switch [l4,on] [1.1]
Switch [l4,off] [0,1]
Switch [l5,on] [1.7,2.7]
Switch [l4,off] [1.7,2.7]
Switch [l5,on] [1.7,2.7]
Switch [l4,off] [1.7,2.7]

Switch [l4,on] [0,1]
Switch [l4,off] [2.0,∞]
Switch [l4,off] [2.0,∞]
Switch [l4,off] [2.0,∞]
Example

Switch $[?l, on]$ [0, ∞] \[0, 1]\ Switch $[?l, off]$ [0, ∞]

Switch $[l_4, on]$ 1.1 [0, 1] Switch $[l_4, off]$ [1.1, 2.1]

Switch $[l_4, on]$ 1.7 [0, 1] Switch $[l_4, off]$ [1.7, 2.7]

Switch $[l_5, on]$ 1.8 [0, 1] Switch $[l_4, off]$ [1.8, 2.8]
1. Systems to Diagnose
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Generating chronicles

- By hand (expert knowledge)
- Machine learning
  - From simulation or real data (cf. [Fromont et al., AIME 2005])
  - From model (cf. [Guerraz–Dousson, DX 2005])