Monitoring of Manufacturing Processes

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Problem Space

- **Process Order**
- **Time**
- **Availability**
- **Time for executing replacement**
- **Cost**

### Process Flow

1. **Alarm**
2. **P1: Machine break down**
3. **P2: Machine break down**
4. **P3: Machine break down**

#### Costs

- **Optimization problem locally**
- **Optimization problem in the cloud**

**Notes:**
- $T_a$
- $T_1$
- $T_2$
Monitoring

- **Goal**: analyze an ongoing process to find out whether it behaves according to expectations.
- **Input**: collection of data during system implementation.
- **Output**: the discrepancy found (if any) => no explanation.
- **Terminology**: the system of terms belonging to a specialized subject.
- **Typical example**: monitoring a milling machine.
Monitoring: Terminology

- **System**: set of discrete elements (components, constituents) interconnected or in interaction.
- **Process**: a series of actions or steps taken in order to achieve a particular end.
- **Observations**: measurements obtained from the system or the device to be monitored.
- **Anomaly**: happens when observation conflicts with the way the system is meant to behave.
Monitoring: Terminology

- **Parameter**: an entity for which the current value can be relevant to the purpose of detecting abnormal behavior.
- **Norm**: the expected value or value range of a parameter in the case of normal behavior.
- **Discrepancy**: indicates abnormal behavior of the system being monitored. E.g., small-deviation and medium-deviation.
Monitoring: Problem Formulation

Given:
- A manufacturing process
- A set of observations

Determine whether the ongoing process behaves according to expectations.

Abnormality

Normality
Monitoring: Default Method

- Starts when new findings are received. We need a transfer function:
  - Receive

- After reception of new findings, four inferences are defined for processing the data:
  - Select
  - Specify
  - Compare
  - Classify

Monitoring: Method Control

- Receive (external information -> new-findings);
- Select (new-findings -> parameter);
- Specify (parameter -> norm);
- Compare (norm + new-finding -> difference);
- Classify (difference + historical-data -> discrepancy);
- Historical – data := finding ADD historical – data;

Monitoring: Inference Structure

Transfer function

Inferences

Static role

Dynamic knowledge roles

Taken from “Knowledge Engineering and Management The CommonKADS Methodology”
Monitoring: The Logical Theory

Some definitions

• **Process**: A pair \((PD, PARA)\), where
  - \(PD\) is process description
  - \(PARA\) is a set of parameters been selected

• **Set of Observations** \((OBS)\)

• **Observed Process**: A triple \((PD, OBS, PARA)\), where
  - \((PD, PARA)\) is a process, and
  - \((OBS)\) is a set of observations
Monitoring: The Logical Theory

Some definitions

- **Parameter** $x \in PARA$: one parameter that is measured during one manufacturing process.
- **Observed Value** of the Parameter $x$: $V(x)$.
- **Expected value** in the case of normal behavior: $Norm(x)$. 
Monitoring: The Logical Theory

- \( PD \) and \( OBS \) can mention a unary predicate denoted \( AB (x) \), which is interpreted with the meaning “parameter \( x \) shows an abnormal value”.

- Symmetrically, we have \( \neg AB (x) \) for representing “parameter \( x \) shows an normal value”.

Monitoring: The Logical Theory

- If $\text{Norm} \ (x)$ is a specific value, we have

<table>
<thead>
<tr>
<th>$\neg AB (x)$</th>
<th>$V (x) = \text{Norm} \ (x)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$AB (x)$</td>
<td>$V (x) \neq \text{Norm} \ (x)$</td>
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</table>

- If $\text{Norm} \ (x)$ is a value range, we have

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Monitoring: The Logical Theory

- When $AB(x)$ is true, for each $x \in PARA$, we can compute the distance of parameter $x$ from the normal value:

$$Dis(x) = \sqrt[2]{|V(x)|^2 - |Norm(x)|^2}$$

- Then, the classification of $x$ could be represented:

$$Dis(x) \cup C(x) \rightarrow D(x),$$

Where $C(x)$ is the classification for $x$. 
Monitoring: Anchoring Problem

- Processes need to "talk about" the same physical objects.
- Anchoring is the problem of connecting, inside an artificial system, symbols and sensor data that refer to the same physical objects in the external world.
- Needs to be solved in any robotic system that incorporates symbolic components.

Monitoring: Method Variations

- Sometimes there is an ordered list of the potential discrepancies, e.g., *small-deviation, medium-deviation*.

- Model-driven monitoring: executed at regular points in time, e.g., each hour.

- In many domains monitoring and diagnosis are tightly coupled.
Monitoring: Discussion

- Process description \((PD, OBS, PARA)\). For \(PD\):

\[
\text{EV}_1 \xrightarrow{t_1} \text{EV}_2 \xrightarrow{t_2} \text{EV}_3 \xrightarrow{t_3} \ldots \xrightarrow{t_{n-1}} \text{EV}_n
\]

E.g. If \((EV_1, t)\) and \((t_1 + t_2 + t_3 + \ldots + t_{n-1}) > t_{max}\), then there is 80% of possibility that machine will break down at \(EV_n\).

\(t_{max}\) is the threshold value of duration that one abnormal behavior can cause the machine break down.
Thank you!