Efficient Monitoring of Multi-Disciplinary Engineering Constraints with Semantic Data Integration in the Multi-Model Dashboard Process

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Motivation & Goals

Motivation:
- Heterogeneous and Multi-Disciplinary Engineering (ME) Environments.
- Changes in individual disciplines can have an impact on product and project quality and need to be identified early.

Key research question focus on:
- How to enable selective observation of critical project parameters in heterogeneous environments?

Goals of the paper:
- Multi-Model Dashboard Process (MMD).
- Feasibility Study on MMD Prototype Tool Implementation.
Engineering Process Data in ME Projects
Challenges & Needs

1. Engineering Team Workspace for parameter and constraint definition unclear.
2. Data collection in heterogeneous engineering environments are inefficient and error-prone.
3. Central Dashboard approach for project-level parameter and constraint evaluation is missing.
Related Work and Research Issues

- **Risk Management** in Heterogeneous Engineering Environments
  - Distributed and heterogeneous engineering tools and data models might lead to defects (even across disciplines) that are hard to identify.
  - Critical project parameters need to be monitored to identify changes / deviations early.

- **Awareness of Constraints** in Multi-Model Industrial Plant Engineering Environments
  - Dependencies of parameters/constraints across engineering disciplines.
  - E.g., Constraints must be observed to guarantee max. power consumption, max. heat radiation, max. weight, or available development effort.

- **Data and Tool Integration in Engineering Environments**
  - Individual tools apply a variety of tools and data models that need to be well integrated.

**Research Issues:**

- How to establish a **process that supports the selective observation** of critical engineering project parameters and constraints (the MMD process approach).
- How can a **tool support** the MMD process to enable efficient and effective parameter and constraint observation (prototype implementation).
MMD Process Approach

- Local Engineering Level (within private workspaces) vs. Project Level (in team workspaces).

- **Definition** of parameters and constraints according to stakeholder needs; Goal is to have an agreed list of **required** and **available** parameter/constraints.

- **Mapping** of local concepts to common concept (knowledge engineer).

- **Monitoring** of subscribed parameters on local engineering level.

- **Evaluation** of parameters and constraints on project level.

- **Publication** of evaluation results and notification of changes and/or constraint violations.

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**Project Level**

1 Definition Phase:
   1a. Parameter
   1b. Constraints

2 Mapping Phase
Local vs. common representations

3 Monitoring Phase
Observation of critical parameters

4 Evaluation Phase:
   4a. Parameter
   4b. Constraints

5 Publication Phase:
Notification of Constraint violations

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**Local Engineering Level**
Mapping of Local Representations to Common Concepts

- Individual Local tools and data models.
- Overlapping (data) areas to enable synchronization between engineering plans coming from different disciplines.
- Mapping of local representations to the common data model (contribution of a knowledge engineer).
Candidate Use Cases

- Observing critical project parameters can address several needs within heterogeneous and distributed engineering projects (e.g., in project consortia)

**Examples Use Cases:**
- **UC-SI:** Automated process monitoring of a production system simulation, e.g., observation of conveyor capacity.
- **UC-DE:** Plant design and construction, e.g., impact of process design on heat radiation.
- **UC-EL:** Electrical systems design, e.g., observation of the overall power consumption in a configuration of devices.
- **UC-PM:** Project effort and cost monitoring based on project planning and individual effort reporting systems within project consortia.

**Use Case Parameters Related Data**

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Parameters</th>
<th>Related Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC-SI</td>
<td>Throughput, Cycle Time</td>
<td>Items per time interval, duration, number of items</td>
</tr>
<tr>
<td>UC-DE</td>
<td>Maximum weight and applied weight</td>
<td>Capacity of basement, individual weights of equipment</td>
</tr>
<tr>
<td></td>
<td>Cooling power needs and capacity</td>
<td>Cooling capacity, heat radiation of machines</td>
</tr>
<tr>
<td>UC-EL</td>
<td>Power consumption and needs</td>
<td>Power needed by equipment, overall power available</td>
</tr>
<tr>
<td>UC-PM</td>
<td>Time and project plans and effort</td>
<td>Individual milestone planning, working effort per person/artifact</td>
</tr>
</tbody>
</table>
Step 1: Parameter / Constraint Definition

Evaluation of the Prototype Implementation

- UC-PM: Project effort and cost monitoring based on project planning and individual effort reporting systems within project consortia.

- Parameter (Variable) and Constraint definition.

- Available Artifacts/Files: XLS, CSV, PDF, TXT, individual engineering plans (if needed)
Step 2: Mapping and Step 3: Monitoring
Evaluation of the Prototype Implementation

- **Mapping** of local representations to common concepts (representations).
- Typically Knowledge Engineers support the mapping process.
- Established links can enable **continuous monitoring** (of subscribed) parameters in local representations.
Step 4: Parameter / Constraint Evaluation
Evaluation of the Prototype Implementation

- Parameter and Constraints Observation
- Evaluation of simple and more complex parameters/constraints
- Short summary of evaluation results (validity flag)
- More details on involved parameters for further analysis

Evaluation Result Summary
Step 5: Publication and Notification
Evaluation of the Prototype Implementation

- Role-specific selection of parameters and constraints (in individual contexts) to be evaluated, e.g., for project management purposes.
- Notification based on changes and constraint violation
  - Via E-Mail
  - Accessible via MMD
Cost / Benefit Considerations

- MMD enables
  - Focused definition of success-critical parameters and constraints
  - Selective observation and monitoring of subscribed parameters and constraints
  - Efficient publication and notification mechanisms.

Process Performance Consideration

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Effectiveness</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual</td>
<td>MMD</td>
</tr>
<tr>
<td>1a Parameter definition</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td>1b Constraint definition</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td>2 Linking parameters to local representations</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>3 Change monitoring in local engineering models</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>4a Parameter evaluation</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td>4b Constraint evaluation</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td>5 Publication of parameters / constraints</td>
<td>o</td>
<td>++</td>
</tr>
<tr>
<td>Overall</td>
<td>o</td>
<td>++</td>
</tr>
</tbody>
</table>

Legend: ++ Positive Effects, -- Negative Effects
Summary & Future Work

Summary

- Heterogeneous and Multi-Disciplinary Engineering (ME) Environments.
- Changes in individual disciplines can have an impact on product and project quality and need to be identified early.
- The MMD enables the selective observation of subscribed parameters and constraints across engineering disciplines in heterogeneous environments.

Future Work

- Investigation of scalability constraints and further development of MMD features.
- Application in various industry contexts.
Thank you ...

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