Assessment of Digital Twin manufacturing frameworks

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In 2017 our team issued a call for Digital Twin manufacturing framework examples.

- 10 examples were received from 4 countries

We classified the examples and used them as input for a new ISO 23247 standard.

The author then extended the classifications and used them to measure the performance of a small scale digital twin framework.

The team results are shown on slides 3 and 4, and the rest describe the authors results.
Framework classifications

<table>
<thead>
<tr>
<th>Level of Detail</th>
<th>Physical Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>material/component level (production item)</td>
<td>Personnel</td>
</tr>
<tr>
<td>process level (production line)</td>
<td>Equipment</td>
</tr>
<tr>
<td>site level (many processes)</td>
<td>Material</td>
</tr>
<tr>
<td>enterprise level (supply chain)</td>
<td>Process Definition</td>
</tr>
<tr>
<td>regulatory level (industry sector)</td>
<td>Product Definition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication styles</th>
<th>Application Paradigm</th>
</tr>
</thead>
<tbody>
<tr>
<td>closed loop adjustment</td>
<td>real time control</td>
</tr>
<tr>
<td>collision prevention</td>
<td>off line analytics</td>
</tr>
<tr>
<td>visualization</td>
<td>preventative maintenance</td>
</tr>
<tr>
<td>off line analysis</td>
<td>health check</td>
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</tbody>
</table>
Framework benefits

- **Owner/Operators**
  - Want to know real-time comprehensive status of their manufacturing/production
  - Want to drive optimization and production efficiency to maximize profit

- **Production/Machinist/Operators**
  - Want a more intuitive user interface
  - Want to prevent mistakes

- **Engineers**
  - Want more comprehensive view to understand the true value of their efforts
  - Want to eliminate non-value add tasks such as data re-entry

- **Maintenance**
  - Want insight to why equipment is failing
  - Want windows of opportunity to do preventative maintenance

- **Subcontractors**
  - Want access to information so they can bid more easily and accurately
  - Want ability to share manufacturing processes

- **Equipment suppliers and builders**
  - Want to make it easier to implement and integrate their products
  - Want to efficiently monitor equipment performance for improved performance

- **IT developer / integrator**
  - Want to be certain organizational security and access control protocols are being followed
  - Want system to robust, flexible, fault tolerant, accurate, scalable and wherever possible non-prescriptive

- **Regulatory agencies**
  - Want to prove that a process has been followed
  - Want a standardized interface into product information

- **Software vendors**
  - Want a consistent, reliable, affordable interface to external data, tools and systems
  - Want to make it easier to deploy their solutions

- **Standards Development Organizations (SDO's)**
  - Want to promote their standards
  - Want to enhance their value by becoming part of an eco-system
Two Digital Twin qualities

• Observable
  • A digital twin is a model of something that is observable in the real world.
  • Describes one or more aspects of the real world phenomenon.
  • Makes it easier to understand, use, control, or operate.

• Measurable
  • The digital twin is “meaningful” to measure.
  • Will learn something about the physical twin.
  • Will not get the same result for every twin.
Digital Twin machining experiment

- Small scale framework (one agent)
- Shown on two five axis machine tools at IMTS 2018
- Twin performance measured after the show from log files
Small Scale Framework

Physical Twin

Digital Twin
## Experimental results

- Twitches are differences to the lowest significant digit of a value
  - Many twitches are roll overs

- Changes are new values in the tool location
  - Many changes are on the same path

- Points are locations where the direction of machining changes
  - These must be captured to make an accurate digital twin

<table>
<thead>
<tr>
<th></th>
<th>Twitches</th>
<th>Changes</th>
<th>Points</th>
<th>Change %</th>
<th>Point %</th>
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<th>Short</th>
<th>Long</th>
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<tbody>
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<td>5.00E-03</td>
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</tbody>
</table>
Small Scale Framework

- **Digital Twin Challenges**
  - We can measure models in real time
  - Identify issues, optimize processes
  - Coordinate multiple operations

- **Digital Twin Benefits**
  - Stronger, lighter structures
  - Reduced tooling costs
  - Adaptive manufacturing
Proposal for medium scale

Twin Server
• Single large memory space
• Many cores (128)
• One core per agent

Applications
• Collision prevention
• Dynamic scheduling
• Accuracy management
Large Scale Framework

ISO 23247
Part 1 Overview
Part 2 Architecture
Part 3 Digital Representation
Part 4 Information Exchange

Complete automotive or aerospace plant
Conclusion

• A digital twin is a measurable model of a physical element that can be observed in the real world.

• A digital twin agent processes messages streamed from sensors and uses them to synchronize the current state of digital twins with that of their corresponding physical elements.

• A small scale framework manages one agent. A medium scale framework manages multiple agents in a shared memory space. A large scale framework manages multiple levels of agents distributed between many memory spaces.