Spinning a Smart Digital Thread for MBSE of Cyber Physical Systems

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• Challenge - Disintegrated Silos-of-Excellence

• What is a Digital Thread?
  • Use Cases
  • Graphs – a mathematical formalism for Digital Threads

• Digital Thread in action using Syndeia (Demo)
  • Building
  • Querying
  • Publishing
  • Digital Thread API

• Digital Thread for Smart Manufacturing – NIST Case Study

• Open Standards and Protocols
Disintegrated Silos-of-Excellence

- Diversity of models
  - Requirements
  - Architecture (SysML, UPDM, AADL, ...)
  - Design / Manufacturing
  - Software code, tests, releases
  - Simulation (lumped param. -> 3D FEA/CFD)
  - Project management
  - Test Management

- Configuration Management (CM of CMs)
- Impact analyses
- Information propagation
- Continuous integration / milestone releases

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Digital Thread – A Simple Example

If I change this requirement, what is the downstream impact, e.g. to CAD and CAM models?

Requirements (e.g. DOORS-NG)  Mechanical Design (CAD, e.g. NX, CREO, STEP)  Manufacturing (CAM, e.g. MTConnect)  Quality & Inspection (e.g. QIF)

Trace the CAD and CAM models for this part and compare attributes against test results.

Inter-model relationships  Intra-model relationships
Digital Thread Use Cases

1. Unified entry point to access distributed product data
2. Seamless navigation and unified search
3. Link / Relate model elements
4. Model Transformations
5. Track changes
6. Information flows to propagate changes
7. Finding and fixing broken relationships
Graphs – A Mathematical Formalism for Digital Thread

• Graph – Nodes and Edges
• Nodes and Edges may have
  • Name
  • Type (Typed Graph)
  • Properties (Property Graph)
• Edges may have
  • Direction (Directed vs. Undirected Graph)
• Graphs can be
  • Stored
  • Queried (Pattern matching)
  • Traversed (e.g. Breadth-first, Depth-first)
  • Generated and Transformed
  • Analyzed
Product Models as Graphs

Simulink model

System Model (SysML)
Contents

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• Digital Thread for Smart Manufacturing – NIST Case Study

• Open Standards and Protocols
• Builds a **digital thread** for your system

• Provides services to:
  • **Relate/Link models**
  • **Generate models**
  • **Compare and sync**
  • **Visualize and query**

• Syndeia Cloud / REST API

Visit [www.syndeia.com](http://www.syndeia.com) to learn more and download
Digital Thread in action using Syndeia (Demo)

1. Building the Digital Thread
   - SysML (MagicDraw)
   - Requirements (Jama)
   - PLM (Windchill, Teamcenter)
   - Project Mgt. (JIRA)
   - Software (GitHub)
   - Parts Library (MySQL)

2. Querying & Publishing
   - REST API
   - Graph Queries
   - OpenMBEE
      - Model-driven Views

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Access and Search Multiple Model Repositories

例——通过单一接口（Syndeia — www.syndeia.com）连接多个企业模型仓库
Drag-n-Drop to Generate Models & Relationships

Example using Syndeia (www.syndeia.com)

Switch repos

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Pattern Matching to Generate Relationships Across Models

Find all matches between elements in a SysML package and issues in JIRA project such that name of the element is contained in JIRA issue summary.

Generate Relationships between matches.
## Compare & Synchronize Inter-Model Relationships

Example using Syndeia (www.syndeia.com)

<table>
<thead>
<tr>
<th>Conn ID</th>
<th>Source</th>
<th>Target</th>
<th>Latest Target</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>e3f03...</td>
<td>Unmanned Aerial Vehicle</td>
<td>000464/C;2-Unmanned Aerial Vehicle</td>
<td>000464/C;2-Unmanned Aerial Vehicle</td>
<td>The block Unmanned Aerial Vehicle...</td>
</tr>
<tr>
<td>wimax module : WiMax Module</td>
<td>wimax module : 000472/A;1-WiMax M...</td>
<td>wimax module : 000472/A;1-WiMax M...</td>
<td>Part property wimax module and...</td>
<td></td>
</tr>
<tr>
<td>visual camera : Visual Camera</td>
<td>visual camera : 000475/A;1-Visual Ca...</td>
<td>visual camera : 000475/A;1-Visual Ca...</td>
<td>Part property visual camera and...</td>
<td></td>
</tr>
<tr>
<td>trackers : Sensor</td>
<td></td>
<td></td>
<td>Part property trackers has no co...</td>
<td></td>
</tr>
<tr>
<td>thermal camera : Thermal Camera</td>
<td>thermal camera : 000476/A;1-Therma...</td>
<td>thermal camera : 000476/A;1-Therma...</td>
<td>Part property thermal camera an...</td>
<td></td>
</tr>
<tr>
<td>software : Software System</td>
<td>software : 000487/B;1-Software Syst...</td>
<td>software : 000487/B;1-Software Syst...</td>
<td>Part property software and part...</td>
<td></td>
</tr>
<tr>
<td>payload controller : Payload Controller</td>
<td>payload controller : 000470/A;1-Pay...</td>
<td>payload controller : 000470/A;1-Pay...</td>
<td>Part property payload controller ...</td>
<td></td>
</tr>
<tr>
<td>modem : Spread Spectrum Radio M...</td>
<td>modem : 000474/A;1-Spread Spectru...</td>
<td>modem : 000474/A;1-Spread Spectru...</td>
<td>Part property modem and part o...</td>
<td></td>
</tr>
<tr>
<td>ir detector : Wide Angle IR Detector</td>
<td>ir detector : 000477/A;1-Wide Ang...</td>
<td>ir detector : 000477/A;1-Wide Ang...</td>
<td>Part property ir detector and pa...</td>
<td></td>
</tr>
<tr>
<td>gps : GPS</td>
<td>gps : 000466/A;1-GPS</td>
<td>gps : 000466/A;1-GPS</td>
<td>Part property gps and part occu...</td>
<td></td>
</tr>
<tr>
<td>gprs module : GPRS UMTS Module</td>
<td>gprs module : 000473/A;1-GPRS UM...</td>
<td>gprs module : 000473/A;1-GPRS UM...</td>
<td>Part property gprs module and p...</td>
<td></td>
</tr>
<tr>
<td>flight controller : Flight Controller</td>
<td>flight controller : 000469/A;1-Flight...</td>
<td>flight controller : 000469/A;1-Flight...</td>
<td>Part Property flight controller an...</td>
<td></td>
</tr>
</tbody>
</table>
Graph Queries on Digital Thread (1/2)

Get DOORS-NG requirements linked to JIRA issues
Get all GitHub issues related to DOORS-NG requirement “Object ID Requirements”, and get all relationships to / from those GitHub issues.
Publish Digital Thread Views as Web-Based Documents

Relationships between model elements in the digital thread (SysML, JIRA, and Teamcenter PLM shown here) are queried using Syndeia’s REST API and published in OpenMBEE View Editor as tables.

Click on the links to open in JIRA or Teamcenter.
REST API for building apps for Digital Thread

Syndeia Cloud 3.2

- Heartbeat: Monitor server status
- API: REST API Swagger Documentation
- Demo: Watch in action
- User Guide: Access the complete documentation for Syndeia 3.2 here
- Tutorials: Access the complete set of tutorials for Syndeia 3.2 here
- Help Desk: Visit our help desk to ask questions, report issues, and suggest improvements.

Relation Management
- GET /api/v1/artifacts/{id} Get an artifact given the artifact id
- GET /api/v1/artifacts/externalkey/{externalkey} Get an artifact given the artifact external key
- GET /api/v1/artifacts/container/{contKey} Get all artifacts given the container key
- POST /api/v1/relations Create a new relation
- GET /api/v1/relations Get all relations
- PUT /api/v1/relations/{key} Update relation given the relation key
- GET /api/v1/relations/{key} Get a relation given the relation key
- DELETE /api/v1/relations/{key} Delete a relation given the relation key
- GET /api/v1/relations/{key}/versions Get all versions of a relation given the relation key

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Digital Thread for Smart Manufacturing
Case Study with NIST

Testbed model for proof-of-concept – Configurable UAV

Enclosure Box for an Avionics assembly used in the Configurable UAV
Available data and models for the Enclosure Box

- **SysML** model of the UAV and the payload
- CAD models for multiple variants and revisions of the Box *(SolidWorks files on GitHub)*
- Design flow management in **JIRA**
- 20 instances of each part are manufactured. For each instance:
  - Machine sensor data streams for each part instance *(MTConnect 1.3 XML on GitHub)*
  - NC code data - ISO 6983 *(G-code files on GitHub)*
  - First article inspection reports *(QIF 2.1 XML on GitHub)*
  - Receiving inspection reports *(QIF 2.1 XML on GitHub)*
Approach for organizing the digital thread – Schema and Related Models

Product Concept Level

- Jama: Box Reqs
- Jama: Cover Reqs
- NIST MTC CRADA ASSBLY
  - NIST MTC CRADA BOX
  - NIST MTC CRADA COVER

Design Variant Level

- JIRA: Box Design Status
- GitHub: Box Design CAD
- NMC ASSBLY Rev D
  - NMC BOX Rev D
  - NMC COVER Rev B

Part Instance Level

- GitHub: Box Mfg Data
- GitHub: Box Quality Data
- GitHub: Box Incoming Data
- NMC ASSBLY SN D01
  - NMC BOX SN D01
  - NMC COVER SN B01
Example Graph Query on Digital Thread for Enclosure Box

$ MATCH (m:GitHub_File)-[r1]-(n:Block)-[r:Allocate]-(s:Block{name:"NIST_MTC_CRADA_BOX"}) RETURN m,r,...

CAD File > nist_mtc_crada

Design Variant > NIST_MTC_C...

Product Concept > NIST_MTC_C...

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Open Standards for Digital Thread – Some Examples

- Systems Engineering – SysML v1.x / SysML v2, UPDM/UAF, AADL
- Product Model Data – ISO 10303 (STEP), OSLC, PLCS, QIF
- Simulation Standards – FMI, HLA (ISO 1516)
- Data flow formats – JSON, XML, CSV
- API standards - OpenAPI
- Databases – JDBC, SQL, Gremlin, openCypher, GQL
- Manufacturing – MTConnect
References


