Implementing a Native XML Database

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Database Requirements

Two main files in database
- Missions: List of space missions and the technological capabilities with associated metrics required/desired by each mission
- Technologies: List of existing and proposed technologies, along with the capabilities they offer and associated metrics

Modest size requirements
- No more than a few thousand records in each file

Handle hierarchical data well
- Mission structures are hierarchical in nature

Easily modifiable structure
- Requirements and technologies are ever-changing

Ease of Use
- Data entry/modification, data extraction
- Documentation

Cross-platform access
- Analysts may use their own computers to extract data
Technical Approach

Hierarchical database
- Better match for handling hierarchical data than relational DB

Use web browser based interface
- Cross-platform and easier to user

Standard protocols and interfaces
- Allows pieces to be replaced if needs change
- Cross-platform

Use Java as the language
- Good support for client/server, XML, web interface

XML Schema for schema description
- Turbo XML from TIBCO for schema design & modification

XQuery for querying database
- Qexo is open source, but incomplete
- Looking for alternatives
Data does not easily fit into tables
  ❖ No clean rows and columns
  ❖ Hierarchical in nature
  ❖ Poor match for relational database storage
  ❖ Would require large numbers of sparse tables

Ideally suited for XML format
  ❖ High ratio of object types to number of objects

Added XML bonus: suitability for Web use
  ❖ Many tools exist for display and manipulation of XML data

Disadvantages
  ❖ XML data uses lots of storage space—tags are repeated for each entry
  ❖ Retrieval can be slow
  ❖ Memory based DB => upper size limit of 1-2 GB
Why Not Use a Table?

Example—A mission capability such as Formation Flying can contain a number of optional systems, such as:

- Formation Initialization, Fine Formation Flying, Stop & Stare Formation Flying

Each of the above has its own set of optional systems. Formation Initialization might require:

- Target Acquisition, Positioning, GN&C

GN&C might require some of the following subsystem capabilities:

- Collision/Constraint Avoidance, Fault Tolerance, Formation State Executive, Formation Executive, etc.

Difference instances of GN&C require different sets of capabilities

These requirements are met more efficiently by a hierarchical structure than a tabular one
### Mission Capabilities:

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>34</td>
<td>Mission Capabilities:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>1. Multiple Spacecraft Integration &amp; Testing</td>
<td>316.6</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>2. Launch, Cruise &amp; Orbit Insertion</td>
<td>316.6</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>3. Multiple Spacecraft Ground Control</td>
<td>316.6</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>4. Spacecraft Infrastructure (Power, Thermal)</td>
<td>316.6</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>5. Formation Flying</td>
<td>256.2</td>
<td>Y</td>
<td>125</td>
</tr>
</tbody>
</table>

### Table Details:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>5.2.2.1.</td>
<td>Acquire Relative Bearing</td>
<td>3.8</td>
</tr>
<tr>
<td>47</td>
<td>5.2.2.2.</td>
<td>Acquire Relative Range</td>
<td>3.8</td>
</tr>
<tr>
<td>55</td>
<td>5.2.3.1.</td>
<td>Collision/Constraint Avoidance</td>
<td>1.9</td>
</tr>
<tr>
<td>56</td>
<td>5.2.3.2.</td>
<td>Fault Tolerance</td>
<td>1.9</td>
</tr>
<tr>
<td>59</td>
<td>5.2.3.3.</td>
<td>Formation State Estimation</td>
<td>1.9</td>
</tr>
<tr>
<td>61</td>
<td>5.2.3.4.</td>
<td>Formation Executive</td>
<td>1.9</td>
</tr>
</tbody>
</table>

### Parameters:

- **Acquire Relative Bearing**: 3.8
- **Acquire Relative Range**: 3.8
- **Collision/Constraint Avoidance**: 1.9
- **Fault Tolerance**: 1.9
- **Formation State Estimation**: 1.9
- **Formation Executive**: 1.9

### Unit Details:

- **Degree**: 1
- **Degree/minute**: 10
- **Degree/second**: 50
- **Hz**: 25
- **100 Hz**: 1
- **200 Hz**: 1
- **100 Hz**: 1
- **100 Hz**: 1

### References:

- **Field of Regard**: 10 x 10
- **Bearing Knowledge**: 1.0 degrees
- **Bearing Rate Knowledge**: 1.0 degree/minute
- **Operational Range**: 15-100 meters
- **Range Knowledge**: 1.0 meters
- **Range Rate Knowledge**: 1.0 cm/s
- **Accuracy**: 1
Hierarchical Display

- Deployment
  - Separate_SC
    - Verify_SC_Separation
    - Provide_Delta_V
    - Collision_Avoidance
    - Structural_Deployment
  - Coarse_Form_Man_Reconfig
    - Position_Acquisition
    - HS_SC_To_SC_Comm
    - GNC
    - Positioning
  - Fine_Form_Flying
  - Stop_Stare_Form_Flying
  - OnTheFly_Observation
  - Init_Lost_SC_Acquisition
XML vs Tables

data volume

little

XML

Tables

lots

structure
Overall Architecture

Turbo XML
- Design data structure (schema)

XEdit
- Input data
- Add branches
- Modify data

Mission File

Technology File

NMP Database

Reports

XEval
- Generate queries
- Maintain query library
- Query database
Developed by this task to handle mission and technology data for NMP

- Changes to schema do not require XEdit modification
- Instead, new JAR files encapsulating schema information are generated by Castor

  Castor is open source code that generates Java descriptor files for each XML element in the schema—used for data binding purposes

- XEdit is then run with the new JAR files

Inputs data to database and allows hierarchy branches to be added or deleted

- Branch modification is controlled by information in the schema

Can enter data values or modify them
Adding and Deleting Branches
Modifying Data Values

### XEdit: NMP's XML Database Editor

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range_Knowledge</td>
<td>2 cm</td>
</tr>
<tr>
<td>Range_Rate_Knowledge</td>
<td>0.0026 cm/s</td>
</tr>
<tr>
<td>RRK_Measurement_Duration</td>
<td>continuous</td>
</tr>
<tr>
<td>Operational_Range</td>
<td>30–1000 m</td>
</tr>
<tr>
<td>Bearing_Knowledge</td>
<td>0.0628 mrad</td>
</tr>
<tr>
<td>Bearing_Rate_Knowledge</td>
<td>6.77x10^-5 mrad/s</td>
</tr>
<tr>
<td>BFK_Measurement_Duration</td>
<td>continuous</td>
</tr>
<tr>
<td>Field_of_Regard</td>
<td>1.22 rad</td>
</tr>
<tr>
<td>Update_Frequency</td>
<td>1 Hz</td>
</tr>
</tbody>
</table>
Querying the Data

Web based interface
- Allows for form based customizable queries
- Accessible through any web browser
- Easy to navigate

Java Servlet backend
- Processes HTML from posts
- Interfaces with Qexo (Xquery engine)
- Query results formatted in HTML

Fully customizable query editor is under development

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New Millennium Program
Developing and testing advanced technology in space flight.

NMPDB Queries

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Sample Query #1
Find all missions that use capabilities addressed by "IRAS" technology

[Execute Query]

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Sample Query #2
Find all Capabilities of Mission MagCon

[Execute Query]

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Sample Query #3
Find all Technologies that address any Capability needed by mission MagCon

[Execute Query]
Current Status

Database server computer set up

Software installed

- Mandrake Linux
- NetBeans for Java development
- TurboXML for schema development
- XML Transform for reorganizing database
- Castor for data binding
- Qexo for data querying

First version of XEdit delivered

Web based query interface demonstrated for sample queries
Future Plans

Revise XEdit as needed

Improve database reorganization process

Purchase/modify/write database XML Query engine

Purchase/write GUI for query generation

Report generator
  - Can export data to spreadsheets for further analysis

Implement multi-user capabilities
  - Assign write privileges to only certain users
Summary

Hierarchical XML database matches structure of the data

Mix of commercial, open-source, and in-house software

Industry standards being used: HTML, XML, XSchema, XQuery, Java Servlets

Have acquired or developed tools for schema generation, data entry and modification, data querying

Currently working on developing visual interface for data queries
Acknowledgement

The NMP Office sponsored this work