Multi-model Environment: Links between Objects in Different Building Models

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Reasons for Separation of the Models

• Earlier research has recognized problems in the use of one integrated building product model:
  ◦ PM4D Final Report (Kam and Fischer 2002)
  ◦ John Haymaker recognizes the need for several models in his Ph.D. research: “Perspectors” (Haymaker et al, 2003)
  ◦ However, to our knowledge, a formal division to separate building product models has not been published

• Reasons for the separation of instantiated models:
  ◦ Different data content and structure of the models
  ◦ Greater flexibility if the models are connected with a “thin” link
  ◦ Access control; who can change a specific model
  ◦ Specific for the separation of requirements & design models:
    • Internal structure of design software does not support shared attributes; multiplication of requirements if in design model
    • Alternative designs which all should meet the requirements
    • Reliability; removal of a design object does not remove its requirements
    • Distinction between requirements and properties
Separation of Models: Direct & Indirect Links

- Two main issues:
  - Current IFC specification does not have a method for links between two different models ⇒ Linking method must be defined.
  - Definition of direct and indirect links on project basis by end-users is too difficult and laborious ⇒ The requirements model specification must be detailed and include both link types.

A generic model or a specification consisting of only few requirements is not possible to use in practice.
Basic Concept: **Space Requirements**

- **Requirements Model**
  - **Space Program Types (SPT)**
    - Office type 1
      - type specific requirements
  - **Space Program Instances (SPI)**
    - Office room O1
      - type requirements
      - required area
      - number of rooms
      - department
      - adjacency
    - Office room O2
      - type requirements
      - required area
      - number of rooms
      - department
      - adjacency
    - Meeting room M1
      - individual requirements including area, number of rooms, department and adjacency
    - Lab room L1
      - type requirements
      - area
      - number of rooms
      - department
      - adjacency

- **Design Model**
  - Physical space instances with locations
  - **Space instances**
  - Indirect requirements for bounding elements and technical systems

Links between Objects in Different Models

- **Requirements Model**
  - **Requirements Object**
    - **Requirements Data**
  - **Model Type & Address**
  - **Object Link**

- **Design Model A**
  - **Design Object**
    - **External Object Reference**
    - **Design Data**
  - **Model Type & Address**
  - **Object Link**

- **Design Model B**
  - **Design Object**
    - **External Object Reference**
    - **Design Data**
  - **Model Type & Address**
  - **Object Link**

Design objects are linked to their requirements, but requirements are not linked to the design objects.
The links between the design/production/maintenance models must be two-directional.
Modified IfcExternalReference: Express-G

EXTENSION IfcExternalReference

ENTITY IfcExternalReference
ABSTRACT SUPERTYPE OF (ONE OF IfcLibraryReference, IfcClassificationReference, IfcDocumentReference, NewExternalObjectReference);
Location : OPTIONAL IfcLabel;
ItemReference : OPTIONAL IfcIdentifier;
Name : OPTIONAL IfcLabel;
WHERE
WR1 : EXISTS(ItemReference) OR EXISTS(Location) OR EXISTS(Name);
END_ENTITY;

Modified EXPRESS specification:
ENTITY IfcExternalReference
ABSTRACT SUPERTYPE OF (ONE OF IfcLibraryReference, IfcClassificationReference, IfcDocumentReference, NewExternalObjectReference);
Location : OPTIONAL IfcLabel;
ItemReference : OPTIONAL IfcIdentifier;
Name : OPTIONAL IfcLabel;
WHERE
WR1 : EXISTS(ItemReference) OR EXISTS(Location) OR EXISTS(Name);
END_ENTITY;
GUID Problem: Internal & Interoperability ID

Some Examples of Links between Requirements and Design Models
Basic Relations of Indirect Requirements

Project
- Site
  - Building
    - Building Stories
      - Spaces
    - Systems
      - Building Envelope
      - Circulation System
      - Structural System
      - Technical Systems

Basic Relations in the Requirements Model

Requirements Model
- Project Objectives
- Site/Design Requirements
- Building Requirements
- Story Requirements
- Space Requirements

Design - Production - Maintenance Models
- Project
- Site
- Building
- Story
- Space

Legend:
- Part of PMB
- Part of CPM
- Other relevant elements

7 main-level objects
30 sub-level objects
275 requirements

Grey elements are not in the scope of the research.
Example: *Space Lighting Requirements*

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CodeReference</td>
<td>References to lighting codes related to the space</td>
</tr>
<tr>
<td>Daylight</td>
<td>Daylight required in the space</td>
</tr>
<tr>
<td>NoDaylight</td>
<td>Daylight not allowed in the space</td>
</tr>
<tr>
<td>Darkenable</td>
<td>Description of shade requirements for windows and other openings</td>
</tr>
<tr>
<td>MaxLuminance</td>
<td>Maximum illuminance in the working area</td>
</tr>
<tr>
<td>MinLuminance</td>
<td>Minimum illuminance in the working area</td>
</tr>
<tr>
<td>LuminanceDistribution</td>
<td>The luminance distribution on different surfaces in the field of view</td>
</tr>
<tr>
<td></td>
<td>determined by the reflectance and the illuminance on the surfaces</td>
</tr>
<tr>
<td>LightingAdjustability</td>
<td>Description of the required level of individual lighting control in the</td>
</tr>
<tr>
<td></td>
<td>space</td>
</tr>
<tr>
<td>LusterReflection</td>
<td>Allowed level of luster reflection in the space</td>
</tr>
<tr>
<td>ColorRenderingIndex</td>
<td>Required minimum color rendering index for light sources in the space</td>
</tr>
<tr>
<td>MaxColorTemperature</td>
<td>Maximum color temperature of the light sources in the space</td>
</tr>
<tr>
<td>MinColorTemperature</td>
<td>Minimum color temperature of the light sources in the space</td>
</tr>
<tr>
<td>DirectionalLighting</td>
<td>Description of the required level of directional lighting</td>
</tr>
<tr>
<td>GlareIndex</td>
<td>Required maximum glare index for light sources in the space</td>
</tr>
<tr>
<td>ShadowFormation</td>
<td>Description of the balance between diffuse and directional light in the</td>
</tr>
<tr>
<td></td>
<td>space</td>
</tr>
</tbody>
</table>
Solution for the Information Granularity

ENTITY NewProjectObjectives
  SUBTYPE OF (NewRequirement);
    GeneralObjectives : OPTIONAL NewRequirementsDescription;
    TotalBuildingVolume : OPTIONAL NewRequirementsAttribute;
  END_ENTITY;