Product Family Modelling in The Construction Industry

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Product Family Modelling

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  - Different kind of product models
  - Object models, GDL, IFC, PLIB, etc.
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- Product Family Models as the foundation for building models
  - Attributes, domains, domain constraints – relational constraints
  - From product family model to finalised product model
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**Product Modelling - A Strategic Research Area**

- Design methodologies - the design process
- Design knowledge – reuse of existing solutions
- The product model – properties, components and structures
- Representations - multiple abstraction levels:
  - dual view: requirement versus fulfilment
- Applications based on product models
  - Graphic presentations – multiple views
  - Model manipulation – virtual Reality
  - Product configurators
  - Product documentation
**Topic: Product Models and The Building Model**

- **Building Model**
  - Model of Standard Object/End-product
    - Finalised
  - Model of Standard Element/Product
    - Parameterised
  - Model of Structured Product
    - Finalised/Parameterised/Configurable

**Suppliers Configuration**
- Proprietary Product Family Model
- Open Product Family Model

**Designers Configuration**
Object Models as the foundation

- Models are built from objects
- Object properties are specified
  - Geometry
  - Materials
  - Prices
Building Model Design Tools – Libraries of Object Types

Ex: furniture
Import of Product Models into Building Models

- **Libraries of object types**
  - Standard object types are included in design systems
  - Additional library object types can be inserted
  - Preliminary design can be carried out by selection of such objects
  - Relationships between objects are automatically maintained by the tools

- **Insertion of external models of building objects and products**
  - GDL based models – GDL interface is required
    - GDL models are parameterised
  - IFC based product models – interface is required
    - IFC models are not parameterised
  - Product models based on the ISO-PLIB standard??
Exchange of GDL Product Models

- GDL objects can be formulated with parameters
- Product families can be represented by GDL models
- Each product family can be represented in one model
- Each end-product is defined by a set of parameter values
- GDL models can be imported into CAD systems e.g. ArchiCAD
- Object-represented models can be built from GDL models
- GDL models can be integrated with larger product models
- A possible basis for product development in networks
Industrial Foundation Classes (IFC)

- A basis for building modelling
- IFC is the currently most dominating data model
  - Based on STEP/ISO10303
  - Newest version IFC2x(2)
  - Approved as ISO/PAS 16739
  - Well accepted by leading parties in the industry
- IFC defines a foundation for building design
  - A hierarchy of object types (classification)
  - Relationship types for linking objects
  - A large set of building object types are defined
  - A large set of concepts are defined internationally
Objektklasshierarki i IFC 1.5.1 (Projektrapport Tarandi 990305)
IFC saknar åtskillnad mellan funktionella och fysiska objekt
**Building Modelling With IFC Objects**

**IFC Object Types**
- Contain an initial set of attributes
- Additional attributes can be defined – property sets
- Attributes defining 3D geometry
- Additional attributes for materials, surfaces, cost, etc.

**IFC based objects in the building model**
- Building models are created by selection of object types
- Specified by assigning attribute values
- Stepwise specification can be performed to further detail
- Objects can be exchanged via a standard format
- Export from and import into a number of building design systems

**IFC is a foundation for developing product models**
**Product Models – Towards Mass Customisation**

Three forms of product models

- **Finalised models**
  - All attribute values are assigned unchangeable values
  - E.g. special building objects, as-built end-products, etc.

- **Parameterised models**
  - Values of a subset of the attributes can be modified
  - E.g. most building elements, windows, doors, beams, columns, etc.
  - Building products like stairs, gates, etc. could be developed
  - Often transformed to finalised end-product models

- **Configurable models – models of product families**
  - Attributes as well as components and structure are defined
  - Can be reduced to parameterised or finalised models
Product Models and The Building Model

Building Model

Model of Standard Object/End-product - Finalised

Model of Standard Element/Product - Parameterised

Model of Structured Product - Finalised/Parameterised/Configurable

Supplier Configuration

Designer Configuration

Proprietary Product Family Model

Open Product Family Model
Product Family Models is The Foundation

Product family models are often proprietary
- Suppliers perform the configuration to finalised product models

Building architects need parameterised or configurable models
- Some degree of openness is required
- With open product family models, the designer can perform configuration

New approach: semi open product family models?
- The manufacturer can perform configuration to a certain point
- The manufacturer delivers a still configurable or parameterised model
- The designer can perform further configuration or finalisation
- Each manufacturer can secure his competitive uniqueness
- The designers can maintain a higher degree of freedom
Product Models and Product Family Models

PF

CP₁, CP₂, ..., CPₖ, ..., CPₙ

PP₁, PP₂, ..., PPₖ, ..., PPₙ

Product Family

Configured Product

Physical Product

Model World

Real World

Configuration

Manufacturing
Modelling of Products and Product Families

Basic concepts

- Product Model – the synthetic view
- More precise concepts: Product Family and Product Family Model
  - Product family: set of end-products
  - Product family model: synthetic and generic model of product family
  - Product model: model generated from a product family model
  - Product: end-product manufactured from its product model

Product family model

- Key issues: determination of properties of the end products
- Structural view of product families
  - Modularisation, modules versus attributes, functionalities
Typical view: the structural view

Product Level

Module Level

Component Level
Product Specification: attributes versus modules

![Diagram showing the relationship between attributes and modules in a product family.]

- **Product**
  - **Attribute 1**
    - **Module 1**
      - \( C_1 \), \( C_2 \), \( C_3 \)
  - **Attribute 2**
    - **Module 2**
      - \( C_4 \), \( C_5 \), \( C_6 \)
  - **Attribute 3**
    - **Module 3**
      - \( C_7 \), \( C_8 \)
    - **Module 4**
      - \( C_9 \), \( C_{10} \)
  - **Attribute 4**
    - **Module 5**
      - \( C_{11} \)
Product Family Models

Attributes - product attributes and module attributes

- Data types: numeric, boolean, string, etc.
- Domains: the set of possible attribute values
  - enumerated values
  - intervals
- Domain constraints: OneOf, AtMostOne, AtLeastOne, AnyOf, Optional
- Default values, optional

Examples related to doors:

Door.Doorstep Optional [Yes, No] Default[Yes]
Door.Handle AtMostOne [<list of handles>]
Lock.Screws one of [0..10]
**Product Family Models**

Relational Constraints

- Define the solution space
- Set of relationships – relation expressions
  - logical, examples:
    - Door => Lock
    - Door.Material <=> Doorstep.Material
  - arithmetic, example:
    - Door.Hinges >= [2]
- Inference engine is very efficient:
  the inference time decreases with increased number of user selections

Baan: E-Configuration Enterprise system – The Cava Language
From Product Family Model to Finalised Product Model

- The product family model can be developed from top
  - Level of detail is related to the need for configuration
  - Further details can be added simultaneously

- A configurator can be developed based on this model
  - Normally configurators produce models of finalised end-products
  - The product model may be public but the configurator is proprietary

- It should be possible to generate public models
  - Such models could be parameterised or configurable on a lower level
  - With constraint based configurators it is easy to generate such models
  - The already made configuration decisions can simply be added to the original constraints as additional constraints
  - A derived configurator can be generated
Sample development projects in Denmark

F. L. Smidt & Co.
- Product: cement manufacturing plants
- Configurator for tender support

Aalborg Industries – www.aalborg-industries.com
- Product: modular boilers
- Configurator for calculation of budget cost

Demex Electric – www.demex-electric.dk
- Product: electric control panels
- Product configurator for layout and component selection

Triax
- Product: Parabolic antennas
“End-to-end Availability Solutions for Data Networks”

APC provides power protection, environmental control and site monitoring services that are designed to proactively identify and correct problems before downtime occurs.
APC: Product Selector/Configurator

Solutions

Simple UPS accessories Configurator

Complex Solution Configurator

Cable Selector

Service Selector
**APC: Results / Outcome**

![Diagram showing time (Hour) for different processes](image)

- **Qualification of lead**: 12 hours
- **Needs Assessment**: 16 hours
- **Quote Generation**: 12 hours
- **Order Configuration**: 8 hours
- **Build & Ship**: 4 hours
- **Install**: 4 hours

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Conclusion

Product Modelling - A Strategic Research Area
Building Modelling: Industrial Foundation Classes (IFC)
Product Models – Towards Mass Customisation
- Finalised – parameterised – configurable
- A need for import of open configurable models into building models
Product Family Models – The Basis For Product Configuration
- Object-oriented representation of product families
- Definition of attributes: data type, domain and domain constraints
- Definition of relational constraints
Balance between proprietary and public information
- Makes it possible to provide semi-open configurable models