Multimodel-based exploration of the building design space and its uncertainty

Hervé Pruvost
Dr. Peter Katranuschkov
Prof. Raimar Scherer

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Scope of presentation

1. Multimodel method: motivation and usage

2. Extension of Multimodel method for BIM design space exploration

3. Integration of uncertainty in BIM information space

4. Simulation and collection of computed metrics
Multimodel:

- Initially developed in German research project „Mefisto“ (2009-2012), further development since then:
  - buildingSMART „MMC Project“
  - DIN-SPEC 91350
  - ISO/NP 21597 (Information Container for Data Drop)
- Proposes a method and a data exchange model for integrating and linking together information from different engineering domains
- Offers a exchangeable project data resource for enabling and easing collaboration in building design and construction.
- Integrate heterogeneous and domain-specific data into a common data exchange model while maintaining native data formats.
Goals of this work:

- Enabling building design optimization with regard to several criteria reflecting different engineering domains.
- Integrate different heterogeneous information from different application domains for the sake of a energy-efficient building design.
- Allow for making and modelling several changes in this information.
- Support uncertainty analysis of different building design options.
- In one single simulation request, simulates n (1 to hundreds) different building design options.
Multimodel = set of m application models and n link models + annotations as metadata.

- Application Model
  - Embedded or referenced
  - Multiple files and formats (IFC, GaebXML, CSV, etc.)

- Link Model
  - links.xml
  - LinkModel.xsd

- Multimodel metadata
  - multimodel.xml
  - MultiModel.xsd

- Container
  - Contain all data mentioned above (e.g. as zip file)
Example of Multimodel for construction planning

Multimodel:
**Explicit, neutral & ID-based links** between the application model’s elements

- Bill of Quantities [GAEB-XML]
- Building [IFC]
- Schedule [MS Project]
- Link Model

**Links:**
- Item ID = 1.3.10
- IfcColumn ID = i$aq12
- Task ID = 343456
- Unit Price => 49.76 €
- Storey => 16
- Start => 21.06.2013 12:00:00
Multimodel Container used as exchange model within a collaborative design work

- Simplified BPMN diagram of a design workflow focusing on building energy
Extension of MM for support of different design solutions and uncertainty analysis

**3 levels of Multimodel data variations:**

- **Design alternatives:**
  - one IFC model each

- **Design variants:**
  - Based on design alternatives
  - one Link Model each

- **Stochastic realizations:**
  - Based on design variants
  - Set of randomly sampled values of some specific variables

IFC model as central product model

Data from other application models: **product templates, district energy system model**, etc.
Integration of uncertainty in analysis workflow

- Some application models are associated with uncertainty: e.g. occupancy model, climate model, energy system...
- Sampling-based approach applicable with existing market solvers (e.g. TRNSYS, EnergyPlus...)
- Stochastic variables transformed into a set of sample values included into MMC
Risk metrics derived from uncertainty and its simulation

Stochastic variables (Regressors)

- Climate
- Building usage
- Component failures

Cost KRIs
- Operation costs variance
- Maintenance costs variance
- Investment costs variance
- ...

Sustainability KRIs
- Energy demand variance
- CO2 emission variance
- ...

Vulnerability KRIs
- System failure rate
- Average unavailability
- Mean Time to Failure
- ...

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Occupancy modelling for energy simulation:

- Occupants interact with the energy system in two ways, indirectly by emitting heat, and directly by interacting with the energy system or energy relevant appliances (e.g. light switches).
- Foundation for both is the presence of the occupant.

Method: 1st order Markov Chain (Richardson et al., 2008)

- Simulates number of present/active occupants per zone
- Differentiates between zone types (e.g. kitchen, bureau, ...) and day types (e.g. weekday, weekend)
- Flexible modelling and fast computation time

Sampling service:

Occupancy data (room types and max nb of occupants) preliminary linked with IFC model in MMC

- Use of “transition probability matrices”
- Generation of samples (time series of occupant numbers)
Data generated by sampling for occupancy:

- From each transition matrix, an arbitrary number of samples can be generated
  - Time series representation:

```
Graphical representation of 1 sample of occupant numbers
```

- Tabular representation for further usage in energy simulation tools:

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Example of 4 samples with 10 minute time step and occupancy density (occupant/m²)
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For enhanced accuracy, the climate data samples are real weather data records from the past that are formatted in the weather data format TRY.

Example of weather data time series in the TRY format. Data for Chemnitz, Germany, retrieved from DWD (Deutscher Wetterdienst)

Variables:
- Outdoor temperature
- Wind speed
- Wind direction
- Humidity
- Solar radiation
- Etc...
Application to reliability analysis of energy system

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Application to reliability analysis of energy system

Top/Down curves expressed as a set time series embedded in the Multimodel Container and linked to related ES components:
Data variation model example for energy simulation in early design

3 design variants

Related IFC-GUID (one IfcBuilding and 20 IfcRoom entities)

1 Cimate
20 occupancy time series
n samples
Visualization of results from uncertainty analysis

- Visualization of simulation results in term of energy demand for heating by three different design variants (Granlund Optimizer)
Weighting and normalization of KRI for assessing compliance of actual risk level against risk appetite
Conclusion and future Activities

- **Conclusion:**
  - Multimodel method extended to fasten and facilitate setting and simulation of a large amount of variants and uncertainties in a collaborative building design workflow.
  - Method adapted for assessing uncertainty on the basis of standard simulation tools.
  - Generic variation model was developed for describing stochastic realizations of BIM data as well as several types of design alternatives.

- **Future works:**
  - Encompass more simulation domains e.g. structural analysis, reliability analysis, life cycle cost...
  - Apply for sensitivity analysis.
  - Couple with cloud-computing technologies.
Thank you for your attention