Switching to a holistic perspective on semantic component models in building automation: tapping the full potential of automated design approaches

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Agenda

Design of Building Automation Systems
Formal Component Models
Typical Practical Problems
BA-GSem – Graph-based Semantic Component Model
Conclusion & Next Steps
Design of Building Automation Systems

Challenges

Highly complex design process

— Many trades
— Huge number of nodes
— Diversity of technological solutions
  – Many communication technologies
  – Many manufacturers
  – Many devices / device variants available
— Interoperability issues

→ Computer-based design tools required for design space exploration
Design of Building Automation Systems
Automated Design Approach

Domain Knowledge
- Based on **VDI 3813** standard
- Domain functionality modeled as function blocks

Algorithms for System-Synthesis
- Exploration of design space
- Multiple Design Candidates determined based on information flows

**Product Repository**
- **Formal models** of functionality for automation components

**Result:**
Multiple Design Candidates
Formal Models of Device Functionality

General Device Model

Building automation system = network of communicating devices
— Functionality
— Information Exchange

Aspects of Device/Product & Modeling Aim:

— Hardware → Physical connections
— Device Application / Software Modules → Logical connections
— Semantic Model → Functionality
Formal Models of Device Functionality
Typical Practical Problems

1. **Consistency** of functionality model
   - “Can a certain functional model be transferred to other device variants?”
   - “Is software ‘TemperatureController‘ usable for a specific device variant?”
Formal Models of Device Functionality
Typical Practical Problems

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2. **Effort** for model specification & model quality
   - “Does each device variant need a whole functional model?”
   - “Are there implicit constraints for functionality assignment of device variants?”
Formal Models of Device Functionality

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3. **Limited model expressiveness**
   - “What is the information flow and processing in the software?”

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**Software Module: tctrl**

```
Semantic Model

Temperature Controller

T_ROOM

V_SET

T_SETPTS

P_ACT

T_SETPT

T_SETPT

T_SETPT

Adjust Temp. Setpt

Calculation

T_SETPTS

T_SETPTS

T_SETPTS

Network Input

Peripheral Interface

Network Output

valvePos

tempSetptDial

roomTemp

occupState

T_SETPT

T_SETPT

T_SETPT

valvePos
```
Formal Models of Device Functionality

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3. Limited model **expressiveness**
   - “What is the information flow and processing in the software?”

4. Heterogeneous model **quality**
   - “Can the models be used for the engineering task?”
Formal Models of Device Functionality
State of the Art

Classification approaches (eCl@ss, ETIM, profiCl@ss)
- Distinguishes device classes
- Focus on isolated aspects (procurement), coarse functionality

Electronic self-description (LON-XIF, KNXPROD)
- Software interface modeled in formal manner
- Technology-specific models, lack detailed semantic information

Preliminary semantic component model [Dibowski2011]
- Technology-neutral semantic component model
- Interface modeled coarsely (software / semantic), no links between aspects
- Monolithic component models
Formal Models of Device Functionality
Requirements

1. Precise Modeling
   - Offer structures with high level of detail

2. Ease of Specification and Use
   - Effort for creation in acceptable magnitude
   - Effort for usage in acceptable magnitude

3. Robustness of Use
   - Cope with heterogeneous levels of detail
Formal Models of Device Functionality
Contributions

1. Precise Modeling
   – Offer structures with high level of detail
     → Graph-based semantic model BA-GSem

2. Ease of Specification and Use
   – Effort for creation in acceptable magnitude
   – Effort for usage in acceptable magnitude
     → Identification of important component aspects for modularization

3. Robustness of Use
   – Cope with heterogeneous levels of detail
     → Discussion of impact on system design tasks
BA-GSem
Existing Component Models

Level of Detail: Sem1
— Set of Semantic Functions

Level of Detail: Sem2
— Set of Semantic Functions
— Semantic Type Annotation for Datapoints
BA-GSem
Graph-based Semantic Component Model

Level of Detail: Sem3 (BA-GSem)
— Functional Component Model of a Software Module
— ... in context of an operation mode (= parameterization)

Legend:
- Semantic Information Flow
- Software & Semantic Mapping
- Semantic Data Point (Network)
- Semantic Data Point (Periphery)
- Software Data Point (Network)
- Software Data Point (Periphery)

OM: Operation Modes
FB: Semantic Function Block

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Conclusion & Future Work

Recap
— Automated design approaches require functional component models
— Drawbacks of existing component models
  – Isolated aspects
  – High effort
  – Low Expressiveness

Proposal of BA-GSem
— High-expressive graph-based semantic model for BA components
— Contains different aspects & relationships → enables modularization

Next steps
— Further reduction of specification effort → Tooling support for model specification
— Integration with product information modeling tools
Thank you for your attention!