Enabling Warehouse CAD – Semantic Template for Model Based Warehouse Analysis and Design
Outline

- Motivation
- Prior work / Context
- Design concept
- Design semantics
- Warehouse semantics
- Integrated semantics
- Future Work / Remaining challenges
Motivation

- **GOAL:** Model driven approach for warehouse analysis and design – Warehouse CAD

- Tools that enable new warehouse designs to be completed faster, cheaper, and with better resulting performance require a formalized understanding of the artifact and a standard representation of its components.

- Need for comprehensive formal semantics defining the meaning of symbols used for describing (i) warehouse resources and activities, (ii) warehouse control, (iii) intermediate abstractions used during design, and (iv) the warehouse design process.
Prior work / context

GOAL

Warehouse CAD

Comprehensive formal semantics

Prior work

Design Workflow
Author(s): Goetschalckx, McGinnis, Sharp
Published: IMHRC 2008, Dortmund

Order picking blocks
Author: Geißen et al.
Published: Informs 2010, Austin

Order picking analysis
Author: Blunck, Vogdt, McGinnis
Published: IIE Conference 2011, Reno

Control Model
Author: Friemann, Klennert, McGinnis
Published: IIE Conference 2010, Cancun

Profiling
Author: XYZ
Published: ABC
**Design concept: Functions & streams**

- **Starting point:** Most abstract warehouse specification possible:

  ![Diagram of a warehouse with in-stream, out-stream, and implementable function]

- **Functional design:** Creating 1st iteration function flow network (FFN) by splitting up streams up to the point of implementable functions (→ design semantics)
  - Nodes split up streams or join streams → transformation of streams
  - Arcs conserve streams → transformation of place

- **Warehouse design:** Designing nodes and arcs of FFN (→ warehouse semantics)
Systems engineering process for warehouses

- **Design semantics ≠ Warehouse semantics**

- **Design semantics** used during functional design phase → until implementable functions are identified (functional decomposition)

- **Warehouse semantics** used during operation strategy & equipment selection, sizing & dimensioning, defining department and overall layout
Design semantics – Functional Design

- **Design semantics**
  - supports functional design
  - depicts functions and streams
  - describes what should be done / shows which transformations should take place and their rates / deviations

- **Functional design from most simple warehouse specification, which is**
  - Warehousing function: Transforming input streams into output streams

- **Function flow network showing implementable functions**
  - Functions transforming time, space, orientation, quantity, compilation, status, value
  - E.g. check quality, transport/put away, store, pick, assemble, palletize, pack
Design semantics

- Functional Design Example: Simple; 1st iteration Function Flow Network
- Possibility of splitting up functions and streams in subsequent iterations
Warehouse semantics

- Warehouse semantics
  - describes how sth. should be done
  - depicts detailed warehouse specification
    - includes processes, structure, resources, and requirements
    - includes warehouse control
    - “easy” readable and accessible
    - allows different views on artifact
  - supports analysis and design of arcs and nodes of FFN
    - Enable model transformation and model execution
  - enable creation of libraries/pre-defined components to capture expert knowledge
Specifying order picking (warehouse semantics)

■ Library element “Order picking with static supply of staging units” (left) (captured expert knowledge)

■ Cut out from specification in adherence to warehouse semantics (right)

Geißen et al., “Evaluation of Decision Criteria to Select Efficient Order Picking Systems” at Informs Conference 2010, Austin

Analysis of order picking (warehouse semantics)

- Used parameters are part of warehouse semantics
- Combination of existing models and warehouse semantics

Design decision support

Observing picking performance

Integrated semantic model

- Integrating **design semantics** and **warehouse semantics** within ONE semantic model.

- Support of whole warehouse design process:
  - from functional design to
  - detailed specification
  - enabling consistent Warehouse CAD
Integrated semantic model – Context within design process
Integrated semantic model – Structure & Containment Tree

Adapting INCOSE´s “Cookbook for MBSE with SysML”

- using repeating expressive descriptors
- containment tree “easy” to access and to update
- enabling division of labor, because knowledge of subsystems bundled within subfolders

Views on warehouse elements and libraries:
- analysis, behavior, structure, requirement, types
SysML representation of Integrated semantic model (top level)
Future work / Remaining challenges

- Identify what types of tools for which tasks are best
  - How to link these tools with SysML semantics
  - Model transformation
- Creation of comprehensive libraries
- Further semantics-checks and extensions of semantics
- Implementing Integrated Warehouse CAD-Framework
Thank you!

We are glad to answer your questions!