A Reuse- and Prototyping-based Approach for the Specification of Building Automation Systems

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Properties of Building Automation Systems

Desired Control of Physical Effects
Properties of Building Automation Systems

**Coupling of Physical Effects**

![Coupling of Physical Effects Diagram]

<table>
<thead>
<tr>
<th>type of building</th>
<th>total sensors and actuators</th>
</tr>
</thead>
<tbody>
<tr>
<td>university building with 100 offices and computer labs</td>
<td>2,500</td>
</tr>
<tr>
<td>Burj Al Arab and Jumeirah Beach Hotel, Dubai</td>
<td>26,000</td>
</tr>
</tbody>
</table>

**Size**

- handling of complexity

**Number of Identical Products**

- small ➡ efficient development

**Life Span**

- long ➡ traceability
Development Process

Requirements Engineering

- Building Description
- Problem Description
- Needs
- Object Structure Specification
- Requirements Description
- Task Description
- Domain Dictionary

Requirements Specification

- Object Structure
- Informal Object Type
- Requirements Modeling
- Formal Object Type

Development Step

- Library
- Defects
- Input
- Activity
- Output
- Check
# Reuse

## Expected Benefits
- high **quality** products
- short **development time**

## Reuse Operations

![Diagram of Reuse Operations]

**Evaluation**
- **metric** to quantify gain of productivity
  - *a posteriori* ➞ assessment to gather experience
  - *a priori* ➞ estimation to support development decisions

## Prototyping

## Expected Benefits
- high **quality** products
- short **development time**

## Prototyping Environment

![Diagram of Prototyping Environment]

**Evaluation**
- quality
  - number and types of errors found
- effort
  - prototype application
  - benefit for design
Case Study

Object Structure Specification

building description:
22 rooms, 3 hallway sections

object structure:
25 object types, 920 instances

Case Study

68 needs
Task Description

“Shortly before a person enters a hallway section, the lights
should be turned on, if necessary.”

126 tasks
Requirements Description

“Compute and propagate the light settings considering daylight.”

“Determine occupancy using door.”

126 strategies
Requirements Modeling

“If a door reports the possible entrance of a person (newHW-
DoorEntrance), set occupancy (occupied) to true and report it
(newHWOcc).”

37 SDL object types
Requirements Modeling

Process HWOcc

unoccupied
newHWDoorEntrance

newHWOcc
occupied
Evaluation

- total effort: **26,000 min**
- reuse operations: **118**
  - no artifact found: **37**
  - external: **67**
  - internal: **14**
- prototyping sessions: **45**
  - average duration: **82 min**
  - defects (simulation): **23**
  - defects (phys. env.): **10**
  - defects (inspection): **24**
  - prototype generation: **10 min**
  - code size: **10 MB**
- productivity:
  - reference is earlier case study
  - total gain: **94%**
  - gain caused by reuse: **22%**

Perspectives

Development Process

- expansion: design and new domain
- workflow concept
- quality metric

Reuse

- finding reuse candidates
- effort estimation

Prototyping

- earlier prototyping
- feedback loop
- mixed simulation
- design support
Reuse

**Metric**

- **reuse operation**

  - relative integration effort
    \[ E_{\text{rel,integrate}} = \frac{E_{\text{adapt}}}{E_{\text{create}}} \]
  
  - relative effort for artifact \( a \)
    \[ E_{\text{rel},a} = R_a \cdot E_{\text{rel,integrate}} + (1 - R_a) \cdot 1 \]
  
  - assumption: complexity correlates to effort
    \[ K_a - E_a \]
  
  - relative effort for project
    \[ E_{\text{rel}} = \sum_a \frac{1}{K_a} \cdot \sum_a K_a \cdot E_{\text{rel},a} \]

- **relative productivity for project**
  \[ \frac{P_{\text{reuse}}}{P_{\text{no reuse}}} = P_{\text{rel}} = \frac{1}{E_{\text{rel}}} \]
## Case Study

### Data

<table>
<thead>
<tr>
<th></th>
<th>CS3/1</th>
<th>CS3/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of object types</td>
<td>25</td>
<td>37</td>
</tr>
<tr>
<td>total complexity [units]</td>
<td>688</td>
<td>1826</td>
</tr>
<tr>
<td>total effort [min]</td>
<td>19,000</td>
<td>26,000</td>
</tr>
<tr>
<td>effort per complexity unit</td>
<td>27.6</td>
<td>14.2</td>
</tr>
<tr>
<td>total relative productivity $P_{rel}$</td>
<td>1</td>
<td>1.94</td>
</tr>
<tr>
<td>range of complexity $K_a$ [units]</td>
<td>6..58</td>
<td>9..114</td>
</tr>
<tr>
<td>range of relative effort per artifact $E_{rel,a}$</td>
<td>1</td>
<td>0.44..1.35</td>
</tr>
<tr>
<td>relative productivity $P_{rel}$ caused by reuse</td>
<td>1</td>
<td>1.22</td>
</tr>
</tbody>
</table>

- correlation $K_a - E_{rel,a} = 0.87$

### Quality

- distribution of errors and removal effort

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Andreas Metzger – OMER-2 Workshop – Herrsching – May 10, 2001
Workflow Concept

Testbed

Communication Hierarchy