A Knowledge Domain Structure to Enable System Wide Reasoning and Decision Making

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CONTENT

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• Knowledge domain pattern
• Knowledge domain structure
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CONTEXT: SUPPORT REQUIRED TO HANDLE COMPLEXITY GROWTH

To architect and design a system, decisions on trade-offs have to be made
• Architect satisfies stakeholder needs by technical solutions

Trend is that the system complexity increases\(^1\)
• Number of functions, components, and interfaces increases

Reasoning about decision impact becomes increasingly hard
• Tracing the decision impact throughout the system is crucial

To handle complexity growth, architects require support for:
  - Understanding of and reasoning about decision impact
  - Tracing decision impact throughout the system

CONTEXT: DECOMPOSE SYSTEMS IN KNOWLEDGE DOMAINS

- Knowledge domain (KD): specific area of knowledge and information by a team

- Running example: electric bicycle case
  - Trade-off on cost and usage

Electric bicycle case
CONTEXT: DECOMPOSE SYSTEMS IN KNOWLEDGE DOMAINS

- Knowledge domain (KD): specific area of knowledge and information by a team

- Running example: electric bicycle case
  - Trade-off on cost and usage
  - Source of misunderstanding:
    1. Definitions or terminology
    2. Relations between knowledge domains
    3. Owner
    4. Knowledge domain scope
    5. Abstraction level
CONTEXT: REASONING, UNDERSTANDING, AND DECIDING IS THE CHALLENGE

• Other approaches
  - System architecting: provides multiple views but difficulties on making relations explicit
  - System designing: determine decision impact, but often lacks overview

• Challenge:
  - Reason, understand, and decide about the system-wide impact, whilst using explicit relation
  - Avoid sources of misunderstanding between knowledge domains to enable decisions
• Contributions:
  - Multi-disciplinary architecture reasoning structure, with explicit relations, for system wide reasoning and decision making
  - Knowledge domain pattern, to capture essential information
  - Relations, for both qualitative and quantitative reasoning
  - Approach was investigated and validated in the industrial context of Océ professional printing systems
LANGUAGE ELEMENTS TO CREATE AN INFORMATION STRUCTURE

Electric bicycle case

Frame
- Material: aluminium
- Cost: $400
- Default size is m. The size will effect the stiffness and cost of the frame
- Stiffness: 110 Nm/°/kg

Usage: recreation

Seat post
- Comfort: medium
- Cost: $50

Marketing
- Usage: recreation
- Frame cost: $400
- Seat post cost: $60

Information structure

Legend
- Language element
- Structure information
- Model
- Block
- Transformation
- Parameter
- Validation
- Relation

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Relate information:
- Relate qualitative
  - Relation (R) describe relations
- Relate quantitative
  - Transformations (T) and validations (V) between parameters
  - Model computes output values for transformation and validation

Information structure:

- Usability
  - Block
  - Frame
    - Stiffness: 110 Nm/° /kg
    - Cost: 400. - $
    - Material: aluminium

- Marketing
  - Usage: recreation
  - Frame cost: 400. - $
  - Seat post cost: 60. - $

- Seat post
  - Comfort: medium
  - Cost: 50. - $

Frame cost is around 4 times as high

Default size is m. The size will effect the stiffness and cost of the frame.

Usage: recreation

Frame stiffness: 100 Nm/° /kg

Seat post comfort: low

Model computes output values for transformation and validation.
KNOWLEDGE DOMAIN PATTERN TO STRUCTURE INFORMATION

Architect and owner
• Define the scopes of a knowledge domain via title and background
• Avoids misunderstanding via structured information

Pattern elements
- Essential information
- Advised information
- Visual supportive information

Diagram:
- Frame
  - Title
  - Main entity
  - Relation
  - Explanation
  - Transformation
- Seat post
  - Sub entity
  - Background
  - Main entity
  - Transformation
  - Explanation

- Frame:
  - Stiffness: 110 Nm/°/kg
  - Cost: 400.- $ (material: aluminium)

- Seat post:
  - Comfort: medium
  - Cost: 50.- $
KNOWLEDGE DOMAIN PATTERN ENABLES OWNER TO REASON

Reasoning:
• Qualitative
  - Via relations between blocks or parameters
  - Owner decides if changes needed to changing input
• Quantitative
  - Via transformations between parameters
  - Owner searches input values that result in the desired output values
• Knowledge domain owner decides if changes are acceptable

Frame
- Stiffness: 110 Nm/°/kg
- Cost: 400.- $ 
- Material: aluminium

Seat post
- Comfort: medium
- Cost: 50.- $ 

Frame cost is around 4 times as high

Default size is m. The size will effect the stiffness and cost of the frame
Relate knowledge domains (KDs)

- Validations decouple KDs
  - Colours shows agreement between KDs
  - Model is agreed contract between KDs
  - Observe impact of KD change on other KDs via validation
- Qualitative or quantitative reasoning over KDs on the impact of a change
- Absence of validation indicates KD isolation!
Knowledge domain structure enables system wide reasoning

- Avoids misunderstanding
  1. Explicit definitions and terminology
  2. Relates knowledge domains
  3. Shows owner
  4. Provides knowledge domain scope
  5. Similar abstraction levels

- Enables trade-off investigation for architecture or design decisions
• Validation indicates disagreement “Marketing” and “Usability”
  - Architect can search solution and understand the trade-off

**Knowledge Domain Structure Trade-Off Example**

**Usability**
- Lisa
- Frame stiffness: $100 \text{ Nm/°} / \text{kg}$
- Seat post comfort: low
- Efficiency: 93%
- Usage: recreation

**Frame**
- Default size is m. The size will effect the stiffness and cost of the frame
- Frame cost is around 4 times as high
- Stiffness: $110 \text{ Nm/°} / \text{kg}$
- Cost: 400.- $
- Material: aluminium

**Seat post**
- Cost: 50.- $
- Comfort: medium

**Marketing**
- John
- Usage: sports
- Frame cost: 400.- $
- Seat post cost: 60.- $
- Drivetrain cost: 150.- $

**Electric Drivetrain**
- Mary
- Efficiency: 95%
- Cost: 145.- $

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• Validation indicates disagreement “Marketing” and “Usability”
  - Architect can search solution and understand the trade-off
• Convince “Usability” knowledge domain to change
  - Validation between “Usability” and “Frame” shows disagreement

**Usability**
- Usage: recreation sports
  - Frame stiffness: **115 Nm/° /kg**
  - Seat post comfort: low
  - Efficiency: **95%**

**Frame**
- Default size is m. The size will effect the stiffness and cost of the frame
- Stiffness: 110 Nm/° /kg
  - Cost: 400.- $ (Material: aluminium)
  - Comfort: medium

**Marketing**
- Usage: sports
  - Frame cost: 400.- $ (Usage: recreation sports)
  - Seat post cost: 60.- $
  - Drivetrain cost: 150.- $

**Electric Drivetrain**
- Efficiency: 95%
  - Cost: 145.- $
• Validation indicates disagreement “Marketing” and “Usability”
  - Architect can search solution and understand the trade-off
• Convince “Usability” knowledge domain to change
  - Validation between “Usability” and “Frame” shows disagreement
• Convince “Frame” knowledge domain to change
  - Validation between “Frame” and “Marketing” shows disagreement

Reveals “Marketing” internal trade-off between “Usage” and “Frame cost”
• Update targets
• Investigate alternative solutions for “Usability” or “Frame” knowledge domains

Electric Drivetrain
- Efficiency: 95%
- Cost: 145.- $

Marketing
- Usage: sports
- Frame cost: 400.- $
- Seat post cost: 60.- $
- Drivetrain cost: 150.- $

Frame
- Frame stiffness: 115 Nm/° /kg
- Seat post comfort: low
- Efficiency: 95%
- Usage: recreation sports
- Frame cost is around 4 times as high
- Cost: 500.- $
- Material: aluminium
- Comfort: medium

Usability
- Usage: Lisa
- Usage: David
- Usage: John
- Usage: Mary
- Usage: sports
- Frame stiffness: 115 Nm/° /kg
- Seat post comfort: low
- Efficiency: 95%
- Usage: recreation sports
- Frame cost is around 4 times as high
- Cost: 500.- $
- Material: aluminium
- Comfort: medium

Seat post
- Cost: 50.- $
- Comfort: medium

Default size is m. The size will effect the stiffness and cost of the frame
CONCLUSIONS

A multi-disciplinary knowledge domain structure to support architects for qualitative and quantitative system-wide reasoning

- Knowledge domain pattern to capture essential information
- Explicit relations inside and between the knowledge domains
  • Decouple knowledge domains by validations that indicate the level of agreement
  • Trade-offs are made visible to support decisions
- Stake holders are coupled to technology in a diagram reflecting the organization

• Future work: structures to support reasoning in large industrial systems with hundreds of knowledge domains
QUESTIONS?