AEROSYSTEMS

A REVIEW OF KNOW-HOW REUSE WITH PATTERNS IN MODEL-BASED SYSTEMS ENGINEERING

CSD&M - 18/12/2018

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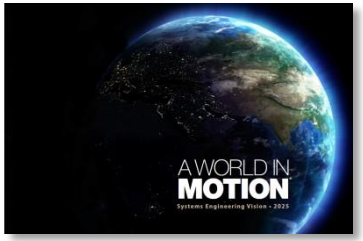
AGENDA

1. MOTIVATION
2. CHALLENGES AND RELATED WORKS
3. LITTLE HISTORY OF PATTERNS
4. PATTERNS FOR SYSTEMS ENGINEERING
5. PATTERNS FOR MODEL-BASED SYSTEMS ENGINEERING (MBSE)
6. CONCLUSIONS AND PERSPECTIVES

MOTIVATION

(INCOSE SE VISION 2025)



- *"Composable design methods will leverage **REUSE** and validated **PATTERNS** to configure and integrate components into system solutions." (p.28)*
- *"**MBSE** has grown in popularity as a way to **deal with the limitations of document-based approaches**, but is still in an **early stage of MATURITY** similar to the early days of CAD/CAE." (p.38)*

*"**Formal systems modeling is standard practice** for specifying, analyzing, designing, and verifying systems […]."* (p.38)

PROBLEMS

- **How to transfer and manage know-how available for REUSE?**
  - Important to step back and see the "big picture"
- **How to improve CAPITALIZATION ? Are PATTERNS a possible solution?**
  - Formalism adapted to the application domain (p.38)
- **How to overcome the many inhibitors of MBSE adoption?**
  - Gap with the current engineering approach (Vogelsang et al., 2017), (Huldt and Stenius, 2018)
- **How to evaluate MATURITY of a reuse process within a modelling framework?**
  - Confidence in the models/patterns to reuse

Conversion to an MBSE approach is facilitated by the formalization and reuse of know-how in the form of patterns

State of the art about know-how reuse, pattern reuse in a MBSE framework

CHALLENGES AND RELATED WORKS (1/2)

Complexity of systems keeps increasing

- Engineers cannot individually have a complete view of the project
  - Knowledge and know-how sharing with other engineers
- Projects are not started “from scratch”
  - Reusing the knowledge and know-how from previous projects
  - To be efficient : save time, money, and resources
- Transferring knowledge and know-how between engineers to foster reuse
  - Static know-how vs Dynamic know-how (Mourtzis et al., 2016)
  - Individuals experience vs Shared information (Miled, 2014)
  - Providing solutions vs Constructing solutions (Gzara et al., 2003)

CHALLENGES AND RELATED WORKS (2/2)

Approaches of reuse

- ***Opportunistic reuse*:** when the first project was not developed with reusable capacity. It is the lowest incidence of reuse (Rockley et al., 2003) because the act of reuse is the responsibility of the engineer's goodwill;
- ***Planned reuse*:** when the first project was developed with reusable capacity. In this case, reuse has been integrated in the development process in order to highlight and foster reusable contents (Rine et al., 1998);
- ***Variance*:** use of something already developed during a previous work, in a slightly different form (AFIS CT MBSE, 2018). For example, on a product line, there is a common core model but different options (Niu et al., 2013).

The concept of pattern

- Proposed generic guides to ease and systematize construction of complex systems (Cochard, 2017)
- Used in all stages of the development cycle (Gzara et al., 2003)

Can REUSE of PATTERNS help us counter today's systems rising complexity?

LITTLE HISTORY OF PATTERNS: from Architecture to Systems Engineering

*"Each pattern describes a **PROBLEM** which occurs over and over again in our **ENVIRONMENT**, and then describes the core of the **SOLUTION** to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice"*

(Alexander et al., 1977)

Architecture

First works:

- proposition for the creation of a SE **Pattern Language** (Barter, 1998)
- proposition of a **methodological framework** based on the reuse of patterns during all the lifecycle (Cauvet et al. 1998; Gzara 2000)
- proposition to use **patterns libraries** to support a methodological framework for the conception of product information system (Conte et al., 2001)

Systems Engineering

1977 **1995** **1998** .....

Software

"Design Patterns: Elements of Reusable Object-Oriented Software."

(Gamma et al., 1995)

Design Pattern : general, reusable solution to a recurring problem in the design of object-oriented applications = **PROVEN SOLUTIONS**

PATTERNS FOR SYSTEMS ENGINEERING (1/2)

CHARACTERISTICS

- Patterns "*are not created from a blank page; they are **mined***" (Hanmer et al., 2004)
  - ***Individual contributions:*** *used of own experiences or ones from colleagues;*
  - ***Second-hand contributions****: interviews with experts or by guiding another person;*
  - ***Workshops/Meeting contributions:*** *groups of people who brainstorm the elements of a patterns*.

SE patterns are embedded in existing designs !

- Pattern seems to possess an inherent **triptych**

{Context, Problem, Solution}

- Systems Pattern Form (Cloutier et Verma, 2007)

Patterns needs explicit documentation

Form Heading	Explanation
Pattern Name:	The name of the pattern should be descriptive to enable the pattern user to understand the usage.
Aliases:	Other names by which the pattern may be known
Keywords:	Keywords which assist in locating appropriate patterns in a repository
Problem Context:	Brief discussion of the types of situations in which the problem may occur - it should be broad enough to allow for any number of situations in which the problem may arise
Problem Description:	What is the problem this pattern can be used to solve?
Forces:	What challenges exist in the problem being addressed by the pattern, and the problems in applying the pattern? May also include constraints the pattern may impose if used. May describe the pattern from multiple views
Pattern Solution:	Discussion on how the pattern solves the problem being addressed.
Diagrams:	This can be one or more diagrams necessary to represent the pattern. This can be any notational method desired.
Interfaces:	Discussion of the critical interfaces or information flows necessary in implementing the pattern - what parameters of the interface can change and which ones can not. What are the interface dependencies, if any?
Resulting Context:	What are the unaddressed issues remaining when the pattern is applied/used.
Example:	An example of how the pattern may be applied. Usually in the form of a diagram or model
Pattern Rationale:	Why the pattern works
Known Uses:	Where else is the pattern being used in other places or applications?
Related Patterns:	Other patterns that may work in conjunction or in association with this pattern
References:	Other information that may be useful in understanding or applying the pattern
Author(s):	Who documented the pattern? May add a date if desired.

EXAMPLES

- System Of Interest (SOI)
  - *Control-Command* (Pfister et al., 2012)
- Systems Engineering Activities (SEA)
  - *Reuse process for Innovation* (Majchrak et al., 2004)

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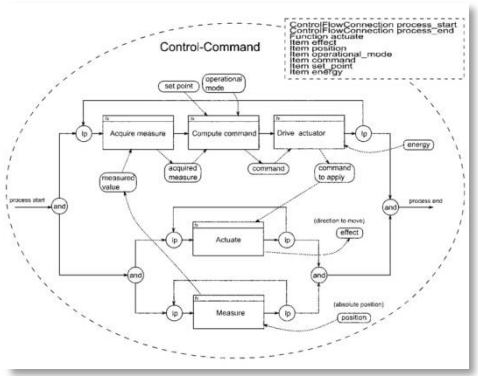

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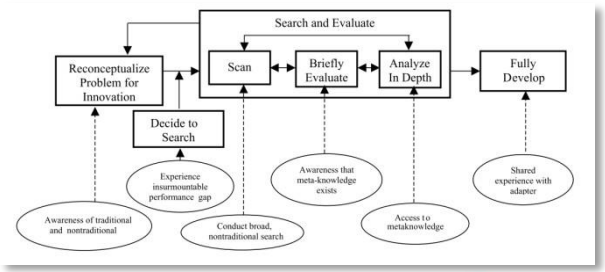


PATTERNS FOR SYSTEMS ENGINEERING (2/2)

VALUES AND LIMITS

+ Patterns allow people to solve complex problems by **leveraging experience, knowledge and know-how** from their predecessors
  - *In SW : larger the team size was, the greater the use of patterns was for documenting changes* (Hanmer et al., 2004)
  - *"should offer the same comfortable learning experience as a conversation with trusted colleagues"* (Haskins, 2005)

+ Patterns are valuable to mitigate risks (Schindel and Peterson, 2013)
  - *Not re-experiencing the same mistakes and reworks*
  - *Handle markets, technologies, environments evolutions*
  - *"Hero Culture" is not a long term solution*

! Patterns are **not a magical solution**
  - *SE Patterns require an adequate notation that allows their documentation* (Cloutier et Verma, 2007)
  - *A process flow has to be defined to use SE patterns* (Cloutier, 2006)
    - *How to find/mine the right pattern?*
    - *How to store, select, adapt patterns?*
    - *Is the chosen pattern an applicable pattern?*
    - *How are we making engineers aware of patterns they don't know?*
    - *…*

Patterns create a common lexicon between engineers

Patterns are not "silver bullets"

PATTERNS FOR MODEL-BASED SYSTEMS ENGINEERING (MBSE) (1/2)

REUSE OF MODELS

S — STRENGTH

Improve development:
reduce time, improve maturity, facilitate V&V

W — WEAKNESSES

Lack of:
expertise on modelling, maturity of previous version of models

O — OPPORTUNITIES

Easy to envision:
digital limitations vs physical limitations

T — THREATS

Reuse of models:
developped by providers, customers,…
Intellectual Property transfer

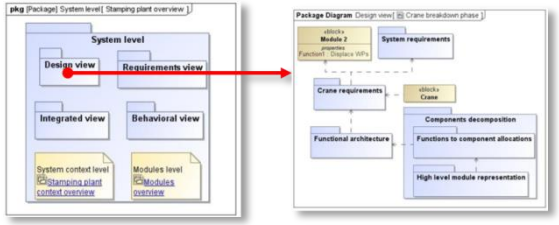
MBSE PATTERNS USE CASES

- Guide the development process in a MBSE framework (Schindel and Peterson, 2013)
  - *engineers do not need to be expert of modelling methodologies*
- Analyze complex systems through patterns mining (Kalawsky, 2013)
  - *the discovery of patterns help provide an explicit way to articulate common concepts*

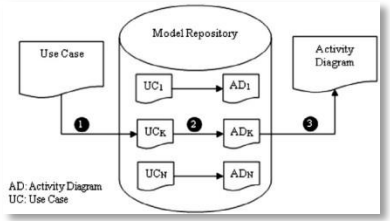
Patterns helps tailoring an adequate solution

PATTERNS FOR MODEL-BASED SYSTEMS ENGINEERING (MBSE) (2/2)

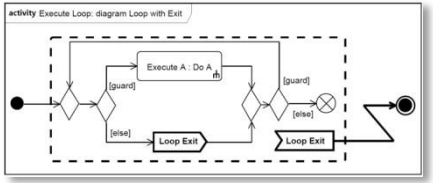
EFFORTLESS MODELLING WITH PATTERNS



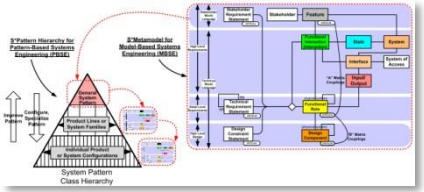
- Guide the development process (Barbieri et al., 2014)
  - *SysML design pattern (package)*
  - *improve traceability*
  - *facilitating the impact analysis*



- Semi-automatic generation of diagrams (Paydar and Kahani, 2015)
  - *candidate patterns*
  - *manual selection*



- Focus on what needs to be modelled and not the aesthetic of the model (Gasser, 2012)
  - *resizing of the diagram is automatic (“insert policy”)*
  - *work in an algorithmic way of thinking*
  - *focus on the expected behaviour than on the aesthetics*



- Patterns as “re-usable models” (PBSE) (Schindel et al., 2015)
  - *identify types of “regularities”*
  - *extend MBSE through configurable models*
  - *gain the benefits of MBSE without being an expert*

CONCLUSIONS AND PERSPECTIVES

PATTERNS FOR MBSE

+ Guide the development to avoid deviation
+ Benefit from the concepts of MBSE without being an expert of modelling methodologies
– Syntax and semantics of some modelling languages (RFP SysML 2.0)
– Tools interoperability (heterogeneous environment) (Shani and Broodney, 2015)

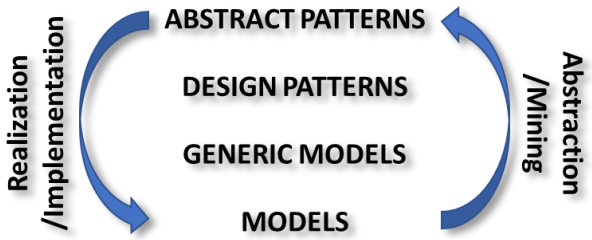
Act of capitalization is not self-evident !

PERSPECTIVES

> Characterization of **patterns abstraction level**

> Improve the general **maturity** of reuse approaches
  - Characterize **maturity** of patterns
  - Define a **process of maturation and reuse** of patterns
    - *capitalization, selection, reuse, and update*

> Implement the process in a MBSE software tool



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