A Multi-Disciplinary Research Approach, Illustrated by the Boderc Project

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Abstract

Research of Multi-Disciplinary subjects is complicated by its nature. Systems Engineering is the application area of the research results. Systems Engineering is applied in industrial or commercial domains. The drivers and culture in these domains differ quite a lot from the drivers of the (academic) research community. We will discuss and illustrate a research approach called *Industry-as-laboratory*. We will discuss how to get from industrial problem to a research hypothesis, and how to validate the hypothesis.

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status: preliminary
draft
version: 0.1
1. domain

2. ESI research projects: industry-as-laboratory

3. multi-disciplinary research approach

4. challenges

5. summary

"soft" sciences

abstraction
The Domain: Printers and Copiers by Océ

31x5E

2050

2090
Many multi-disciplinary problems in product development

Mechanical engineering precedes
Electronics engineering precedes
Software engineering

Most of the problems show up late in engineering and in the integration phase

For instance mechatronics assumes 1 ms response
Software promises 10 ms response

Lack of systematic approaches to detect / solve these problems in early phases

Lots of tuning, trial and error
Unpredictable project timing and costs
2. ESI research projects:
industry-as-laboratory
academic research

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From Mono-Disciplinary to System

- process
- organization, people

- evolvability

- robustness

- cost

- performance

- reliability

- multi-objective design methods

- performance and resource prediction

- single aspect design method

- YAPI

- hybrid methods

- Mechanical Engineering
- Electrical Engineering
- Software Engineering

- VHDL
- UML
- RMA

ESI focus

- multi-disciplinary design
- mono-disciplinary design

- process issues

Legend:
- rather soft
- well defined but soft
- well defined

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FIESAmethodLayers

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Exponential Pyramid, from requirement to bolts and nuts

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IALApyramid
Technology Management Cycle

Exploration of new ideas
- Literature search
- Creative option generation
- Try out

Application of technology
- Industry as laboratory

Consolidation of know how
- Reflection
- Write articles
- Create courses
Method research requires application of methods

Product Development

- Application of **hard** technology
- Consolidation of know how

Research

- Exploration of new ideas
- Application of **hard** technology
- Exploration of new ideas
- Application of **soft** technology
- Consolidation of know how
- Application of **soft** technology
- Consolidation of know how

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ARMcyclePDvsResearch
Industry as Laboratory

source of inspiration

application playground

industry

challenging problems

apply new engineering methods

research

hypothesis

evaluate

observe results

improve

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Stakeholders

industrial problem

Océ → Boderc → ESI

industry

generic solutions

embedded systems engineering:
performance reliability evolvability

academia

challenging research
Critical Success Factors for projects

- **Océ industrial project**
- **Océ industrial owner**
- focus
- large scale project
- co-location 3 days/week
- active involvement of scientific supporters
- selection of multi-disciplinary team
- industry as laboratory
- to have impact

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ESIprojectCSF
Project as Carrier for Capability Development

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ESICcapabilityVsProject
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industry

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From Industrial Problem to Validated Research

- industrial problem
  - research questions
    - quantified propositions
      - hypothesis
        - criteria
  - options to be researched
- industrial goal
Boderc Research Project Goal

Boderc goal =

A specific methodology
to predict
system performance
within industrial constraints and restricted design space
and analyze,
discuss,
document,
and communicate
throughput,
quality
people, process,
project duration,
and cost
multi-disciplinary

based on modeling
and analyze,
discuss, document,
and communicate
throughput, quality

power
computing
response time

within industrial constraints and restricted design space
What Formalisms, Models, Techniques, Methods and Tools are needed?

What is an appropriate level of abstraction and effort to model?

What determines the useability of models?
Methodology

Formalisms languages/syntax: differential equations, timed or hybrid automata, finite state machines, et cetera

Models instantations of formalisms to understand, explore, optimize or verify specification or design

Techniques to get the required information from models: e.g. performance

Methods to provide guidelines how to use formalisms, create models, use techniques and apply tools

Tools to support efficient application of formalisms, techniques and methods
The product creation lead time will be reduced significantly by the use of multi-disciplinary models during the early product development phases.
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   - "soft" sciences
   - abstraction

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mathematics | physics | medicine | human sciences | charlatan
---|---|---|---|---
hard | prediction | statistics | descriptive reasoning | handwaving
prove | confidence | evidence based | plausible | convincing
 certainty | | ||

architecting methods

crypto | biometric identification | human factor
example: security | |

legend
- hard science
- soft science
- no science
Soft problems can be approached with a scientific attitude.

soft is not in conflict with scientific attitude

- research question
- hypothesis
- heuristics
- principles
- facts
- analysis
- evaluate
- open debate
- make explicit
- substantiate
- try to validate

body of knowledge
cases
Systematic Know-how to cope with Growing Complexity

- Creative systematic repeated creative systematic methods
- More performance and functionality causes more complexity and requires more effort
- Active work on systematic methods reduces effort and the need for a lot of creative effort

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RORMimpact
Moving in the \textit{meta} direction

\begin{itemize}
\item \textbf{meta}^0\hspace{1cm} \textit{bottom line:}\hspace{0.5cm} \textit{product creation}
\item \textbf{meta}^1\hspace{1cm} \textit{enabling:}\hspace{0.5cm} \textit{architecting method}
\item \textbf{meta}^2\hspace{1cm} \textit{pro-active:}\hspace{0.5cm} \textit{research of architecting method}
\item \textbf{meta}^3\hspace{1cm} \textit{scientific foundation:}\hspace{0.5cm} \textit{method to research architecting methods}
\end{itemize}
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"soft" sciences abstraction

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Carrying Industrial Partner (CIP)

industrial problem

industrial goal

research

research questions

quantified propositions

hypothesis

criteria

options to be researched

results

soft factors

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MDRAsummary