Industry and Academia: Why Practioners and Researchers are Disconnected.

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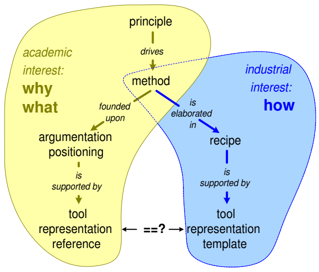

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Abstract

The industrial world and the academic world have grown far apart. The distance between the worlds primarily originates from different goals and different means of support. This is a problem in the areas of systems engineering and multi-disciplinary design. These areas are relatively young, providing lots of opportunity for research. Education in this area is scarce. Publications are tangible examples of the gap between the two worlds.

In this paper we discuss the needs of both communities with respect to publications, education, and research. The mutual understanding of each other's needs may help to bridge the gap between academics and industry.

version: 0.6 status: concept 27th July 2005

1 Introduction

This paper explores the gap between the industrial and academic worlds. To get the differences clearly on the table the formulation of the viewpoints, the examples, and the conclusions are somewhat exaggerated. Of course, academic people exist who are not afraid of the uncertainty in multi-disciplinary design, and who appreciate typical industrial papers. Vice versa, industrial people exist who like scientific rigor, and who appreciate typical scientific publications.

We zoom in on the industrial research needs in the areas of multi-disciplinary design and systems engineering. The gap is experienced also in publications, where the differences are rather tangible, as discussed in the next section. The two worlds meet each other in education, because the academic world is the main educational supplier of the industrial world. We close with recommendations and conclusions.

2 Research Needs in Multi-Disciplinary Design and Systems Engineering

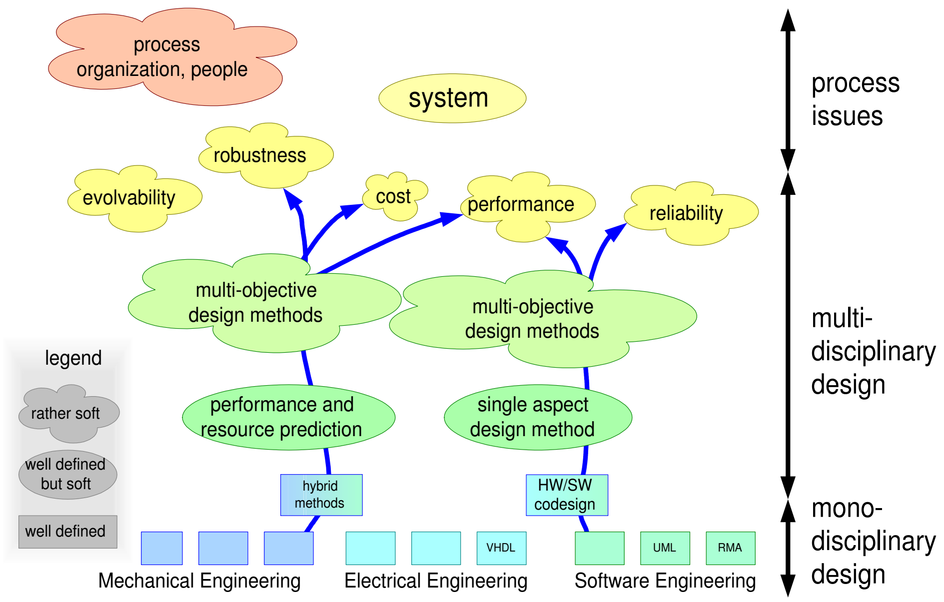

Figure 1: From Mono-Disciplinary to System

Conventional research areas are mono-disciplinary: mechanical, electronics or software engineering. Some bi-disciplinary niches exist, for instance hybrid methods where continuous electro-mechanical models are combined with specific discrete events. These research fields are relatively mature, although some doubts exist about the maturity of software engineering[2]. Researchers in these areas are used to well-defined problems that can be researched in depth. Mono-disciplinary methods are often based on mathematical rigor. A lot of uncertainty pops up when we move to multi-disciplinary problem solving. The problem itself is only partially defined, while at the solution side different formalisms have to interoperate, such as discrete (software) and continuous (mechanical) models. Figure **??** shows the methods with as vertical axis the degree of multi-disciplinary interaction. The form of the method is an indication how well the method is defined and how much uncertainty is left.

In the industrial context the *system* level is often relatively well defined in a systems requirement specification. Such a specification describes the functionality of the system and quantifies the main performance characteristics. The translation of these requirements into mono-disciplinary design choices, however, is still full of unknowns. The many (dependent and interfering) design dimensions that have to be managed at the same time are causing a lot of uncertainty. In Figure **??** the methods at this level are called *multi-objective design methods*.

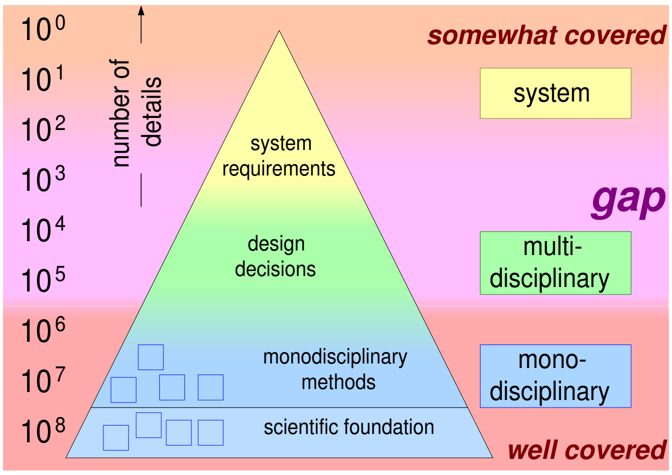

Figure 2: The Gap-Size is Multiple Orders of Magnitude

The translation of system requirements into detailed mono-disciplinary design decisions spans many orders of magnitude. The few statements of performance, cost and size in the system requirements specification ultimately result in millions of details in the technical product description: million(s) of lines of code, connections, and parts. The technical product description is the accumulation of *mono-disciplinary* formalizations. Figure 2 shows this dynamic range as a pyramid with the system at the top and the millions of technical details at the bottom. The methods to be established address the multi-disciplinary area. In Figure **??** this is the range from *single aspect* to *multi-objective* design methods. In the pyramid,

Figure 2, it is the area of translating hundreds of system level requirements into tens of thousands of design choices.

2.1 Methods or Tools Research?

Many research proposal address *tools*. Industrial stakeholders ask for tools. Tools are perceived as ready-to-go solutions. Unfortunately tools do not provide any value, unless they are well embedded in a method. A method is a generalized description of a way of working. Methods have several attributes: a *goal*, a *decomposition* into smaller steps, a possible *order* of taking these steps, *visualization(s)* or *representation(s)* and *recommendations*.

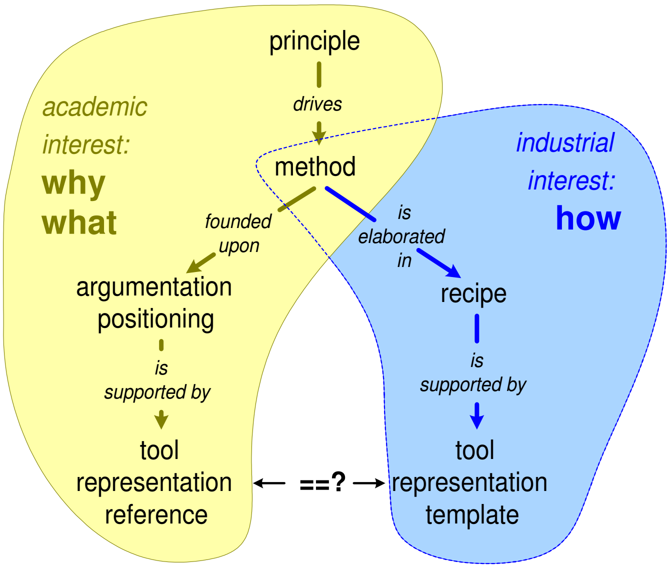

Figure 3: Both academia and industry share an interest in methods. However, the industrial interest is focused on applying the method, while the scientific interest is towards founding the method scientifically.

The industrial and academic people share an interest in methods. However, the industrial people are focused on the *practical application* of the method. The engineers in industry ask for ready-to-go recipes, supported by tools, representations and templates (see right hand side of Figure 3). The academic people are interested in founding the methods. The method has to be positioned in the existing scientific body of knowledge, and argumentation has to be provided to found the new additions of the method (see left hand side of Figure 3). Tools, representations, and references to existing scientific foundation support this scientific process. Although industry and academia use the same words, *tools* and *representation*, they might mean entirely different entities.

The objective of research should be methods, where tools can be developed or used as means. The transferable know-how is consolidated in the method description. The broader industrial application of the method might require the development of supporting tools.

2.2 Discussion

The industry is struggling with multi-disciplinary design. Trial and error approaches and experience-based implicit methods are dominantly used. A lot of research questions exist in the area of multi-disciplinary methods. Both industrial as well as academic people have reasons to escape in tool research. However, methods are the common ground for both parties, while tools are only means.

3 Publications

Industrial people dislike academic papers and vice versa. In this section we discuss the needs of both communities with respect to publications and summarize the two viewpoints in a comparison table. Two fictional examples are shown to illustrate the viewpoints. We discuss the consequences of the different publication interests.

3.1 The Industrial viewpoint

Industrial employees select articles of which the subject is clearly industrially relevant. A good article is valuable and useful for the reader. In an industrial context that means that the content is goal and solution oriented. In many cases goal and solution depend on a broad context and on an integral understanding of the problem in the context. To make it useful the content of the article must be practical, the "how to" style fits well.

The industrial setting is a smooth operational environment, an economic must. Responsibilities and accountabilities are well defined. Articles with a single author are normal. When articles have multiple authors this is often an indication of diffuse responsibilities.

Providing pointers to related relevant information may support articles:

- more context information *(zooming out)*
- neighboring information (e.g. describing the previous or succeeding processing step) and alternatives *(same abstraction level)*
- more detailed information (e.g. detailed measurements, computations, or more detailed method) *(zooming in)*

References are expected to help the reader to quickly find the most relevant information.

The writing style must be clear, understandable and entertaining. The reader should be *invited* or *seduced* to read the article. In many cases a good article starts with the example case and the benefits and then the underlying theory is discussed. Information that is not relevant for the reader is noise. Noise distracts and hides the more relevant information. Good articles must have a high signal-to-noise ratio.

The economic viewpoint in industry is that writing and reading articles is a *cost*. Clear benefits are needed to justify this cost. One of the benefits to write articles is public relations, but there is a lot of tension with Intellectual Property Rights (IPR) and confidentiality of information.

3.2 The Academic Viewpoint

In the academic community the subject of the article must have scientific relevance. The article must contain some *new* or *original* claim. The claim must be well positioned in relation to *all* existing scientific publications. References in the article serve only to relate statements in this article to existing articles. The following references can be recognized:

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- towards a broader context (for instance, our experiment fits in the generic experimental setup of ACCMOR[1]).
- towards original inventors (this idea was first presented by ...)
- towards competing articles, explicitly discussing the positioning.
- towards articles that provide evidence for statements in this article

The entire focus of referencing is to keep the scientific patchwork together. Scientific articles are knowledge oriented. The new knowledge has to be captured, mostly in the *why* and *what* style. The argumentation must be clear, painstakingly precise, and unambiguous. Ambiguity is avoided by using formalizations, for example formulas. Every statement is either supported by a reference or by verifiable facts. Every step is connected to the previous steps.

A strong scientific publication culture exists. This culture is reflected in the way of referring as described earlier. But the determination of the list of authors (who is on the list? what is the order?) is very sensitive. All contributors are part

[1] ACCMOR is one of the large high energy physics experimental set-ups of the late seventies. In these high-energy experiments huge experimental setups are used for many experiments, generating lots of different articles, but sharing the same set-up.

of the list of authors. The real author gets the front position, scientific supporters and reviewers follow.

The economic reality for academia is that publications and citations determine funding (and standing). This creates a tremendous drive to publish.

3.3 Comparing the Industrial and Academic Viewpoints

The viewpoints of the industrial people and the academic people are completely different. The table in Figure 4 shows an overview of both publication viewpoints. The goal of industry is to design and sell *products*. Paper and knowledge are (necessary) means, not a primary goal. The goal of universities is *knowledge* creation and distribution. Paper and publications are primary goals.

	industrial	*academical*
relevance	useful, valuable	new, original
orientation	goal, solution	knowledge
content	practical, how to	theoretical, why, what
style	clear, understandable juicy, low noise	clear argumentation, no loose statements
references	service to the reader	positioning in existing science
author	single author	all contributors as author
economic driver	writing and reading = cost public relation vs IPR and confidentiality	funding based on number of publications and citations

Figure 4: Comparison of Industrial and Academic Publication Viewpoints

Subsections 3.4 and 3.5 discuss the differences by using two made-up examples.

3.4 Industrial example: How to use spline interpolation

Spline-interpolations are existing well-known algorithms. However, the use of these algorithms is limited, because most engineers have insufficient understanding of the algorithm. An article that makes an advanced, but existing, algorithm understandable and that provides recommendations for the application is highly relevant from an industrial viewpoint. Industrial people primarily read articles to use the content. This article is relevant for the industry, because it addresses an actual problem and provides directions for the solution.

This article will not contain references to the original inventor of splines, nor the scientist who derived the limitations caused by accuracy and stability requirements. This type of references is noise: if you follow the reference you get information that you cannot apply. It will contain references to educational books about interpolation and more detailed articles explaining the accuracy and stability balance. It might also refer to an article describing the broader context where these algorithms have been applied.

Block diagrams and response curves will illustrate the article. Formulas are only given when needed to use the algorithm, no derivations are provided. Derivations are a typical example of noise: you don't use them, while they create a lot of complex content.

The academic opinion about the same article is harsh: no *new* differentiating content, no foundation or positioning in the existing scientific knowledge is provided.

3.5 Academic example: Accuracy and stability trade-off for spline interpolations

This paper, written by a PhD student, explores a niche of the well-known spline interpolation algorithms, focused on the accuracy and stability balance. This article has scientific relevance: the new and original value is the formal derivation of the relationship between accuracy and stability, in a given set of boundary conditions. The assistant professor provides the PhD student with ideas, references, and direct feedback. The professor played a role in the initial positioning and takes care of the final review. The PhD student is the first author; the assistant professor and the professor are both on the list of authors. The article gives the complete derivation of the accuracy stability relationship, including numerical analysis and experimental evidence. More fundamental derivations, such as the spline interpolation algorithm itself, are covered by references to the original publication.

The industrial interest in this paper is void. The described extension covers a niche that is never used in industrial practice. The article itself is very noisy, because it contains all kinds of complex formulas that you don't need during the application and it contains all kinds of references and positioning statements to stitch the minor fragment of new knowledge to the existing knowledge. In the unlikely case that the industrial engineer has questions, the two professors refer to the third author for answers, so who is responsible here? Even worse, an article that provides application value cannot be found in the bibliography.

3.6 Discussion

The needs and interests of industrial and academic people are often opposing and conflicting. The papers have different goals, and different target audiences and related culture. When writing, it is recommended to write separate versions for industry and academia. Some copy/paste re-use between the papers will be possible, but the acceptance by the target audience must take precedence over reuse and related writer efficiency concerns.

Different publications are needed for industry and academia.

How can we improve the flow of information between the academic and industrial world, if we separate the articles for the target audiences? How do we stimulate cross-fertilization between these worlds? Cross-fertilization is an effective way of learning. We don't pretend to have the complete answer to this question. Understanding the background of the alien world is a starting point for communication across the boundaries of the worlds.

Part of the answer might be to write articles that adhere to the culture of the other world. For instance, the industrial engineer could explain more *what* and *why* questions. However many academic demands will pre-empt industrial writing efforts, for example the need for a well-defined scientific positioning. Academic people are able to write articles that are interesting for industry, however it forces them into a completely different writing style. More emphasis is needed for the practical use and much less for the argumentation and foundation.

Another option is to create scientific channels for multi-disciplinary problems, for instance magazines, and conferences. At this moment INCOSE is one of the few multi-disciplinary outlets, where industry and academia meet each other.

4 Education

The struggle with multi-disciplinary design in industry is partially caused by the lack of education in this area. A major question is which party is capable of providing education in multi-disciplinary design? The academic community is the main educational supplier of the industry. Is the academic community capable of providing multi-disciplinary education?

The current academic culture conflicts with the characteristics of the multi-disciplinary problems. The laboratory setting of today's research does not provide relevant experience for today's industrial problems. Both actual experience and culture are needed for effective education.

Several alternatives can be considered:

- Create an academic multi-disciplinary research environment and use this background to develop multi-disciplinary education.
- Create research groups outside the current academic environment to study and transfer multi-disciplinary methods.
- Create separate educational entities, such as training departments or consultancy firms, to provide multi-disciplinary education.

5 Recommendations and Conclusions

We have shown the differences in culture between industrial and academic people. These differences are the most acute in multi-disciplinary areas. Common ground can be found in the research of multi-disciplinary methods.

The publication culture is also completely different. This difference is so large that separate publications are recommended for industry and academia.

At this moment academic parties are not capable to provide multi-disciplinary education. It will cost a lot of time to build up the required experience and culture to create this capability in academic circles. It is recommended to start with research groups outside the current academic environment, but to actively strive for a change in the academic environment, so that these research groups can evolve towards academic groups.

Today's academic culture encourages people to stay in their own discipline. Entering new scientific areas is disabled by this cultural attitude. The industrial world is suffering from this effect, because most of their problems arise across disciplinary boundaries.

6 Acknowledgements

Feedback from ESI and Philips colleagues did help significantly to shape this article. Amongst the contributors are: Ton Kostelijk, Roland Mathijssen, Martin Rem

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[2] David L. Parnas. Software engineering: An unconsummated marriage. *Communications of the ACM*, page 128, September 1997. This article can also be found in ”Software Fundamentals, Collected Papers by David Parnas”, Addison-Wesley.

History

Version: 0.6, date: June 27, 2005 changed by: Gerrit Muller

- textual changes
- changed status in concept

Version: 0.5, date: October 25, 2004 changed by: Gerrit Muller

- textual changes
- changed status in draft

Version: 0.4, date: September 26, 2004 changed by: Gerrit Muller

- updated abstract
- replaced rigidity by rigor
- added text about ambiguity in the academic viewpoint.
- added text to the comparison of academic and industrial publication viewpoints.
- choose logo: GIAabstractionHierarchy

Version: 0.3, date: September 21, 2004 changed by: Gerrit Muller

- added figure of shared interest in method

Version: 0.2, date: September 10, 2004 changed by: Gerrit Muller

- moved system section more upfront.
- changed article title.
- removed statement about language correctness

Version: 0.1, date: September 1, 2004 changed by: Gerrit Muller

- Added education and research to the scope of this paper
- Integrated the publication oriented content in a single Section

Version: 0, date: August 23, 2004 changed by: Gerrit Muller

- Created, no changelog yet