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EIMS - A FRAMEWORK FOR ENGINEERING PROCESS ANALYSIS

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ABSTRACT

Due to various factors the engineering processes in product development get more and more complex. Nevertheless, the dynamic character of this processes and their steadily changing context makes continuous process investigation and enhancement necessary, in order to exploit the high optimization potentials hidden within existing workflows. For such a process analysis a clear understanding of the process' inherent structure is mandatory, for the analysis phase as well as for the following synthesis.
In this contribution, the authors refer to various existing models that describe the engineering process as a system dealing with different kinds of information and information processing systems. The existing models are extended by a new view onto the engineering information system. Additionally, the authors focus on the relations and the inherent hierarchy between the existing views, showing that this knowledge is crucial in order to realize a systematic approach for engineering process enhancement.

OBJECTIVES

Nowadays engineering processes are characterized by a growing degree of complexity. This complexity is caused by the need to cover more and more phases of the product lifecycle as well as by the fact that such product development processes are spread over various and globally distributed engineering domains. But still process enhancement is one of the key topics to achieve sustainable success in daily business.
Aiming at process enhancement, the reality shows quite often up as conglomerate of separate aspects.
Almost any engineering process is not „just“ a topic of process or method. The engineering process is influenced by various factors, all of which can be called as a unity the "context" of design or engineering processes. In order to keep in touch with nowadays challenges in globally distributed markets, it is necessary to gain understanding about these influencing factors. Aiming at the enhancement of engineering processes, the consideration and isolated improvement of single factors will not deliver the expected results.
Therefore it is necessary to gain knowledge about existing processes, their inherent components and the relations among them. While various methods and techniques for process modelling are well known and are being applied since a long time, the context for the application of these methods is not described in a sufficient way [1]. This contribution introduces a framework for modelling as well as analysing engineering processes. The key objective of this holistic approach is to pay attention not only on the modelling and optimization of single components of the Engineering Information Management System, but especially on the interdependencies between them.

STATE OF THE ART

In applied research work in industry, one of the major activities is the description of existing engineering processes in order to define and exploit optimization potentials. Thereby, the application of existing process modelling techniques has shown insufficient results. Related research work from Scandinavia came to the same findings, leading to the introduction of the so-called Engineering Information System [2]. They define the Engineering Information System (EIS) as "the unity of

processes, information, organization and information systems that support the management of engineering related information". They divided the EIMS into four different views, the process, the roles, the systems and the information itself, with all of them being linked to each other, as shown in Figure 1.
In this definition, basic influencing factors, called views are named. It is quite similar to the so called "dimensions of Product Lifecycle Management (PLM)", which are introduced by Abramowici et. al. [3]. They define the dimensions engineering organisation, engineering processes, product data, IT-systems und product strategy.

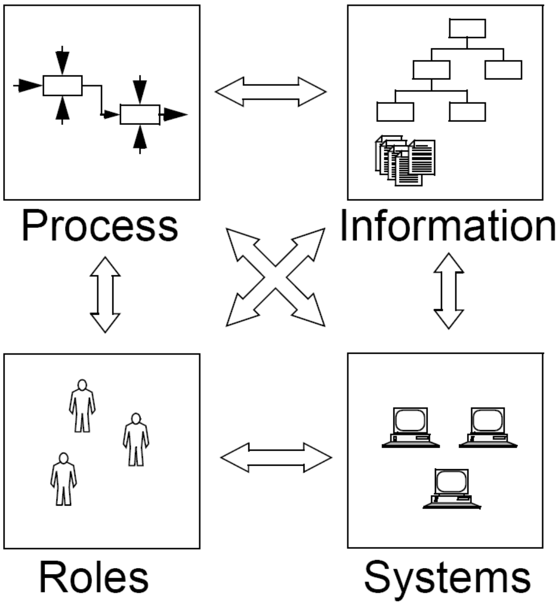

Figure 1 Engineering Information Management System, according to [3].

Basing on these two frameworks, Vielhaber [4] extends the definition of EIMSs by introducing a new view. In order to detail what is happening during the engineering process, he defines methods, which are applied in the engineering process, as another dimension.
Tureson delivers another framework, consisting of the views Process, Methods, Information, Applications and Infrastructure [5]. This so called "Pater-Noster" framework is driven by practical experiences with the background of the introduction of PLM systems and strategies in automotive industry. However, it fits quite well with the requirements percepted by the authors of this paper. But although all these different frameworks are well described and their feasibility has been proven in reality in many research projects, dealing with these models has led to the assumption that a proper investigation and enhancement of them could pay off in even better results during process analysis.

NEED OF ACTION

The application of the EIMS during various research projects has shown quite good results. The EIMS inherent methodical approach led to a systematic way of describing and analysing different engineering processes. But while interacting with the EIMS, a bunch of new questions arouse, and while research work was going on it became obvious that these questions need to be answered in order to achieve a deeper understanding of the EIMS and to gain better results when it comes to the prediction of the consequences of process changes.

For a first investigation, the following questions have been formulated:

- Which views/dimensions do necessarily belong to an EIMS?
- Which borders of an EIMS exist and what is the "thing" on the other side of the border?
- Which level of detail is feasible?
- Which logical constraints do exist between the views/dimensions of an EIMS?
- How can two EIMSs interact or be mapped into one?

The answering of these questions in the following chapter will deliver an enhanced definition of a framework for engineering process analysis.

DEFINITION OF EIMS AS A FRAMEWORK FOR EINGINEERING PROCESS ANALYSIS

Basing on the given approaches and the remarks above, the authors define the Engineering Information Management Systems as follows:

Definition

The Engineering Information Management System (EIMS) consists of the views process, methods, information and data, organisation and information systems. The EIMS describes all relevant views and supports a structured description of the context of engineering processes. All items that effect the process belong to the EIMS, the items that do not effect the process belong to the environment, see figure 2. The environment comprises the surrounding of the engineering process, for example the market, legal situation and economics, and other, non relevant boundary conditions, that have only a subordinated influence on the investigated process.

Which views/dimensions do necessarily belong to an EIMS?

The known approaches, as discussed in the chapter before, are sharing a quite big common understanding. They understand the process as the leading view for an analysis, whereby the process becomes to a vital part in every approach. Every one of the different frameworks introduced above contains the views information and systems, respectively applications. Also the methods that are applied during the engineering process are taken into consideration. What is missing in all this descriptions is a kind of internal order between these different views. In all of the mentioned models, the different views are related towards each other, leading to the key argument that the Engineering Information System as a whole must be addressed when process improvements are established. And also the relations among the different views have not been investigated in detail yet. But looking at the different views in detail, a kind of inherent hierarchy could be established.

The internal structure of the EIMS, as it is understood by the authors, is shown in figure 1. It could be described as follows:
A certain process is embedded into a special environment, whereas knowledge about this environment is important in order to understand the process context. Within a process, the participants apply special methods within their daily work. These methods describe the activities that have to be performed by the experts. Therefore, a defined set of information is required, in the sense of input data as well as output data that is generated within the activity. This information is generated out of data that is stored in databases. The generation of information out of this data is done with information systems that are applied within the context of a method. For example the method of investigating the crash behaviour of a new developed car body implies the application of a numerical FEM Tool that again implies the generation of a finite-element mesh out of the car body's product data. As a result of this activity, information about the car body's rigidity is derived out of the computer model, based on the user's experience, and distributed among the other development departments as new information.

Regarding the human factor in the phase of process analysis, most of the existing models do not proper describe its importance. Only Svensson defines the roles of people in an engineering process as a separate view, aiming at different roles in a PLM context. Nevertheless, this point of view is too narrow. It is a human being which acts in the engineering process, making decisions, interoperating with computer tools and applying methods. Therefore it is important to capture this topic in a separate view. Since people interact with each other, and, with regards to Svensson, of course having different roles, the authors of this paper introduce organisation as a new view, containing as one essential part the human factor. In the related research projects it became obvious that this is one of the key factors when process changes and enhancements should be made.

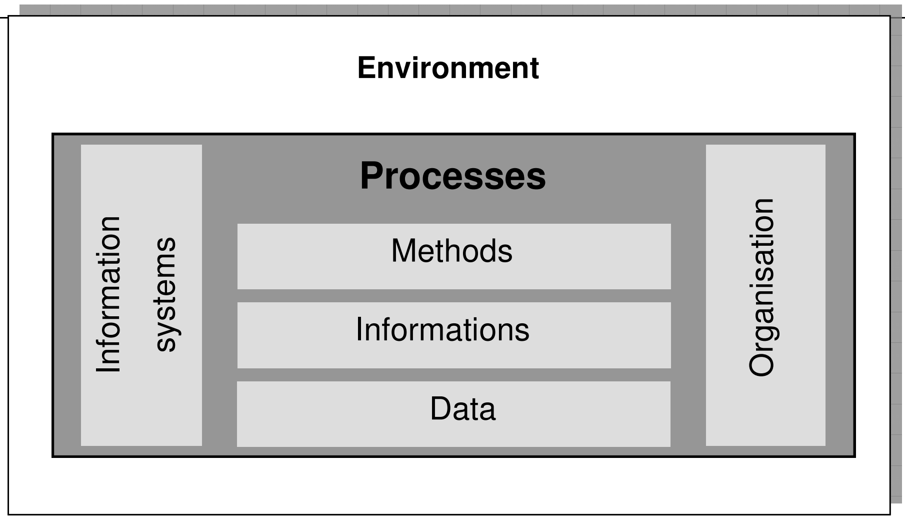

Figure 1. The views of the Engineering Information Management System

The six views and the relations between the views of the EIMS are defined as follows:

Processes

Processes are the totality of business processes within the EIMS' borders. Processes do have a temporal component that can vary to a high degree among different kinds of processes. Within these processes, one or more activities can be found. These activities are described with regards of their content and are linked towards each other, thereby creating a workflow. Processes are scalable, which means their description and their level of detail follows the needs of the investigated business case. For example the overall development process of a car is such a process, or, on a more detailed level, the design process of a production unit.

Methods

Methods are the basis for the different processes. Together with the information models they deliver the fundament for the process supporting IT systems. Methods do describe how the different activities within the processes or sub-processes shall be accomplished. In VDI 2219 the term method is described as "a planned approach in order to achieve a certain result" [6]. The need for the application of a certain method can influence the information view, because the method might need a defined set of information. From another perspective, the use of a certain IT-system within one activity can allow the generation of a variety of new methods. A method is always applied by a human being and the interpretation of the results of a method provides a basis for decision-making in engineering processes.

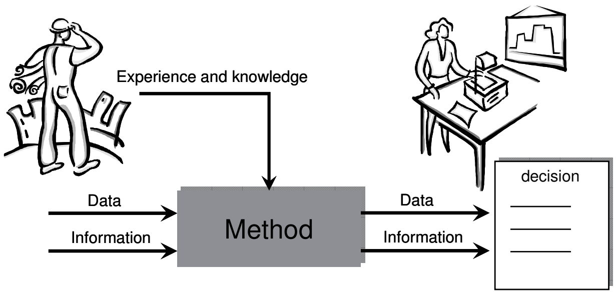

Figure 2. The understanding of the view method in the context of EIMS

Information

Within a defined process, the application of a method requires certain information. The term information is thereby defined as the interpretation of data in a certain context, following the ideas of the semiotic triangle described by Schappert [7]. While data represents the syntactical view, the information itself delivers the semantic view. In a third step, the pragmatic application of this information leads to knowledge. In processes the information is being exchanged in the sense of a communication, delivering the information coded in the data, as described by Smithers [8].

Data

As mentioned in the section before data is coded information. It is represented in a defined syntax, for example in a binary code. The data's main purpose is to transform information into a readable machine code to allow a processing with IT Systems. Without any context dependant interpretation, data alone is worthless.

Information systems

Information systems do support the participants within the processes activities. They apply or imply certain methods and process information that is coded in data. Within the EIMS two different kinds of information systems are distinguished. The first group are the so-called authoring systems that generate or decompose data and the related information. The second category is the management systems that are used for the organisation and distribution of the data and information. The relevance of this second sort of systems has increased significantly during the last decade, since the amount of data generated and handled within the different processes is steadily increasing.

Organisation

The organisation is the description of the internal set-up of a business area within a company. Thereby a company's organisation can be analysed in two ways. First, the hierarchical set up can be described, delivering detailed information about the structure of different departments and the reporting system. Second, the processing organisation can be investigated, e.g. by following a certain order through the different departments along a process chain. The decision about which of these views on a company's organisation should be applied is dependent on the use case.

In the context of the EIMS, the human being is embedded in the organisational view. This refers on the idea, that the information about the participation of a certain engineer or worker within a process makes only sense when he or she is seen in the context of the related home department and its mission. This background information helps to understand the human's behaviour in the EIMS and allows an optimal support of the relevant role. And in the end, the acceptance of a new method or process by the users decides whether a project is a success or a failure.

The understanding of the different views and their relations among each other is essential when process enhancements shall be made. Looking at these relations, different approaches for process improvements can be found. One phenomenon that can be observed in industry quite often is the tendency to buy a new software tool and to try afterwards to integrate it into existing process landscapes. More feasible seems to be the approach to focus first on the methodical aspect by asking the question "Who needs which kind of information at which time in the process?". If the relevant information is defined, the selection of possible IT tools is limited automatically. Additionally, the temporal constraints can define the organisational aspects by assigning a certain activity to a certain domain within the overall process. Of course, in real processes a lot of compromises must be found, as there is already an existing process landscape. And changing an existing system always leads to resistance and inertia. But nevertheless the EIMS framework helps to find a more systematic way for process enhancements and allows more accurate predictions about the consequences of changes. If a proper analysis of the EIMS is done in the beginning of a research project, the influence on all different views can be easily displayed and predicted.

Which borders of an EIMS exist and what is the "thing" on the other side of the border?

The border of a system which should be used for the analysis of engineering processes is the engineering process itself. Every item that affects the process can be useful on the one hand, because it helps to achieve a positive effect. On the other hand it can be restrictive and thereby cause a negative effect. Therefore, every item has to be taken into consideration. In the context of this article, the authors define the borderline of an EIMS as the border between the process and the environment.

Which level of detail is feasible?

Dependent on the aims of a process analysis, it can be quite a big difference between the "feasible" levels of details. But focusing on the two views information and applications, this paper provides two suggestions in order to be able to map different levels of detail.

Referring to the view "information", it might be feasible to differentiate between information and data, as afore mentioned in the description of the semiotic triangle [7]. In the beginning of the process analysis, it is not necessary to go down onto data level and to describe each process step in bits and bytes. Focussing on the relevant information makes much more sense at this stage, because that's the level of detail that is understood by the process participants. But as the solution concepts derived out of the analysis is getting more and more detailed, the transfer of the EIMS onto data level shall be performed. At this stage of a real project, software specialists should be involved to discuss the technical feasibility of the new concepts or possible restrictions within the available systems. Potential extensions in the IT-systems functionality can be predicted and operating costs can be assumed. Starting with such detailed discussions in the beginning of a project can easily lead to the projects paralysis.

Mapping of EIMSs

It happens quite often, that the challenges of the optimisation of engineering processes are taking place at the interfaces of processes, domains or organisations, sometimes called cross-domain interoperability. Thus, the question of how to structure such a heterogeneous context when using the EIMS rises up. On the first sight, there are in principal two ways leading to the target of one unified description.

The first opportunity is the "view by view" manner. It means that while applying the analysis, one leads all relevant information for each view together. In case of two partial processes this will lead to 2 times 6 views.

Another opportunity is to understand also very heterogeneous process crossing different interfaces and domains as **one** process. That means in a way to collect all relevant effects together in process and then, driven by the process derive the EIMS with the relevant views. This second opportunity delivers as an advantage the opportunity of a proper consideration of time issues. While focusing on **one** process and then deriving **one** EIMS, it is obvious hat there is just one timeline to consider. In the case of two or more EIMSs, it can be quite tricky to create "synchronised" views on what is happening in the processes.

RESULTS

Additionally to existing approaches, the enhancement of Engineering Information Management System was achieved by the introduction of two new views. First, a differentiation between the entity "information" and the underlying "data" was established, following the model of the semiotic triangle that defines information to be the semantic view on data.

Second, the view "method" was introduced, as the link between information, the relevant information system and the organisational aspects. Furthermore, the establishment of the view "method" allows it to consider the influence of experience and knowledge of the applicators of methods in engineering contexts. Organisational aspects, that include the human factor, lead to the idea that one of the relations between "organisation" and "method" can be seen as the degree of complexity the participants of a certain engineering process are confronted with.

The application of this model in process analysis scenarios delivers, besides an adequate description of the design context, the ability of precisely identifying action fields. Additionally, it allows modelling and thereby understanding the consequences of changes of single components for the overall design context.

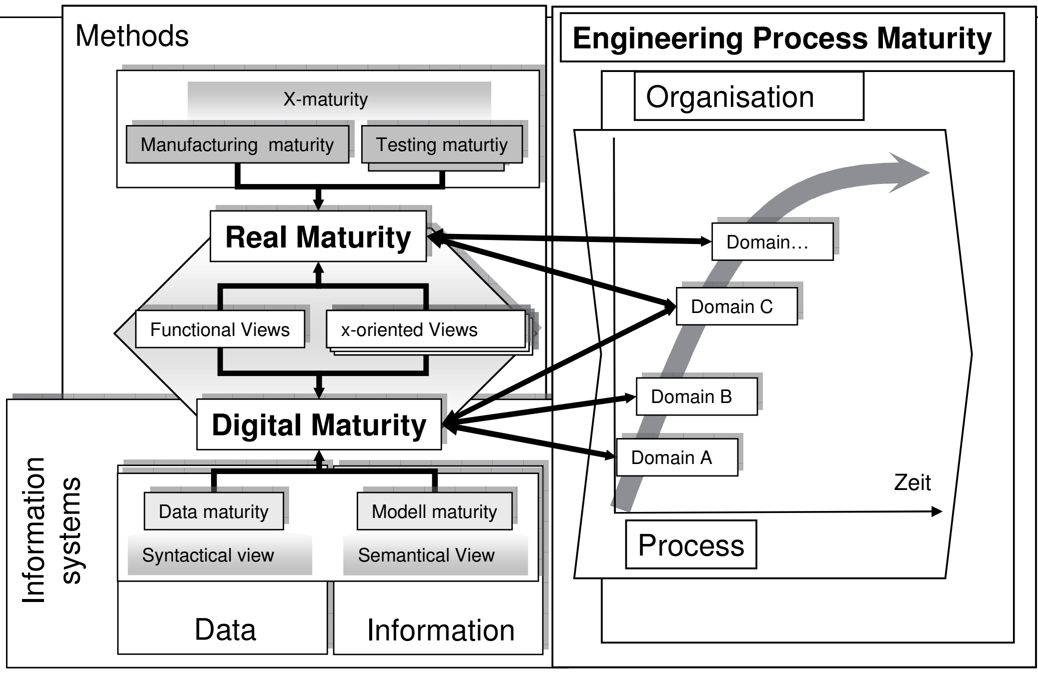

Figure 3. Engineering Information Systems and Maturity

DISCUSSION

The defined framework was applied in various research projects showing its capability for process analysis and optimization.

As depicted in Figure 3, it has shown also potential to get clear on the term maturity and how the different views of an EIMS contribute to the overall performance of maturity in the product development process of car industry. Figure 3 bases on the so-called maturity map, a model which is introduced by [9]. The maturity map delivers a holistic view on maturity. In bringing these two models together, new insights are created, and the structural set-up by the EIMS shows which steps will have to be done in order to optimize the investigated processes.

In another research project, the EIMS was used to investigate the possibility to set up a new layer of data management systems, so-called Team Data Management systems, to allow a better support of parametric and associative engineering design process in engine development. During this project, the above mentioned approach of starting with the information analysis and later on go on detailed data model level was evaluated. Additionally, the EIMS was used to predict consequences in other related departments like the machine planning or the rough-part design department.

KEY CONCLUSION

Whenever trying to improve engineering processes, a clear understanding of these processes within the related departments is crucial. The framework discussed in this paper delivers a unified and sustainable approach to do such an analysis.

Furthermore it delivers different alternatives for the establishment of new methods, systems or information models. It was successfully applied in different corporate research projects, dealing with the implementation of information systems such as EDM/PDM, advanced CAD methods or cooperation models among distributed development teams. By focusing on the components and their relations, the engineering information management system as a whole could be addressed when improvements are realised. Further research work will focus on a detailed analysis of the character and the differences of the relations among the different views.

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