USABILITY COMPLIANT SUPPORTIVE TECHNOLOGIES IN SIMULATION-DRIVEN ENGINEERING

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ABSTRACT

One major characteristic of engineering procedure is the conduction of product development processes by efficient application of computer-aided tools (CAx-tools). But given that the development of those CAx-tools is mostly carried out by non-engineers, the systematic engineering practices are considered in a subordinated way. The current paper deals with a methodological approach to link theoretical simulation basics with practical program use special focusing on design-proximal simulation by finite element analysis (FEA). Examining the support functions (help documents, …) of existing programs, their potentials are revealed. With the help of an implementation concept is demonstrated how modifications of the user interface, using tailored workflow schemes as well as modular handbooks can lead to major improvements in user support.
By a complete conceptual redesign of the supportive technologies, the user-program-interaction can be customized for engineering needs. The situation specific adaption of respective proceedings is dependent on the simulation type as well as the users' state of knowledge, which is to be shown in the second part of the essay.

Keywords: simulation-driven engineering, usability, FEA, CAx, supportive technology

1. OBJECTIVE

Current product development processes, in order to be efficient, are conducted by the use of modern computer aided tools, such as computer-aided design (CAD) and finite element analysis (FEA) [1]. Users of these so called CAx-programs mostly are of engineering backgrounds, following systematic engineering methods of work. To provide efficient work conditions it is therefore essential to enhance these procedures providing corresponding supportive technologies.
Software developers with no or only few engineering experiences mostly carry out the development of engineering programs. Hence systematic engineering practices are considered in a subordinated way, which is the major problem in this context [2].

Therefore a methodological approach is needed to link theoretical knowledge basics with practical program application considering the structure of user support.
Beginning with detailed disquisition of users' requirements concerning program use, modeling strategies and data acquisition, different state of art user support is examined revealing their strengths and their potentials.
The second step contains needed modifications to fit the product developers' needs with newly designed supportive technologies. Thus concepts for improved usability as well as modularizations are considered for simulation-driven engineering [3].
Finally the usability compliant rework of the GUI and user help is shown by the conceptual redesign of a finite element simulation software.

2. POTENTENTIALS OF CURRENT SYSTEMS

First of all the current situation in user support systems must be analyzed. By examination of several state of technology simulation programs as well as by evaluations of user forums, program workshops and support mails and end-user interviews following challenges could be itemized:

- no consideration of the user's level of knowledge
- information overflow; no situation specific support
- lacking information on needed simulation data
- missing guidelines and workflows
- interface problems for data exchange
- the absence of retrieval opportunities for formerly projects and search routines for analogies
- …

One problem is the different level of users' knowledge. Experienced developers will have to cope with redundant information that is not helpful for them, but with render the process confusing; whereas new users are confronted with another information overflow. On the one hand the latter group is provided with every piece of general information the program provides and they have to decide which is important and which isn't. On the other hand specific information to conduct their particular design task is missing or hidden in vast amounts of general helping documents.
Missing guidelines and workflow schemes leading through the specific simulation process constrict efficient work, provoking unnecessary iterations important steps were accidently left out or crucial information is missing [2].

3. METHODOLOGICAL APPROACH

In order to generate tailored user support enhancing the design process and simulations several modifications and adaptations of current technologies have to be comprised. Conflict here in order not to overdo and to constrict the user in spite of helping, there is the necessity of balancing support and well-intentioned paternalism. According to user interviews certain fields have been identified to be reworked. Therefore the following artifacts were taken into consideration and modulated where necessary:

- workflow schemes
- handbooks
- graphical user interface
- supportive framework for situation specific support

3.1 Human-computer interaction

To generate a widespread user support especially the usability of the features to be, must be focused on. So the GUI (graphical user interface) must be arranged in an intuitive way so that the usability (facilitation of using and learning) of the program can be assured. According to EN ISO 9241-11 guideline (guidance on usability) usability is depending on three basic issues [4]:

- effectiveness for problem solving ("Task completion by user")
- efficiency for using the system ("Task completion in time")
- user satisfaction working with the system

All three requirements are closely related so that they cannot be seen separately but rather as a unit.

Concerning the effectiveness for problem solving the basic program shape is to be designed in very clear structures. So in case of simulation software basic schemes must be derived for particular simulation tasks, so that an initial selection of the respective intention is possible. In further proceedings guidelines containing which steps have to be performed and in which order, as well as for each sub-process situation specific support is to be provided, such as essential input data and expected output information; and for the latter how to interpret these results (see chapter 3.3).
Arranging an intuitively usable GUI and provision with crucial information, strongly enhances the efficiency of the described computer-aided system.
Responding to the specific users' need, concerning technical background, established engineering practice and practical experiences raises the product developers' cooperativeness in using new system. Thus has to be admitted that it is always difficult to introduce new systems, mostly due to experienced users' reservations using new, unconventional technologies differing too much from already known systems. Therefore a wide range of different end-users have been interviewed to face this task.

3.2 Prerequisites for programs' usability compliance

To fulfill the just described criteria further requirements for user friendly design are described in EN ISO 9241-110 (dialogue principles) are to be taken account of [4]:

- suitability for the task
- suitability for individualisation
- suitability for learning
- self descriptiveness
- conformity with user expectations
- ...

The suitability for the task requires appropriate functionalities for the respective design tasks, meaning that all needed steps as well as information have to be provided specifically for the particular task. "Individualization" constricts this area to only the needed information, so that a situation specific support can be offered.

To facilitate learning the user has to be guided through the process by intuitive arranged functionalities, workflows and information, which provides implicitly a certain self descriptiveness. Bijective pictograms enhance recognition conducting different design tasks. Furthermore they can be conceived quicker without reading corresponding tooltips, which accelerates program use (Figure 1).

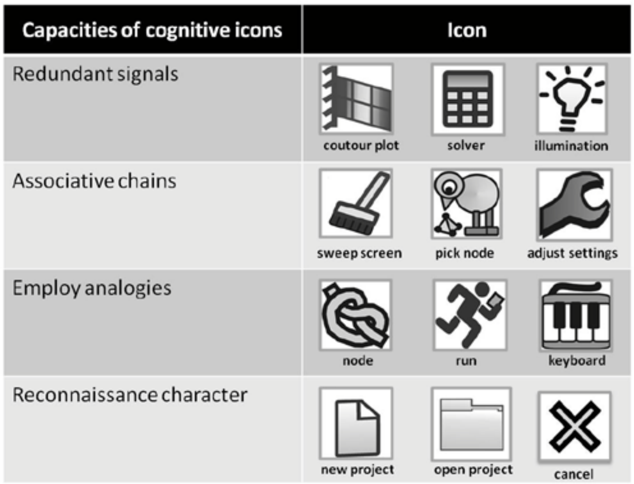

Figure 1: Capacities of cognitive icons

Redundant signals imply expected program features for functions such as a calculator for starting calculations. Using associative chains like a broom for sweeping the screen comprises a mental link with the icons' "regular" function. Additionally the use of ambiguous symbols, like the node of a rope or in a FE-structure, creates analogies. Finally the application of similar pictograms, formerly used in other software, implicates a certain reconnaissance character to facilitate new programs' use.

Pooling functions for different stages of the simulation process in combination with usual reading directions left-to-right and top-to-bottom allows intuitive use, by giving an implicit workflow to work through. With similar colors being used for these function pools, creates an easily to follow process idea. Tooltips combined with cunningly chosen cognitive icons support the achievement of the respective simulation task because of improved function retrieval.
Collaterally to enhanced overview and usability, the concept inhibits an overwhelming stimulus satiation providing only brief information to work with. If more data is needed modularized handbooks and other situation specific help can be consulted (see chapters 3.3/4.1).

Finally considering the conformity with user expectations contains their level of knowledge and experience; a senior engineer for instance won't have to be reminded of certain simulation specialties in contrary to a beginner who has to be introduced in this field. This issue will be discussed in the following chapters.

3.2 Efficient workflow design

Effective product development implies efficient program use; hence certain steps have to be arranged cunningly to coherent workflows. In this context the retrieval of the right information at the right time is one crucial objective. Therefore knowledge about the respective design situation is essential to provide situation specific user help. A finite element analysis for instance can be decomposed into three major steps: pre-processing, processing and post-processing (Figure 2).
In order to receive realistic simulation results the calculation models' preparation, the so called pre-processing, is arbitrative. Successional solver modules calculate displacements, stresses and nodal forces. The post-processing enables the developer to interpret the results and to determine the parts' stability and reliability [1][5].

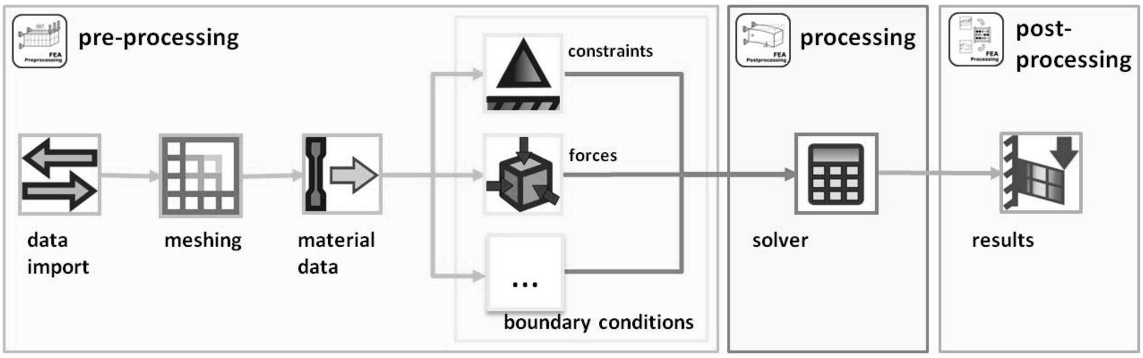

Figure 2: Standard FEA-workflow (linear)

3.3 Situation specific support

Detaching for instance the pre-processing in FEA-simulation originates following sub-steps containing different problems in data procession (Figure 3).

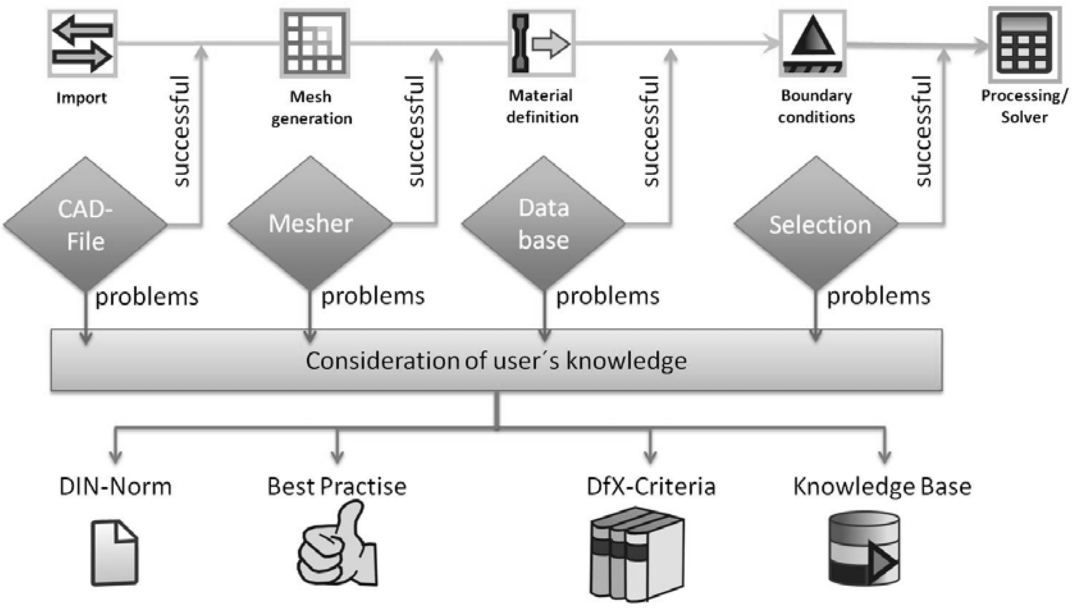

Figure 3: Crucial steps in pre-processing (according to [10])

In every stage specific knowledge is needed, such as norm compliance, best practice documents stored in a suitable database. Cross-linking common methods like DfX-criteria enables the user to improve parts not only during the simulation but even in synthesis steps. Design for X (DfX) provides a methodological approach to build and modify parts to fulfill certain targets like e.g. mechanical stability and manufacturability. So in case the FEA points out the part will not withstand its loadcases, the developer must be provided with design proposals for e.g. placement of roundings to reduce stresses. These recommendations can be combined to strategies for proper program use [6] [7].

4. CONCEPTUAL IMPLEMENTATION

Preconditioned the processes are conducted by human developers it is essential to provide them with the necessary information according to their respective experience without constraining their creativity. Therefore standard user dialogs have been analyzed according to the users' needs, with special focus on inexperienced operators. For the revealed potentials, solution proposals have been developed, in order to show practical applicability, though being a generic method.

4.1 Needful help documents

In all areas of the product development, in particular in the area of the software technology, however many technically advanced products often fail because of inadequate documentation or poor and non-intuitively usability. In order to support users of different levels of knowledge also different ways have to be considered. Normally there are two ways: On the one hand only one manual containing every information available for the program or process; on the other hand there are more sophisticated systems using a checklist like in classical workflow management systems showing which steps already were executed and what is still missing. Both systems are only suitable for more or less advanced users due to the fact that no difference is made when which information is provided leading to an information overload [1].

Within the scope of a new conception of user support modular layout is a promising approach. Therefore the program support provides a modular design of necessary information in different documentation artifacts which can be used specifically and needs based without constraining the user offering too much information at a time.

Monolithic manuals containing every detail of the respective program are the dominating sort of help documents. Overstraining users, these documents are rarely utilized to solve problems of simulation practice. Integrated search functionalities, which most programs have, can additionally complicate instead of solve the problems, being to unstructured and again result in data overload.

So for situation specific support it is necessary to split up these manuals in sub sections to be able to provide as much help as needed, with less superfluous information. The surplus information that remains enables these instructions to be executed independently without additional guidance.

Tailored manuals for specific tasks unfortunately imply partially redundant data and certain initial efforts. But these efforts have to be taken nevertheless to conduct the process in the first place. Given that for legal compliance project data has occasionally to be stored for years; saving them in a retrievable way (indexing, central database storage) is only the next step. So the advantages of more specific user information (with view on future projects) outbalance the negative aspects.

4.2 Rework of user dialogues

One example is the design of the material choice dialogue. An inexperienced user would not know which material to choose for the respective parts, but normally other facts are noted. Therefore a customized wizard should respond to the users' knowledge. In interviews following major criteria could be identified [8]:

- material properties
- manufacturing methods
- use cases

Material properties

According to usability standards not direct questions for the materials' names (although this option should be offered for the case the material is already known) but for the wanted properties is asked:

- density
- maximum strength
- maximum strain

- ...

These material properties can be shown quite clearly in e.g. Ashby-Diagrams [8] or portfolios. Implemented in computerized models they allow a graphical selection of properties in a very distinctive way [Figure 4] [6].

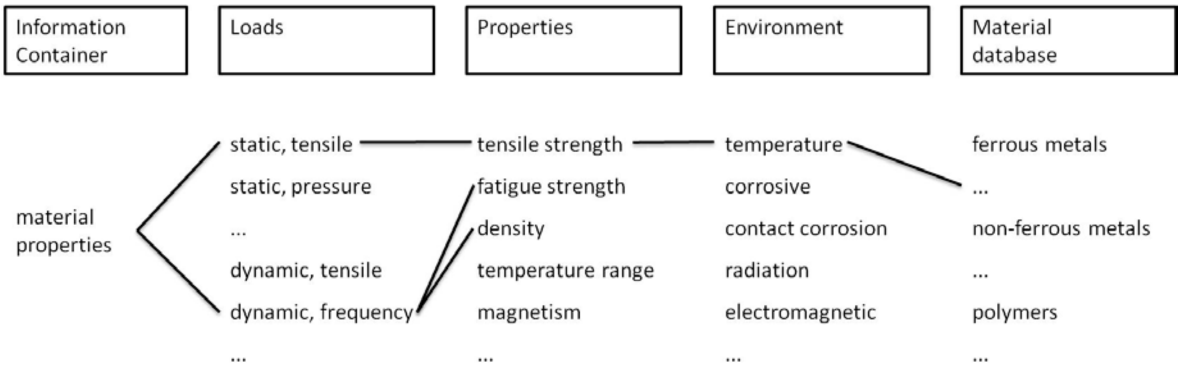

Figure 4: Concept of property-based material selection

Depending on the type of applied loads applied the respective essential material properties are proposed. Certain characteristics additionally depend on environmental conditions like temperature (e.g. the maximum of the Young's Modulus decreases with rising temperature) but also ultraviolet radiation (which is most unsuitable for a wide range of polymers). The operating range is defined by materials' properties like tensile strength, maximum strain and temperature range. The expected part mass for instance can be defined by an initial automated request for the product volume and propose materials depending on their specific density [9].
Therefore a new type of material database containing not only standard material data (such as Young's Modulus or Poisson's Ratio), but rather interactions with other materials and environment is to be implemented.

Manufacturing methods
With "manufacturing methods" the companies' knowhow can be considered appropriately. Similar to material choice by material properties the expected material behavior and adequacy is considered. If processing methods like milling, cutting or welding are chosen only suitable materials are proposed. Additional information comprises best practice documents, DFX elementary instructions (as help in case of potential iterations) and experiences in material use for similar projects.

Use cases
"Use cases" cover similar projects with respectively applied materials. Therefore a differentiation of loads, design and operation conditions has to be included. A database containing a pool of practical examples enables the user to reuse enterprises' and stakeholders' knowledge for current and follow-up projects. Adding short information (pictures, descriptions) facilitates the choice. In contrary to design catalogues, complete examples are shown instead of principle solutions only. Being aware the creation of those examples comprise high initial efforts a basic set of representative examples has to be provided with an option for extension and storing own experiences. These experiences, reflecting the enterprises' core competences, can also be used to train new employees on the job [5].

Possibilities and limits
The presented concept for user support in material choice has its limits: A well-defined material database is a crucial requirement. Most producers don't have or don't release their material data, so that only incomplete data is available. Furthermore the material properties can only be regarded to a certain degree of granularity, to cover a wide range of use cases instead of being too specific and constricting too few use cases. The possibilities of such a user support are the quick training on the job for inexperienced or new employees, helping them to cope with their current design situation as well as building a situation specific database containing material data in combination with their practical

usability, generally and in former projects. This facilitates assigning materials quickly with reference to standard applications.

4.3 Automated support

In contrary to chapter 4.2 there is also the possibility to automate user support in decisions only experts could respond properly. With the help of the "processing"-stage of FEA this type of supportive system is illustrated.

Therefore the comprehension of simulation models' particular data in combination with computer hardware used is implemented. According to the specific design situation (model size, mesh parameters, CPUs, RAM, etc.) a suitable solver is proposed without users' action necessary. Only proposing solutions and leaving the choice to the user helps to decide well-informed without patronizing [10].

All generated data will be stored in a project folder, such as import files, material datasheets and simulation results. Specially referring to first-time users there is a kind of decision log journalizing every action in process steps that has been conducted. By this the whole procedure of simulation is traceable. In case the corresponding worker is temporarily not available colleagues can more easily comprehend the process' status and the operation method.

Without constricting the user the functionalities of (semi-)automated dialog selection and decision logging the user is not constricted in his creativity. Given that the final determination lies with the user, only a key note is allocated.

5. CONCLUSION

5.1 Summary

The presented approach allows more explicit adaption to the particular simulation context. The vital importance of context sensitive user support for CAx-processes is one of the main topics in modern product development. The lack of adequate supportive technologies for CAx-tools can only be handled by innovative new approaches in simulation-driven design. By assigning simulation data to situation specific procedures, profound databases can be created, helping to handle varying simulation tasks in a more sophisticated way. As idealized assumptions can lead to misinterpretations, numerical methods imply critical scrutinizing of their results. Therefore the exegesis is crucial for the parts' behavior and thus the efficiency of the simulations. Well-defined workflow walkthroughs amend the approach.

Making project, product and process knowledge available for a wider range of engineers, renders follow-up simulation jobs more standardized and offers hence better methodical procedure.

5.2 Outlook

Another scope of simulation-driven engineering is to achieve similar quality standards for FEA-calculations as they are usual in other steps of the design process: reasonable development within the planned time frame (predictable component behavior), high production quality (low failure rate) and use of existing resources (human as well as technical resources).

The concept proposed in chapter 4 is currently being implemented and tested with groups of end-users of different backgrounds and states of knowledge. Additionally a wider range of industrial partners has to be included to fit the approach with practical demands. So that user support is constantly being improved.

Objectives of future research will be working out further crucial information, process steps need to be handled with. Next step is to enable a flexible supporting system dealing with simulation data by attaching project data to process stages.

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