Title:
Knowledge Integration in CAD-CAM Process Chain

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Introduction:
Knowledge Based Engineering is an omnipresent topic in the CAx environment. Engineers of different departments are trying to define their knowledge to implement this in CAx systems (e.g. CAD or CAM systems) [2]. All for increase the own work or to support the following processes with more knowledge. For recurring tasks, the system the Engineers are using doesn't change. To support this task the CAx systems has to be modified. For increasing the following tasks, the interfaces between the CAx systems has to be analyzed. In both cases an expert system is necessary to implement the functionalities to the CAx systems.

In this paper possibilities are investigated to link knowledge domains and with this to increase the expert effort. For this, the knowledge will be extracted from structured text files (such as XML files) by an expert system. Another possible source is a database with company and international standards, which can be accessed directly or through a web service. Furthermore, the benefits of web services in that field will be analyzed. This paper will show, how a manufacturing knowledge integration in CAD systems will support the planning and work preparation. This knowledge is distinguishable between conventional and additive manufacturing.

Main Idea:
Many tasks the designer has to do can be automatized. But the current CAD systems doesn't offer all needed functionalities. For e.g. if a keyway has to be attached to a shaft, the designer gets at best a user defined feature to attach and he has to look for the right size by checking the shafts diameter. Then he has to look in the standards, which key he can use. If the company and international standards are digitalized and saved in a database, an expert system can analyze the possible various sizes and let the designer just select one of them. The tasks of diligence can be done automated. In this step the template of such features has to be more intelligent. The information which are needed for manufacturing are determined with the selection of the size. The data, required by the production planner, has to give him as a suggestion, so that he can use this data or discard it, but not has to look for it once again.

By looking at the process chain design and manufacturing in additive manufacturing, the conditions differ from conventional manufacturing. The designing process is very dependent from the additive manufacturing system and the settings for the specific build process. Also, in this area there are benefits by supporting the designer with knowledge to reduce the queries to the production planner.

CAx Systems Knowledge Integration:

Almost each department has different knowledge domains. These differentiate for the data and information which the domain contains and in the way these are stored. The first step is to think about possibilities of linking knowledge domains.

Extracting Knowledge for Integration

Initially the knowledge of an expert has to be defined and stored in a structured way, so that the expert system can access this data correctly. This step can nearly be done independent of the expert system. Just the extracted data has to be saved in a way that is readable by several systems. The data of company and international standards are usually saved in tables. The information about the logic of using and connecting the data can't be saved into a table easily. Regarding the conventional and additive manufacturing, the required process data is not the same.

While designing parts to build with conventional manufacturing, the designer doesn't need to know which machine will manufacture this part. The production planner knows the information about required cutter etc. Most important difference, the machine and cutter are selected after designing the model. In conventional manufacturing each part is manufactured alone. All these data can be saved in tables easily, for e.g. machine or cutter parameters [4].

While manufacturing parts in the additive way (like Selective Laser Sintering (SLS) or Selective Laser Melting (SLM)), many (same or different) parts are built together to make use of the whole build space. So the process settings define the design parameters. For e.g. the reachable surface roughness is dependent from possibly added supports or the slightest gap between materials is depended from the process settings. For this an AMP-XML file was created to define all process parameters including machine data. This file can be filled by the production planner with the AMP-Tool [6]. Fig. 1 shows the application and interfaces between engineering and work preparation.

Expert System

To implement knowledge into the CAD system without additionally burdening the designer, it is necessary to use an expert system. There are different types of expert systems which can be distinguished between the integration depths in the CAD system [5]. To implement manufacturing knowledge into the CAD system, an integrated KBE system is necessary, especially when disturbing the workflow of the designer is not desired. In this depth of integration the design of the expert system is very much dependent of the application program interfaces (API) of the CAD system. For both manufacturing types the expert system is already programmed for different CAD systems. The designer can access all available function for production-oriented construction from a single ribbon in the cad system.

Accessing Data

The knowledge saved as data in the XML files, similarly simple text files or JSON files can be read with different parsers in nearly each programming language. So, the data can be read by the expert system. XML and JSON are structured files and should be preferred. The data can be extracted by the keywords. By using simple text file, the structure of the file has to be known by every expert system. The validity of XML and JSON files can simply checked with Schema files [1].

With equal ease the data of a database can be read. Nearly each programming language offers database connectors to request data by sending a SQL Select statement. But for this each expert system has to know the structure of the database and the needed SQL strings. In most cases the standards are dependent of many information, which are connected with other standards or tables. Just filtering a table of standards is not enough to get a form of a standard. For this database function are necessary or the logic of the data dependence or every special case has to be defined in each expert system. In that case the database cannot be changed in its design or source. For example, switching from an international to a company standard requires changing all expert systems of each CAx system.

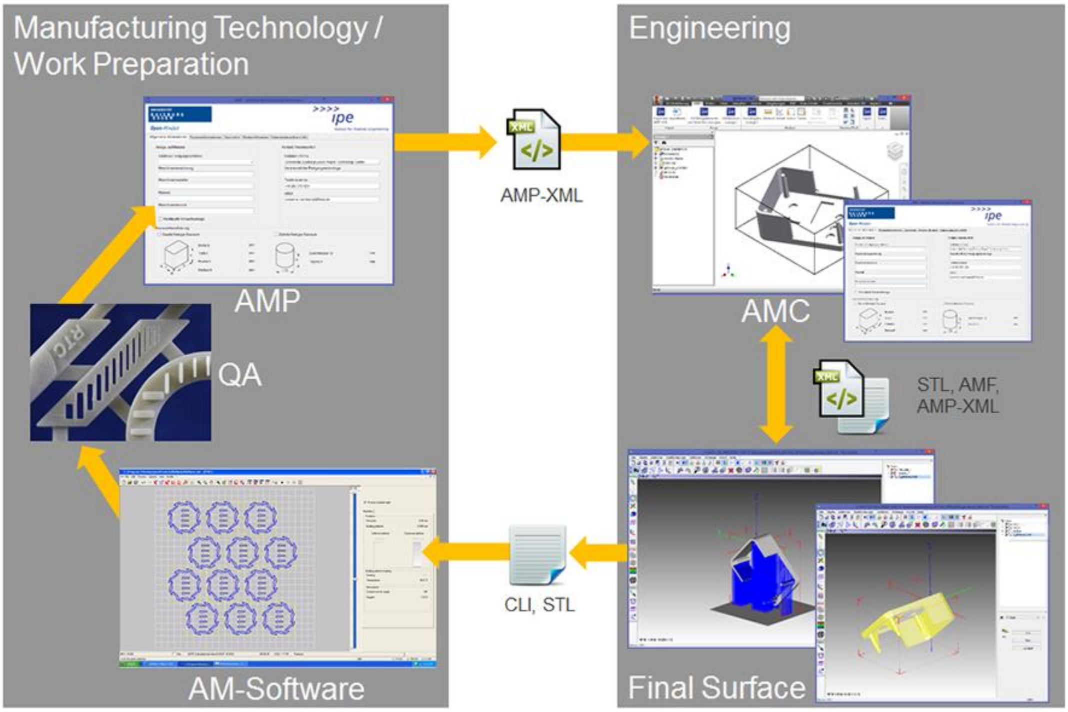

Fig. 1: Application and interfaces in additive manufacturing.

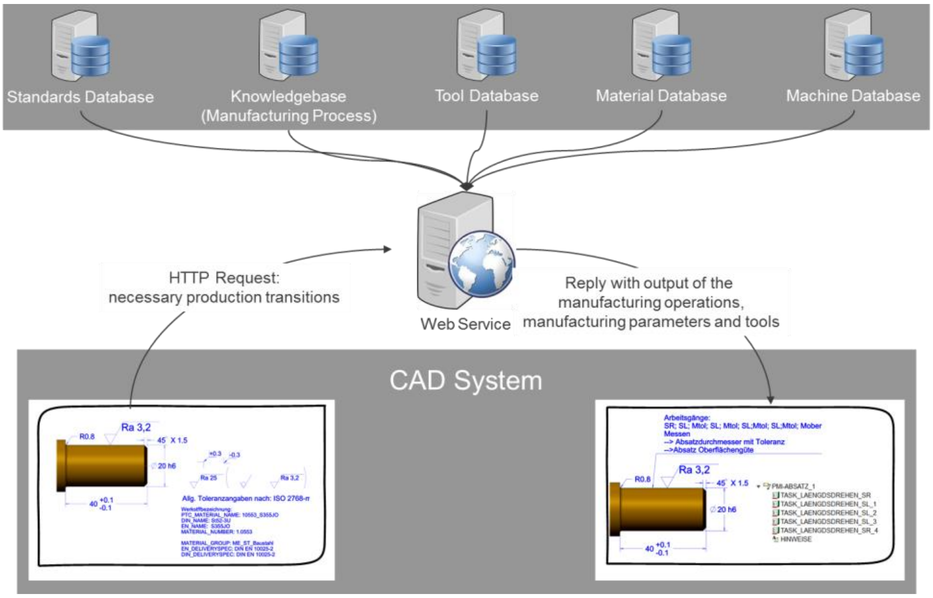

Fig. 2: Web service to get database information in CAD system.

For this the access to the data should be managed by a RESTful web service [3, 8]. By using web services, the needed information can be obtained by a HTTP request. The URL contains all information that is necessary to get the answer from the web service. The web service contains the logic to get the data of the table or other sources like files etc. and to connect these in the right way. Depending on the web service the answer can be a JSON, XML, HTML or other formats. The expert system can validate this answer with the schema and read the data with the parser. In case of changing the structure of a database or similar, it's just necessary to adjust the web service. There is no need to change the expert system in that case. Fig. 2 shows the workflow of getting data from different databases through the web service and integrate the replied data in the CAD features.

The API for the web service is designed with RESTful API Modeling Language (RAML) [7]. The main structure of the web service is described in this single file. This file is used to generate the view layer of the Apache Tomcat web server. After the access from the expert system to the webserver is verified, by requesting the example data, the other layers can be programmed.

Knowledge Integration

The expert system has to implement the knowledge into the CAD system. The integration depth depends on the type of information. Most of the data extracted are saved as parameter in model or in feature. Here it is not enough to save the data only, a time stamp and the version of the standard has to be saved also as information for better traceability. According to this, the designer has to decide if the expert system should keep the knowledge on the current status of the database or leave it at the last state. First the expert system starts a query from the database and filters data to the possible forms. The designer gets an offer of possible sizes. After selection one, these parameters are transferred to the feature in the CAD system.

Anyway, a preparation of the model is a basic prerequisite. Either the preparation has to be done manually before integration or it has to be done by the expert system. In conventional manufacturing the feature is prepared and saved as user defined features. These individual groups always contain an analysis feature with all information which are required for the query. If it is not just a semantic feature, then there are feature to create the geometry. Finally, there is always at least on note feature. This note contains different manufacturing templates, where manufacturing information can be saved [3].

In additive manufacturing the only prepared item is the part template. One of the most important function is changing orientation after designing the part. So, the part can be brought to the position and orientation of the build process in the machine after designing the part. All other information are implemented directly by the expert system without preparing the model. Examples are the build space of the machine, bounding box of model or slice data.

Using Knowledge in Pursuing CAx Systems

In conventional manufacturing the knowledge can be extracted automatically from the CAM module of the CAD system, by reading the information from the manufacturing template. In other CAx systems constellations the transfer of knowledge has to be done by expert systems which convert the knowledge from one domain into another. In some cases the knowledge can't transferred directly. Then a structured text file, for example JSON file, is needed to provide the implemented knowledge for other systems [4].

For additive manufacturing there aren't so much CAM systems or modules. In this example a direct transfer trough the expert system is realized, where the process and model information are transferred to Final Surface [6].

<u>Summary:</u>

This method shows how a knowledge integration in the CAD model can increase the own but also following tasks. Mainly the knowledge integration should help the designer to create parts or feature which can be produced without recurring demand.

The implementation has shown, that connecting different information in one point is useful. In that case changes should not require changes in the CAD system or in the database. Just the adjustment of the web service is required.

Just in comparing conventional and additive manufacturing it can be seen, that the approaches are different, but the main benefit is to reduce the constant iteration between current and following tasks.

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