The Usage of Feature-Technology for Knowledge Processing in the Scope of Design-Embedded FEM-Analysis

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Summary:

Design and analysis by use of feature-technology leads us from merely entity-based methods on to characteristic-based concepts. A Weld-point for instance is not anymore processed by beam-elements, but by an intelligent information-container, that additionally contains the involved geometry, as well as technological-parameters like strength-requirements, tolerances, costs, and further.
In the same way other design-characteristics are represented and processed by the system. The goal is to build up and represent the hole productmodell merely by the use of features.

Advantages are the simple usage of feature-based systems and in addition the aspect, that part of our knowledge is captured automatically, while building up a model.

This article describes the state of the art regarding to feature-technology in the scope of design-embedded FEM-analysis. It shows FEM-features currently supported and requirements for a FEM-feature-library, that takes pattern from usual machine-elements.

Additionally we show a concept, that automatically extracts knowledge and experience from given feature-structures of CAD/FEM-models. A database-search with various similarity measurements provides users having problems by finding a similar problem-pattern with a corresponding solution. The concept and tool is called case-based-engineering and is developed as a shared project by industry (Binde & Wallner Engineering GmbH) and a research institute (DiK, University Darmstadt)

Keywords:

Knowledge-based design, FEM Assistant, FEM Feature, Case Based Reasoning, Case Based Engineering, Expert System, Similarity Measurement, Wissensbasierte Konstruktion, FEM Assistenzsystem, Fallbasiertes Schließen, Expertensystem

1 Introduction

The integration of the feature-technology into the digital product development processes counts as an assumption for successful knowledge-representation ("passive knowledge"), as well as knowledge-processing ("active knowledge"). Passive knowledge means all information that additionally to the shape (geometry) describes or explains the product in its technical realization.[1]

2 Development of Technologies in the Scope of CAx

The requirements of today's companies in the scope of production is characterized by a permanent increasing complexity of the products, growing quality demands, increasing pressure on costs and decreasing time to market. Therefore the virtual product development and the CAx-technologies are pushed massively, because they count as a key for success. The development of these technologies can be classified in four coarse categories.[2].

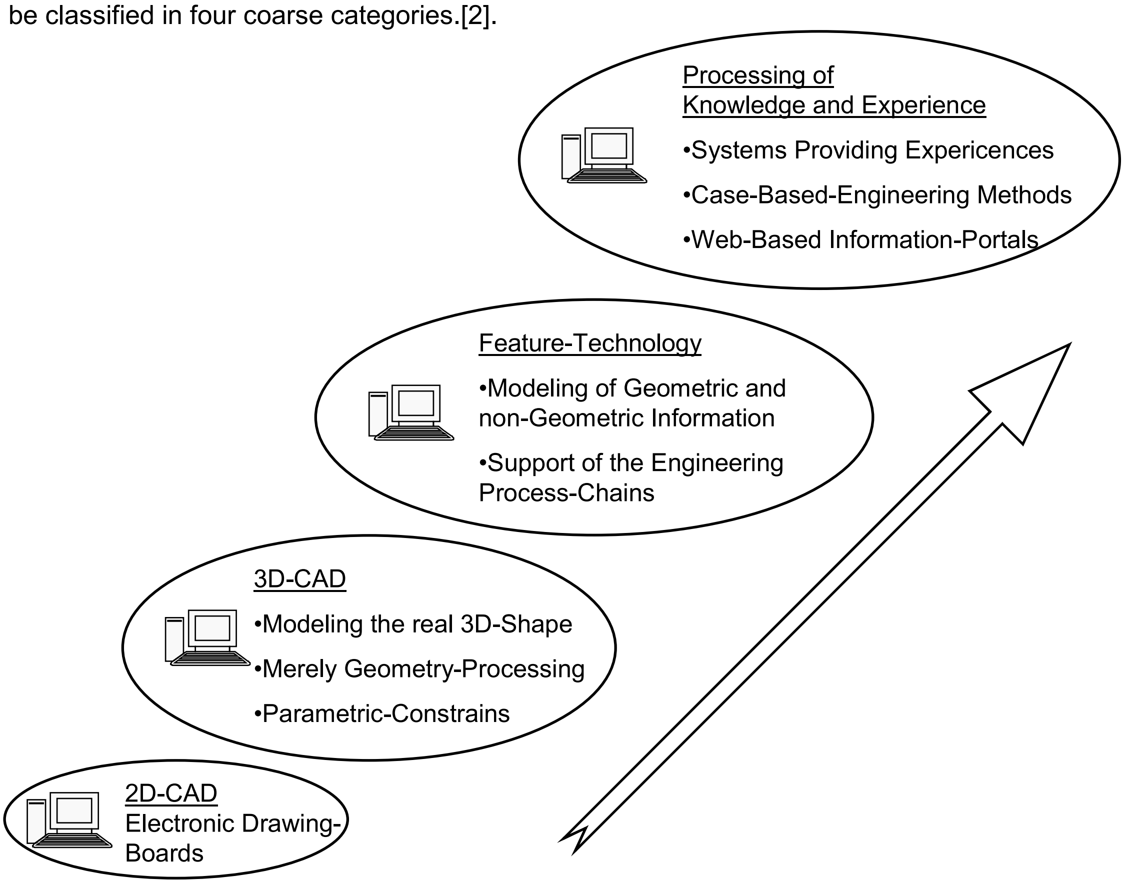


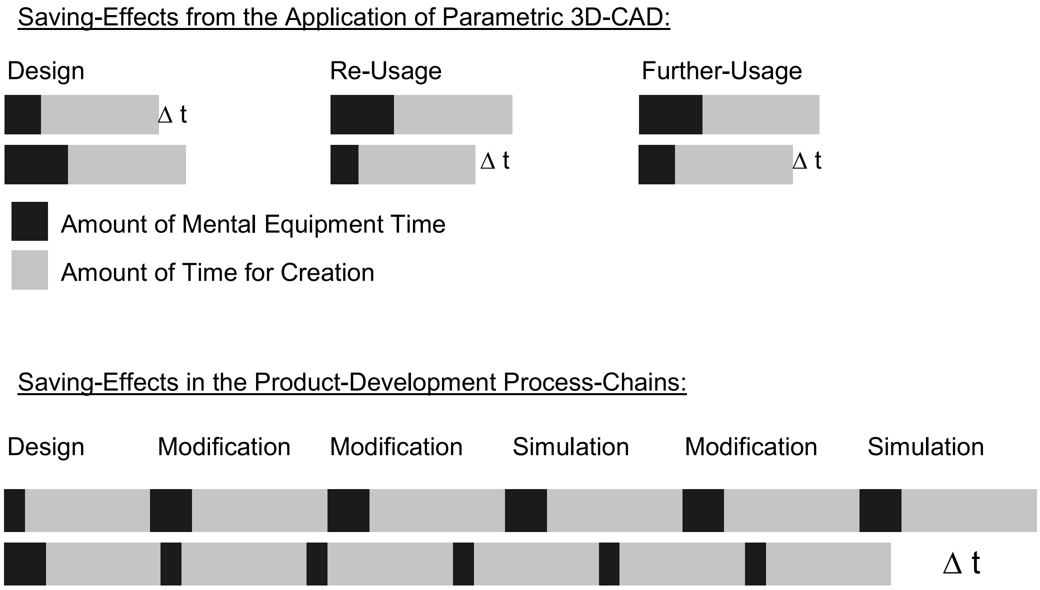
Fig. 1: Development of Technologies in the Scope of CAx

2.1 2D- and 3D-CAD

In the past there have been drawing-boards, that have been substituted by 2D-CAD-systems.

The transition to 3D-CAD-systems was a large step, because parts and assemblies where represented in their real 3D-shape. Lots of CAD-following processes have been influenced massively and new methods have been developed: Kinematical packaging analysis, mass-analysis and others. The FEA-process was improved also, because in the same way the development of automatic volume-meshers came up.
With the integration of geometric constraints (parametric) into the CAD-model powerful methods for building variants and part-families appeared. The possibility to reuse past-CAD-models was improved.

Today's modern systems have realized 3D and parametric modeling in a nearly perfect manner. The mathematical CAD-engine-kernels allow the design of highly complex geometries. Different classes of geometries, like free-form and analytic shapes can be combined without problems. Nearly any geometry can be build up in a parametric kind, so variants can be created automatically. This advantage is used by FEM optimisation tools for instance.[3]



Source: Prof. Anderl, TU Darmstadt

Fig 2: Time Saving-Effects

2.2 Feature-Technology

Feature-technology exceeds the merely geometry based design process. We try to process geometric and non-geometric information together. This method implements further reality into the model, that more and more becomes a virtual product. In addition the extended information can be extracted and further used by following engineering-processes like CAM, FEM or others.

A feature is a digital representation of a special interesting characteristic of the product. This characteristic is usually of technical, design specific, commercial or any other nature. A feature represents a special view on the product description. Therefore a feature filters out the relevant product-properties of that special characteristic for a given context.[1]

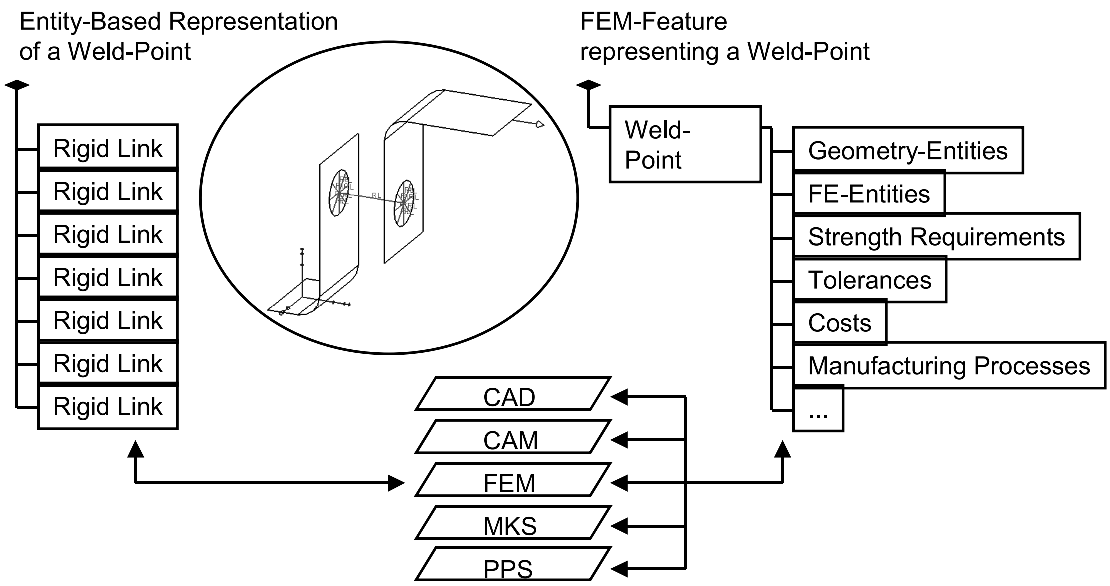


Fig: 3

In the scope of engineering a feature is an information-container, that can be filled with or extracted for knowledge from different views or different contexts.

That's why the proper application of features depends strongly on the active context and the definition of feature-libraries is application-specific and sometimes even company-specific. For the context of design-embedded FEM-analysis we give some examples of general usage features:

- Load features:
  - Pressure,
  - Forces,
  - Bold-load,
  - Torsion-moments,
  - Acceleration Effect,
  - Rotation Effect
- Assembly-contact features:
  - Bonded (glue-) contacts
  - Frictionless slide contacts without separation
  - Frictionless contacts with separation
  - Frictional contacts with separation
  - Weld-features
- Contacts or boundary conditions, that are automatically extracted from assembly mating conditions [4]
- Features for Boundary-Conditions:
  - Fix boundary conditions
  - Symmetry-conditions
  - Simply supported conditions
  - Pinned support
- Thermal conditions:
  - Thermal structural loads
  - Constant applied temperature
  - Temperature-flow
  - Convection
- Features for solutions and validations:
  - Stress-, strain-, displacement- requests
  - Convergence-testing with adaptive mesh-refinement
  - Fatigue-feature
- Features for coupled analysis:
  - Thermal-structural analysis
- Features for special machine-elements:
  - Press-fit feature
  - Screw-connection feature
- Features for preparation of geometry:
  - Face-compounds, section-meshing
  - Automatic small feature removal
  - Face-subdivisions

Most of those features are available in today's integrated CAD/FEM-systems. The features are used as predefined software tools providing a user-interface and letting the user insert the interesting characteristic to the model. The feature should be shown in a feature navigator, providing a documentation of all special interesting characteristics of that context.

If the required characteristic is not available as a predefined software tool, the method of manually feature definition should be available [5], letting the user create the characteristic in the entity-based way first. In the next step the user creates a group for the entities and applies descriptions and attributes to the group manually.

Another method of feature processing is the application of feature-recognition algorithms.

3 Knowledge- and Experience- Processing by Use of Feature-Technology and Case-Based-Engineering Concepts

Our goal is the integrated product model. That means we need to create virtual products, that do not need to be explained anymore by persons. All information about the development, the manufacturing, the usage, the hole product-lifecycle is held in the digital product description [6]. The product model can be opened or edited by a user-interface, like a CAD-system and the user can read or extract or insert knowledge about the active context.

With a successful processing of knowledge and experience we try to insert those information, that very often stays as “special knowledge” in the heads of the developers.

The concept and softwaretool Case-Based-Engineering (CBE) supports these requirements. CBE is developed by the company Binde & Wallner Engineering GmbH Wiesbaden in conjunction with the institute DiK at the university of Darmstadt.

3.1 Automatic Knowledge Acquisition by Use of Features

When talking about electronic processing of knowledge and experience a question of interest is if it is possible to store those characteristics, that contain our knowledge and experience by computable elements. Case studies show [7], that in the scope of design embedded FEA [8] the following information have to be processed:

- Design Context
  - Administrative information: User, date, customer,…
- Solver parameters
- Part for analysis and its properties
- Adjoining parts and forces, resulting from them
- Contact Conditions, Support Conditions
  - Form-feature on which the contact is established
  - Coupling-Conditions
  - Semantic information of the contact (Connection-Properties: Screw, Sold, Weld, …)
- Results:
  - Form-feature:
    Geometric element of result validation (planar face, cylindrical face,…)
    Semantic-information of that geometric element (Blend, Hole, Cutout, …)
  - Mesh-Properties at validated result (Tet / Shell, Element-Size, Quality)
    Geometric preparation or idealization in this area

These information can be held by computable elements and it can be shown, that today’s feature-based CAD/FEM-systems, more or less, already do so.

Sophisticated, feature-based systems in conjunction with up to date trained users build up piece parts only by use of CAD-form-features. So each piece part is represented and automatically documented as a list of features or in other words design-characteristics. FEA-result requests like stresses or displacements as well as loads are applied on those form-features too, so these information are stored and documented in the model automatically. Assembly-features build mating-connections between the parts and also are applied on those form-features on the piece parts.

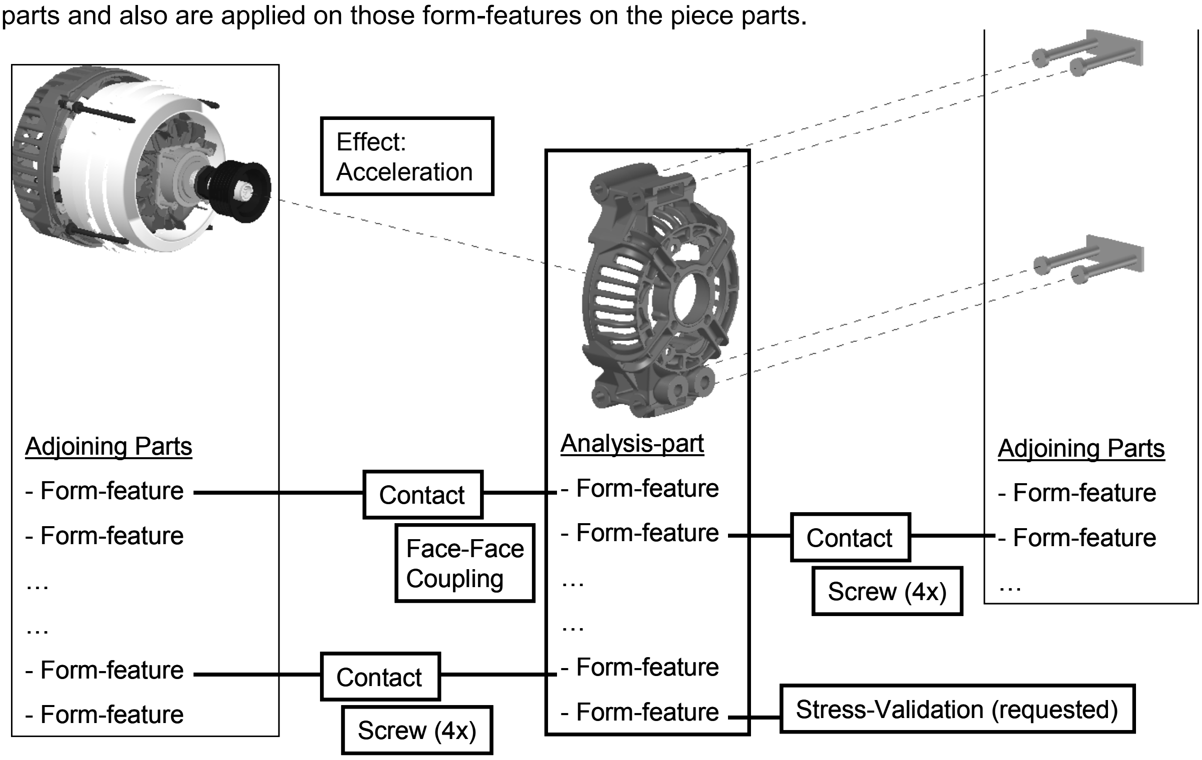


Fig 4: Possibilities to insert knowledge as computable elements to the model

3.2 Knowledge Extraction by Scanning Past Cases

The case-based-engineering concept takes use of those information that are stored automatically in the virtual product. At present it is limited to the scope of FEA for designers. It scans the database of a successfully solved FEM-problem and extracts design-characteristics as well as the dependencies between them. This way it can scan a hole database of files for feature-patterns. It communicates to the CAD/FEM-System over an xml-interface.

So the case-based-engineering system can be used for extraction and demonstration of the knowledge-contents of past analysis cases. Sometimes it has to recognize features and convert them to a neutral form. It puts the characteristics and their dependencies in a navigator and provides transparency to the user.

One important aspect for automatic knowledge extraction is the recognition of the relevance of features. In FEM the relevance of parts or even special regions of a part can be derived from the quality of the mesh, that is applied. A high quality mesh means, that it is a part of high relevance. This way the system can tell between analysis-parts and “help-parts”.

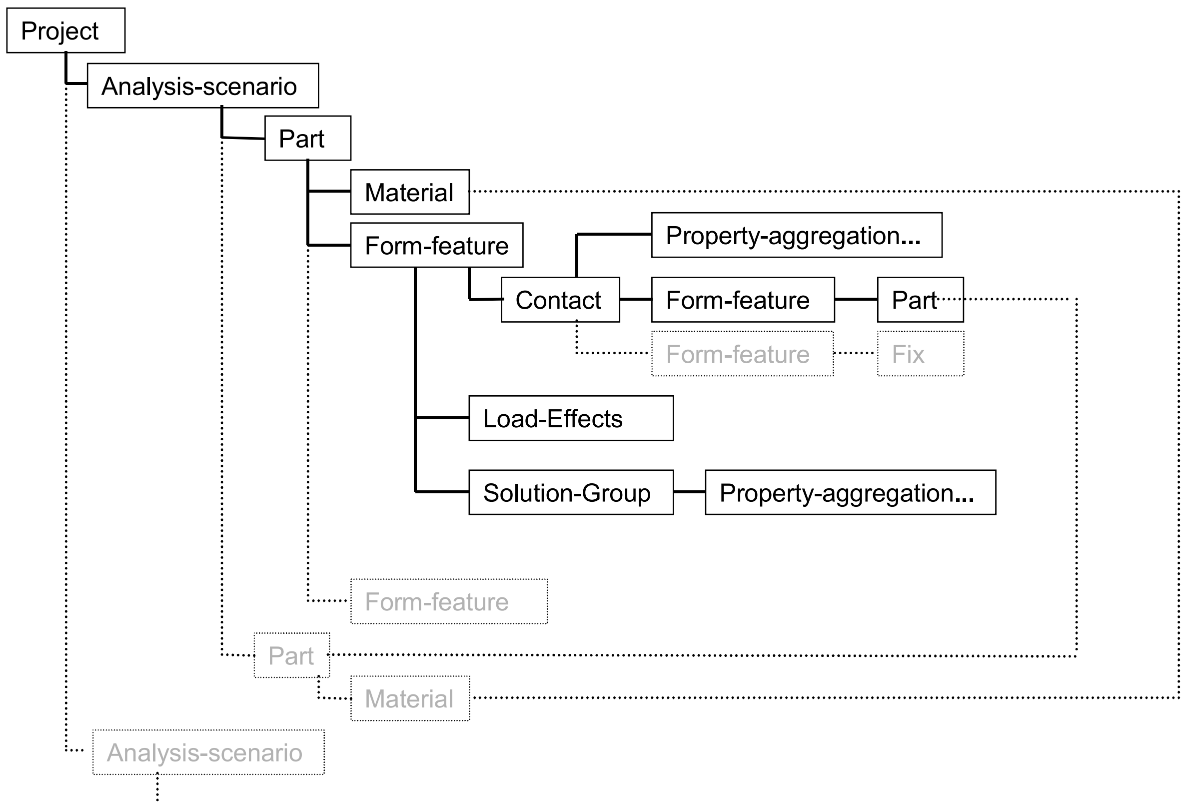


Fig 5: Example-graph of FEM-knowledge elements

3.3 Manually Knowledge Acquisition

In addition, the CBE-system can be used as a feature-modeling system. This way the user manually inserts feature-information to the analysis-case. That feature-information represents further knowledge about the case, that maybe could not be inserted by the provided features of the CAD/FEM-system. It offers the creation and manipulation of those types of features, that are commonly known as machine-elements.[9].

Manually feature-definition is necessary, because in practice the CAD/FEM-systems as well as the users do not work perfectly. That's why we need possibilities to manually insert or correct the given information. This method also provides the possibility to build up a feature-structure in the CBE-system from scratch.

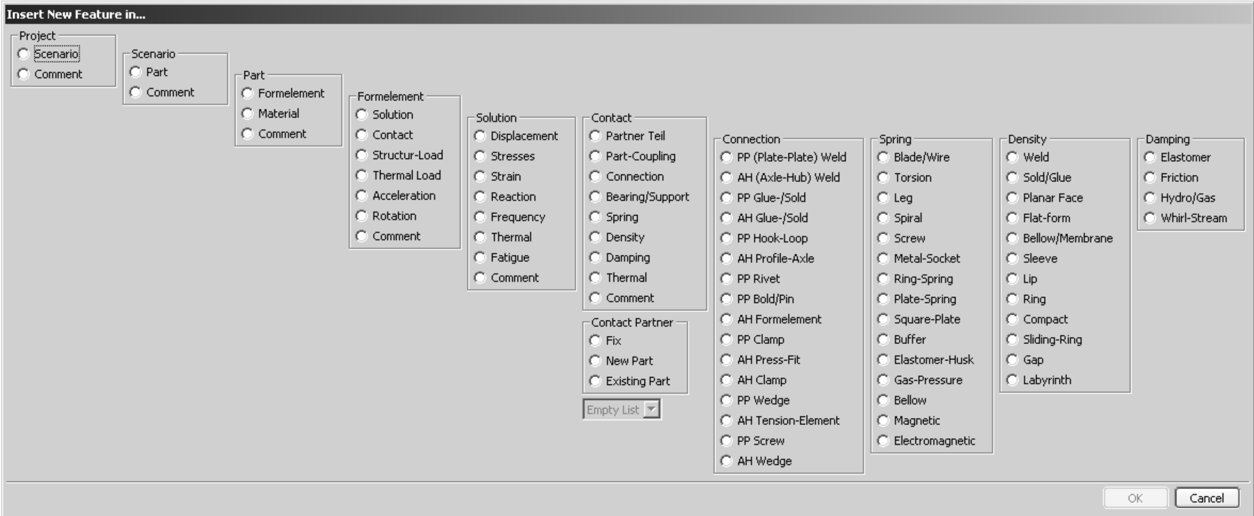


Fig 6: The library of FEM-features provided by the CBE-system

3.4 Connection-Features as an Example

Connections are an example for complex features, that should be processed by a modular concept. In the first approach a connection is defined simply as an element between the target and assembling part. This empty contact-element represents an early phase of design, when you still do not know the exact type and properties of the connection. It acts as a black-box.

In the next step information about the involved form-features can be applied, so the virtual product gets knowledge about the geometry and semantics, that you want to connect, for instance a hole on the first side with an axle on the other side.

In the following information about the coupling can be applied, for instance the fitting and the kinematics. Also information about the type of connection, for instance a plate/plate-screw-connection is inserted as an object with special attributes. If you want, you can further insert spring-, density-, damping- elements and their attribute-descriptions.

Many of these connection-information can be extracted automatically from the model. Others have to be applied by the user.

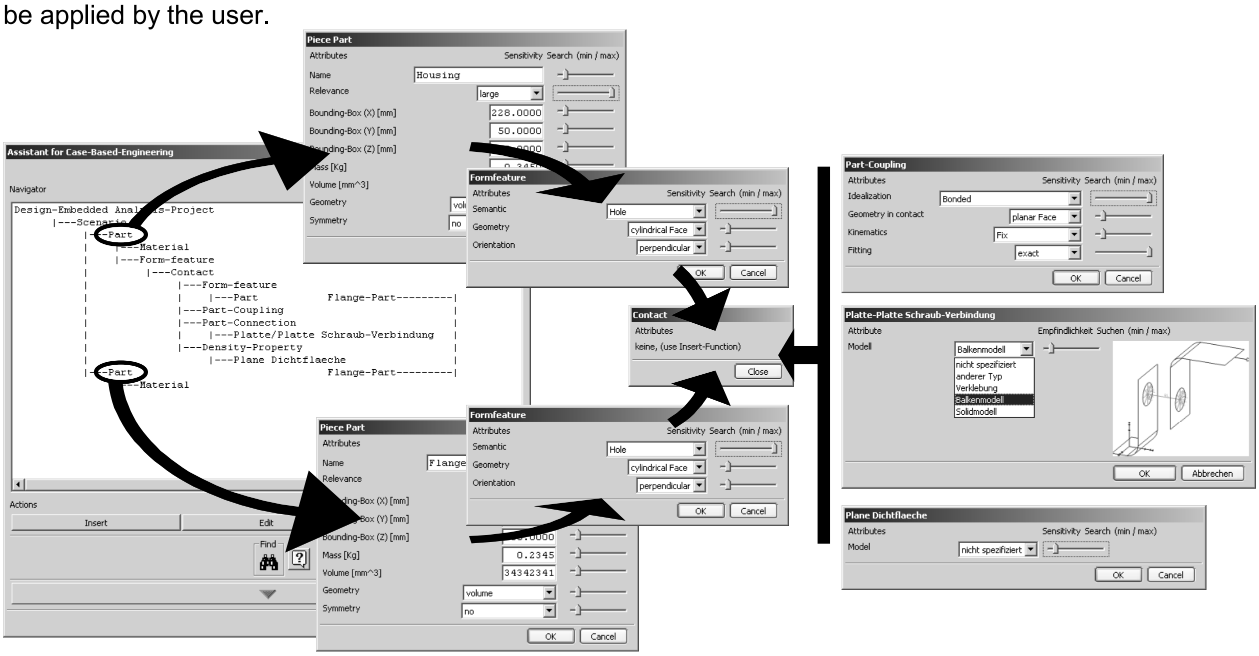


Fig 7: CBE-Feature engine showing a modular build connection

3.5 Knowledge-Reuse by Recognition of Feature-Patterns

The feature-structures and their attributes can be understood as the soul of a project or case. We have shown methods for automatic knowledge acquisition to build up the case and knowledge extraction for demonstration of the contents. In the next step we show a knowledge searching concept, that builds on these two methods.

The CBE-system provides methods to compute similarity between cases. One of the similarity-measurements is the “containedIn”-function. This function performs a graph-matching of two given graphs. The first graph models the task-pattern, that shall be solved. The second one is taken out of the database of successfully solved cases of the past and is called the test-pattern. The containedIn-function responds true, if all features of the task-pattern are found in the test-pattern and all dependencies are found in the same way.

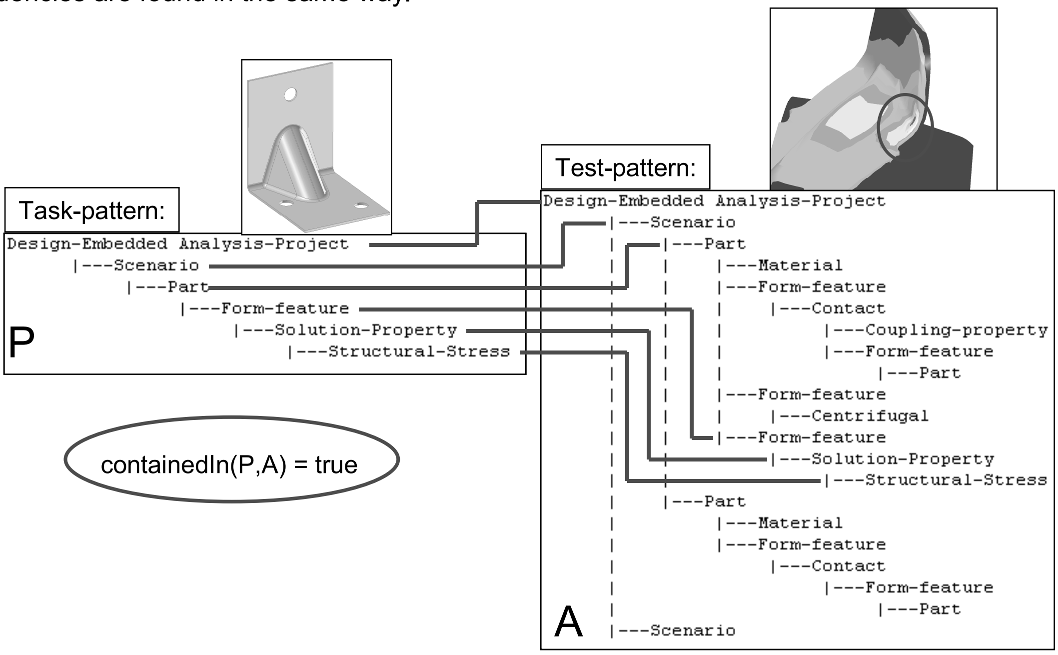


Fig 8: The containedIn-Function scanning a database for patterns of similar problems

The algorithm cycles through a database of virtual product-files and stores all matches. If there are many matches, the corresponding features in the task and test-pattern are validated for their similarity too. This is done by calculating the nearest distance between their weighted attributes (manhattan distance)

$$sim(p,q) = \sum_{i=1}^{n} |p_i - q_i|$$

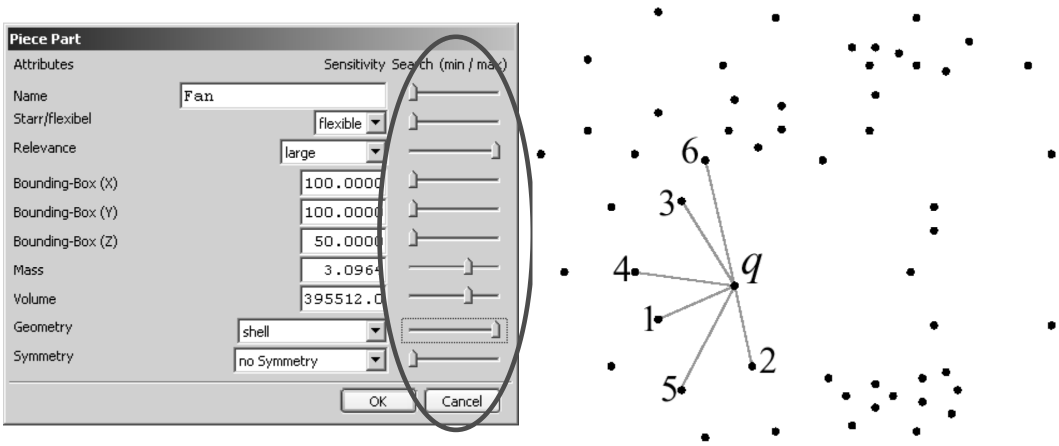


Fig 9: Manhattan-Distance-Method to find the six nearest neibours

Further there are methods available to perform inexact searches, that can tell if features are of large or small relevance. Parts of small relevance are excluded by the inexact search.

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