Title:
Automation of Drafting Execution by Schemes Definitions and Feature Recognition

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Introduction:
In the product design field, Design Automation (DA) is commonly intended as the possibility to obtain geometric shapes of parts and assemblies starting from a set of initial specifications by means of autonomous software. DA systems generally enhance the capabilities of parametric feature-based 3D CAD systems to alter the geometry and the parts arrangements following a set of predefined options. The scope of DA applications is centered on products families characterized by a good level of configurability or dimensional variability. Typical examples are gearboxes, electric motors, metal shelves, hydraulic cylinders.

Configuration refers to approaches and tools to identify valid sets of input parameters given a set of independent variables chosen by an user and a set of commercial and/or technical constraints [4]. Proposed approaches include rule-based and constraint-based systems while research and industrial applications have shown good potentialities of such systems. The link of DA systems to configuration engines has been also investigated [5] as effective design tools.

Although DA systems claim the ability to generate both 3D geometry and technical documentation, the phase of generating robust dimensioned drafts of the configured product is often neglected. Technical drafts is the traditional way of representing a product from a technical point of view while 3D representations has shown undisputed capabilities of facilitating design activities and building virtual mockups. However, drafts are still used as the official way to document a product, communicate to production, propose and share data about variants in catalogues.

In the case of large families of configurable products, the possibility to have the technical drawing of every required family member may become critical. Moreover, products usually experience continuous updating in the shape of the components, number and arrangement of parts and addition of new variants. These aspects require constant drawing updating and resources involved in repetitive and low-profile drafting tasks.

In this context, this paper presents an approach to automatically generate technical drawings of members of product families. Some systems have already been proposed in the literature aiming at paradigms to generate views and dimensions of generic 3D mechanical components [1-2]. In particular, automated procedures to obtain dimensioning in relative short time has been developed in the form of macros or coding activities such as the well none Visual LISP in the AutoCAD system [7]. Nowadays, modern CAD tools propose functionalities to support the drafting activities in 3D-2D associativity environments. It usually refers to view arrangement templates in order to speed-up the execution of similar drawings. Finally, some 3D CAD systems provide automated 2D dimensioning plug-ins which are able of browsing the geometry of a part and instantiate dimensions on the basis of embedded search algorithms [8]. However, the goal is the identification the dimensions of the main geometric features of a mechanical component seeking to cover the whole set of dimension or locations.

In general, these approaches show some limitations. The first one concern the fact that drawings content is fixed and it is not possible to determine the desired dimensional information. In fact, the dimensions are decided by the system on the basis of the geometric features of the product. The second one concerns the applicability which is restricted to single parts.

In this paper the focus is set on the definition of an abstract drafting scheme which is valid for a certain product family, or a subset of it, and it is applied to the generic member in order to obtain views arrangement and dimensions according to a predefined application purpose. For instance, a drawing of a group could be produced for manufacturing reasons or to be inserted in a technical catalogue or in a spare parts manual. Each of these applications requires different representation approaches, different sets of dimensions and variability in the additional data, for instance tolerances, to be reported in the drafts. The geometrical entities which are involved in the dimensions to be added are searched by means of feature recognition algorithms which ensure the capability of identifying the required entities among the family members.

Main Idea:

Fig. 1 outlines the proposed approach and the flows of exchanged data. The input is given by the 3D geometric model of a product and the relative Bill of Material (BOM). The product could be either an assembly or a single part. Since the approach is oriented to families of product alternatives, the model may originate from interactive modelling activities or, more likely, from configuration modules of PDM/PLM systems. The expected output is a dimensioned draft of the product represented by one or more orthogonal projection and the required annotations.

The approach splits in two main phases. The first concerns the definition of a knowledge base which encapsulates the rules and the Drafting Schemes which need to be followed to accomplish the execution of the drawings according to the characteristics of the product family and their final use (i.e. production, documentation, …). This is an off-line phase accomplished by a designer using a dedicated interface. The second phase refers to the actual, repetitive and autonomous on-line utilization of the system to realize dimensioned drafts. The first phase is based on the cited Drafting Schemes which contains an object-oriented data structure and some rules to choose the views, the dimensions type and positioning. A scheme applies to a set of similar 3D models usually corresponding to the variants of the same product family and is based on a general description in order to be applied in various application domains. The structure of a scheme is reported in Fig. 2. It initially reports the list of sheets and views required by the draft. Attributes such as sheet sizes, units, view projection directions, scales are defined. Then the list of dimensions belonging to a certain view appears. Each dimension is associated to presence rules which are to be satisfied for the dimensions to appear in the final drawing. The most obvious and trivial rules regard the presence of the dimensioned part and the possibility to identify the target geometric element. Other rules are connected to the model attributes. This approach allows the number of required schemes to be reduced and condensed.

A scheme also defines how the geometric entities (edges, faces, points, …) which are the target of the dimensions are to be searched and identified in the whole product geometry.

The second on-line phase includes three application modules and the interaction with a CAD system to load the 3D geometry and to generate the 2D one. A first module, called *Geometry Import*, reads and analyzes the model geometry from the CAD system and other additional attributes coming from the BOM, such as part codes, categories, material, description. The product geometry is read and converted in a B-Rep format which includes standardized geometric formulation for edges, faces and topology. This conversion step helps the successive entity search algorithms since the expected geometric formulations types are reduced.

The second module, namely *Dimension Entities Identification*, elaborates the geometry in order to identify the entities to be sized. An entity can be of different type: edge, face, silhouette curve, vertex or construction element such as axis or a centre mark.

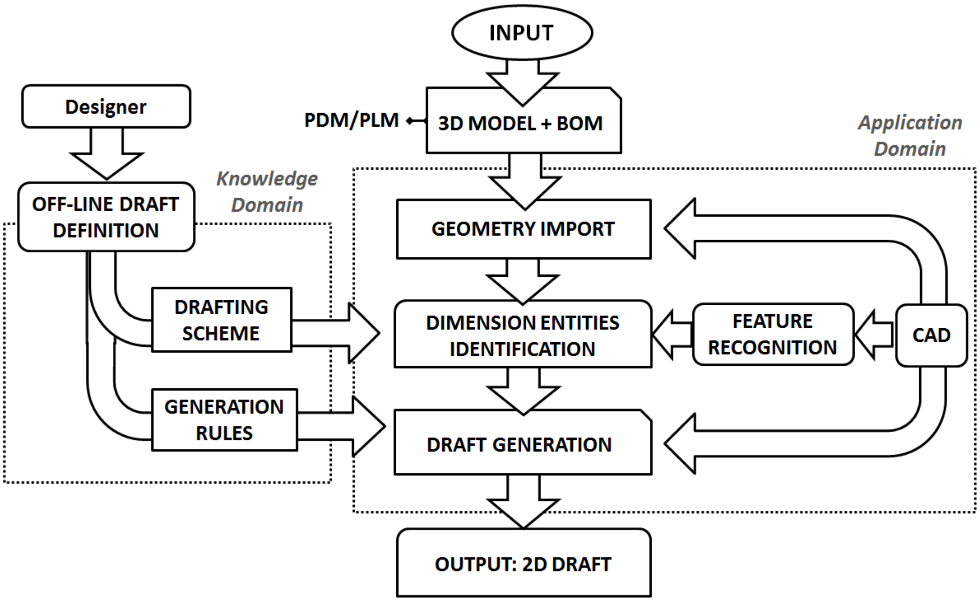

Fig. 1: Workflow of the approach.

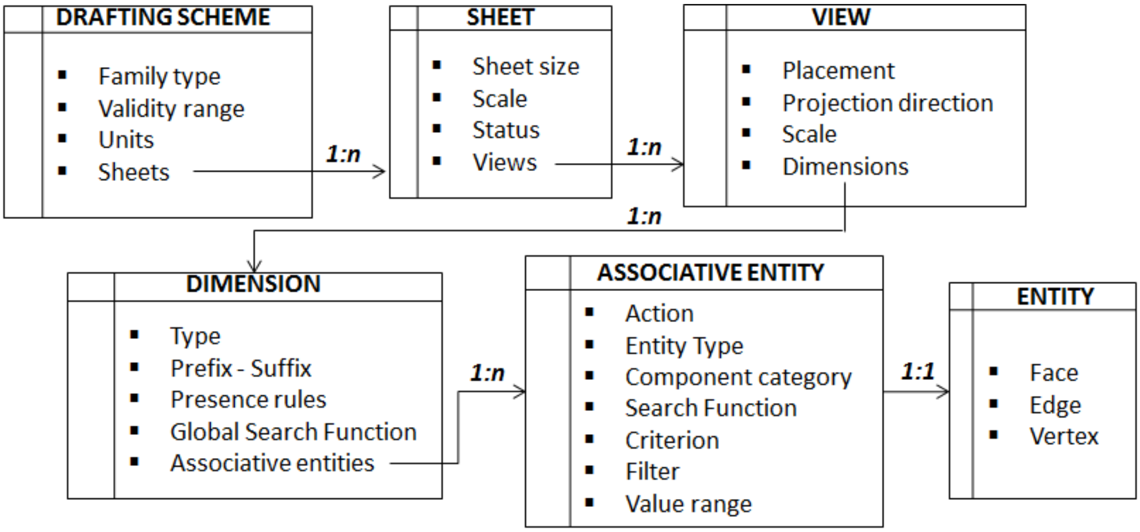

Fig. 2: Structure and data contained by a Drawing Scheme.

The entities are searched though feature recognition algorithms which seek to recognize aggregates of entities with a clear design meaning such as pockets, holes, fillets, etc…, from the whole B-Rep geometry. To this aim standard feature recognition approaches have been employed [3, 6] and extended in some parts. In particular, customized feature recognition functionalities are provided and exposed as functions which can be chosen in the Drafting Scheme.

The actual entities search is accomplished by proxy objects called *Associative Entities* and a two-steps search. An Associative Entity links to an existing entity (edge, face, …) or defines a derivative geometry (axis, center line) to be added. Candidate entities are at first sorted out by a *Search Function* which operates on the basis of some filters and criteria. Then a *Global Search Function* selects the required entities for the dimension being under realization.

The last module is the *Draft Generation*. It provides a connection to a CAD tool through the APIs to drive the autonomous execution of the technical drawing making it available in formats such as DXF or PDF. The elements to be drawn are provided by the selected Drafting Scheme and the input rules. For instance, some views or dimensions may be inserted depending on the presence of certain components or the spatial arrangement of some 3D parts as resulting from the configuration activity of the input model.

<u>Implementation of the approach:</u>
The proposed approach has been tested on the autonomous execution of technical drawings of a family of gear motor assemblies. The gear box can assume several configurations on the basis of the axes relative position, size, transmission ratio, number of redactions, type of flanges, mounting position, etc. The drawings are generated for documenting the gear motor sizes and interfaces and are destined to machine designers.

Fig. 3 shows the graphical user interface (GUI) of the prototype tool which has been developed, while Fig. 4 reports an example of result. The chosen examples refer to a drafting scheme which includes one sheet and two projected views. About 30 dimensions are defined and more than 70 geometric entities are involved in the definition of the dimensions.

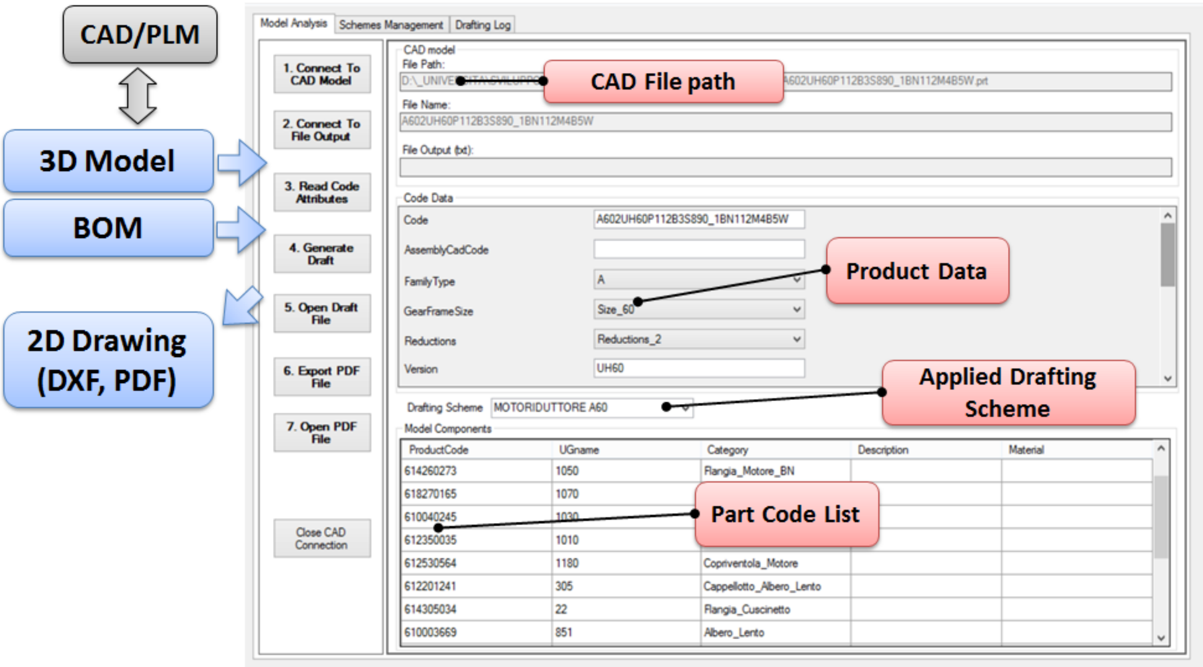

Fig. 3: GUI of the prototype application tool.

<u>Conclusions:</u>
The traditional tools for the automation of modelling or drafting activities suffer the rigidity of the specific application contexts. In order to overcome such limitations, the proposed approach leverages flexible drafting schemes which can be realized within a dedicated user interface without coding activities and the power of feature recognition algorithms to associate the required dimensions to the correct geometric entities.

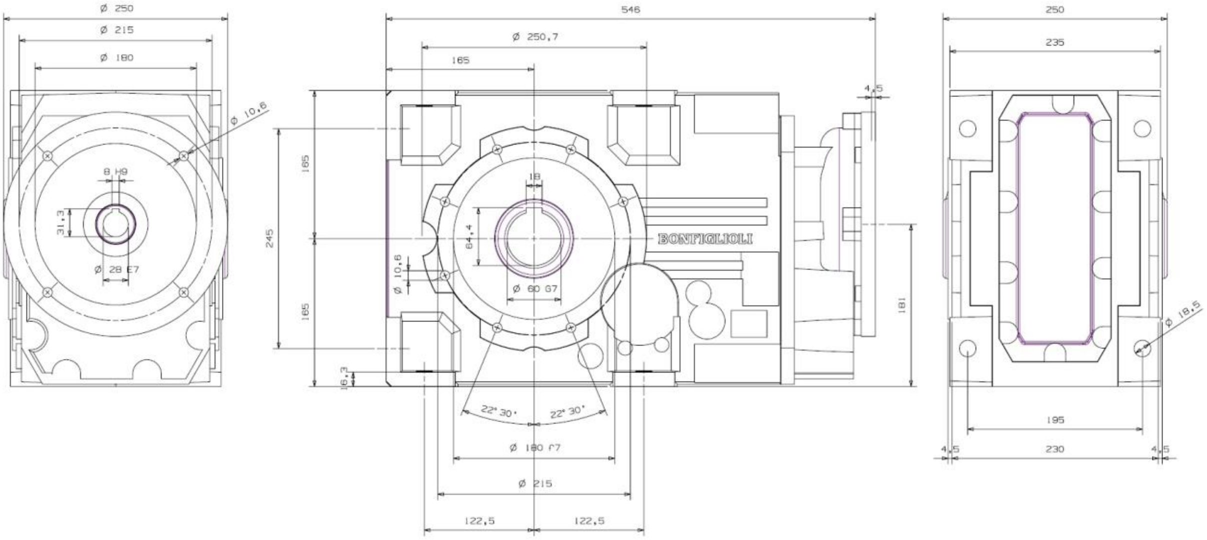

Fig. 4: Example of dimensioned drawing obtained from the 3D model of a gear motor.

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