Title:
A Theoretical Framework for Supporting a Novel Design Development Process: An Interactive Semantic-based Approach in Computer Assisted Parametric Design

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Abstract:

The laborious process of designing mechanical parts and assemblies (sheer number of stages and different complex activities required) is leading to strong pressure from users to improve the actual systems. Modern CAD software allows detailed design of parts and assemblies, but is quite limited in part parameterization and cannot offer the abstracted higher-level construction that users need right now. Although some of the actual CAD models provide feature-based design which semantically may include product information, it not includes "a sound basis to reason with knowledge" [1]. Detailed design of parts involves features creation, defining dimensions and tolerances (usually requested for the manufacturing process) which is tedious and non-intuitive due to the actual interaction techniques and used interfaces. These shortcomings indicated an immediate need for new development.

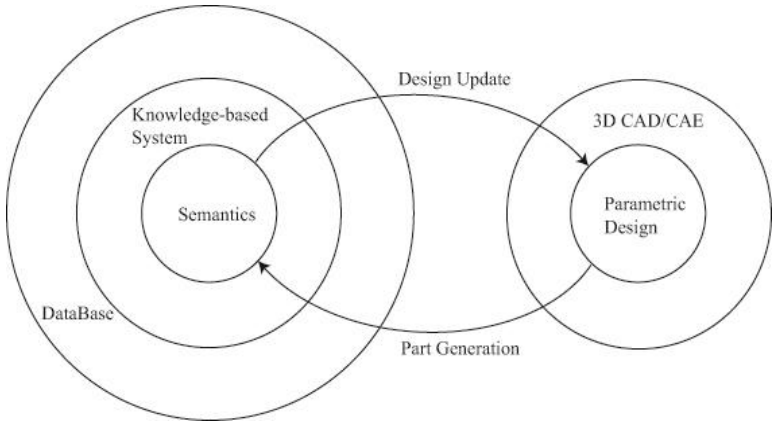
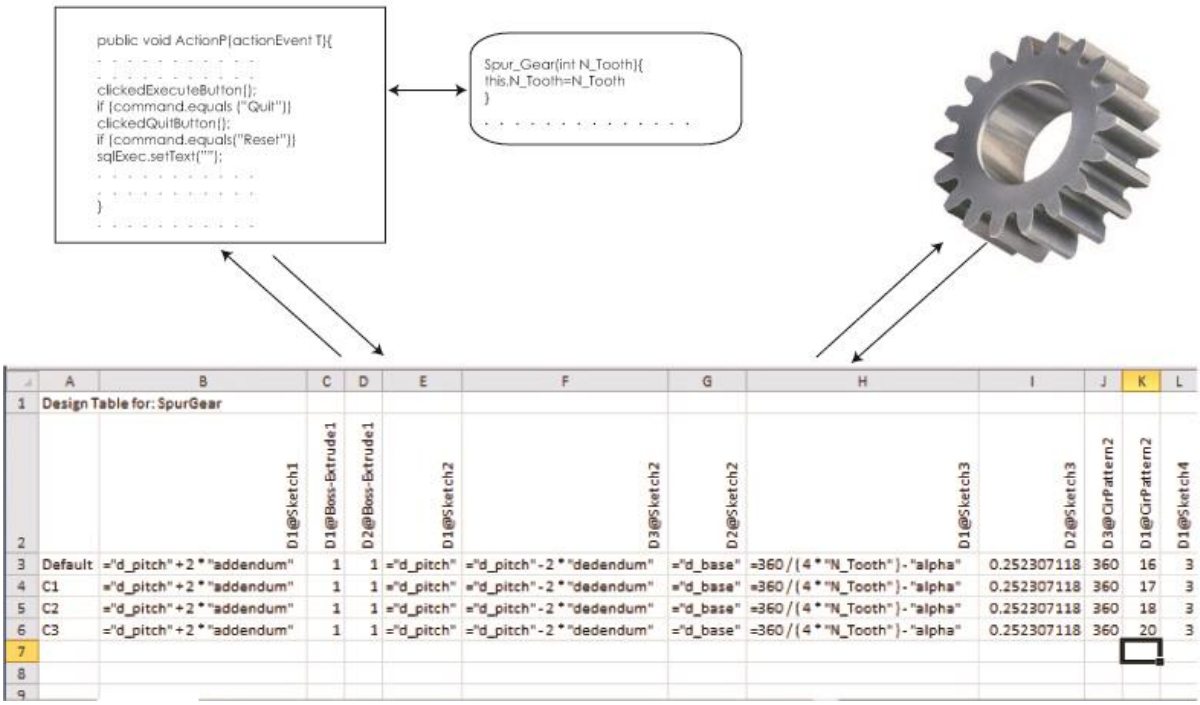


Fig. 1: Design development process by integrating parametric modelling with a semantic-based component system in the process of 3D CAD products creation.

An efficient way to reduce design time can be obtained through the use of parametric design by modifying the features and the dimensions of existing similar parts [7, 8]. The development of parameterized CAD can allow users to change product models for various parameter and constraint values [15]. A complete model parameterization - including the establishment and automatic maintenance of parametric dependencies - would allow the reuse of the existing models and geometry

through dynamic modification of the parts stored in a semantic-based CAD library [16]. This reflects the nature of design and removes much of the tedious repetition from CAD modelling when changes are required in a prototype product, which thereby increases productivity of CAD users and reduce "lead times and costs for new products" [3] in all design phases.

Modern CAD systems also lack simplicity in their interfaces [8]. The power of a semantic-based component [2, 16] system could be combined with alternative access techniques to allow the use of scripting and natural language (instead of just drop-down menus) to associate parameters/variables controlled by external sources/scripts to parts and assemblies. The parametric modelling, which follows a top-down approach [5] to integrate components in the final assembly, used algebraic equations to define relations inside the parts. This allows new product creation [6,7,17] and manipulation with less designer intervention and a friendlier machine-user interface based on the user's natural communication abilities, that is, a more "natural" communication with the system.



	A	B	C	D	E	F	G	H	I	J	K	L
1	Design Table for: SpurGear											
2		D1@Sketch1	D1@Boss-Extrude1	D2@Boss-Extrude1	D1@Sketch2	D3@Sketch2	D2@Sketch2	D1@Sketch3	D2@Sketch3	D3@CirPattern2	D1@CirPattern2	D1@Sketch4
3	Default	="d_pitch"+2*"addendum"	1	1	="d_pitch"	="d_pitch"-2*"dedendum"	="d_base"	=360/(4*"N_Tooth")-"alpha"	0.252307118	360	16	3
4	C1	="d_pitch"+2*"addendum"	1	1	="d_pitch"	="d_pitch"-2*"dedendum"	="d_base"	=360/(4*"N_Tooth")-"alpha"	0.252307118	360	17	3
5	C2	="d_pitch"+2*"addendum"	1	1	="d_pitch"	="d_pitch"-2*"dedendum"	="d_base"	=360/(4*"N_Tooth")-"alpha"	0.252307118	360	18	3
6	C3	="d_pitch"+2*"addendum"	1	1	="d_pitch"	="d_pitch"-2*"dedendum"	="d_base"	=360/(4*"N_Tooth")-"alpha"	0.252307118	360	20	3
7												
8												
9												

Fig. 2: Design change by integrating parametric modelling with semantic -creation and update of a 3D CAD gear component.

In this paper a theoretical framework for supporting a novel design development process by integrating interactive modelling with a semantic-based component system in the process of 3D parametric CAD products creation (and to investigate relevant novel interfaces to improve efficiency) is considered (Figure 1). The framework use of a knowledge-based system [4,9] of existing parametric parts/models that allows design reuse, part(s) storage and extraction (from an associated database). The knowledge-based system uses a natural language processing set of integrated rules/scripts [11] as interface between the user and parts parameter for mapping questions/commands to a corresponding SQL query. Rules are the key parameters that control design reuse in the inference process. Each rule considers a suitable substitution of the parameters/variables to infer a new possible design according the design variations considered by the user. Over and under constrained designs detected during parts and assembly redesign process (due to conflicting dimensions) allows users to trigger a procedure for part re-parameterisation.

A simple example of a parametric modelling and its associated semantics - which exemplifies the use of natural language and show the benefit of the proposed framework - is considered in the design creation and update of a 3D CAD spur gear component design. The spur gear was selected from a gear database (previously created) which includes spur, rack and pinion, helical, face, worm, hypoid, bevel, and screw gears, as well as gear assembly containing train and compound gears prototypes. The parametric design of each mentioned gear prototype has been constructed using features based parametric equations and Boolean intersection/reunion operations. The parametric design of the each gear assembly was created using a top down design control through parametric equations.

The parts and assembly database consists of generic objects (mechanical parts/components such as gears, screws, etc) which includes objects instances (parts dimensions, materials properties, relations between the mechanical parts) and possible hierarchy attributes. Inside the database the inheritance mechanism (which generalizes hierarchy) is considered, each mechanical component/part inherits all the characteristics from its "super-class, that is, a pinion inherits the properties of the corresponding spur, worm of whatever type of gear is considered in the final assembly. The knowledge-base includes both syntactical and semantic information to reveal important gear characteristics such as Poisson Ratio, Young Modulus and other properties of the used material, as well as spur gear geometry including pitch diameter, tooth profile, number of teethes, just to mention some of them.

In the design update of the spur gear particular geometries are carried out (from the initial prototype) through a suitable substitution of the key parameters to infer a new design variation considered by the user. The use of the natural language in the proposed framework (considered very acceptable by users [10]) may have wide ranging applications in all aspects of science, technology and education which use CAD including product design, artistic design and others. Moreover, further work may imply the development of a Natural Language Interfaces which will allow a direct and immediate computer-user dialog.

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