Parametric Design Methods for car body design

Luca Avallone [1], Gennaro Monacelli [1], Federico Pasetti [2], Fabrizio Giardina [2]

[1] *Elasis S.C.p.A.*
[2] *Fiat Auto S.p.A.*

Abstract

This work describes a new design methodology for car development process based on the archetype concept, modular systems and parametric and associative CAD. An archetype is defined by a parametric model of a component or system configuration. Car body archetypes can be developed using a parametric and associative CAD.

The archetype models contain geometric constraints and design rules. The methodology contains the representation of the car body design process based on the use of these parametric models.

Using this methodology, engineers can define the frame of a new car body, respecting the company standards. The principal benefit is the reduction of the design development time as the modification process is optimised. Furthermore the design history is recorded and the same parametric models can be re-used for several vehicle projects.

1. INTRODUCTION

Elasis and FIAT Auto started to test parametric and associative (P/A) techniques at least 6 years ago [1], in order to create some archetypes of an entire Fiat vehicle. Fiat was one of the first automotive companies to test P/A features in the development of a new car.

Car body design is a very critical and time-consuming activity because it is deeply linked to body style. The most frequent design modifications during car development process, in fact, depend on style changes.

For this purpose P/A design seems to be very attractive for designers because it enables to speed up the process of geometric features updating, according to the new style changes. In this way, designers don't waste time in boring and repetitive activities without adding value. The project goal was to develop a new P/A design methodology in order to:

- reduce modification time during the development of a new car body;
- reuse the same parametric models for future platforms.

The methodology was based, not only on P/A design, but also on the concept of *archetype* and *modular platform*. The archetype is a set of logical and parametric features of an object or system. With these archetypes it is possible to build the model of a single component or a whole system. The modular platform is a platform that can be used for several types of vehicles with specific modifications. A car body, in fact, has usually made for only one vehicle with its specific platform, while a modular platform can be used for several cars (usually in the same car segments) and can be adapted to the current style.

The developed methodology is able to manage modular platform and style modifications.

2. STATE OF THE ART OF CAD SYSTEMS

Nowadays the most advanced CAD systems are based on features, parametric modelling and associative environment concepts. These types of systems are called generally parametric and associative CAD (P/A CAD) or feature based CAD (FB CAD), even if we have not found on the market a product that implement all these capabilities at the same level [2], [3], [4]. In this paragraph we will examine the meaning of these concepts: feature, parametric and associative.

Features are physical o logical elements of an object that an engineer can use during the definition of the geometrical model of the component. Examples of feature are through hole, slot, pocket, chamfer and so on. Therefore features can be seen like a sequence of geometric operations (building blocks) that has an engineering meaning for product definition. Engineers usually look at the feature like a physical constituent of a part. Therefore the *feature model* is a data structure that represents a part or an assembly mainly in terms of its own features [5].

In a *parametric environment*, user can completely define a geometric feature with some parameters, so he will be able to modify it changing the parameter values instead of deleting geometric entities (for example, a surface offset could be modified acting on the offset parameter).

In an *associative environment*, user can catch the relationships between objects, features (i.e. the tangency between a segment and a circle could be kept also if the circle's radius is varying or if a designer replaces the circle) and different process phases (i.e. CAD Model, FEM model an Drawing). User can define relationships between systems and components in large file assembly (*multimodel associativity)*.

Another important property of these systems is the capability to store in their database all the operations made to define the product model: this is called *design history*. In some case it is possible to re-update parts of the product model, just re-executing the relative design history steps.

The last concept regards the variational systems. A *variational CAD* allows user to create geometry not fully constrained, therefore user can fix some parameters that are useful, leaving the other parameters unconstrained.

The main expected benefits from these systems are the optimisation of the user productivity in modeling and the reduction of the modification time.

Our design methodology has been developed using these CAD characteristics and the implementation of car archetype systems that will be explained in the following paragraph.

3. CAR BODY DESIGN METHODS

The methodology was based on P/A CAD but also on the concept of *archetype*. An archetype is a set of logical and parametric features of an object or system that can be used to build the relative CAD model [5]. In figure 1 is illustrated the building process of an anterior pillar using its archetype design. Each rectangle represents a feature and each arrow represents an operation made on features. The generated CAD model can be modified in flexible way and sometimes with an automatic procedure.

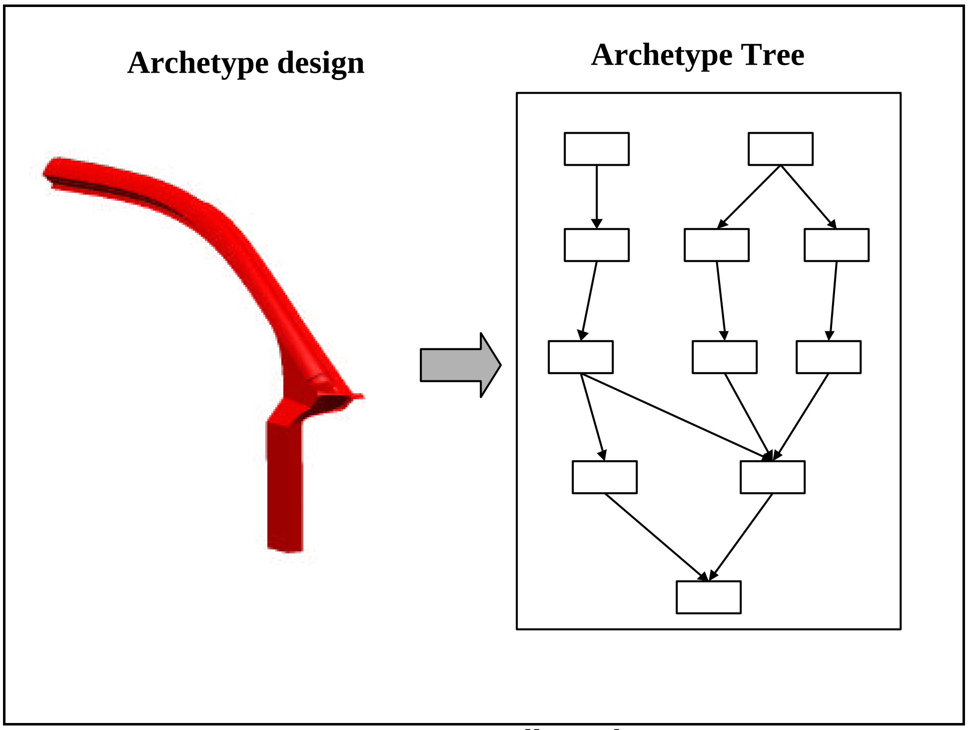

Figure 1. Anterior pillar archetype.

Instead of building a unique model file with a whole set of features, we usually split the feature relationships into more files, for better manage the archetypes. In figure 2 it is shown that an archetype might be composed by three files:

- the first file gives only a set of surfaces and construction features;
- the second file uses these features to build a primary model;
- the third file allows to obtain the complete part.

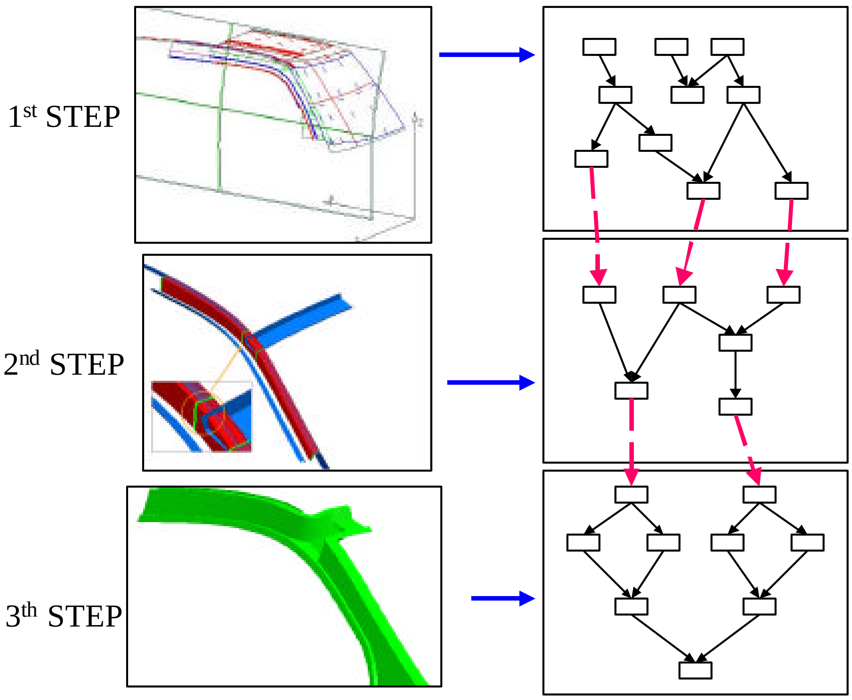

Figure 2. Example of an archetype split in three models.

A designer starting from an archetype can generate different components, simply changing its parameter values. This is another advantage of the archetype design.

The example reported in figure 2 shows the archetype anterior pillar construction.

In order to develop the design methodology and the relative archetypes it was set up a development team composed by engineers coming from different departments of Elasis and FIAT Auto. The phases of design methodology were the following:

a) Define the vehicle reference model (developed with explicit CAD systems and procedure)
b) Build the design development history (list of modifications)
c) P/A modeling of new vehicle model (archetypes definition and implementation)
d) Optimisation phase
e) Models update during vehicle development
f) Design method implementation

The first step was to analyse the explicit CAD model of a car body design, in order to understand its design history, in particular the most common and frequent design modifications. After this analysis, we tried to understand the logical constraints and the most appropriate parameters for every model and the definition of reference archetypes. The result of this step was a tree, in which there were macro logical constraints among different archetypes and the relative updating sequence. Next phase consisted in developing P/A archetypes of components and systems. The archetypes were tested in order to evaluate their reliability: this was the optimisation phase concerning the parameter modifications and the feature links of each archetype.

The last phase consisted in the implementation of the single steps of car body design method.

It is to underline that this P/A method doesn't limit the creativity designer, but augments his productivity respecting company procedures and standards [6].

The design methodology is mainly based on the top down approach focused on two different levels:

- Vehicle level
- Component level

There were two different teams in order to manage the different levels:

a) The *vehicle level* is managed by the project manager that, with reference to the car decomposition (see i.e. figure 3), assigns the single vehicle systems to each system *team leader* (TL). Then TLs assign the component areas to each engineer and define the rules to manage the interfaced components (master-slave strategies). Furthermore TL defines the system assembly, the carry over components and the feasibility studies. At this level, we can say that the main activity consists in defining the car body decomposition in beams and nodes, as shown in figure 3.

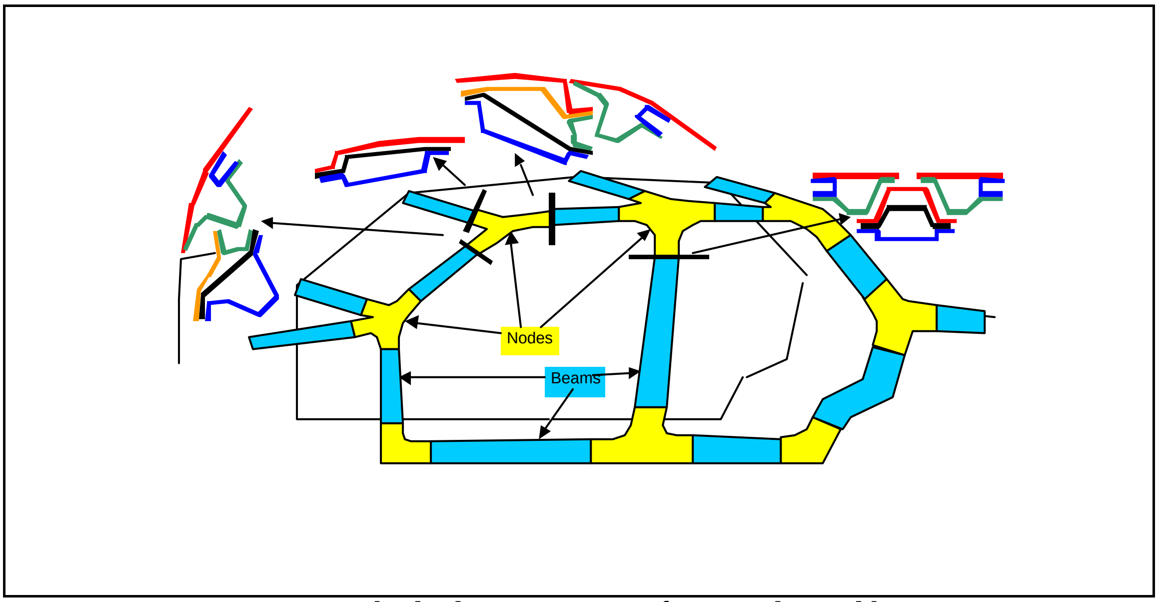

Figure 3. Car body decomposition of into nodes and beams.

b) The *component level* is managed by engineer that has the responsibility to develop the relative group of nodes and beams, with specific archetypes.

In figure 4 is reported the general schema that contains the relationships among explicit and P/A environment and the parametric hierarchy of vehicle systems and components.

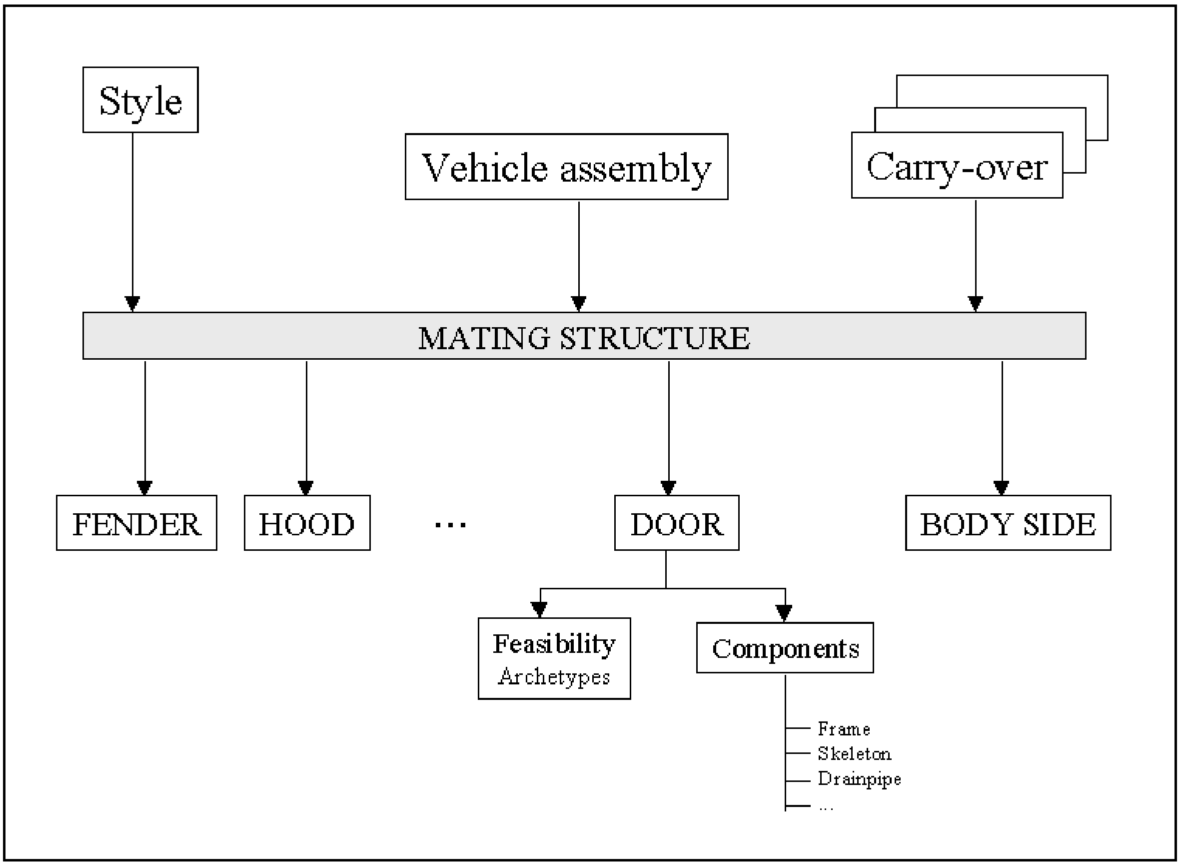

Figure 4. Top down organisation of vehicle systems model generation.

The Style is a set of explicit entities as well as the carry over parts or components. The assembly is managed by a TL who is responsible for the updating of documents of the whole vehicle design.

The mating structure is the gateway between the explicit entities and the P/A environment.

In figure 4 are represented all the relationships for car door systems.

An example of general updating tree has shown in the figure 5. Note that every part is made by a sequence of different files that are the archetypes.

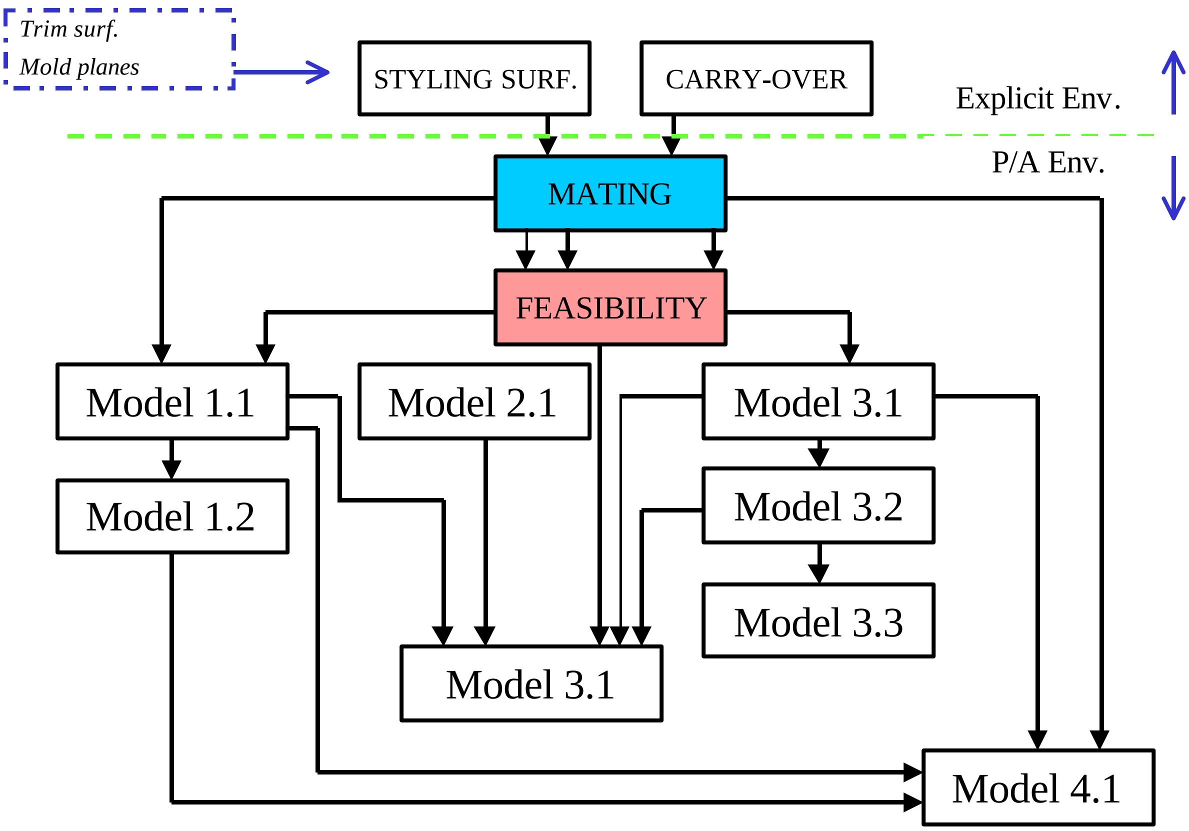

Figure 5. The updating tree.

The explicit entities are style surfaces and carry over components. The mating structure allows us to link explicit geometry with the P/A environment.

The feasibility contains mainly beam, production constraints and section archetypes. The hierarchy of the P/A models is a cascade, without loops that could cause problems during the model regeneration process.

The updating tree could be managed in the future by a software system that builds automatically the design tree.

4. BENEFITS OF METHODOLOGY

In this paragraph are shown some results obtained by the application of the methodology in body design context. In the figure 6 is shown the so-called 'A-Node' model of car body.

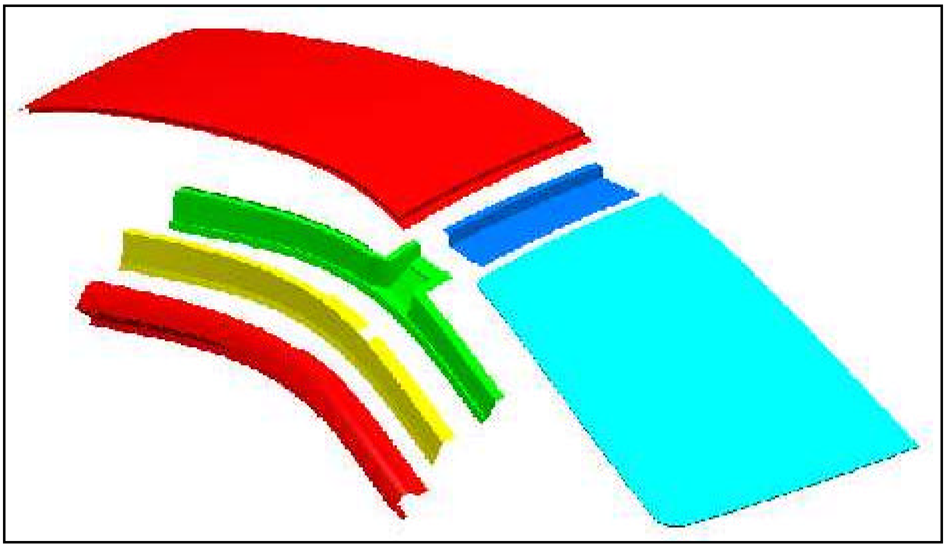

Figure 6. Sub-assembly of car body.

In the figure 7 are compared, in qualitative manner, the traditional process of modeling an A-node and the new method based on P/A approach. As we can see, the development time of A-node model is longer for P/A method, because it is necessary to build P/A library archetypes. When a style change occurs, the P/A library enables to reduce design time because it is reduced the modifying phase. On the other hand the explicit design take always the same time for every style change.

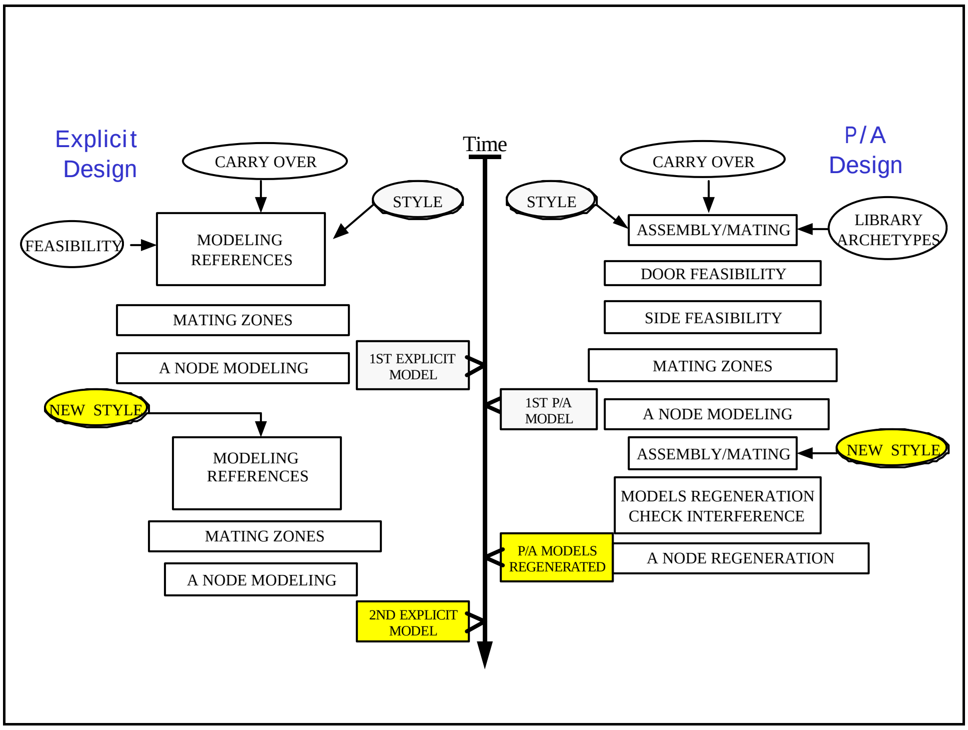

Figure 7. Explicit and P/A method comparison

For these reasons we can say that P/A approach seems to be robust enough to manage several style modifications, saving time and costs. In order to cover different system typologies we are developing an archetype library of beam and nodes shared for the same car segments.

Furthermore, it is necessary to build the documentation for each archetype, so that a new designer is soon able to modify the archetype.

Other vehicle systems seem to be good candidates to use the same methodologies: for example, the car platform design and the electrical cabling design.

5. CONCLUSIONS

The developed P/A CAD methodology seems to be a useful tool in order to apply the best company practices and component standardisation, without limit the designers creativity.

Company emphasis is focused on modifications management because it affects on product development time and, consequently, on the process flexibility related to styling modifications, continuous refinement and new concepts implementation. In that way, each modification can be executed in a short time, respecting all the product and process constraints.

On the other hand, the use of P/A CAD has a great impact on the traditional process and on the job designer: more skills are necessary. It also needs a more powerful hardware installed to satisfy feature-based design. For this reasons the P/A CAD has to be justified with accurate return of productivity and product quality improvement.

6. REFERENCES

[1] G. Monacelli, A. Quaglione, *L'impatto delle nuove tecnologie CAD nell'ambito della progettazione automobilistica: una metodologia di analisi*, ADM, Caserta, Settembre 1995.

[2] CATIA Reference Manual, Dassault Systemes, 1996, 1997,1998,1999,2000.

[3] Unigraphics Reference Manual, UGS, 2000.

[4] Pro/Engineer Reference Manual, PTC, 1995, 1996, 1997, 1998, 1999, 2000.

[5] J.J. Shah, M. Mantila, *Parametric and Feature-Based CAD/CAM,* John Wiley and Sons Inc., 1995.

[6] L. Morello, F. D'Aprile, *Associative CAD in Vehicle Development through Simultaneous Engineering,* ATA, Firenze, Febbraio 1997.

[7] C. Floyd, A comparative evaluation of system development methods, IFIP, 1986

[8] U. Cugini, D. Ferretti, G. Colombo, *How to Represent Design Rules in a Parametric CAD System*, International Symposium of Advanced Geometric Modeling fir Engineering Applications, 1989, F.L. Krause & H. Jansen eds.

[9] C. D. Potter, *Utilizzare al meglio la Modellazione Solida*, CG Computer Gazette, N°1, 1996, pp. 26-33

[10] L. Brooke, *Creating the best CAD/CAM System*, Automotive Industries, December 1996.

[11] J. Hoschek, D. Lasser, *Computer Aided Geometric Design,* AK Peters Wellesley, Massachussets, 1993.

[12] G. Farin, *Curves and Surfaces for CAGD: A pratical guide,* Academic Press, 1997.

[13] K. Lee, *Principles of CAD/CAM/CAE Systems,* Addison Wesley Longman Inc., 1999.