SUMMARY OF SCIENTIFIC AND TECHNICAL RESULTS

CONTRACT N°:	**G1RD-CT-2000-00037**
PROJECT N°:	**GRD1-1999-10385**
ACRONYM:	**FIORES-II**
TITLE:	**Character Preservation and Modelling in Aesthetic and Engineering Design**
PROJECT CO-ORDINATOR:	**think3 / Universitaet Kaiserslautern**

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PROJECT STARTING DATE:	1st of April 2000
DURATION:	36 months
Date of issue of this report:	24th of May 2011

Project funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)

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1 Introduction

This document gives a brief summary of the work done by the FIORES-II consortium and the scientific and technical results achieved during the three years of the project running from April 1st 2000 to March 31st 2003.

The different parts of this document are a compilation of the official final report of the project.

2 SCIENTIFIC AND TECHNICAL RESULTS

2.1 WP1 "Application Modelling"

2.1.1 Task 1.1: Property Analysis and Modelling

The main goal of work package WP1[1] beside the styling workflow improvement has been to achieve a formal structure in aesthetic properties and terms related to aesthetic character, in order to capture original intents of designs.

The relationships between geometrical elements of a product shape and its aesthetic characters that has been established within the WP1 development, enabled the consortium to specify those values of shape characteristics and parameters that, once processed by a computer system, could compute the design model conforming to the original intention.

Therefore, WP1 was a fundamental work package since its outputs were mandatory to fulfil the project objectives. The involved partners were mainly industrial end-users who finally will take advantage of the results carried out.

Thus, it has always been clear that a good start will have led the consortium to a successful result. However even though conceptually the overall goal was easy to understand, practically a lot of difficulties arose when we started to organize the different works to be done and deepen the matter.

For what concerns the dictionary-of-terms for instance, at the beginning a lot of terms have been taken into consideration. The aim was to create a common language among the partners but it was not very clear which are the most significant terms we had to consider.

Moreover, when we tried to sort this list in order to select the most important terms in relation with the general work-process chain, it turned out that there were different terms or languages used in different phases of the product life cycle. Therefore, the dictionary categorized **two groups** of documents:

[1] Also called "Application Modeling"

- List of emotional terms describing the so-called "**Marketing Language**" (language of the Trends) used to communicate the purely emotional character of a model for example when a customer talks to a car dealer.
- List of designer terms describing the so-called "**Designer Language**" (language of the Trades) used among stylists, designers, CAx operators[2], and model makers in order to communicate the design intent.

The last one in particular kept our attention. We were interested in designing a "*language of command*" whose *words* could be used to modify curves and shapes like they were modelling tools. For this scope a restricted list of terms has been sorted and for each term the consortium fixed its semantics i.e. a direct relationships between geometric elements and conveyed characters has been formalized. We have called these terms "**Modifiers**".

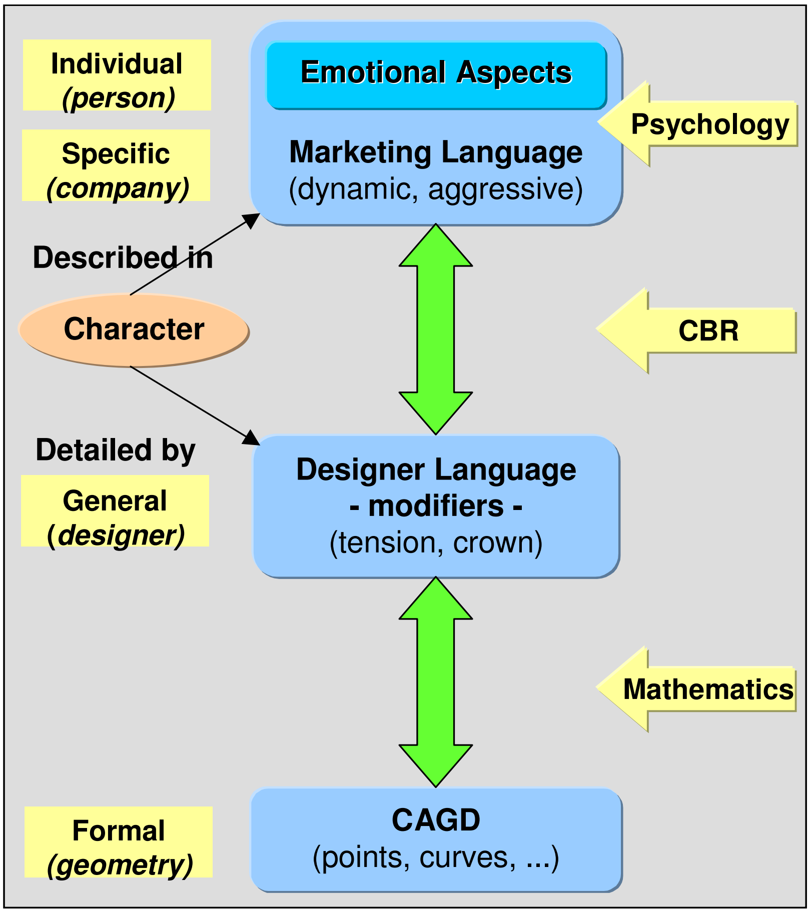

Fig. 1: From Emotions to CAGD

[2] People working with CAD systems. They can be stylists themselves or any other person (sometimes also called "*surfacers*") who helps the stylist realising their design in a computer way or any other CAD system user.

Modifiers have been considered by the end-users of highest importance for application use. They were seen as the ideal intermediate language between purely technical terms of the CAD world and the often very emotional terms of the Marketing Language. However despite our effort some ambiguities remain but the end-users claimed to be ready to get accustomed.

The next goal was to define the area in the product life cycle where the FIORES tools could be applied. Pondering the benefits of character capturing and manipulation in the various possible application areas, the end-users decided to choose the CAx operators and their modelling task as the target application for FIORES-II.

This decision is visible in deliverable "*Application Scenario*" which is split into three groups of documents:

- **Present status of application** describing the present application workflows at the end-user sites which are subject to the FIORES improvements.
  Doc: "The Styling Design Workflow".
- **Future application scenario** describing how FIORES tools could be integrated into the present workflow. The most important result in this scenario was the end-users' request to adopt the designer language in FIORES CAD tools that works as "Modifiers" on existing models: "*Put more tension into this curve*!". The chosen scenarios were described in the following documents:
  - "Application Visions for FIORES-II", and more detailed in:
  - "Future Application Scenario" and
  - "Supplements to Future Application Scenario".
- **State of the art** describing the present CAD support in the relevant design workflows, and a "Status of the art of the research on the relationships between shape and emotion".

Knowing about the different languages used and possible application scenarios, the interviews which followed could concentrate on certain aspects of these languages and their application areas as well as on useful example parts. Quite a variety of interviews were needed to achieve the desired results. This means to:

- identify the elements characterizing the product,
- check the association between the shape and relation of these elements and the emotional aspects,
- identify aesthetic and technical conditions including the information flow.

2.1.2 Task 1.2: Emotion, Aesthetic, Geometry Relationship Analysis

Task 1.2 was very closely related to the above mentioned work in Task 1.1. All deliverables were directly connected to the emotional character investigations. The in-depth interviews performed by LPC were developed with regard to experiences from other interviews, which made it easier to select a meaningful panel of persons for interviews on emotional character capturing.

The goal of the interviews with designers and stylists was to record the language, gestures, drawing movements, and emotional expression of the designers while they were speaking about their trade and their personal realizations.

A *first examination* of the interviews has been performed in order to:

- get a global view of the material,
- select the most significant scenes for further analysis (using tools as NOMINO and later CBR),
- write down the most significant part of the interviewee's talk.

A *second examination* of the selected parts was performed in order to extract from the scenes those sequences that were of interest for:

- the graphic activity of the interviewee,
- the interviewee's emotions, either by facial expressions or by gestures,
- the interviewees' talk that has been processed with the program NOMINO.
- Later in WP2 we analysed the interviewees facial expressions and gesture with "OBSERVER" (from Noldus Information Technology) a program for the analysis of verbal and motion speech interactions.

To conclude, despite a delay, all the important results for the project process have been obtained:

- Task 1.1: property analysis and modelling, especially:
  - Interviews: Web-based and Person-to-person.
  - Future Application Scenario with target field of FIORES-II in the design process.
  - Language: Marketing (emotional) and Designer terms.
  - User requirements.
  - Example parts ("Box concept", Bottles).
- Task1.2: emotion, aesthetic, geometry relationship analysis.
  - In-depth-Interviews were done and some preliminary evaluation performed.
  - We organised ourselves in such way that the difficulty of this task had NO delaying impact on the further project flow, especially concerning the software prototype.

2.2 WP2 "Formalisation and Fundamentals"

2.2.1 Task 2.1: CAGD Fundamentals

The purposes of the Work Package 2 (WP2) were to:

- Formalize the notions established during WP1, in particular the Modifiers.
- To set up and validate the corresponding fundamentals.

The in-depth interview analysis achieved by end of February 2002 confirmed that the CAGD work that **has been carried out was rather successful although some points were completely covered**. As a matter of fact even if results seem simple to understand (once formalised) they were expensive and difficult to achieve. The translation of users' feeling into equations was more difficult than expected. **Fortunately we succeeded to capture almost all the user's intents.**

A subset of the so-called *Modifiers* issued from WP1 has been studied. It consists of:

- Crown,
- Lead-in,
- Convexity / Concavity,
- Softness / Sharpness,
- Tension,
- Acceleration.

They were defined on a twofold perspective:

- As a modification tool (relative mode – RM) that can be used either in a direct mode under a user's control or in an optimisation mode i.e. as a way to control or limit the variation of the corresponding aesthetic character during optimisation loops.
- As a measurement tool (absolute mode – AM) that can be used to compare shapes, hence useful for CBR treatment.

Among the studied Modifiers, Crown has been discovered applicable only in a RM and Lead-in a generation mode, while the others were usable for both modes. Later we called Crown and Lead-in "*Operators*" rather than Modifiers (see some illustrations in § WP4: Prototype Implementation).

It must be noticed that their accuracy to reveal shapes discrepancy (AM) was not fully satisfying from a pure mathematical aspect. The computation of the Modifier values were based on integrals of geometrical properties that fit user's average evaluations. In addition, they suited the optimisation process requirements where derivable functions are better handled. This average fit does not permit to distinguish "too similar cases". Nevertheless the

AM Modifier values can be considered as a kind of "hash-coding[3]" for accessing higher-level information than the geometry of a shape. As in any hash-coding process collisions exist, but we conjectured that the intersection set of all the collisions will be small enough not to disturb the CBR process. To decrease the collision effect we studied a curve Global Similarity based on curvature vertices[4]. It could be used as a CBR filter to compare "only" already similar shapes. However we did not need to use it during the prototype test.

In RM the users often request modifications that preserve boundary conditions (position, tangency, curvature). It must be remembered that sometimes such constraints can be incompatible all together. The request has been studied as much as possible but not all Modifiers cover this point and their overall consistency was not at all discussed. This point is not as important as it looks like, because in general a set of inconsistent requests leads the thinkdesign Global Shape Modelling tool[5] to results that have a low quality hence indicating that something is wrong in the request. This problem would become more important for a final industrial product, but it was acceptable at the prototype level.

For each Modifier a list of pending points concludes their study. The team validated as much as possible the theory by using formal computation tools (mainly Mathematica) as well as thinkdesign (the chosen development platform). Base tools were developed to help the validation. Two were particularly interesting: the generation of polynomial planar curves having a monotonic curvature used first for Crown then reused for other Modifiers and a thinkdesign component "hook" where, in collaboration with WP3 (Software Design), a host structure for external components has been implemented very early to validate also the software rules and component mechanism and UI. This work helped the Tension, Acceleration, Softness and (up to some extent) Convexity studies. To understand user's intents it was useful to prepare sets of experimental and synthetic curves, for this various generative methods were implemented and several short evaluations were requested to the users who responded rather quickly but not always in a consistent way. The in-depth interviews even helped us to converge as well as a couple of technical meetings mixing theoretician, developers and end-users.

Almost all Modifier studies were conducted with rather good results. As an overall conclusion we considered that this work was successful and promising.

[3] "Hash coding" is an IT technique used to code (to give) a numerical name (in general a memory address) to each entity of a set which cardinality is much bigger than the space of possible names, thus collisions (homonyms) often occur and must be handled.

[4] Points of maximal, minimal, null curvature.

[5] Used to propagate all Modifier modifications.

2.2.2 Task 2.2: Aesthetics and CBR

The task had three objectives to be achieved: a formal specification of characters, a CBR test scenario for Aesthetic Properties and a feasibility study.

A Formal Specification of Characters

The purpose of this task was to describe the elements that represent a character of a product in a "computer processable" form so it can be used within CBR tools. The requirements needed to describe a character of a product that must be preserved were extracted from WP1 results.

Especially an overview of the formal character specifications was issued in document WP1 "Application Modelling" Summary Report.

Results: From the previous analysis we concluded that a character can be represented by a set of Aesthetic Properties (AP), each of them having a set of Geometric Characters (GC). A GC is evaluated by its corresponding Modifier. Therefore each AP has its own characteristic set of Modifier values. The AP belongs almost always to the curve class and sometimes only parts of them are meaningful (i.e. subject to modifications)[6]. A formal CBR information structure for FIORES-II was specified.

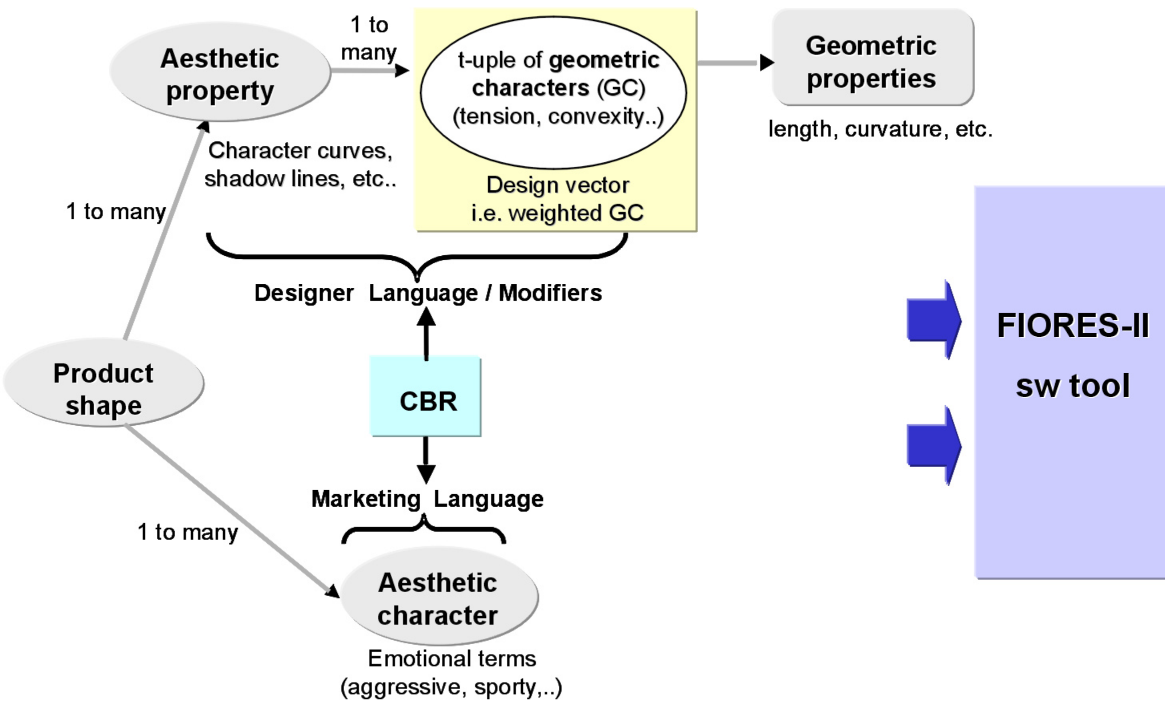

Fig. 2:Character – Aesthetic Property relationship.

[6] In the following only the term Aesthetic Property (AP) is used - unless otherwise specified. The project is restricted to curves of the shape of the product.

A CBR Test Scenario for Aesthetic Properties

The intended objective was to establish a scenario for testing character specifications and similarity measures. The CBR test scenario was the starting point for the feasibility study that was carried out.

With the help of the previously defined specification of a character, it has been shown how to use this specification, its restrictions and (in conjunction with a CBR tool) its features to preserve a character.

Results: It would be possible to define such a character specification when some modifications on the CBR tool are done (especially "learning"[7]). These modifications were developed and evaluated in a bench test application representative of the specific frame of FIORES-II.

Conclusion: The Application Scenario from WP1 was transferred to the CBR test scenario and also in reverse the CBR test scenario was applied to the Application Scenario.

A Feasibility Study

This objective was to validate the concepts for the formal specification of character. A feasibility study was done using data gathered from end-users. Results were evaluated and used to create cases in the CBR tool.

Results: The study shows the practicability of the concept used (see "Application Scenario"). The design situation can be mapped to Aesthetic Properties and can be captured in CBR cases. The retrieval of a character is possible.

Summary of Task 2.2:

- A CBR tool was applied to a bench test application representative of the specific frame of FIORES-II but independent from the final application scenario.
- In cooperation with the CAGD people within the consortium, a description of CBR cases was established. As a result we defined a logical information structure to handle the mapping between emotions (given by Marketing Language) and shapes (characterized by Aesthetic Properties) including information about clients, customers, designer studios, companies etc.
- With regard to CBR, similarity measure using feature weights[8] was done for evaluation.

[7] "Learning" in CBR means that the CBR system reacts sensitive to tendencies occurring from data input ("cases") and is able to adjust itself.

[8] Weights related to Aesthetic Characters and Aesthetic Properties resp. Modifiers. Global Feature Weights describe the effect of each Modifier for a specific character independent from the Modifier values. Local Feature Weights describe the allowed range of Modifier values for a certain character.

- A CBR test scenario was chosen as a starting point for the feasibility study.
- To validate the formal specification of character, a feasibility study on emotional aspects in Aesthetic Character specification including first tests using the CBR test scenario was performed and analysed (by usage of examples and the list of terms from WP1).
- The feasibility study shows that a segmentation of curves of the shape into sub-curves is done by all end users in a similar way (in the survey these sub-curves are considered to be (very special) Aesthetic Properties). Therefore it was useful to implement this approach in the FIORES-II prototype.

2.2.3 Task 2.3: In-Depth Interview Analysis

How can we imagine the design process, and the designer’s activity? Basically, there are two ways:

- The first one is *a priori*. As one designer rightly put it, it is *à la* Michelangelo: the artist has a full fledged project in his mind, waiting for being carved out of the clay. This is the etymological notion of a project: a mental image thrown on a piece of paper (see Panofsky, 1924).
- The second one goes the other way around, *a posteriori*. The project is a construction both objective and social. The project develops through a series of objects, extremely fuzzy to begin with, then as work progresses, more precisely defined. At every stage of the development, persons involved in, or concerned with the project, interact socially in order to validate the realisation of the design.

The analysis of the recorded interviews favoured the second interpretation.

- How designers do express aesthetic intent by use of graphic tools and means, was examined through the following points:
  - What is the framework within which designers perform their task?
  - What are they assigned to, what are they free to or invited to suggest?
  - Which tools and which means are available to that end?
  - What is the designer’s intent: what does he want and how does he knows it?
  - What is the process of its realisation: how is the intent made actual?
  - What is the validation process: how is the realisation of the intent recognised as such?

We concluded that the designer’s work progresses through validation and modifications of the previously validated stage i.e. the style is in general a "**social construction**" thus “Modifiers” tools were confirmed and welcomed.

2.3 WP3 "Software Design" and WP4 "Software Implementation"

2.3.1 Task 3.1: Environment Selection

Before implementing the software prototype, choices of common hardware and software environments as well as development and communication rules among the partners involved in the prototype development were done. The Intel-based Personal Computer running Microsoft Windows NT4.0 was selected.

After an objectively analysis of available tools, thinkdesign, a product of think3, has been selected as the software development platform. The partners discussed and selected other tools required for the development, i.e. compiler (Visual C++) and source repository to support concurrent software development (CVS).

The FIORES-II software prototype was a complex system developed by different companies. To ensure efficient development, communication, building and delivery rules as well as software engineering rules were established. The prototype was defined as to be component based and the Unified Modelling Language (UML) was chosen as a specification, visualisation and documentation language while the Interface Definition Language (IDL) was chosen to define interfaces between components.

2.3.2 Task 3.2: Prototype Design

During this WP3 task we focused on the design of the FIORES-II software prototype intended to demonstrate the main features of the project:

- Product shape modifications via Geometric Character.
- Preservation of the Aesthetic Character while doing modifications.

The component architecture we used preserved rooms for the ineluctable late requirements that occur in any actual implementation. Nevertheless we tried to be rather exhaustive in the main component breakdown as well as in their interface analysis.

The UI part of the prototype has been considered in a rather traditional way to allow the user a quicker training time.

The following prototype features illustrate the results of this task. The shape modifications were designed be done either by user interactions, or automatically while optimising the product shape to fulfil some engineering constraint(s). The maximization of the volume has been chosen.

Thus, the FIORES-II user was expected to be able to perform the following actions:

- To modify a shape with the aid of the Modifiers.
- To enter a CBR case in the knowledge database i.e. "to teach" the CBR-tool.
- To check if a modified (new) shape preserves (has) a given Aesthetic Character.

- To define and perform an optimisation task to fulfil an engineering constraint while preserving the Aesthetic Character (with the aid of the CBR knowledge data base).

Main components to support these prototype features were defined as (Fig. 3):

- thinkdesign component, which provided the display, basic CAGD functionalities and user interactions (selecting a curve by picking it, etc...), and a specific external component "hook" designed at the beginning of WP3, implemented and used by think3 for its own Modifier studies.
- The FIORES-II application, which used the thinkdesign component to perform FIORES-II actions, provide the FIORES-II specific user interface and connections to other non CAGD components like the CBR tool.
- The Modifier component, which was plugged directly in thinkdesign and contained the Modifier' functionalities.
- The CBR tool (CBR Works), as a stand-alone component accessed in server mode by the FIORES-II application to perform the Aesthetic Character management.
- The Optimiser component, which was used by the Modifiers component to perform calculations as well as by the FIORES-II application to perform optimisation tasks.

Moreover, the FIORES-II prototype made an extensive use of the hosting system (thinkdesign in short td) to perform general purpose user actions like save and load a shape to/from a file, create some specific sections, silhouette, etc.

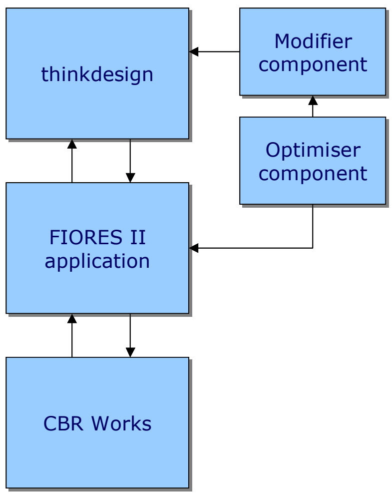

Fig. 3: Technical components of the FIORES II prototype

Regarding the fulfilment of the objectives assigned to the prototype, we can state that:

- The direct use of the Modifiers surely fulfilled the shape modification requirements.
- The character management (CBR part) and thus the optimisation loop efficiencies relied on the effectiveness of the measures provided by the Modifiers. The design of the prototype took into account the possible evolution due to Modifiers measure improvement. **The component approach was a key point here**.
- The quality of the CBR results depended also on the amount of stored data i.e. the greater the number of cases stored, the better the CBR knowledge. The development plan intended to make available first the measures of Modifiers, in order to allow the users to store their data as soon as possible. Although the format of the stored data was designed to accept evolutions, fundamental changes in the measures would imply either the loss of stored cases, or their re-engineering.

As a conclusion we can state that the main points of architecture were achieved and that the Work Package was reasonably successful. Moreover, since the main partners of this task were also involved in the implementation, a smooth transition with the WP4 occurred.

2.3.3 WP4: Prototype Implementation

As mentioned above, the transition with WP3 went rather smooth. This part of the project was obviously the most important one. It was successful despite some problems due to a distributed team that were not so acute, thanks to the component architecture chosen in WP3. Several technical discussion and workshops were held either in a classical meeting way or using web based regular meetings.

Three main versions were delivered and several patches for bug fixes. All planned items were carried out. Moreover, some of the WP2 pending points were solved on the fly of the implementation. Some points could have been done better (Sharpness Modifier, UI of some commands) but for a cost and a delay incompatible with the project time frame. The end-users could test all expected domains and the prototype allowed the WP5 to proceed to very positive measurements and conclusions.

Figures below illustrate the effects of the developed modifiers and operators. Some differences are subtle but exist, i.e. characters can change with slight modifications.

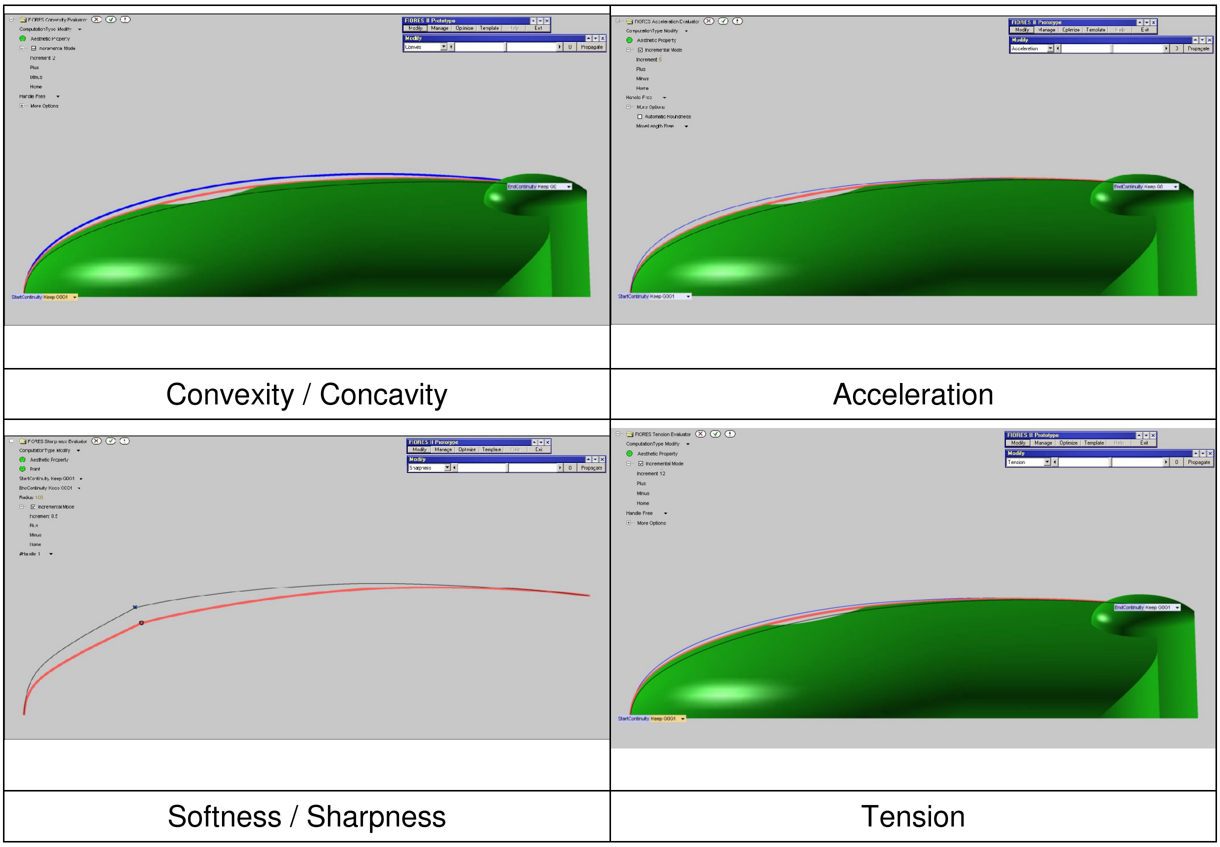

Fig. 5: Modifier effects.

The process is different for the operators: it is a generation one that consists in finding piecewise defined curves that fulfil boundary conditions and are curvature monotonous.

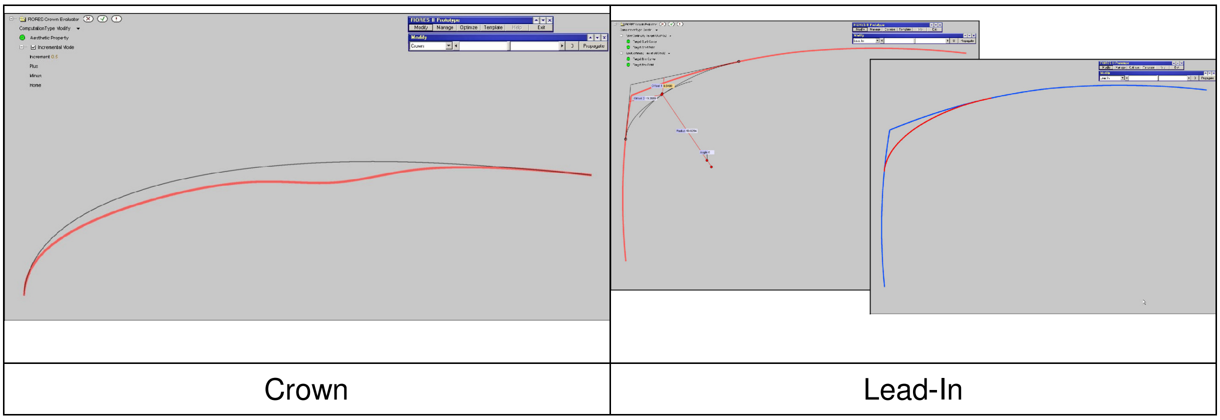

Fig. 5: Operator effect.

Overall the shortness of this paragraph should not hide the **huge and successful effort** made by the partners involved in this WP. **The prototype was ambitious but we made it and as mentioned above it is in daily use in some partner sites**. Moreover we are proud to demonstrate it because it constitutes a proof that **an actual breakthrough was reached** (see below the WP5 measurements and the conclusion).

2.4 WP5 "Validation and Evaluation"

2.4.1 State-of-the-Art Review

The state-of-the-art analysis performed by WP1 confirmed that currently no system treats aesthetic and emotional shape characters. Moreover the work carried out by WP2 on Modifiers let us expect a breakthrough in the way stylists and CAx-operators would handle shape modifications. It was far from the currently available tools that are very stuck to the so-called Bezier control net modifications. **As a matter of fact, Modifier-based commands constitute a high level semantic way to consider the geometry since they convey users' aesthetic intents.** They will be "**aesthetic intent features**" with the advantage to be applicable on any kind of geometrical representation.

As showed in the WP2, the fact that styles of products are (in general) **social constructions** enhanced the need of a CBR tool that allows the context adaptation. **The association between CAGD and CBR for the mix between strict computation of Modifier values and fuzzy information of emotions conveyed by a shape was again a breakthrough.**

2.4.2 Task 5.1: Validation and Evaluation

This work package presented the results of the FIORES-II Software Prototype test.
The test checked the component functionality and provided feedback in order to improve the Software Prototype. It was made through a template of essential criteria to assure the fulfilment of the prototype objectives.

Each partner involved has designed a CAD model to test the Modifiers and the CBR module, in order to draw conclusions about the degree of fulfilment of the designer's expectations.

The Modifiers were considered to be very useful tools due to the fact that they were easily understood, but there were some exceptions to this opinion, especially related to the Sharpness Modifier which was found to be in poor shape or difficult to understand. In addition, some users thought it needed further development.

CBR module was found to be very useful and considered to be a good tool to increase the intellectual level of an organisation. The module works well but it has a very complicated starting process and is difficult to understand.

2.4.3 Task 5.2: Evaluation of Concept

To better understand the new instrument potentialities, the project's end-users have performed benchmarks between their standard Modelling computer-aided systems (Rhino, Alias, ICEM, etc.) and the FIORES-II prototype.

The wide spectrum of FIORES-II potentialities has been evaluated in terms of time and costs saving even though it must be specified that it has not been possible to make comparisons between solutions concerning the use of CBR and Optimisation functionalities since they were absolutely new tools.

Among various benefits listed in the report, one particularly important came out clearly: using standard processes when modifications have to be applied on a virtual model, the knowledge of the methods utilized during the construction phase is extremely important. Especially when products are developed in co-design with external suppliers, managing the modification process is always difficult because data are exchanged via neutral files (i.e. IGES, VDA, Step, etc.) which do not contain any information about the model construction history.

On the contrary, **the FIORES-II software package gave finally the possibility to work on the mentioned virtual models in an absolutely free way, leaving the history out of consideration.**

The following results were measured:

End-users	With classical tool time in minutes	With FIORES-II time in minutes	Gain
ALESSI	255	5	98%
EIGER	40	11	73%
FORMTECH	Between 11 and 40	16	Between –45 and 60%
PININFARINA	230	5	98%
SAAB	451	5	99%

Thus, the approach was (is) extremely different from the traditional one: **there is no need to use control points and it becomes possible to work with every kind of mathematical representation**. Surprisingly, as the reader could infer from the figures provided by each single end-user, the introduction of the prototype within a standard product workflow might lead **to save 90% of the time** normally dedicated to the virtual model modification phase!

2.5 WP6 "Exploitation and Dissemination"

2.5.1 Exploitation and Dissemination

The exploitation started a bit earlier than originally planned. This revealed a strong interest at least for what concerns the scientific and software aspects. IMATI started contacts to establish a Network of Excellence for the 6th Framework, SAMTECH decided to make available in the current release of their commercial BOSS-Quattro platform the new features and enhancements coming from FIORES-II development, UDK industrialized and applied the results of monotone curvature within industrial design and think3 initialised the study of the industrial extensions of the Modifier parts by delivering the Modifier commands as a live plug-in of each release of their product for their beta sites. As a consequence, some of this consortium, some of think3 customers and partners can continue to use daily the prototype while following the standard platform evolution. The other Exploitation activities were mainly related to internal training.

The three already explained domains: end-users' applications, underlying computer tools and research are subject to exploitation. The first exploitation domain will be performed via a workflow improvement that will support a parallelism between aesthetic and engineering designs, the second one will be the industrialisation and marketing of the SW modules by the SW partners and the last one already started is done via dissemination work.

The following activities were performed:

- An Internet-based study of the CAD/CAM/CAE market particularly in the Computer Aided Industrial Design and Styling (CAIDS) branches has been done.
- Each partner refined its exploitation strategy and summarised it in the preliminary version of the Technological Implementation Plan (TIP).
- In some application companies, internal dissemination presentations have been prepared and performed to initiate the future internal exploitation.

3 FINAL RESULTS AND CONCLUSIONS

This three year project has been carried out by a consortium of 14 partners largely distributed all over Europe whose origins, specialities and skills are quite different but complementary. **The genesis of the project has been explained by the will to extend the Engineering in Reverse approach issued from the previous European project FIORES to the more qualitative domain of feeling, fashion and shape characters.** The original goals were ambitious, but, as usual, the reality obliged us to make compromises between the time schedule, the effort, the individual wills and capabilities. However, despite some tough periods the Consortium faced and some still pending points, this project brought a couple of results:

- **It has been proved that the qualitative domains of emotion and shape characters are accessible to a quantitative analysis via CBR and adequate CAGD techniques.** It is only a beginning but it will be continued in the future and probably more results will come out of this mixed approach.
- **The style is very often a social construction that can be described by two languages**, one using a rather general and common vocabulary conveying emotions

while the other one with a more restricted vocabulary but closer to specialists supports the shape modelling (in its general meaning). This explains why the modifications (**Modifiers**) of shapes are as (or even more) important as their generations.

- The end-users' tests of the resulting Modifiers and their influence propagation through the whole shape showed a **quick users' acculturation** that is another proof of the technical language and (more subtle) of the want of such tools (due to the lack of current ones).
- Finally, beside the above results the prototype implementation demonstrated the **power and flexibility of a software component architecture** that permitted the "dialog" between four very different systems (i.e. User Interface, CBR, CAD, Optimisation) and led to **a prototype that can be used (up to some extents because it is only a prototype) in an industrial environment on actual applications**.

For all the above results one could consider that **FIORES-II has been successful** but after using FIORES-II prototype there are other several reasons to be hopeful about the future of the proposed tools, namely:

3.1 CAGD Impact

- Times to modify shapes are clearly lower than using traditional methods. **The gain of time could be evaluated from 20 min to 2 days i.e. minutes versus hours or even days of work depending on the company and the difficulty of the change to be made.**
- As a consequence, **FIORES-II offers the possibility to create many solutions, different from each others, as character of the same object, in a time shorter than the one required for a unique modification with standard methods.** In some cases, 10 minutes have been enough to create a new proposal, achieving all the quality standards of the company where it would have taken several hours of work.
- **The modification approach without the use of traditional control points seems to be more intuitive and it is not necessary to foresee what it has to happen for / after the modification** (number of control points, continuities, degree, etc…). **The end-users get rid of mathematical and topological constraints, just focusing on their intents.** This opens the door for more user-friendly tools directly accessible to the stylists.

3.2 CBR Impact

- **CBR is able to manage and compare mathematical properties of a curve with other curves, to establish the percentage difference, to link the style to whom and for whom it has been developed and to place all these information at the disposal of a small or big Project Team.**
- The **possibility to manage "families" of product** is very important especially for a company that produces objects very different one from each others. CBR can become **an intelligent archive of the patrimony and the knowledge of a company**.
- Each Operator can be connected to CBR server to take advantage of the Part Family already saved, to create other characters for the Part Family and eventually can position him / herself in the whole company character frame.
- Aesthetic property extraction and family definition constitute important **stylists' templates to create scenarios for working with the shapes**. It allows for a better consistency between different actors as well as a help for beginners or new comers.
- CBR tests of character allows CAS operators to know where some changes made in the shape are higher than the allowed by the definition of the character database, and could remade or re-evaluate the change.

3.3 Both with Optimisation Impacts

- Tools that change geometric properties of the shape to achieve engineering constraints while taking care of the maintenance of the character are on the way. Despite the computation time of the prototype not being always as short as wished, it remains rather acceptable compared with standard approach. It is clear that for an industrial product this part should be improved but it is clear as well that **optimising engineering constraints (even simple) while preserving a shape character, as demonstrated in FIORES-II, is far from being achieved in the same time frame with any other tool of the market including manual approach!**

3.4 Conclusion

This collection of above reasons allows **FIORES-II Consortium to be very pleased with all the work carried out**. We think that the scenario opened by FIORES-II will offer better ways to modify and create shapes, while getting closer CAS language to professional language. At the same time we think that we have demonstrated the main aim of the project i.e. the possibility of providing a couple of tools that allow stylists, designers and engineers to be directly successful in design intent.

Moreover, we foresee that **the "aesthetic intent features" conveyed by the Modifiers will become as successful as mechanical features are today** and, despite the fact that we would have wished much more CBR cases for a deeper understanding of the relationship between characters and the way to propagate Modifier impacts to the whole shape, we are confident that **Engineering in Reverse applied to the aesthetic will become a new Computer Aided Design Paradigm**.

Finally, after having successfully faced some organisational and communication issues, the Consortium carried out the project in the proposed budget and time frame. This helped to build up a "community of people" who will have pleasure to meet again for further collaboration whenever the opportunity will occur. All partners agreed to continue and collaborate after the end of the project.

4 ACKNOWLEDGEMENTS

The scientific coordinator would like to take the opportunity to thank all the partners to have accepted his "variable moody" for the success of the project and in particular Cristiano Colosio (ALESSI) and Paolo Bertoni (PININFARINA then STS) for their support and help during the tuning phase of the prototype since it was not really in their work plan to help so much the WP4.

Finally, on behalf of the consortium, the coordinators thank the EU to have given us the opportunity to show that sometimes dreams can become reality and in particular our project officer who trusted us to overpass the tough period of the first half project!