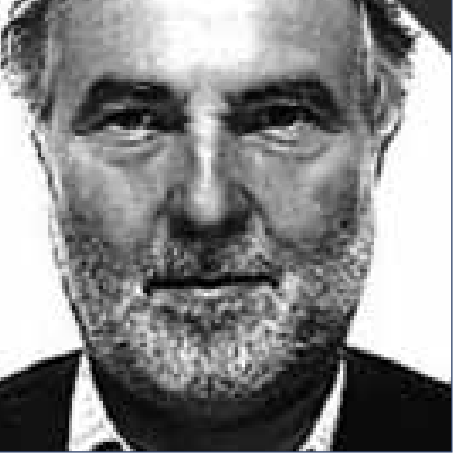
PRESERVATION OF ARCHITECTURAL HERITAGE | PROGRAMMING, MAINTENANCE, REHABILITATION OF THE BUILDING AND URBAN SYSTEMS | RADIATION SCIENCE AND TECHNOLOGY | ROTARY WING AIRCRAFT | SANITARY - ENVIRONMENTAL ENGINEERING | STRUCTURAL SEISMIC AND GEOTECHNICAL ENGINEERING | TECHNOLOGY AND DESIGN FOR ENVIRONMENTAL QUALITY IN BUILDINGS AND URBAN CONTEXT | TERRITORIAL DESIGN AND GOVERNEMENT | URBAN AND ARCHITECTURAL DESIGN | **VIRTUAL PROTOTYPES AND REAL PRODUCTS** | WATER ENGINEERING | AEROSPACE ENGINEERING | ARCHITECTURAL COMPOSITION | ARCHITECTURE, URBAN DESIGN, CONSERVATION OF HOUSING AND LANDSCAPE | BIOENGINEERING | BUILDING ENGINEERING | DESIGN AND TECHNOLOGIES FOR CULTURAL HERITAGES | ELECTRICAL ENGINEERING | ENERGY | GEOMATICS AND INFRASTRUCTURES | INDUSTRIAL CHEMISTRY AND CHEMICAL ENGINEERING | INDUSTRIAL DESIGN AND MULTIMEDIA COMMUNICATION | INFORMATION TECHNOLOGY | INTERIOR DESIGN | MANAGEMENT, ECONOMICS AND INDUSTRIAL ENGINEERING | MANUFACTURING AND PRODUCTION SYSTEMS | MATERIALS ENGINEERING | MATHEMATICAL MODELS AND METHODS IN ENGINEERING | MECHANICAL SYSTEMS ENGINEERING | PHYSICS |



# DOCTORAL PROGRAM IN VIRTUAL PROTOTYPES AND REAL PRODUCTS

Chair:
**Prof. Francesco Trabucco**

The goal of the Doctoral Course in "Representation and product development methods - Virtual Prototypes and Real Products" is that of educating (both in the cultural and scientific side) graduates in technical disciplines, which are willing to investigate issues concerning product development with virtual modeling methods and techniques through the phases of concept, functional design, ergonomics design, product use.
Further investigations will concern simulation and virtual testing methods and techniques. The Course is particularly focused on dynamic and evolution of integration and interrelations between methodologies, prototyping and simulation techniques and processes of manufacturing and testing through physical mock-ups.

The following issues have been identified as main features of the Doctorate:

- Industrial engineering design and methods, concerning methodologies and techniques of geometric modeling of complex systems and of human operators/users, shape modelling, virtual prototyping, simulation of physical behaviour of non-rigid materials, modeling and simulation of product development processes, methods and techniques of mixed reality and multimodal interaction integrated by haptic tools.
- Design, concerning basic representation methodologies, representation methodologies applied to industrial design for product and communication, making techniques of physical models, geometric modeling techniques using surfaces and polygons, 3D acquisition techniques, image processing techniques, photorealistic and non-photorealistic rendering techniques, visualization and simulation techniques, model-production techniques from 3D data, Image-Based Modeling techniques, Multimedia, Hypermedia techniques, Web design and Web 3D modeling.
- Industrial Design, concerning the relation between representation and design in different phases and contexts, definition of the design object, definition of methodologies of design and of factors concurring in the form-making process. Specific reference concerns use, fruition and individual/social consuming factors of the product (functional, symbolic and cultural factors); production factors (technical-economic, technical-systemic, technical-productive and technical-distributive factors); creation processes. All these issues are approached with historical-critical, theoretical-methodological and design tools.

The professional profile deriving from the Doctorate Course is capable of efficiently integrating and exploiting technologies and informatics tools for the creation, product virtualization, testing processes, product validation and use, adopting traditional experimentation methods of physical mock-ups.
The graduated doctor is a person capable of interpreting a design intended as representation of evolving ideas; capable of using at best ICT for virtually creating and representing products and processes, and integrating new methods and technologies with traditional practices based on physical prototyping.
The outlined professional profile is of great interest both for the industrial and for the institutional research (Universities and Research Institutes) world. It can easily lead to: an academic career in emerging areas (both research and basic and specialized education); industrial product development teams, which are increasingly managing design and development in an integrated way and with novel technologies; a professional career as a specialist in the development of virtual prototyping integrated system for specific application sectors. We therefore believe that such a professional profile may find wide employment opportunities.

The Introductory courses are intended to uniform the Doctorate candidates' basic skills, after having considered the degree of their actual preparation in the field, and levelling possible lacks.

- Laboratory of art and science for representation
- Computer graphics laboratory
- Fundamentals of computer science for virtual prototyping A
- Fundamentals of computer science for virtual prototyping B
- Fundamentals of mechanical engineering
- Design methods
- Representation of curves and surfaces: theoretical aspects and applications
- Laboratory of CAD

The basic training to research activities covers classes that deal with scientific topics connected with techniques and technologies for product virtual prototyping.
Eleven basic research classes have been implemented, structured as research laboratories.

- Virtual Prototyping
- Interaction Methods and Techniques with virtual prototype
- Laboratory of modelling and simulation of product development processes
- Reverse Engineering
- Laboratory of Image-based & Reverse Modelling
- Mathematical techniques for animation and rendering
- Laboratory for light virtual prototyping

Elective courses and training on specific themes Which include the participation of the Doctorate's candidates to seminars organized either internally or externally to the University, and tutoring activities form the members of the Doctorate's Board.

The Doctorate's Board will integrate the research activity with a series of activities connected with research contracts and collaborations with the industry. The Doctorate candidate will hence have the opportunity to give application to the acquired skills in a case study context and in research and development activities at national and international level.

# SYSTEM FOR AESTHETIC SHAPES EVALUATION BASED ON HAPTIC INTERFACE COLLOCATED WITH A STEREOSCOPIC VISUALIZATION SYSTEM

**Mario Covarrubias Rodríguez**

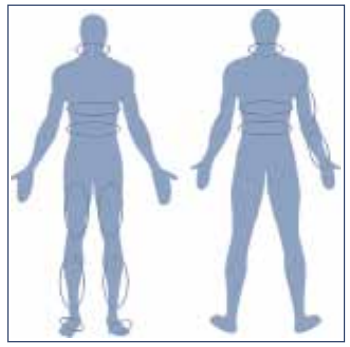
Digital tools for shape creation and evaluation as computer aided styling tools are nowadays largely used for the design of products with aesthetic value, but these tools are too technical for designers. They are more inclined to express their ideas by crafting physical prototypes with their hands in a natural way, rather than using traditional tools based on mouse and keyboard interaction to describe products shape.
Furthermore, the manipulation of surface control points is not an easy and intuitive way for developing new shapes during a creative process. During the development of new concept products, designers need to physically interact with the evolving shapes of the products they are designing to check and evaluate aesthetic features of their products. Therefore, physical representations of the product to interact with are a necessary part of the design process.
The integration of haptic interfaces in traditional design tools would improve us ability and interaction issues and would allow designers to physically interact with the virtual products they are creating. In the past the haptic research community has largely investigated the point-based interaction modality and, as result, many point-based devices with three or six degrees of freedom are commercially available, but these tools are not suitable for shape evaluation and modification during the shape modeling phase.
The design process of aesthetic products includes a typical sequence of activities where physical prototypes and digital models are both used and modified several times in an iterative loop, until the shape is fully satisfactory or the time available to design expires.
While digital models usually focus only the visual aspects, physical mockups allow a better perception of the shape quality.
However, moving from one representation (digital model) to the other (physical mockup) is not straightforward. In fact, the physical model cannot be immediately derived from the digital model, requiring a specific production phase.
Before reaching a final satisfactory product representation, several loops are carried out and, therefore, several physical prototypes are developed during the design process.
Moreover, each time a physical mockup is required for evaluating the product, the design process halts, waiting for the construction of the physical prototype. However, while the other phases of the design process only take a few minutes or hours, the physical mockup production requires more time that can range from days to weeks, causing a bigger impact in the design process.
While in the engineering domain it is possible to reduce the number of physical mockups to very few, because the evaluation is based on quantitative criteria and all the analysis and simulations can be performed with virtual prototyping, in the aesthetic domain, the evaluation is more subjective, vague and multisensorial. In fact, the final result of product conception is not necessarily within the initial domain concerning the object shape and defined by the requirements that are approximated and not well defined. In fact, requirements evolve during the design process and are increasingly focused and defined during the iterative evaluation phase, making physical mockups more crucial and essential for any kind of evaluation.
We developed an innovative design environment for surface analysis and modification. The system allows users to visualize models using a stereoscopic view and the assessment of sectional curves using touch over an haptic strip, complemented with sound to convey information about the quality of the surface.
Aesthetic design process analysis has revealed the importance on the usage of curves, either characteristic or aesthetic, in the creation and manipulation of tridimensional (3D) shapes.

For what concerns shape evaluation, the haptic strip can be seen as a tool for shape analysis. Functionalities of CAS/CAD tools for shape analysis have been developed over the years: functionalities for representing and checking sections, functionalities for representing and checking curvature of surfaces, reflection lines and porcupine diagrams.
Each of these functionalities has been introduced to simplify the perception of class A surfaces quality and are, in general, oriented to the evaluation of a single aspect. Therefore, several functionalities are used together for a better and overall evaluation of the shape. The haptic strip adds an additional and innovative modality for shape evaluation where the perception of the quality of the curve is not based on mathematics or visualisation, but is based on touch, something that is new to the field of tools oriented to design. Concerning modification, users typical actions also start from a characteristic curve belonging to the surface that is pulled, pushed and stretched, in order to reach the desired shape.
Of course, that is achieved by manipulating the mathematical description of the curve or by modifying a physical maquette (that implies acquisition of the digital model of the shape through reverse engineering procedures). In our solution, users can manipulate the haptic strip to change the shape of the surface, and the result is reflected in the digital model being visualized.
The haptic-based immersive environment that we propose here will reduce the number of physical mockups during the design process and will shrink the design time by allowing the evaluation of the product shape and surface earlier. On the other hand, our system will allow designers to perform all the phases of the product design process (concept, modelling, visual and physical evaluation and modification) continuously and without any interruption.
By doing so, we will reduce the need of necessary physical mockups allowing a wider exploration and comparative evaluation of alternatives in the given time. For designers, this would definitely increase comprehension of the shape under development and contribute to improve the product quality and dramatically reduce the development time. In summary, by providing a haptic-based immersive environment, we can expect the following main benefits: Reduce time of the design process and gain time within the development process; allow more time for designers to research on styling issues, so as to obtain better quality of results; increase aesthetic perception of shape (by touching the object besides seeing it); provide possibility of producing variations of style in a very short time; produce many more virtual models in the same time stamp that is allocated today to conceptual design; allow people with different skills (model makers, designers) to work directly on the digital model of the conceptual shape.

# A NEW APPROACH TO THE DESIGN OF WEARABLE TECHNOLOGY

Venere Ferraro

Nowadays there is a great inclination to modify well-being concept and health care by changing the technology in "wearable". Thanks to the rapid-changing of technology the market offers smart phones, Pc held in the hand, wearable calculators etc..
The expression "wearable device" refers to electrical or mechanical systems, which are worn on the human body by means of incorporation into items of clothing, or as an additional apparatus, which is fixed, by straps or harnesses. Such devices can perform functions such as sensing, communications, navigation, decision-making or actuation.
A particularly recent class of wearable devices consists of devices, which are designed to perform specialist sensory perception of the surrounding environment so as produce augmented reality.
In a wide range, a wearable system is a device with a very simple structure thanks to which it' s possible to wear a technological apparatus with common clothes. This kind of device is made up of "wearable" sensors.
In the study of wearable device, the designer has to carry out a research to create an adequate core set of skill and know how in order to manage complex and multidisciplinary issues of these systems.
In this case is needed an interdisciplinary approach to project activity based on a nucleus of multidisciplinary competencies in the specific areas of industrial design, ergonomics, medicine and engineering.
The development of the wearable device design needs to accomplish the requirements of comfort and adaptableness connected to the anatomy of human body.
These aspects require a study about the ergonomics and "***wear***" "***ability***" that literally means ability to wear and concern the physical shape of wearables and their active relationship with the human form.
Steve Mann, one of the founding members of the Wearable Computers group in the Media Lab and considered the ***father*** of wearables, defines wearable computing as "the act of wearing a computer on the bodies". Although there is a wide range of commercial wearable devices there are few products, which truly become ubiquitous and accomplish end-user really need.
The development of a wearable needs a study on placing objects on the human body with regards to mass, size, shape, mechanical properties. The reason of this research is visible in the lately technological developments:



**1. Wearability from ICES**

new technologies simulate body functions and strengthen the organic features. Clothing and prosthesis are instruments thanks to which body redesigns itself. From this reason the wearable should be not an overlapping structure or close architecture but an enveloping film, "a second skin".
The hypothesis for the development of this research activity was the creation of a method and guidelines transferable, repeatable and usable for the design of wearable.
A wearable refers to a class of devices really integrated in daily life, used all the time, wherever the user goes. There is an important distinction to be made: wearable has to be actually ***worn***, and not just carried or held. A wearable needs to both work and look good and be worn in the same way the user wear clothing in order to achieve the paradigm ***anytime, anyplace, by anyone.***
A wearable device needs a new process that crosses the existing ones, demands a disciplinary team, from a mix of different backgrounds, to embrace a collective awareness of new technologies, research methods and design techniques.
The research is developed through three case studies in order to show an approach to the design of wearables different from the technological one.
The design of wearable systems needs to be more focused on the user by involving him since the first step as suggested in participatory design approach.
The new method developed in the thesis resulted from the combination of different approaches such as Munari methods, design thinking by IDEO, co-design etc…
The idea was to build a method resulting from the most suitable to the design of wearable system also considering parameters of wearability, human variability and anatomy.
The method has been validated through three case studies:

- a new monitoring vest for maximising high intensity sport performance
- a band for firemen safety
- a glove for post-stroke rehabilitation

Two main outcomes characterize this thesis, the first one is the structure to shape a wearable and the second one is the method.
This system normally comprises a moisture management 'base-layer' or 'second skin', a mid insulation layer, and a protective outer layer. Elements of personal protection, or body armour, may be incorporated into the system.
The layered system is for sure the practical outcome of this research. A designer, knowing this structure could easily develop projects in the fields of wearable technology because he has a mental scheme to follow while conceiving new concept
This research aimed at satisfying requirements of wearability through an "anatomically correct design". Design with people becomes the main challenges in wearable solutions.
This thesis developed an instrument able to support and guide the design process.

**2. Layered System**

**3. Design Method**

The process developed gives the designer not only the instruments useful to analyze, evaluate and define requirements, performances and project solutions most suitable for the resolution of the single system, but also the chance to address himself in a conscious way to the wearable sector.
The process developed is able to support designer to catch people's needs in new ways, feeling the aspirations and desire, create innovative solutions to meet these needs.
In wearable areas working with people is the only strategic way that design can adopt.
Users often reject objects felt unfamiliar to own body, even if they can improve daily life.
This happens because in past the designer overlooked the relationship between human body and the wearables, which involve both physical and psychological side.

# MULTIMODAL INTERACTION IN THE AESTHETIC PRODUCT DESIGN

**Francesco Ferrise**

The Product Development Process in the last years has benefited from the introduction of some Virtual and Mixed Reality (VR and MR) technologies in some of the steps that compose it, in terms of cost reduction of prototypes that becoming digital are substituting the physical ones, and also the reduction of the time-to-market, being these prototype more flexible, easy to share and modify.
Virtual and Mixed Reality technologies and applications have been historically developed as a support for the design process. After more than forty years from the first products, their technological advances, the reduction of their cost and their major availability on the market has produced a growth of applications that make use of these technologies.
One of the commonly known definition of Virtual Reality, states that "Virtual Reality is a high-end user-interface that involves real-time simulation and interactions through multiple sensorial channels". This definition speaks clearly of the integration of different sensory modalities in the creation of a VR application, and it seems similar to the definition of multi-modality, that speaks of use of different sensory modalities for interactive Human-Computer Interaction applications.
The same definition can also be applied also to the case of Mixed Reality applications, that are similar to VR applications but differently from those, they mix real and virtual information.
What happens often for a large number of applications that are recognized as VR or MR applications is that they exploit only the visual channel. The senses of touch and hearing for example, as smell and taste are still not so used, also if the scientific communities that work in these fields are growing. The use and integration of different sensory modalities requires a structured approach that has to grant that the application is usable and communicates correctly with the final user that is the human.
In the first steps of the Product Development Process the shape of the final product is the major focus of designers. They are used to express their idea of the product by manually sketching on papers, and building some physical three-dimensional representation of the product itself. During the creation of these mock-ups the interaction (with the prototype) is based on the combination of different sensory modalities, basically the visualization and the touch, in which some of them are particularly skilled. The CAD tools that today support the creation of shape need a deep mathematical understanding in order to be correctly used and make use of traditional interaction interfaces like mouse and keyboards conceived and used to deal with texts.
Interactive systems in order to exploit a skill need to be based on the integration of different sensory modalities, and these kind of systems in which the user learns by doing and are called enactive systems.
The integration of different sensory modalities cannot be accomplished without knowing how single sensory modalities work. Then it is also important to know how they are combined and integrated in the perception of the real world and so how human interact with the real world. So before building complex Human-Computer interfaces based on the combination of multiple sensory modalities, it is necessary to understand how the human sensory and perceptual systems work.
The complex field of the human sensation, perception and cognition is not necessarily known to those who develop technologies, also for VR and MR worlds, and the risk is that many interesting applications fail when they come in contact with humans, so when they have to be used. One of the objectives of the work described in the thesis is to synthesize the complex field of human interaction with the real world, trying to extract the information that is necessary in order to create a multimodal interaction paradigm. This synthesis is based on the literature used in the human factors, neuroscience and cognitive psychology academic and research fields.
The first part of the work is oriented to understand how human sensory system works, how humans perceive, and how they understand the meaning of the things they are interacting with (cognition).
Sometimes their combination can bring to an illusory percept. The illusions are very interesting because they can be used in the developing of multimodal systems when it is not possible to use correctly one sensory modality. So it is interesting to understand when an illusion occurs, and why, in order to replicate and re-use it.
Once learned how the human sensory and perceptual systems work, we need to understand how the technologies developed for VR and MR applications make use of the single and of combined sensory modalities.
Then we want to know how they will support us in exploiting a sensory modality when our aim is to create a VR/MR system.
After this analysis we address the main objective of the research work, that is the creation of a model for multimodal interaction with Virtual and Mixed worlds. This model needs to be built around the user, taking into account his way of sensing and perceiving, his way of integrating different sensory inputs and outputs.
This model, being usable for VR and MR applications has to take into account the fact that inputs and outputs can be of different nature, real and virtual, combined together. Then the model has to be able to describe in a simple and intuitive way, and synthesize the complexity of a multimodal application without lacking in details. It has to describe VR/MR application in terms of information transfer and interaction modalities. It has to be thought for a single user but also for multiple users. Being usable for designing complex interaction systems it has to be organized as a design process based on two fundamental steps: analysis and synthesis.
The work has been conducted in the Product Development Process field and we choose to concentrate on the definition of aesthetic shapes in one of its first phases, the concept phase, so we choose two case studies in this step of the process.
The first of the case study has been developed in the context of the FP6-IST-5-034525 SATIN European Project whose aim was to create a multimodal interaction tool based on three sensory modalities, hearing, vision and touch in order to support the industrial designers in evaluating and modifying the shape of aesthetic industrial products. In this case study we want to see how our model helps in describing and designing a multimodal and enactive system that makes use of two sensory modalities, that are vision and touch, in order to replicate an existing task of tactile exploration and evaluation of shapes, and one third modality, that is the hearing one in order to convey to the user information that in not naturally perceived in the real task, like for example the curvature of the shape.
In the second case study we want to see what happens when two different cultures, like those of industrial designers and engineers have to be put together in the definition of a product that is both aesthetic and functional, since the concept phase. So we want to see how our multimodal approach supports us in creating a system that differently from the first one is collaborative, and so includes more than one user. This case study has been developed in the context of the Italian PRIN 2006 PUODARSI project whose aim was to develop an interactive system for shape modeling and analysis where industrial designers and engineers could collaborate in the creation of a functional and aesthetic shape in the concept phase of the Product Development Process.

# ANALYSIS ON REVERSE MODELING APPLICATION WITHIN THE DESIGN PRODUCT CHAIN

Giorgia Morlando

**Abstract**
This PhD thesis deals with 3D digital survey techniques and methodologies applied to the Industrial Design process; these techniques are known as *Reverse Modeling*. The 3D digital techniques allow the passage from a physical object into his digital model with a minor loss of information compared to handmade survey. Design objects are often defined by elaborated and detailed shape that requires very high amount of data and precision in order to describe surface behaviours. For these reasons, digital survey could be the finest solution for design object. Despite experimental method validity, the use of the digital technologies in the Industrial Design process presents some resistances. For these reasons this thesis tends to investigate which problems are related to the introduction of reverse modeling inside the design process. The study of critical situation is addressed to the analysis of the dynamics and the decisional phases that turn around the acquisition of a new technology. Analysis proposes to identify some crucial moments in the business system of decisions both as it concerns the economic subject, both as it concerns who is directly involved in the use of this technology.
The research has been managed through questionnaires and interviews addressed to the firms, these methods allowed to pick a set of data about the designer role in firm, the use of physical models in the definition of the product and the use of the digital survey. These data confirmed some resistances, as pointed out by the analysis of the standard economic literature. With the purpose of pointing out which are the actual resistances for this specific methodology, the thesis proposes a classification of the market sectors from the point of view of the reverse modeling, in order to understand proper instruments for different categories. In this way, the availability of some knowledge helps the overcoming of critical moments and allows a conscious choice.
Conceptual nodes: analysis on the dynamics involved in the decision-making and operational stages that rotate around the acquisition of a three-dimensional digital survey instruments. Analysis on the nature of the resistance in order to deliver some information that allows companies to decide with awareness on the design process.

## Introduction and description of objectives

This PhD thesis investigates the critical moments arising from the use of three-dimensional digital survey within the companies' framework.
The analysis seeks to identify some key points of corporate decision-making both in the economic entity, both in the people involved using this technology. The revision of the resistances that may occur permits to evaluate the information involved in the dissemination of knowledge about tools. Besides, it simplifies and improves the relationship between academic research and companies, in a contest such as the Industrial Design, in which theoretical knowledge and practice finds its maximum expression inside the firms.

## Methodology

In order to achieve the objectives, the work has been divided into the following phases:
Phase I - Definition of the problem and assumptions: the first step, i.e. the choice of the problem and the definition of hypotheses, aims to explore the argument and identify the problem that will be the subject of analysis. In social research, the hypothesis is an assertion, unsure and unproven, regarding the facts involved in the theory. In this research it was necessary to frame the problem of the potential application of reverse modeling in the development product process. The definition of the problems has been obtained through a preliminary descriptive study consisting of interviews and questionnaires carried out in companies. The information obtained allow considering a condition of partial use of 3D digital survey within the companies. Starting from this analysis it was therefore suggested that the reverse modeling is unused because it is considered too expensive, too difficult or unnecessary in the process.
Phase II - Research plan: since the assumption has been done, the researcher must define how to measure the variables and which group of subjects consider, making some evaluation on number and characteristics that the participants should have. In this stage it is also figured out which data collection techniques are most appropriate. The different analysis techniques are investigation, experiment, observation and ethnomethodology. Since it is difficult to implement research in companies (e.g. due to lack of interest or time), I preferred to leave the data collection technique open, choosing between more than one method of investigation.
Phase III - Mapping the state of the art: the third phase of the research consist on mapping the state of the art, through the analysis of books, publications, trade journals, and the economic sector. The analysis revealed the presence of a factor of psychological inertia to change that regards the company at higher levels, i.e. levels of decision making, and at lower levels of the company.
Phase IV – Data Collection: the fourth phase was performed using two main methods: the questionnaire and the interview. Besides these techniques, the observation is the method that characterized the case studies. Observation is the main technique for nonverbal behaviours data collection and may be used with other techniques simultaneously, such as experiments or inquiries.
Phase V - Analysis and interpretation of data: at the end of the data collection phase, there is often a considerable amount of information that is necessary to structure and relate to the assumptions. Data analysis has been done after the data reducing, this step has seen deletion of not relevant information with the analysis and the definition of some categories of study and comparison of information considering the macro arguments. The categories are: design process, role of the designer, realization of physical models, digital survey. In the end, the assumptions have been checked on the basis of the information collected.

## Results

The analysis shows that some companies use a highly standardised design process for the products creation; others instead change the steps according to the object itself, considering that each product has specific problems which should be defined from time to time. For this reason the first type of organization uses a defined number of physical models, while in the second organization the number varies up to the definition of the final form and it could require an iterative process in order to refine the shape that bring to the production of up to twenty physical models.
Similarly, some companies do not insert the reverse modeling within the design chain and do not see any potential application, while others use it regularly for those objects whose formal characteristics make difficult to detect them by hand.
In a heterogeneous setting like Italian companies, it is difficult to define in a statistical manner which is the spread of use of these systems. Despite the difficulty of determining an amount of use, does not lack the capability to analyze the enterprise dynamics. These dynamics are much more complex as minor is knowledge about tools and applications.
By the use of questionnaire and interviews, this PhD thesis improves the understanding of internal dynamics and relationship into the companies' area that regards product design and development, and allows locating the point of view that refers the digital survey. This research permitted to validate the starting assumptions and to provide a greater articulation about the reasons of use of these technologies.

**Key words**
Digital survey, industrial design, digital photogrammetry, laser scanner, resistance to change, process innovation, market sectors.

# SUPPORT TECHNIQUES TO THE PRODUCT DEVELOPMENT PROCESS FOR COMPOSITE MATERIAL COMPONENTS IN THE SERIES PRODUCTION

**Nicolò Pasini**

Until now the design of mechanical composite materials components, both in regard to shape, whether in respect of the production process, it is always assigned to practical rather than theoretical knowledge of manual and automated processes typical of design activity itself. This is the reason why these artefacts are often very expensive and produced in small series, in which there is no guaranteed repeatability, nor shape, nor mechanical properties. The need of the growing market of special composite material, alongside an increase in the number and severity of the criteria for approval, a search warrant to identify, define and mastered in a scientific manner the parameters involved in such activities in order to precede the design of these components for series production. The open issues related to the mass production (medium or large) will be tackled by extrapolating a design method for product development in order to open up new avenues of employment for these materials until now struggling to be used due to the uncertainty in the approach the project and because of the complexity of the necessary checks to the approval of a component, not just in the testing repeatability, but also the quality and prediction of mechanical behaviour over time.

This research aims to investigate the problems that prevent the spread of composite materials in the world of mass production and propose a design method of product development document for including such materials in the world of medium and large series. The research is divided into 2 macro phases: the development of methodologies for designing components made of composite materials for production in series and their validation through a pilot project. The research was conducted primarily at Automobili Lamborghini, a leader in the field of sports cars, which staff has decades of experience in the manufacture of composite parts, and carries within it the various processes and this has allowed to observe and study the many activities required for the product development process. In particular, the development activities of the methodologies begin with a general analysis of issues relating to design long fibre composite materials and a detailed analysis of the issues of that project from the perspective of the magnitude of batch production. This section investigates the major differences in terms of project and process, including a production prototype and a production in series, allowing the isolation of the individual issues that restrict the dissemination of these materials in production. The isolated individual topics will be analysed by employing the method of testing a method based on matrix decomposition of large problems in a sequence of simple problems, according to the guidelines laid down this process by industry experts as Automobili Lamborghini, who for years has been investigating these issues. The topics covered range from the definition of an asset for characterization of materials targeted to the choice of plant equipment and logistics, from the definition of calculation parameters to those of similar process in order to embrace a comprehensive vision of the entire product development process. Building on the analysis of processes typical of the product development process and taking as the typical ones found in Automobili Lamborghini, will perform a task of characterization of various materials and various manufacturing processes, to allow for the product, the choice combination-process material more appropriate. The absence of a solid experience, both in terms of mechanical tests (static, dynamic, fatigue, thermal and corrosion) and in terms of process (geometry of the moulds, materials, temperature, etc..) Indicates a significant deterrent for those who wish to address the problem of designing with these materials. In this area than in others, in the last line, the mechanical properties of the artefact is very dependent on the process used, this is the reason why the simulation of the process is much more important than the structural simulation of the component. With a view to mass production, in fact, the mastery of the process parameters that make the product repeatable is mandatory for many activities, first of all, the approval. In the last line compilation of the matrix of possible combinations allows the identification of innovative processes hybrids. The effort of developing methodologies and then ends with a summary of knowledge gained in this experience, they are drawn together theoretical and practical skills relating to equipment and the process of derivation automotive and aerospace. This summary will be represented by the proposed method, which sums up the characteristics of the project, technical, theoretical and expert operator. The activities hitherto described are accompanied by the constant analysis of the typical components of long-fibre composite material in production at Automobili Lamborghini in order to identify the most suitable component for the pilot project validation. The verification activities of the proposed method, in fact, is embodied in the design of the product development process of a real component which will be put into production at Automobili Lamborghini. In detail, the activities of validation of the proposed method consists in designing two versions of the same components: a prototype and a number. The application of the proposed method in the two extreme cases, allows a wider application of the extension, and allows both to highlight the criticality of this method, generating a real control loop on the definition of the proposed method. Both applications are based on the method of choosing the best combination of material-process with the characteristics of the final artefact. Using the proposed method will address the steps required for the product development process in an automatic way, by introducing a number of advantages: With regard to the prototype, the benefits advantages materialize in reducing design time and validation, providing the correct information about the behaviour of the material, and the reduction of valuation work provides guidelines that define the process more suitable for the given application, with regard to the battery for the mass production, the main advantages are summarized in the repeatability, in terms of mechanical properties and dimensions, which allow not only the approval of the component but also a significant savings in both production (reduction of processing waste) at both quality control (lower parts discarded). The last phase of this research is the application of the suggested method to a real test case, a composite Rollbar. The benefits resulting from the application of the proposed method, compared to the traditional method, are confirmed by better organization of the project, which requires less time and loop optimization, improved design, hitting targets more precisely allocated and a subsequent prediction more accurate business case, which reduces the degree of risk associated with a new project.