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DESIGN 4.0

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ABSTRACT
The phenomenology of 4.0 is investing all fields in design sector, it is indeed crept into the design, production, sale and consumption, making them, in the context of product-system, actually areas to be designed. We are witnessing the rise of design processes managed by algorithms that provide solutions and improvements in terms of efficiency, performance, choice of materials and cost optimization. This contribution illustrates an experimentation of these apparatuses by applying generative design to evergreen products of Made in Italy, with the aim of understanding how these new procedures can be used to provide valid solutions and whether they are destined to supplant the role of the designer.

KEYWORDS
design innovation, generative design, industry 4.0, made in Italy

In the era of 4.0 society, economy and products undergo profound transformations: their life cycle is reduced and their functionality fades, overwhelmed by the speed characterizing the Technological Revolution in progress, which requires the continuous advancement of new products and services. Society is thus forced to adapt to change and to seek new balances. In such a perspective, the Designer 4.0 operates in a system in which innovation and design culture take on new meanings, and research in the design field requires to be 'quick & deep' (Morace, 2018) in an era in which timeliness and connection with the territory must be supported respectively by technological evolution and culture. The phenomenology of 4.0 invests all fields in the design sector, it enters the design, production, sales and consumption making them, in the context of the product system, effectively areas to be designed. This paper describes a generative design experimentation applied to evergreen Made in Italy products, with the aim of understanding how these new procedures can be used to provide valid formal and functional solutions, and whether they are destined to supplant the role of the designer.

The design processes managed by algorithms provide solutions that offer improvements in terms of efficiency, performance, choice of materials and cost optimization. These are design processes in which real-time solutions are shared and all the phases are accelerated, delegating some optimization operations to the algorithms. In this context, the design process takes new paths: the solutions that the algorithms formulate depend on the inputs entered; designers must therefore identify the best solution to the problem based on various parameters, in a path of choice that must be governed. The most complex choices will concern the qualitative aspects, with a distinction between morphological aspects and the study of the shape of the product. While the algorithms are able to elaborate morphological solutions, the study of form is given by intangible components such as emotional values and culture of places, for which only the design culture proper to man can formulate a solution.

One of the central aspects for this research path is the relationship that the digital transformation has with the Italian productive system, therefore the need to understand which 4.0 channels we will have to activate in our manufacturing system and, consequently, which human resources are needed to be trained. Another aspect is the definition of the product and the emerging need to provide designers with some indications for the development of design 4.0. Moreover, Italian manufacturing as a connoting element of our economy, which only in some cases has found a development path 4.0 coherent with a system certainly far from heavy industry, how can it respond to this revolution through the culture of the project? In particular, we are wondering how these transformations will enter into relation with the Italian design culture and with the national manufacturing system condensed in the expression Made in Italy that in the collective imagination represents products of excellence and quality of life.

We can observe how even the role of the designer has transformed from a curator of the formal and functional aspects of the product into a designer capable of orienting company decisions, of interpreting transformations and designing new market scenarios. Italian design was also involved in developing an Italian user experience in product and service design. In particular, the design was able to make the experience of the Italian Life Style tangible, which is mainly composed of intangible values, as a qualitative experience linked to the emotional aspects of the product/service, as in the case of the fashion sector, of the gastronomy, furniture and automotive. In many of these product systems, values such as ‘quality of use’ or ‘usability’ lose their significance as they are dominated by the intangible values linked to the pleasure of owning an Italian product/service and with it experiencing an Italian emotion. Knowing how to design the Italian User Experience, has allowed many Italian companies to impose their products in specific market niches and fuel the success of the Made in Italy brand.

In this context the generative algorithm elaborates morphologies of components and products in relation to the three fundamental parameters that are the same parameters with which bionics studies its own models, i.e. the relationship between form, function and material. The observed digital scenario is destined to invest all production systems, regardless of their size, which therefore need adequate strategies to represent an added value that intensely changes the processes of production, management and organization of knowledge, but does not lose specificity. In this information age we are therefore faced with the need to optimally manage the balance between means and message, in order to safeguard the process of generating knowledge in which the aspect, perhaps primary, of generating value resides in a world 4.0.

The generative process of the project – Generative Design can be defined as a multi-variable problem-solving system that uses Machine Learning algorithms to recognize images, texts and formulate innovative morphological solutions. It is an apparatus able to extrapolate three-dimensional models from two-dimensional images in an autonomous way. The generative process refers to the ways in which nature generates form in relation to growth; moreover, as in nature, the relationship between form, function and material is closely connected, in fact the algorithm generates a relationship between these three factors in order to achieve a perfect balance. The software platform dedicated to generative design development is conceived as a design assistant that, thanks to the range of solutions it offers, allows a broad overview of the complexity of the project. Each proposal is generated taking into account both the requirements previously set by the designer and all the variables linked to the material's feasibility of the object. Generative Design is therefore a design process in which the final product is the result generated by an algorithm capable of optimizing the relationship between form, function and matter. The concept underlying Generative Design could be identified with that of DNA sequence: this code, just like the genetic one, makes it possible to obtain a range of different design proposals that all belong to the same family (Soddu, 1998).

In such a computational framework it could be argued that it is no longer the creative that designs, but the computer. However, the designer still plays an important role as he elaborates and provides instructions to the computer by intervening on the algorithm, making the selection process of fundamental importance for the final result. The generative algorithms therefore allow, unlike the classic three-dimensional modeling methods linked to solid primitive operations such as boleans and intersections, to change the shape of the artifact at any time. Furthermore, Generative Design is a useful tool in the control and manufacture of unique artefacts. The current three-dimensional modeling techniques have given rise to a series of generative processes such as the Wall Grammar, which automatically generates the exterior of the buildings designed starting from the plan and the height of the roof (Larive and Gaildrat, 2006), or the CGA Shape Grammar (Watson et alii, 2008). In the Italian scenario, the most active researchers in the field of Generative Design are in the Co-de-iT network (Computational design Italy), while significant examples of Generative Product Design can be traced to the grater (for Sisma), the fashion accessories Carapace Project and the Feral lamp, born from smoke modeling and made by sintering polyamides (for Idea Factory), all products by Alessandro Zomparelli. Among the pioneers is Neri Oxman, professor of Media Arts and Science at the MIT Media Lab, where he deals with research, digital fabrication, computational design and synthetic biology applied to the project with the aim of reproducing nature's growth processes and applying the sequences used by our genome to create new perspectives in design and architecture (Oxman, 2011).

In summary, therefore, the traditional design compared with Generative Design, presents limits that derive from: 1) Ideation times greater than computerized ones and lower quantity of proposals; 2) Ideas initially rejected that could be re-evaluated; 3) technological and practical constraints; 4) Difficulties in making design changes at an advanced stage. Furthermore, the combination of Artificial Intelligence with the Generative Design capabilities gives rise to a series of competitive advantages in the ideational process thus configured: a) the designer establishes essential parameters such as weight, material, shape and production costs; b) the software uses its own algorithms to calculate a large number of feasible solutions capable of responding to user requests; c) the designer evaluates the best solution with the help of those generated and suggested by the system; d) the behaviour of the building with the simulation is checked; e) the product development phase and the engineering and optimization aspects are checked simultaneously in the design phase; f) we go directly to 3D printing, creating our own model in rapid prototyping. The advantages brought by the Generative Design can therefore be expressed in terms of: i) savings on the timing of the design and industrial processes; ii) analysis of the innumerable solutions among which the designer defines the product; iii) performance improvement and control; iv) saving time (and money) on: tests, simulations, checks, materials, processes, supply chain; v) calculation of production costs.

The experiment – The experimentation carried out investigates the new operating systems for generative design, distinguishing between functional and formal qualities. A first approach examined two iconic products of Italian design: the Superleggera chair by Giò Ponti from 1957 and the Invisible Sandal by Salvatore Ferragamo from 1947. In light of the results obtained, the research team reflected on the new possibilities offered to the development of a new design culture. The generative design process is distinguished by five main phases: Phase 1) Creation of the model; Step 2) Importing the geometry; Phase 3) Attribution of geometries, forces and pre-check; Step 4) Exploration of the outcomes; Step 5) Export.

Phase 1) Creation of the model. The elaboration of the model concerns the optimization of the overall geometry: in particular, attention has been paid to the extrapolation of the simplest and most essential geometries possible, in order to circumscribe the passages. The study models required the reduction of polygon meshes, in specific points of the geometry. These types of tools have made it possible to obtain a more streamlined result in the desired areas, allowing the definition of the remaining parts to remain unaltered. The first phase ended therefore with the export of a model in a universal format.

Step 2) Importing the geometry. Importing the model into the online software, activating its operability. Cloud technology is an integral part of the software and is an indispensable element to exploit the full potential of the program. Generative outputs cannot be created in offline mode. Before importing the model into the Generative Design software it is necessary to convert the mesh and/or nurbs into solids. 3D modeling allows to create, within the program itself, the study models to be imported later into Generative Design. The toolbar offers a series of options – Design, Generative Design, Render, Animation, Simulation, Manufacturing and Design – which, once selected, vary the interface of the program. The resources provided by the software are: the Design interface that allows to work on elementary solids, surfaces, nurbs and meshes; the Generative Design Workspace interface, that is the virtual place in which to load the model, made suitable to generate the outcomes (the first operation is to select the faces of the model that are intended to remain unchanged and indicate instead the spaces to be exempted from the calculation, while as an optional option it is possible to assign a basic geometry, useful to the program to start the algorithmic calculation); the Render interface that allows photorealistic renderings; the Animation interface, which allows to produce videos, as well as the management of key frames, allows to control the scenes of moving objects; the Simulation interface, which allows to choose the type of simulation that the user want to perform (the choice falls between: Static Stress, Modal Frequencies, Thermal Stress, Structural Failure, Non Linear Static Stress, Form Optimization); the Manifattura interface, which allows the creation of tool-paths to optimize the manufacturing phases, whose functions include the simulation of the nozzle movements, speed and inclination, essential aspects for the creation of the components of a product ; the Design interface, which allows to draw shapes in space starting from a product or animation.

Phase 3) Assignment of geometries, forces and pre-check. Within the Generative Design Workspace the model is managed not only from a geometric point of view, but also on the data required by the Pre-check, an activity that the program performs to verify that all the phases preceding the generation of the outcomes have been correctly completed. Assigned to the model the geometries that we intend to keep in the final form: in this phase it can be assigned more than one geometry at a time. Define the geometries to be eliminated during the calculation phase and which therefore represent the spaces that are intended to be kept empty. Finally, the last step provides for the optional assignment of the 'starting-shape': this geometry is considered by the software to be the starting point for processing. Specify the areas of the model subjected to stress, indicating the physical variables of force, pressure, rotational moment and loads, an operation to be carried out in parallel with the choice of the axis. operation to be repeated for each component The program offers three modalities of optimization of the model that allow to decide, which will be the criterion used for the final generative design. If user wants to give shape to the model in rapid prototyping, he/she must use the type of manufacturing (additive), the minimum thickness, the inclination of the work surface and the orientation according to the axes. These data prevent a possible collapse of the artefact during the additive molding phase. User select the material from the library, with which he/she want to generate the outcomes. The software has the ability to create online libraries to load the most used textures. The calculation procedure is online, with a saving in terms of calculation memory for each computer.

Step 4) Exploration of the outcomes. Once the calculation phase is complete, the generated models remain on the cloud. The software provides the designer with four different types of visualization of the model and another visualization mode for the technical characteristics, defining the ranking of the concepts closest to the set requests. The displays show the results graphically and each material uses an identifying colour. On the abscissa axis are shown the values of Mass (lb) and on the coordinate axis the values of the Minimum Security Factor, which ranges from 1,999 to 2,001. Each outcome is accompanied by a technical sheet with all the dimensional, material and performance information of the model. User can view the models produced on the cloud in 'free orbit' viewing, including the 'stress reference'. This visualization mode shows the chromatic variations ranging from red to blue: the maximum and the minimum stress value. At the same time, it is possible to observe the starting geometry and the consequent evolution carried out following the algorithmic calculation. The software also allows the two models to be compared simultaneously – the starting and the ending – to appreciate the differences and/or similarities.

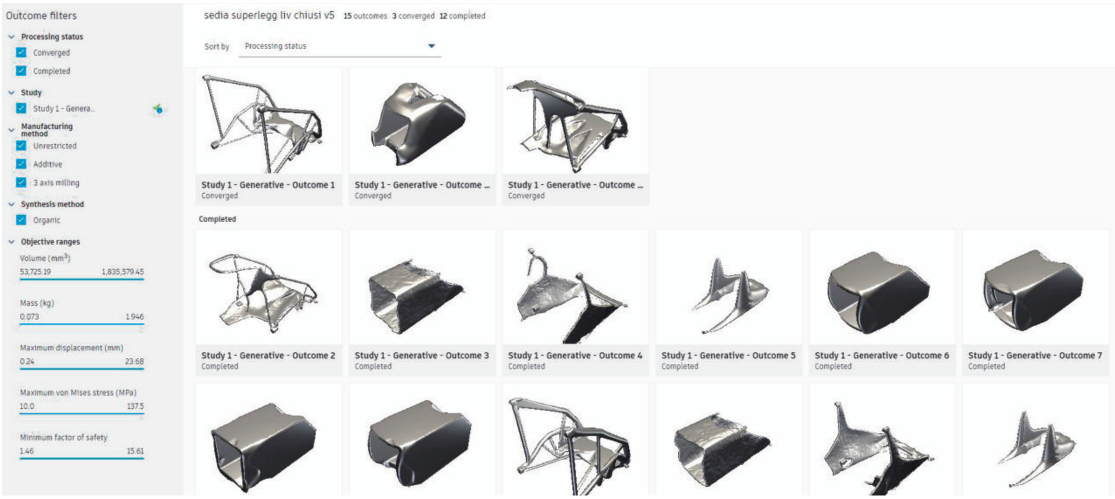
Step 5) Export. Once the concept is chosen, it can be exported in STL or SAT format. Given the universal nature of the file, it is possible to complete the model using any 3D modeling software, the generative design process is completed and it is possible to work on the model or implement it in rapid prototyping.

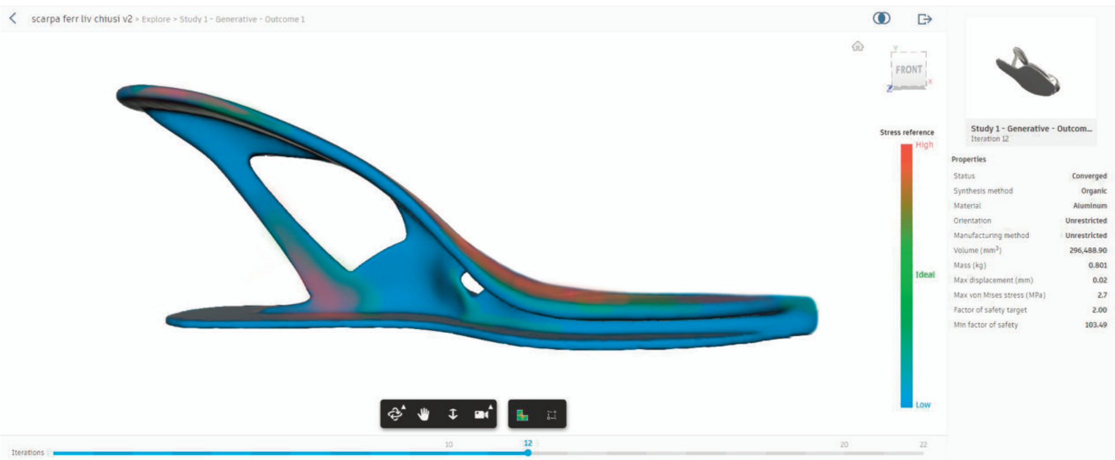
Results – The tests were performed with the aim of testing the potential offered by the generative software, orienting the generative experimentation on iconic Italian design products, starting from 3D models. The software synthesizes the Starting Shape, creating connections with the parts of the model that are wanted to remain unchanged, then the algorithm eliminates the excess material and optimizes the model. Once the Superleggera model was created and the constraints assigned, the software calculated surprisingly unusual formal and structural solutions (Fig. 1). Despite the inclusion of all the required constraints, the algorithmic calculation has not always produced profitable and advantageous results. In particular, with reference to the generative experimentation on the Superleggera, the proposals taken into consideration concerned only 26% of the totality while for the Invisible sandal 90% of the outcomes proposed by the software were interesting and plausible solutions (Fig. 2).

During the outcomes generation phase, the software developed a finite number of concepts on the cloud platform, developed simultaneously to optimize waiting times. Sometimes ineffective cases may occur, that is when the software produces outcomes that are extreme syntheses of the model; this phenomenon does not derive from the type of input inserted but from the type of calculation – subtractive – that characterizes the software. It is possible to retrace the 'interaction levels' to reach the result that best meets the expectations: a process that also allows the evolution of the algorithm to be viewed step-by-step. In the specific case of sandalwood, the chronology of the interaction levels was analyzed identifying the most interesting solutions in the early stages of

Figg. 1, 2 - Next page. *Preliminary outcomes of the* Superleggera *chair by Gio Ponti;* Invisible sandal *by Ferragamo, evolution of the heel and sole structure in relation to the reduction of material and weight.*

calculation compared to those developed at the end of the generative process. Once the outputs have been obtained from the software, it is essential to take into consideration the morphological aspect relating to the form-structure link which is the most satisfactory of the solutions. Finally, the output must be processed by the designer, who ultimately uses the model's own knowledge, skills and sensitivity, also based on his own culture and places. Three possible product typological classes have been identified elaborated by the algorithm on which the designer intervenes. It is possible to define the degree of intervention of the designer according to whether the transformation of the post-algorithm is Low, Medium or High. These classes can provide various types of products within the Generative Design.





In the case of low post-algorithm transformation, the Product is configured as belonging to a class of contemporary artefacts necessary, capable of producing unitary solutions for a diversified public, adaptable to any context. The strength of design lies in the study of the generated form, in the relationship between ethical, social and environmental aspects in which the design culture is called to define a new form of beauty. Products determined by the mastery of the designer who knows how to operate in the parameters, in the constraints and who, through his sensitivity, imposes the solution he prefigured, to the algorithm. In the area of Medium post-processing algorithm, once chosen the best solution among those proposed by the software, the designer defines the shape of the product. It could be argued that this result represents the outcome of the joint work between designer and algorithm, in which both parties contribute to the determination of the result. The product of the post-algorithm medium transformation is an elaborate, detailed, reasoned artefact in which the designer's own knowledge is essential to define the study of form: defining the aesthetics of the product and giving shape to emotions is the exclusive task of the designer. Without doubt the great advantage given by Generative Design is the ability to generate many varieties of functional concepts very quickly, which the designer would not be able to summarize in such a short period of time.

In the case of post-algorithm High Transformation, the product represents the perfect combination of refinement, taste and quality, elements that characterize Made in Italy, which stands out through the relationship between executive care and formal innovation. It is believed that the generative design of the products belonging to this typology should contemplate the broader "post-algorithm" transformations. The internal structure, generated through mathematical calculations, must in fact serve as the foundation on which to base the development of the product. The care of the aesthetic component, in this particular class of artefacts, remains the dominant task of the designer and very often the resulting product is the synthesis between design and the virtuosity inherent in the value of artisan know-how. This value is exactly what the global customer looks for when choosing the Italian product.

Without a classification that can distinguish the different categories of products, one would be led to consider the results given by Generative Design as effective and sufficient, and this could be translated into a 'cultural and creative globalization'. Furthermore, there is no doubt that the greatest advantage of Generative Design is the possibility of obtaining a large number of functional proposals, something that the human designer would not be able to synthesize in such a short time. However, by examining the activity of designer 4.0, a series of critical issues emerge that could occur during the use of Generative Design:

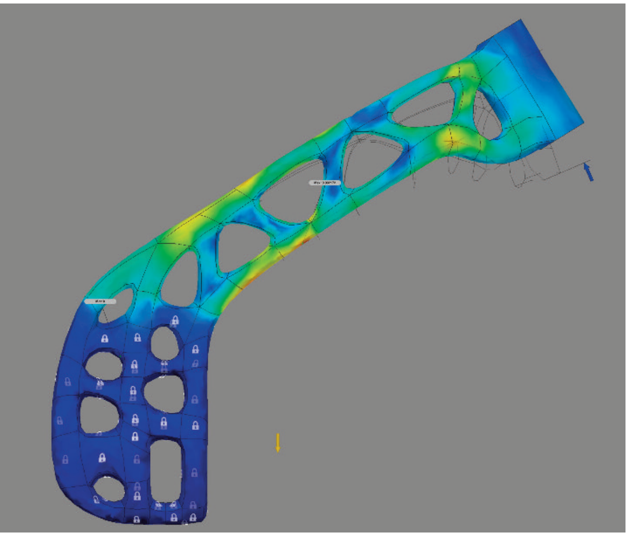
1) given the ease with which the products with 'low post-algorithm transformation' are produced, there is the risk that these will free human creativity from the conception of artefacts, relegating the designer's task to that of a mere data manager to be introduced in the software;

2) What would happen if in a contest of ideas two participants produced products with a 'low post-algorithm transformation' (with outputs not subsequently elaborated by the designer) that are similar? Since the morphology of a product varies based on the inputs that the designer inserts into the software, what would happen if one or more users entered the same inputs provided by the same brief?
3) What would happen if two designers with different degrees of skill on Generative Design software would compete in creating a High Range product? Would it be possible to 'circumvent' the result by limiting human interaction and replacing it with more targeted inputs thanks to optimal software management?

The challenge in experimentation – Once the first experimentation phase was completed and the degree of intervention between the algorithm and designer was defined, the team entered a second phase dedicated to some types of vehicles destined for the Italian high-end manufacturing system. The types of products are a motorcycle and a bicycle; these are objects with different degrees of complexity through which the research team intends to verify the modes of action in the high post-algorithm transformation. The morphological studies on the single components have assumed as 'generative models' of the bionic models to be processed through the generative software. The formal inspiration for the frame and the fork of the bike comes from a spider web that has become a three-dimensional structure with a variable section (Figg. 3, 4), while the bicycle designed for urban use is composed of a frame in fiber profiles of carbon with constant section in which the junction points of the parts are generated by portions of exoskeleton of some insects and designed to be made of aluminium alloy (Fig. 5). The study of the shape managed in real time with respect to the mechanical checks allowed us to check weights and quantities of material to definitively configure the mono-material components, hierarchizing the assembly and disassembly phases.

Conclusions – The results given by the Generative Design appear to be different each time but are identifiable in the same process and undoubtedly provide the designer with suggestions. The research wants to underline that the generation of the form is not entrusted to the digital: it is only an assistant, which optimizes the 'time to market' of the design process and the passage from the concept phase to the product development phase. Generative Design, from a first phase dedicated to the engineering field, goes into the creative field of design, offering innovative solutions in terms of performance, lightness, strength, resource savings, use of new materials, and formal innovation. Generative Design in fact, is not only to be understood as a software but as a modeling procedure of the form in which the designer can control the meanings, performances and material characteristics simultaneously. The study of the form is enriched with further solutions: all the possible variations produced by the algorithms, the designer finds himself in real-time possession of variants that only software is able to achieve.

The difference between the algorithm and the human mind therefore lies in the design



Figg. 3, 4 - Moto Bora*, design by Lapo Corenich: View 3/4 in which it is possible to observe the frame and the fork as connoting elements; Detail of the frame in the generative software environment.*

Fig. 5 - Overall view of the product with a frame made of constant section carbon profiles and joints made looking for the lowest possible weight and a shape that gives the product its identity.

method. While the designer conceives ideas drawing on his knowledge, experience and field research, the software calculates only the inputs. The designer, on the other hand, through his skills, helps to define a formal hierarchy and to determine the meaning, the identity of the products and therefore of the brand through a matrix of signs. As John Maeda (et alii, 2017) recently stated, it seems that the figure of the designer will inevitably have to evolve in a 'computational' sense, so the designer will have to become familiar with the use of codes for the design of products in continuous evolution. Therefore, in this vast panorama of algorithms it is believed that the role of the designer is not destined to become extinct but that it will be more and more incisive in the decision-making, elaboration and finalization phases of the project proposals. The figure of the designer is not destined to change: what will change will be the design process that will therefore require new skills, and in which the generative software will become advantageous tools in concrete support of the designer.

Finally, the team asked a question about the possible repercussions that Generative Design can have on the Made in Italy system and what it means to innovate in the Industry 4.0 era. Italian companies, in fact, produce their own products and services for customers who represent the wellness society, in which not only mere needs must be met. It is therefore considered necessary not only to define more specifically an Italian 4.0 model, but that it is also fundamental to redefine the purpose of the Italian product itself. The 4.0 era is an opportunity for the Italian System, in which innovative processes are to be found in the meanings (Verganti, 2016) that the products or services take and no longer in products that satisfy mere needs. It is therefore believed that the Italian Design System is facing new avenues to be taken to bring formal innovation to the product by interpreting the new 'qualia', qualitative aspects of the experiences that have always identified the Made in Italy product and that cannot be totally delegated to the digital technology inherent in the product/service.

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