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Editors

Advances in Additive Manufacturing, Modeling Systems and 3D Prototyping

Proceedings of the AHFE 2019 International
Conference on Additive Manufacturing,
Modeling Systems and 3D Prototyping,
July 24–28, 2019, Washington D.C., USA

 Springer

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Advances in Human Factors and Ergonomics 2019

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10th International Conference on Applied Human Factors and Ergonomics and the
Affiliated Conferences

Proceedings of the AHFE 2019 International Conference on Additive
Manufacturing, Modeling Systems and 3D Prototyping, held on July 24–28, 2019,
in Washington D.C., USA

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Advances in Additive Manufacturing, Modeling Systems and 3D Prototyping	Massimo Di Nicolantonio, Emilio Rossi and Thomas Alexander

Preface

The AHFE International Conference on Additive Manufacturing, Modeling Systems and 3D Prototyping focused on cutting-edge design and manufacturing processes; it welcomes papers that cover articles, case studies and multidisciplinary studies specifically focused on ergonomics research, design applications, engineering processes, experimental purposes and theoretical methods applied the themes of Digital Modeling Systems and Additive Manufacturing and their cross-sectorial convergences. This book presents the results of recent research work. We believe that the findings presented in this book can either inspire or support others in the field of manufacturing and process control to advance their designs and implement them into practice. Therefore, this book is addressed to both researchers and practitioners.

The papers presented in this book have been arranged into ten sections, as shown below. The first five sections cover topics in modeling and 3D prototyping. Sections 6 to 8 deal with issues in additive manufacturing, while the last two sections are concerned with digital human modeling.

- Section 1 Design and Innovation for 3D Printing
- Section 2 3D Printing Technology
- Section 3 Research on 3D Printing, Design and Digital Modeling
- Section 4 Algorithmic Design and Rapid Prototyping For Cultural Heritage
- Section 5 Recent Developments in Rapid Prototyping for Assistive Technologies
- Section 6 Smart Additive Manufacturing: Sensing, Data Analytics and Process Control
- Section 7 New Materials and Industrial Processes for Additive Manufacturing
- Section 8 Additive Manufacturing and Industrial Production
- Section 9 Digital Human Modeling and Applied Optimization
- Section 10 Digital Human Modeling by Women in Human Factors

The presented chapters depict the influence of worker experience and the technology used to improve work effectiveness. Next, the comparison of non-expert and expert work is studied to find patterns that can be used to improve the technique of performing different tasks by less-skilled employees. The third section deals with outcomes ergonomics have on industrial quality and safety, while the fourth and final section of this book is focused on ergonomic design of future production systems.

The editors would like to thank Sudhakar Rajulu for his contribution to co-organizing the Digital Human Modeling program and Sofia Scataglini for her contribution to organizing the Digital Human Modeling by Women in Human Factors.

The contents of this book required the dedicated effort of many people. We would like to thank the authors, whose research and development efforts are published here. Finally, we also wish to thank the following Editorial Board members for their diligence and expertise in selecting and reviewing the presented papers:

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3D Printing to Innovate the Guitar Design

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Abstract. The paper suggests to reflect and to discuss on Innovation through the 3D printing applied in the field of guitar design. The use of specific 3D modeling software and the development of 3D printing technologies for the creation of objects through additive production, favors new design processes increasingly oriented to the research of complex and personalized forms of musical instruments and electric guitars in particular. Design studios and small companies, with the collaboration of musicians and violin makers, experiment with new languages and advanced production techniques to make guitars, but also very light and transparent electric violins, as well as the prototype of a sax or the concept of a piano.

Keywords: 3D printing · Design process · Guitar design · Selective Laser Sintering (SLS)

1 Introduction

Nowadays, new design processes, increasingly oriented towards the research of complex and personalized shapes of musical instruments, can be favored by the development of 3D printing technologies combined with specific three-dimensional modeling systems and software for the creation of objects through additive manufacturing [1]. Designers, engineers and small companies, in collaboration of musicians and luthiers, experiment new languages true advanced production techniques to make guitars, but also very light and transparent electric violins, up to the collections of small wind instruments, as well as the prototype of a sax or the concept of a piano.

The purpose of this paper is to review my recent research conducted with the help of companies, luthiers, musicians, engineers and designers, in order to address the complexity of 3D Printing for the innovation of instruments and in the field of guitar design. The research has set some main questions: How does the guitar design evolve due to the phenomenon of 3D Printing? How does usability, functionality and aesthetics of the musical instrument change? What are the physical and psychological advantages and disadvantages for the guitarist involved in experimentation and musical research? The research questions have been addressed through a methodology that deals with the combined approach between bibliographic research, Internet, case studies, interviews, direct empirical research and carried out in collaboration with rock, fusion and jazz guitarists. The results in progress concern both the investigation and the



Ma(r)kers: Digital Fabrication as Opportunity for Enhancing Territories Through Hacking, Personalization, Traces

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Abstract. The paper aims to analyze the deep relationship occurring between small proactive communities within urban areas and innovative and collaborative means of production. A categorization is finally given to define different types of products that, by being related to the territory's unique identity, get to be defined as markers, bringers of value.

Keywords: Digital manufacturing · Local communities · Mass customization

1 From Pre to Post: An Economic Evolution Overview

The economic evolution of society evolving from the pre-industrial era to the industrial age, and then to the post-Fordist period has not only influenced the means of production but also (and mainly) the relationship of production with the territories and with the users/consumers.

Over time, the urban development debate has spread over different positions giving rise to many proposals. Let's take as starting point the theories of M. Storper, [1] according to which cities function not only as a spatial agglomeration of economic systems, but also as an agora for local networks of formal and informal institutions, places of political action and intervention, and more generally spaces for social interaction, structured by the face-to-face relationships that link economic activities in the cities to each other and that derives from the strong concentration of activity in some territories, also and despite a strongly globalized economy in which many productive activities have been relocated. Globalization and local interactions are two complementary sides of local development: the urban environment supports and nurtures the development of face-to-face relationship networks that are allowed by the concentration of activities, events, people [2].

During the years of Fordism there was a need to manage the spatial development of fast-growing urban systems while in the 1990s, the need was to regenerate the economic base of de-industrialized cities favoring the development of the tertiary sector. Today instead, in a view of hyper urbanization, the big challenge lies in strategic planning to make our cities transit to a model of local development capable of

generating collective well-being without economic growth, without negatively impacting the development of other territories and within the limits of a planet with finite resources (Calafatti, Chiappini, 2018)¹.

In the last thirty years, during the transition from Fordism to post-Fordism, we have seen, within the cities, a productive delocalization that has caused a significant dispersion not only of economic but also cultural and social capital, as well as individual and community skills.

This progressive development to de-industrialization, exacerbated by the crisis of 2008, becomes a serious problem for the urban economy, and especially for designers, as there is a lack of that system of correlation and potential work that has always determined the relationship between design and manufacturing companies.

In this productive decline, part of the project skills present on the labor market have been re-invented and absorbed by the world of communication and services; in fact, with the advent of post-Fordism, the diffusion of city branding projects has partially restored value to territorial identities and reconstructed a connection between design and territories. These actions have often, however, exhausted their relevance by proposing random or utopian values borrowed from traditional marketing and far from the actual culture and specificity of the “branded” places.

2 Local Micronetworks

“It is therefore about developing new forms of citizenship that integrate the need for global solidarity in the local context. In doing this we realize that the approach of competitive design, the ideologies related to branding and marketing are found in open contradiction with the spirit of this civic sense”- Ruedi Baur²

While the growing atrophy of the formal economy continues developing today, in cities we see a contrary phenomenon based on the relocation of manufacturing activities, the “Small Urban Manufacturers” (Pratt Center, Byron and Mistry, 2011)³ connected to a wider trend taking place in most advanced countries, called “insourcing”: that is basically the rebirth of new forms of micro production within urban and metropolitan areas.

S.U.M develop a production that is highly design-oriented not only for the product but also for the communication model, for the development of the brand, for the use of the attached services and for the experience that is offered.

Their size and their positioning within the cities allow them to come into direct connection with people and citizens; we are no longer in presence of giant companies that do not know their customers personally, but we talk about small interlocutors who develop a new relationship model, also enabled by the Internet and social media, and

¹ Calafatti, L., Chiappini, L., Nuove economie urbane tra innovazione economica e coesione sociale, Territori di ricerca: natura, città e spazio pubblico 3, Milano, 2018.

² Baur, R., Civic city: from the spirit of a design of concurrences to a design of relations, Designing civic consciousness, San Marino, 2018.

³ Mistry, N., Byron J., The Federal Role in Supporting Urban Manufacturing, Pratt center for community development, New York, 2011.

especially enabled by the idea of not building a market but rather a community-market; that is, users who are at the same time part of the processes, passionate about the product and willing to intervene in the development of the project and the production of the product in order to have customized items tailored to the end user, output that defines this type of production. These groups of active citizens must be seen and analyzed as social networks that overlap and change continuously. Their formation depends on several factors, among which the geographical one is obviously fundamental to the formation itself; at the same time, the network can develop to the point of mediating the effects of the geographical position on the shared knowledge within the network, spreading and keeping alive the values and know-how in and out of the territory.

In this way the population of the city itself produces its own culture of consumption, which is propagated within the territorial context to which it belongs; consequently we have the birth of territorial brands, such as “Made in ...”, and consortium systems of micro-producers that create alliances on an urban scale to bring out their production capacities, in a “bottom up” community dimension. No more factories located in a specific place like in traditional industrial cities, but a system of micro-networks that interact with each other and are able to develop a new generation of socio-productive activities, aimed at creating socio-economic value distributed and widespread throughout the territory.

This new strategic orientation is driven by a series of transformations of a social, technological, economic, geopolitical and cultural nature, which make possible to rethink a return to manufacturing production, especially in urban areas, albeit in different forms compared to the past [3].

3 Sharing Economy

Already in 2006, in the article Coase’s Penguin⁴, Yochai Benkler, Harvard law professor, defines the term of commons-based economy, as a new economic model of production in which the creative energy of a large number of people is coordinated in projects mostly without the traditional hierarchical organization.

Predecessor of what, in the coming years, will be called sharing economy [4] defines an economic model based on collaboration and sharing of assets, spaces, skills, in order to derive monetary benefits and not, which would be articulated in:

- *collaborative consumption*: people exchange, share, redistribute products that they do not need and do not use continuously (e.g.: Reoose, Airbnb, Coachsurfing), or pay for access to them rather than acquiring ownership (ex: car sharing);
- *collaborative learning*: open courses or forms of sharing and agglomeration of knowledge from a crowd perspective (e.g. Wikipedia or Future Learn);

⁴ Benkler, Y., Coase’s Penguin, or, Linux and The Nature of the Firm, The Yale Law Journal, New Haven, 2002.

- *collaborative finance*: fundraising in which people can support the creation of projects, businesses, charitable initiatives (crowdfunding) for free or receive a form of symbolic or tangible reward (e.g.: Kickstarter, Produzioni dal Basso, Rete del Dono, Musicraiser); we also find other forms such as peer loans (Ex: Zoopa) or complementary currencies (ex: Sardex).
- *collaborative production*: networks of individuals who collaborate in the design process (ex: Quirky, Zooppa), the distribution of goods and services (e.g. Nimber); distributed self-production (Reprap, Prusa). In this last case, the production processes take place in contexts outside the control of large companies and the innovation and knowledge that derives from it is shared and diffused; these systems work on values that express in an emblematic way the ideologies of the so-called Maker Movement and of the makers, people who are part of the aforementioned movement. These developing interaction patterns and models of relationships in which local and global dynamics intertwine are strongly inserted in communities that gather around the fab lab and makerspace (Analogic sphere); in the same way they are connected to digital communities (Digital sphere) all over the world and thanks to new communication technologies, they can share their knowledge, their experience, their projects and develop new collaborative forms [5].

The urban environment also represents the privileged place where this type of economy can emerge because it is able to concentrate subjects, knowledge and sharing practices: hackers, co-workers, makers, subjects involved in social and innovative social projects, they all are crucial actors of this change, by being carriers not only of unprecedented practices, but also of instances and an innovative ethics devoted to social change [6].

This scenario is reflected in the system of products and artefacts that take on a symbolic value progressively affirming the meaning that the user attributes to them, as a sign of the identity of the place or brand to which they refer.

The specific function of the product (a knife must cut or a lamp must illuminate) loses importance compared to an emerging role as amplifier and witness of traditions and values, which goes well beyond the figurative and formal contents, but is charged with intentions and instances for which the process of technology reinforces and strengthens the symbolic content.

The products are therefore now *markers*, defined by Dean MacCannell [7] as those informational elements capable of activating the transformation of a place into attraction. They differ from other artifacts on the basis of a code of meanings, through shapes, materials and colors, or the brand. Consecration as typical products, bearers of local identity, markers, therefore leads to their cultural legitimacy. They themselves become traces that act on the behavior of visitors, triggering a process of response to the stimulus they induce, able to evoke, in those who perceive it, feelings, emotions and memories, opportunities to know and to make known. The designer is a kind of discoverer looking for traces and potential value to be transformed into real resources.

4 Ma(r)kers' Stories

Within this set of products strongly connected with the individual territorial identities we have recognized the existence of three levels of individuation with which the project and the attitude of the same are related; each of these is analyzed and described by appropriate case studies.

However, the common feature of all these products remains their close connection with the production dynamics of digital fabrication; It is not by chance that the projects mentioned exploit the specific features of the typical machinery of a digital laboratory, such as the high level of customization achievable and the possibility of creating small lines without incurring into production costs that would be unbearable for a traditional company, whose production system is based on mass production of large quantities of artefacts.

Hacked. This category includes existing products that can be hacked to improve their functionality: digital manufacturing allows us to think of additions, substitutions of pieces, alterations to improve /differentiate the basic product.

For example, in the case of a traditional instrument such as a mortar that is updated by adding a piece of plastic that prevents the formation of splashes, or Orange Fiber activities.

Pestatiù. This is an aesthetically revised mortar, designed after analyzing not only the Genoese mortar but also those belonging to other cultures, such as the Mexican Molcajete and the Japanese Suribachi. The first distinctive feature is the inclination of about 25°, peculiarity both at an aesthetic level and also functional as it is designed to facilitate the rotation of the hand; secondly, what captures the eye is the presence of this thin opaque transparent plastic wall affixed to the top of the mortar and which acts as a parasol. The pestle also undergoes a re-design with side grooves which make the grip more ergonomic, whether it is with the thumb upwards or downwards, and the incision on the wider end of four knurls that facilitate shredding. On the material side, instead, three main materials have been used: porcelain stoneware for the mortar, opaque transparent plastic for the splash protection lid and olive wood for the pestle (Fig. 1).

Orange Fiber. Orange Fiber, a start-up founded by a group of Sicilian girls, produces a sustainable citrus fabric; silky and impalpable, it is designed to meet the needs of innovation and sustainability of fashion. It can be printed and colored like traditional fabrics, opaque or shiny, used together with other yarns - like cotton or silk - combining sustainability and innovation with the Made in Italy textile quality.

This fabric is made starting from the citrus pastries, that is the humid residue that remains at the end of the industrial production of citrus juice which can no longer be used but only thrown away as a waste.

Thanks to the production process, derived from the industrial ones, which has been developed and protected by an Italian patent, Orange Fiber is able to produce a high quality fabric capable of combining two pillars of Italian excellence - fabrics and food - and responding to the needs of innovation and sustainability of the fashion industry: in fact, in 2017, the Ferragamo Orange Fiber Collection was launched, whose garments are displayed in the windows of the main Florentine labels in the world (Fig. 2).



Fig. 1. Pestatù mortar, restyling of the classic Genoese model. Project by Chiara Garofalo, Fabio Di Bella and Matteo Barbagelata

The Orange Fiber Capsule Collection was embellished with original prints by Mario Trimarchi, architect and designer, Compasso d'Oro 2016, and his interpretation of the Mediterranean scenery. The innovative texture of Orange Fiber fabrics finds a perfect symbiosis with the designer's dreamy world: lights and shadows, fragrant zagare winds that gently push fluctuating clouds and dreamed images of bougainvillea, distinctive and peculiar traits of Sicilian lands.

Personal Identification. This category includes those products that, thanks to digital production, connect personal identification with the product: products that can be made and customized according to the user's desire and taste, conceived from their conception to be adaptable, custom. This is the case, for example, of glasses, an accessory that has a profound relationship with unique human characteristics and can be completely customized through a virtual interface and subsequently printed to perfectly adapt to the user's characteristics.

Frame. The involvement of active citizenship and the revaluation of the historical heritage are the basis of the project Fabric{Action}, an event organized by three graduates in Product and Event Design (Sara Guagliardi, Alizè Tincani and Annapaola Vacanti) held in February 2018 in an abandoned historic villa in the disadvantaged neighborhood of Sampierdarena, in Genoa.



Fig. 2. Ferragamo Capsule Collection embellished with exclusive author's prints created by Mario Trimarchi, Compasso d'Oro 2016

During the day, special fassamano modular frames printed in PLA were distributed to the public. Each person has freely chosen two formal elements with which to compose their glasses and has then been portrayed with the same frame on the eyes. A filter for sight, but also a way of expressing one's opinion; in fact, every form had been associated with a value, a hope for the future of the neighborhood.

In this atypical and fun way, design has managed to connect citizens in a simple way to the territory, collecting data in a simple and engaging way, allowing everyone to feel personally part of the neighborhood and involved in its future evolution. The experience received positive feedback from all the participants, including even the smallest ones who felt called into question. The result was a collection of more than 200 portraits from which data on the most frequently chosen forms were extracted: apparently, the citizens of Sampierdarena hope for a greater diffusion of culture and tourism for the future of their neighborhood (Fig. 3).

Introvert. "The form inside the form" was the idea that accompanied the Introverso project by Paolo Ulian for Antonio Lupi from the beginning.

In the working of the stone, the rough cut is used to delineate the final shape of the product by tracing a regular series of cuts managed by a cnc machine.

Starting from this concept, Ulian, as in all his poetics and his work, enhances the material resources of his own land, Carrara marble, turned and lightened by a series of cuts that let us glimpse its inner soul, where the block of marble loses its monolithic appearance and turns into something ethereal, transparent, which encloses a secret soul.



Fig. 3. Some of the visitors photographed with their Frame of choice during Fabric{Action} event in Genoa

The will of the designer is to interact with the future user of the product, in fact it is him who leaves the discernment to hide the core, allowing a partial view through plays of light, or it can be slowly unveiled by breaking the edges of the slats with a proactive and conscious action of the interlocutor (Fig. 4).

Restarting from the Traces. This category includes those products that capture references from the traces of the territory they belong to, including them in the design of objects, not only for signs, shapes and materials that recall the history and tradition of the area, but also through work combining craftsmanship, engineering and digital fabrication, adding a symbolic value to the artifact. It is the case in which digital technologies lend themselves to the creation of objects of museum merchandising, craftsmanship or enhancement of the territory. Objects and products thus become witnesses, markers.

Ceramics for the Anthropocene. A significant experience in this context is the one that saw the design of the artifact “Ceramica per l’Antropocene” by designer Francesca Perona, developed as part of the “Be Sm /ART2” project with the local community of ceramists in the area of Albisola Superiore, the Engineering Department of the University of Genoa and the research laboratory on robotic fabrication DigifabTURIN based in FabLab Torino and promoted by Radicate.eu, an independent organization for Research on Art and Contemporary Culture active at the Savona Campus of the University of Genoa.



Fig. 4. Introverso, sink for Antonio Lupi, design by Paolo Ulian, ADI Design Index 2017 selection

The work currently exhibited at the Museum of Ceramics of Savona is a master example of the results obtained by combining conventional and digital craftsmanship with technology, design and territory.

Specifically, the designer, accompanied by a team of engineers and various local artisans, analyzed the data coming from the energy microgrid of the Savona campus, and then represented them physically through the hybrid ceramic artefact, for which numerous local materials were found and used. The collaboration with FabLab Torino has been fundamental to give life to the work by printing the various elements with a robotic arm (Fig. 5).

AlpeRubra. A paradigmatic case study is certainly the project of AlpeRubra.

Dedicated to Valtellina, the land of Maurizio Bresesti, a traditional carpenter, and thanks to the artistic union with the designer Marcello Pirovano, this project is born to tell the story of the territory, through its know-how, embodied in an innovative line of tableware. With the AlpeRubra project the landscapes of Valtellina become narrative forms. Through the digitalization of their morphology, Alpine structures, first mapped by Google data, then reworked through slicing and three-dimensional modeling techniques, are transformed into instrumental objects. The wood of the ancient wine barrels found in the valley receives a new life, continuing the story around the wine that has welcomed: from container for its maturation to an instrument at the service of a food&wine experience. AlpeRubra brings together history with contemporary digital technologies, triggering a strong relationship between the territory and its raw material, through the history of wine as a product able to open its own historical-traditional narration, synchronizing it with the functional technologies of digital manufacturing [8] (Fig. 6).



Fig. 5. Francesca Perona has collected and worked the Savonese clays that were then used at FabLab in Turin where, with the help of a robotic arm, she printed the project



Fig. 6. Alperubra is dedicated to Valtellina, designed by the designer Marcello Pirovano and realized by Maurizio Bresesti

5 Conclusions

In conclusion we can affirm that for a balanced territorial development and an auto sustainable ecosystem, declined in the economic-productive and social-environmental fields, the different stakeholders of the same city network have a vital role: the public administration, the citizens, institutions, associations, small businesses in the area and even some large companies [9].

The creation of a circuit is essential to widely spread this systemic approach; and in this reticulated structure, the hubs, or the connection nodes, should be the FabLabs, which work more and more alongside administrations and in partnership with big and small companies, but nevertheless remain focused on people, in a place where citizens are perceived not only as consumers but as producers able to perform this function by accessing digital construction and knowledge tools.

In this scenario, the activators / catalysts of these practices and who operate in these places, the makers, undergo a further upgrade, as they also create markers definable with the syntasi Ma(r)ker: co-producers and co-designers, who hybridize new technologies to craft production systems, manufacture artefacts that bear symbolic values of belonging and the dexterity of a given territory.

In these terms, we would witness the transition of the common concept of Smart city to the declination that makes it Ratti⁵, Senseable city: a place of sustainable and local production, global cultural connection, circular economy and partnership by different creative forces, just because collective systems that they start from an ethical and social principle and not profit, they are the tools to create new models of territorial development.

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