



Chair:
Prof. Luca Guerrini

DOCTORAL PROGRAM IN DESIGN

Field of study

The Politecnico di Milano was among the first universities in Italy to start a PhD program in the field of design in 1990. Based on this tradition, the PhD program in Design was established in 2008, as the result of a process of substantial re-thinking the way design was taught at PhD level. The program is run by the Department of Design together with the Department of Mechanics and the Department of Chemistry, Materials, and Chemical Engineering.

In its current configuration the program aims at developing professional competence to carry out high quality research in terms of design as a complete scientific field. In this respect, its main topics are: to reflect on the nature of design, with its aesthetic, formal, performance and meaning values, as well as its capability of being an agent of social change towards more sustainable systems; to strengthen the disciplinary core of design; to develop and share a common body of knowledge and methodologies, as well as a complete set of tools able to distinguish the designer from other researcher/professional figures involved in design activity.

Main goal of the program is therefore to train designer-researchers who, while addressing the problems and opportunities of contemporary society, know how to produce original knowledge in design. More specifically, visions, proposals and projects (research through design) must be produced, tools and methodologies developed with which to put them into practice (research for design) and reflections on both design itself and on its fields of application (research into design) must be explored. The program is structured in different fields of research (corresponding to the teaching and operational subdivision of the discipline in the Department of Design, as well as in the School of Design) and in lines of research (corresponding to the specific issues on which research is carried out in the PhD program). As a consequence, there is a strong relationship between the PhD program, the Department and the School, which provides the best opportunities to combine both teaching and research experience during the three-year training program.

In this respect, the program offers the best foundations both for starting an academic career and for employment opportunities in research centers, design enterprises and public bodies.

Mission and goals

The PhD Program in Design trains designer-researchers who, while addressing the problems and opportunities of contemporary society, know how to produce original knowledge in design.

The curriculum lasts three years, during which period both educational and research activities are provided. Some of these activities enable candidates to acquire ECTS credits up to a total of 75; 40 of these relate to structured teaching activities.

The Program develops design skills and analytical abilities, proposes various research methodologies and promotes a collaborative disposition.

The program is structured into various research fields, which correspond to specific research teams within the Department of Design. In order to coordinate research activity over a wide range of topics, teams cluster around three Sections, which are: Design and Cultures; Products Strategies and Services; and Design for Environments, Landscape and Mobility. The research teams - Methods and Tools for Product Design and Materials and Design are active respectively in the two other Departments involved in the program (Department of Mechanics and "Giulio Natta" Department of Chemistry Materials and Chemical Engineering). Research teams also contribute to the teaching activities undertaken by the School of Design.

The PhD program carries out research on specific topics emerging from the research initiatives of all Departments. Each year the Academic Board makes a list of suggested topics to be developed during the three-year training.

At the beginning of the program candidates become effective members of a research team, within which they develop an original research topic (PhD thesis), selected from those on the list mentioned before; this activity is the fundamental core of the learning process.

Parallel to this main activity, candidates are involved in several other educational processes, divided into common and specialist activities.

Common activities are those such as courses and seminars related to the discipline of design and research methodologies and practices, considered in their entirety. Specifically: common activities are proposed to consolidate the cultural and operational background, which is common to all areas of design research.

Specialist activities are those educational activities specifically regarding the areas of research developed by both the PhD program and the Departments.

The Program therefore offers PhD candidates the following opportunities:

- To develop a PhD thesis, working on a specific line of research as members of a research team;
- To participate in courses and seminars on design, on design research and on research in general, developing competences concerning the discipline of design and the profession of the researcher;
- To participate in courses and workshops in which to hone their competences in the design process;
- To participate in workshops, developing high-level specialist competences and acquiring knowledge and tools for the development of their research topic;
- To engage in an internship in an international research center to verify the hypotheses, the methodologies and the results of their work and to consolidate the network of international relationships within which it is found.

Moreover, the activities of the PhD in Design include participation in projects taking place within the research team; participation in conferences (as listeners or speakers); writing of scientific papers; participation, as tutors, in teaching activities, in the perspective of an on-going synergy between teaching and research activities.

Professional qualifications

The Designer-Researcher, which the PhD program in Design intends to educate is a flexible professional figure: a designer who knows how to carry out research and a researcher who uses design tools. At the same time he is also an expert in knowledge management, in constructive interaction among different actors and in the communication of ideas and proposals.

The combination of these skills is useful in a variety of work environments. Specifically: in institutions expressly dedicated to the development of design research, such as universities and research centers; in design agencies and in the most innovative and design-oriented companies; also in public corporate bodies, in service companies and in organizations for territorial development which, increasingly, are faced with complex design problems, which the Designer-Researcher can effectively address, analyze and contribute to resolve.

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A NEW PROCESS FOR THE DEVELOPMENT OF REALITY-BASED VIRTUAL MODELS IN DIGITAL HERITAGE APPLICATIONS

Davide Angheleddu - Supervisor: **Gabriele Guidi**

Design has historically played a key role in museography. It continues to play such a role in the present day through generating solutions for optimising the presentation of cultural artefacts, passing into the domain of museology when the cultural aspect of an artefact is enhanced. Take for example the production of exhibitions which are “tailored” around works such as the recent one by Michele De Lucchi inside the Sforza Castle in Milan which enhances the viewing experience of Michelangelo’s “Pietà Rondanini”.

In the digital era the options of design expand exponentially due to the possibility to create digital copies of ancient works of art, archaeological sites and historical buildings which can be used as virtual replicas. These replicas can serve both for the 3-D visualisation of digital heritage and for the accurate documentation of artefacts which is metrically consistent with the original items. In addition to improving the viewer’s experience, this process offers the possibility to conserve, restore and manage works of art – which is obviously important for national cultural institutions. However, it also results in technological bottlenecks due mainly to the enormous dimensions of the digitalized

models of cultural heritage. The present study examines the manner in which 3-D models are codified in order to create a technology which provides designers with a useful tool for developing new applications for digital heritage. 3D acquisition and modelling with both active and passive techniques for documenting cultural heritage has been widely explored since the early applications of the ‘90s. It has been clear from the first pioneering projects and it is still true now, that the most important limiting factors for the diffusion of 3D models for routinary use in the Cultural Heritage community, are related to their heavy structure. Due to its generation method a digital model originated by range sensed 3D data is a complex polygonal mesh whose nodes are represented by the measured points, that might range from a few thousands to several millions. This involves significant issues in terms of visualization editing and management, differently by most 3D models drawn with a CAD package, made by set of mathematical surfaces and represented in a far more compact form. This intrinsic difference between CAD and acquired models involves well known bottlenecks such as: i) production time. Even not

considering the time needed for registering the single range maps originated by a 3D sensor, often involving the manual time consuming intervention of an operator, the time needed for editing the final mesh might weight up to the 90% of the total 3D processing. Such time is usually devoted to correcting possible topological incoherence and for defining new polygons in place of the unavoidable lack of 3D data due to points not reachable by the 3D sensor or by the photogrammetric camera; ii) size. In the management phase (storing, 3D navigation) the potentially huge number of polygons, and consequently the abnormal size of the related 3D model files (from hundreds of MegaBytes to a few GigaBytes), makes their management not realistic with everyday computers, and usually involves highly specialized software for their visualization; iii) portability. In the post-processing stage (rendering, annotation, semantic subdivision, information exchange between different 3D packages, web visualization) the possible topological incoherencies to which the “raw” mesh is prone and the sub-optimal UV parametrization automatically originated by some software packages within the 3D acquisition pipeline, may involve misinterpretation switching from

different 3D SW packages. This happens more easily on meshes originated by automatic meshing processes with respect to a more robust organization typical of advanced Computer Graphics (CG) tools.

The main reason of these bottlenecks lies in the many processing steps needed to generate a reality-based 3D model, ranging from the raw 3D measurement of points in space (dealing more with optoelectronic sensors and metrological problems), to the 3D mesh generation from such data (more related to the field of computer vision and geometric processing), to the final 3D representation of the same digital object (whose methods belongs more to the world of computer graphics). The path is so interdisciplinary that passing from one step to the other a few incompatibilities may occur, generating a final result whose structure is often not suitable for a further exploitation in the Design of Cultural Heritage applications, needing for that a significant and costly post-processing. With reference to the first issue (production time), a good improvement has been obtained in the last few years thanks to the abrupt development of automatic photogrammetric processes based on the concept of Structure from Motion (SfM), capable to generate dense clouds of coloured 3D points with accuracy and precision comparable to that attainable with active devices, but with the great advantage of completely eliminating the need of range maps registration, involving a considerable manual pre-alignment

work. However, the final mesh editing step, not avoidable in many practical case where the geometry is totally or partially self-occluded, still remain a time-consuming step. Regarding the second issue (size), solutions for dramatically reducing the size of 3D models have been found by the gaming industry, where the need of smoothly navigating into 3D virtual environments, even during quick dynamic actions, impose to generate rendered frames from 3D content in fractions of a second. Therefore, from a few decades, any 3D model animated in a videogame is typically represented by an extremely simplified polygonal geometry, “decorated” with visual features that make such ultra-simplified model appear much more complex and visually convincing. But since this is just a visual effect, the method is often considered by 3D digitization scientists as an approach not rigorous enough for properly maintaining all the amount of metric information available in a 3D model generated by acquired data. However, a proper rearrangement of the model may be actually a good solution that allows to “distillate” the key geometrical features from the original acquired mesh, laying the foundations for solving also the third issue (portability).

This thesis has shown theoretically and demonstrated with experiments in the Cultural Heritage field, that this approach - not new for reducing the rendering time in gaming 3D navigation - can be re-proposed as a high quality systematic method in Cultural

Heritage applications for:

- 1) Extracting the significant information of a mesh even if not fully edited;
- 2) Re-topologizing the mesh in order to distribute at best its polygons according to the object shape;
- 3) Coding the original mesh as a low-resolution base mesh plus a metric displacement map, maintaining the original geometric information;
- 4) Demonstrating, by comparing the original meshes with the new re-coded models, that the previous statement is true even just with scalar displacements, obtaining shape representation errors within an uncertainty in the order of the 3D measurement error.

The advantages of the proposed solution are in brief: smaller meshes involved; cleaner topology; easier parametrization; smaller size of the global model (simplified surface + displacement map). The objects used as examples for the experimental tests are actual Heritage Assets belonging to different museums in Florence and Milan, representing several types of shape complexities that can be found in the cultural heritage field.

The present project thus has created a foundation for meeting the ever-growing demand for digital cultural heritage. These digital works will in turn become cultural artefacts to be preserved and valued, as has already been recognised at an international level by the vast scientific area identified as “Digital Heritage”.

ADDITIVE MANUFACTURING TECHNOLOGIES FOR MATERIALIZATION PROCESSES IN DESIGN PRACTICE

Patrizia Bolzan - Supervisor: prof. Stefano Maffei

The increased interest recently arisen around Additive Manufacturing in the most different areas, together with the hype around digital fabrication have begun attractive for design disciplines from several viewpoints. Additive Manufacturing (AM) has a re-combinatory role in production and design processes. In particular, its potentialities amplify the possibilities for designing new artifacts, both by significantly modifying the existing product categories, and by devising new ones directly responding to the new rules for design and production.

However, AM is not a panacea to all design and production issues; rather, it is another type of production process that designers can choose to apply if necessary. When it comes to 3D printing technologies, the hype provoked by media is causing simplification and mystification of a phenomenon otherwise full of potential.

With these premises, the main hypothesis is that AM can offer great technological potentialities, and thus influence design and production processes. This research explores this subject, with the intent to outline the change generated by AM in design processes. More in detail,

this means to understand in which conditions AM can be the instrument that modifies or integrates the current productive scenario, considering the specific mix of morphological, technological and economical constraints.

The hypothesis is that AM does not replace entirely other forms of production and design; rather, it integrates and expands them in specific ways. The goal of the dissertation is to trace a sharp picture of the evolution of AM in a future-focused perspective. This theme has been analyzed using case studies as research strategy, in order to build an interpretative framework that reads the main characteristics of the phenomenon, through studying the most relevant experiments and artifacts that incorporate the use of Additive Manufacturing technologies.

The proposed analysis can be applied to understand the current volumes of the AM phenomenon, objectively and without evangelical influences: through design practice, it is possible to reach a wide and cross framing. This is useful also to evaluate the feasibility of a project beyond the socio-economical point of view. It is possible to use the filter of design analysis in order to understand the AM phenomenon

in design practice and build an interpretive structure related to AM world: the design/production purpose (1); the AM anthology (2); the morphogram (3); and the shape complexity and choice of AM (4).

The first aspect is about usability features of a product. It corresponds to the interpretation of the relationship between the designer and the design phases. The AM anthology is the exploration of the typology of performance that the product must fulfil made through the direct comparison of data deduced from different sources since today. The results of this analysis is a group of twelve product classes.

The analysis of the purpose morphology, created an evaluation on the level of functional or aesthetic aspects in an output coming from AM tools: just functional pieces, just aesthetic pieces, both functional and aesthetic pieces. The structure morphology defines the presence or not of parts made using different technologies. So, the products can be fully 3D printed, if the object is totally composed by parts made through AMT, or partially 3D printed, if the object has both parts produced through AM and other manufacturing technologies.

The last aspect of the design analysis is about shape complexity and AM typology. The shape complexity aspect is defined on the basis of requirement as tassellation, precision and shape. To complete the analysis, it is possible to identify the design approaches and applications. These additional information give a contribute for a complete identification of the impact that AM may have on design and production.

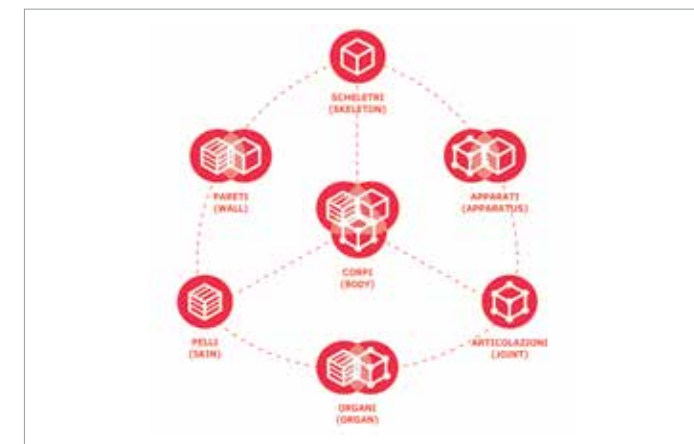
The last filter for exploring the universe of AM outputs considers the architecture of products. As defined in the definition of the Business Dictionary, product's architecture is the description of the ways in which functional elements of a product or system are assigned to its constituent sections or subsystems, and the ways in which they interact. Starting from the definition of the basic geometric elements, it is possible to find three kind of constructions, which shape the product itself: point, line, surface. Having a taxonomic reading

through a parallelism with living organisms, these elements can be defined as skins, skeletons and joints. This is a conceptual transition of central relevance in order to make a critical analysis and interpretation of case studies, because it simplifies and makes the AMT contribution for the artefact materialization easily understandable. From the intersection of the three main elements it is possible to generate complex configurations. After the theoretical analysis, it is possible to construct the framework for the case studies analysis. The choice of exploratory case studies gives back a phenomenological overview of which are the directions of development of AM applications. The outcomes from the case studies analysis produced lots of data. The really interesting information is about the morphological features and the product anatomy. After the analysis and the interpretation, it is possible to open a discussion in order to shed light on the

questions emerged during this research work. The first one is about the changes of the paradigm boundaries. According to the initial hypothesis, AM does not replace neither other technology nor artisan techniques. At last, the intent of this dissertation is not to offer a universal frame to read the world of AM technologies, as this is still evolving quite consistently. On the contrary, the goal is to define the real characteristics of this phenomenon, debunking myths and prejudices. If design outlines new possible applications, conditioning future developments, what is the real contribution of the design in the AM analysis? And, on the contrary, is there any contribution from the AMT to the designer professional growth? Designer is not just a user: he becomes an influencer of application and technological development. Mutually, the technology influences the designer and his designing perception. In conclusion, there are few open issues at the end of the dissertation.

The more interesting, in order to open some new directions of investigation, are two: the first one affects the manufacturing system, and the second one is addressed to the economics.

The charming aspect about AMT it's represented by their continuous and fast development, but this characteristic makes them like technologies which did not already reached a stage of full maturity, useful to bring them into wide scale.



1. Product architecture diagram

EXPERIENCE (VIRTUAL) PROTOTYPING. THE USE OF VIRTUAL TECHNOLOGIES FOR EXPERIENCE-DRIVEN DESIGN PROCESS

Serena Camere - Supervisor: **Monica Bordegoni**

During the last two decades the notion of “experience” related to products has become the centre of an arising interest in both design research and design practice communities. The aim was firstly to understand and demystify the intangible aspects of human-product interaction, how products can elicit specific experiences in people, how people appraise objects, and secondly, how we can exploit this knowledge to design more pleasurable, innovative, meaningful and attractive products. This specific approach has led to a greater inclusion of users’ perspective in the design process, shifting from a mere evaluative role towards representing a source of inspiration and knowledge for designers. Under the names of Experience Design, we can gather different approaches that share a specific goal: to look at people’s experiences, and to specifically design for those. This fundamental change of perspective brought about another shift. Not only the target of the design activity became different (from products to experiences), but also the body of methods, processes and tools shaping the design activity needed a consequent adaptation.

One of the activities in need for redefinition is Prototyping. Design

practice highly values its role in the design process, being traditionally defined as a “learning by doing” discipline. Designers use in fact several forms of prototypes to engage with the product-to-be. The focus, as for Experience Design, shifted from the product itself, to the experience that the product can elicit. Therefore, we can speak of a different approach to prototyping (Experience Prototyping) aimed at supporting a specific approach in product design (Experience Design). The definition of Experience Prototyping is currently under debate in the field of design research. Moreover, current approaches to Experience Prototyping only involve quick-and-dirty techniques, because they are considered the most effective in terms of representation and efficiency. However, current advances in interactive technology offer promising possibilities for Experience Prototypes. The specific technologies involved, referred in this thesis as Virtual Tools, can be employed in several ways, reflecting the several scopes of Experience Prototyping activity.

Thus, the goal of this thesis is to contribute to the redefinition of the prototyping activity to support Experience Design, describing its characteristics,

which methods and tools it involves, the differences for which phases of the design process it is applied in, which are its purposes. Furthermore, we aim at having a closer look of how technology, and more specifically Virtual Tools, can empower the prototyping activity, by providing designers with new resources for Experience Prototyping activities.

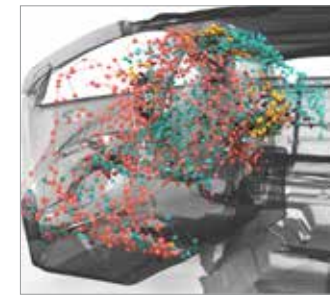
By raising the following research questions, we aim at understanding the key variables that affect the construction of Experience (Virtual) Prototypes: 1) How can we prototype an Experience? 2) How can Virtual Tools support Experience Prototyping? 3) How can product designers exploit Experience (Virtual) Prototyping into their design process? By answering these questions, we have the means to contribute to the disciplines of design research and virtual technologies research, as well as to design practice. The targets of this thesis are manifold: researchers who aim at advancing the field of virtual technologies for product design; design practitioners looking for a better understanding of the scopes and methods of Experience Prototyping; design researchers who are interested in understanding how to virtually

prototype an Experience. Three parts, each dedicated to one research question compose the thesis:

> **Part I** provides a theoretical dissertation on the notion of prototyping, as an activity supporting the design process, its changing role for Experience Design, and the characteristics differentiating the present from the past. Part I includes two chapters: the former, **Chapter 1**, aims at discussing the characteristics of prototyping, as it is currently treated in literature. It proposes a basic model of the role of prototypes, which is used to refine the definition of Experience Prototyping. **Chapter 2**, instead, focuses on a review of the approaches to Prototyping, providing example, and discussing their limitations and benefits.

> **Part II** proposes the use of Virtual Tools as techniques to support Experience Prototyping. It introduces the available virtual technologies, examining their properties and potentials in **Chapter 3**. In **Chapter 4**, we present the empirical work conducted to corroborate our theoretical assumptions. To test the value of Experience (Virtual) Prototyping in the design process, we established two different case studies for two different moments of the design process. The first activity, named Mapping Interactions, applies virtual technologies at the very early stages of the experience-driven design process, i.e. before concept generation. The second activity, referred as The Experience Map,

focuses on the elaboration of a new tool to support interactive virtual prototyping. In **Chapter 4.1**, we present one research through design for Mapping Interactions, which was carried out to stipulate a method to use Motion Capture as for Experience Prototyping. In **Chapter 4.2** we introduce the second case study, the Experience Map, and present the two empirical studies involving designers that were implied to elaborate and test the tool.



1. Visualization of human motion data achieved in ‘Mapping Interactions’ (case study 1)

> **Part III** aims at assessing the value of Experience (Virtual) Prototyping for the design process. **Chapter 5** starts with an overview of design creativity and design thinking theories, to understand



2. The Experience Map, a tool aimed at fostering parametric prototyping

how we can assess the benefits of new tools for the creative process. In **Chapter 6.1**, with the fourth study of this thesis, we evaluate in practice the use of the method derived within Mapping Interaction activity, in a workshop with designers. In **Chapter 6.2**, we present three different applications of the Experience Map: one validation study with designers, two simulated design projects with design students, and one real-setting use of the Experience Map in a design agency.

Both cases have been challenged through numerous empirical activities. From these results, the thesis contributes with knowledge on the specific methods and on the general benefits of virtual technologies for experience-driven design.

COMPOSITE OF HEVEA BRASILIENSIS RESIN REINFORCED WITH COIR FIBRE (COCOS NUCIFERA): MANUFACTURING OF FOOTWEAR

Célia Regina Da Costa - Supervisor: Barbara Del Curto

In recent decades, the process of environmental degradation and various ecological environmental issues have prompted scientists to focus more on this problematic area. Environmental issues are moving new projects towards producing and using materials that do not harm the environment and will not accumulate in the environment in the end-of-life phase. In order to preserve the environment, the use of biomass materials such as coir, bagasse, sisal, jute, etc. has been intensified in several manufacturing sectors. Therefore, it is of great importance to understand the physical and other properties of these materials and know their structure to explore new future applications. This has resulted in the creation of increased awareness concerning the use of natural fibre-based materials composites. Today, the use of polymers materials in the construction of new products is highly common. Polymeric materials reinforced with synthetic fibres such as glass, carbon, etc. create the advantages of high stiffness and strength, as well as low density compared to conventional materials. Despite these advantages, the use of synthetic fibre-reinforced polymer composites has a tendency to decline due

to high costs, as well as having an adverse environmental impact. In this sense, the area of polymer composites reinforced with natural fibres represents a plausible alternative in the field of engineering materials for design applications. The appreciation of alternative materials embedded in biomass materials as an option to conventional material should allow the generation of products with high quality, aesthetics and productivity and a reduced potential impact of environmental pollution. This study aims to develop a sole and a moccasin male footwear from coir fibre and natural resin. Composite variants were made and analysed to check how they are influenced by different arrangements and concentrations of fibres and resin. The main objectives in this study are the processing, characterisation and analysis of composites to be applied for the manufacturing of shoes, providing support to the design for the development of the shoe. Materials science and engineering will be involved to formulate the processes that can turn natural resources into useful products. Employing concepts of manufacturing engineering together with collaborative design tools have made it possible to develop a

concept shoe. The composites are made of natural resin (*Hevea brasiliensis* L.) and coir fibres (*Cocos nucifera* L.). The involved composites were performed with by a hand lay-up moulding technique. Coir fibres were used as a tissue without any treatment. The fibres were arranged randomly, posteriorly with parallel orientations to analyse which is the best fibre reorganisation in the composite, i.e. which distribution ensures better resistance to the composite. Strength measurements were carried out to measure the extent of fibre orientation. Tensile modulus, tensile strength and tear strength of the composites were analysed to investigate their performance. The characterisation of the coir fibre and composites were conducted by the following tests: evaluation of the composite structure using a stereomicroscope, tensile testing, optical microscopy, Scanning Electron Microscopy (SEM), and Fourier Transform Infrared Spectroscopy (FTIR). This first part was essential because the coir fibre and the composite developed are not strongly known by academic community in terms of their applications for footwear. The results of the characterisation of coir fibre showed that it does not differ

with respect to other coir fibres studied. Coir fibre is considered a poor reinforcing fibre in rubber due to its low strength and lack of physical characteristics, which are essential for a reinforcing fibre. The interfacial adhesion between coir and natural rubber can be improved by treatment of the coir fibres. The addition of the matrix with aligned fibres improved the tensile strength of the composite. Despite the composite presenting inferior features, it is appropriate as a material in the manufacture of soles and footwear. They were

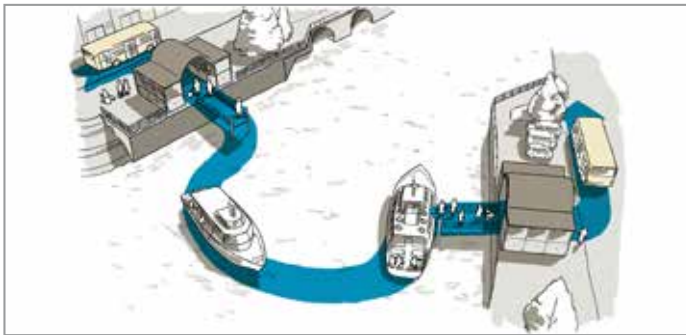
developed in accordance with the product design process and product development process with some minor variations during the processes performed. In this context, this research investigates the design possibilities of integration in the creation of a sole and a shoe using the composite developed during the research. It was raised the process of production and development of shoes and soles at the same time, whereby we developed a product for the footwear industry to meet the purpose

of creating solutions for waste from coconut husk generated in using commercialisation "in natura" by use of coconut water. Using the design of the tools for manufacturing footwear products, the work adopts creative processes based upon research in the areas of aesthetics, materials, ergonomics and human behaviour as well as scientific research. The project allows the interrelation of design, material technology and engineering to meet the technical prerequisites for functionality, shape, aesthetics and cost.

THE SEAMLESS JOURNEY. A UNIVERSAL DESIGN APPROACH TO WATER-BASED PUBLIC TRANSPORT SYSTEMS

Sebastiano Ercoli - Supervisor: Andrea Ratti

Accessibility to public transport systems is a key factor for the social inclusion and quality of life of people with disabilities. This thesis, focused on water-based public transit, aims at answering to the following research questions: are current systems accessible for everyone? How can their accessibility be improved? The thesis moves from the consideration that the world population is ageing at an unprecedented rate, and in a pervasive and enduring way. In most of the developed Countries, this spectacular achievement is matched with a fertility rate below the replacement level. The coupling of these trends is resulting in a fast rise of the elderly population. Moreover, age is often related to functional changes that result in some forms of disability: the huge change of the population structure is further blending the already vague bond between "disability" and "non disability". The sum of these tendencies is having a deep impact in many fields, such as economic growth and healthcare policies; indeed, it has important consequences also in design theory and practice; the design of marine public transport should be adapted to the change. The topic of accessibility – the quality of designs or services of being accessed and used by



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everyone – has traditionally been considered an issue concerning a restricted target, the disabled persons. The problem was usually faced *ex post*, with special, "dedicated" modifications to an already designed product or environment originally conceived for "standard" users. An example of this approach is offered by step lifts on the side of a flight of stairs, or lifting platforms to get in a bus. Today, the Italian Institute for Statistics (ISTAT) says that in the Country one in five persons is more than 65 years old, and one in eighteen persons is more than 80 years old. The approach of dedicated solutions is not suitable any more: impaired persons can not be considered a minority any longer and – even more important – segregating solutions are not considered acceptable by the users. Consolidated design approaches such as Design for All,

Universal Design or User-Centred Design all demonstrated that the improvement of accessibility for vulnerable users results in an improved service for everyone. The answer to the research question comes in form of a guide for the improvement of accessibility of ferry transportation services for all passengers, including vulnerable users – people with temporary or permanent disabilities, pregnant women, elderly people, and children.

The work is structured in three main sections. The first section (chapters 1–4) illustrates the context, of which a theoretical interpretation is offered. It presents an overview of the general topic of public transit, and in particular of water-based passenger transport on short routes, offering an interpretative

model of the use of the service from the point of view of the passenger, which considers it as a journey, the use of the ferry being only a phase of a longer action finalised to reaching a destination. It provides an analysis of the current legislation on the topic in different Countries. Furthermore, it presents a chapter dedicated to the user: after the exposition of statistical trends of the population, there is a focus on the models of disability and on how they contributed to change the perception on disability itself. The concept of residual functions is introduced, together with the International Classification of Functioning, Disability and Health (ICF), which is the key used to assess the accessibility of journey phases. Body functions are illustrated singularly, concentrating on the restrictions in ability resulting from their impairment. The second section (chapters 5–8) illustrates the methodology adopted for the study and shows its application on two main cases. Chapter 5 deals strictly with the methodological approach, offering an overview of the combination of methods chosen for the research and explaining their strengths and weaknesses. In chapter 6, the journey is broken up and analysed in its single phases: (1) gathering of information and buying process,



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(2) travelling to vessel, (3) waiting for sailing, (4) boarding the vessel, (5) sailing, (6) getting off the vessel, and (7) travelling to destination. For each phase, significant cases and experiences are presented and analysed systematically. Chapters 7 and 8 present the two main case studies developed in the thesis: the water-based public transit services provided by İzdeniz in the metropolis of İzmir, Turkey, and by Gestione Governativa Navigazione Laghi in the three main lakes of Northern Italy – Maggiore, Lario, and Garda. The third part is composed by two chapters. The first presents the results of the research in form of a design guide addressed to designers, naval architects, and operators; the results are organized according to the phases of the adopted journey model. Each phase is further subdivided in all its designed elements

– products, environments, services – which contribute to the general aim of accessibility. At last, chapter 9 illustrates the conclusions, together with retrospective considerations and suggestions for possible next steps.



3.

DESIGNING SERVICE EVALUATION A NEW PERSPECTIVE FOR SERVICE DESIGN PRACTICE

Francesca Foglieni - Supervisor: Stefano Maffei

Co-supervisor: Beatrice Villari - External examiner: prof. Nicola Morelli

Evaluation is a blurred and underexplored topic within the service culture. Furthermore, it is an underestimated and unstructured practice, wherein a codified and acknowledged definition of *service evaluation* does not yet exist. This research aims to build the necessary knowledge for framing and operating service evaluation in the service design practice by **making use of service design as an intermediary for the introduction of an evaluation culture within the service culture** and by developing a conceptual evaluation model for services that helps address service design itself.

This is an explorative, theoretical research originates from the challenges posed by the contemporary socio-economic context, which requires **public and business organizations to continuously innovate, undertaking a never-ending learning and transformation process.**

In this context, service design is recognized more and more as a driver of innovation, however a systematic approach that allows service design practitioners to build trustable and shared evidences upon the problems they identify and the solutions

they propose in response to the complex and ever-changing reality is still missing.

Evaluation is suggested as a possible solution to fill this gap, since measuring the value of services, considered as the fundamental bases of exchange in the contemporary context, becomes crucial **to understand what is happening today and how to change it for the better, in a continuous innovation perspective.**

Several questions that will be addressed by this research emerge from this intuition, such as *what does it mean to evaluate a service? What can be evaluated and what are the objectives of service evaluation? What is the contribution of evaluation to service design and to service innovation?*

To answer these questions, it is first of all necessary to understand what it means to evaluate in order to then apply evaluation to service peculiarities. For this reason, the first part of the research lays on an extra-disciplinary context of investigation and consists in the exploration of evaluation literature within the field of social sciences. In this field, program evaluation studies represent the point of reference to achieve an overall understanding of the evaluation

theory and practice. According to these studies, **evaluation is defined as a process based on shared evidences aimed at building a hypothesis of reality about the value of what is evaluated, for learning and transformation purposes.**

To reach these purposes, the evaluation process needs to be designed by the evaluator in collaboration with decision-makers and eventually other stakeholders, which together define what is going to be evaluated, when, why, and from which perspective, according to the context in which the evaluation is situated and the understanding of *individual and collective value systems* of the actors involved.

To understand how evaluation is specifically conducted in service organizations, what is evaluated in services, and for which purpose, the second part of the research shifts to the exploration of the service culture, focusing in particular on *service logic* literature developed in the fields of service marketing and management. The concepts of value and value creation in services are analyzed by looking at the phenomenology of evaluation in the service sector, through the analysis of case studies selected from literature,

experiences collected in the field, and by mapping the most diffused service evaluation methods and techniques. What emerges from this exploration is that **in the service sector a systematic approach to evaluation as well as a systemic vision on how to determine service value are missing.** This is due to the fact that there is a discrepancy between the conceptualization of *service value* originating from an all-encompassing process of value creation that involves a provider, a customer and a joint perspective, and the effective evaluation of *service quality*, considered as the main measure of value, for which evaluation is usually restricted to the use of the service from the user perspective.

Since value for the provider does not coincide with value for the user, even though both are fundamental for value to be created, a *service evaluation framework* is proposed as first result of the research, which interprets evaluation studies and service logic studies and provides **a systemic vision upon how to assess the overall quality of a service, including a comprehensive definition of service evaluation.**

Similarly, the service design approach does not include a systematic and systemic vision on evaluation. Literature exploration, completed by an analysis of experiences collected in the field, shows that **the focus of evaluation in the service design practice is to assess the value of service design itself,** typically through the evaluation

of projects and prototypes, in the attempt of consolidating its role as driver of innovation. On the other hand, when the contribution of service design to innovation is taken for granted, evaluation acquires a different value, especially when applied to mature existing services that need be redesigned in response to contemporary requirements. In these cases **service evaluation and service design can be integrated in a unique process, contributing to each other in a reciprocal way.** On one hand *service evaluation* supports service design in understanding the value of the current service and identifying drivers of change. On the other hand, thanks to its multidisciplinary and participatory approach, the service design mindset and tools can support the design of the evaluation strategy in agreement with what is asserted by evaluation studies.

According to these insights, the third part of the research describes the development of **a service evaluation model for service design, with the purpose of pragmatically supporting service design practitioners and people operating in the service sector in undertaking a continuous innovation process of existing services that is based on trustable and shared evidences.**

The model, which corresponds to the second result of the research, reflects upon what can be evaluated in a service to determine its *overall value* in a redesign perspective and proposes a set of guidelines to

be followed for the integration of *service evaluation* and service design. The set of guidelines is then accompanied by a *meta-tool* consisting of a repertoire of service design tools that support the process execution, and includes evaluation methods and techniques stemming from program evaluation and service marketing and management, as well as service design research tools suitable for data collection, interpretation and visualization. In developing this model, it is also important to reflect upon the role of the service designer and in particular upon the new competencies he needs to face evaluation, at least at design level.

What emerges from this research is that **there is space for an evolution of the service design practice toward the introduction of an evaluation culture.** In fact, the synergy between these two cultures could effectively meet the emerging need to develop a culture of change within service organizations in preparation for complex and rapidly changing future challenges.

DESIGN AND DECISION AIDING FOR MOBILITY SERVICES AND SYSTEMS

Alessandro Luè - Supervisor: Alberto Colorni

Designing mobility services and systems is a “wicked” problem that often cannot be solved using exclusively mathematical and systematic methods, such as those of *Operational Research* (OR). Solutions to wicked problems are never “right” or “wrong”; they are only “better” or “worse” in respect to certain points of view. My research focuses on *design* and *decision aiding*, which share the same underlying challenge, i.e. designing or aiding decisions in real-world wicked problems. Decision aiding, in particular, actually originated within the OR community, where many researchers and practitioners recognized the limits of pure optimization. The thesis is composed of two parts, focusing respectively on the *methodological* side and the *practice* side, which represent “two sides of the same coin”. An extensive theoretical analysis is accompanied by the practical experience matured in supporting design activities in real world mobility projects. The main historical research developments regarding design and OR have been reviewed through the main literature milestones, looking for similarities and interconnections. Starting from the initial attempts and difficulties to use systematic

mathematical methods to real-world (wicked) problems, the two communities reacted in different ways, developing diverse approaches and practices. However, on both sides there are needs that can exploit and enhance the connections between the two fields: on one hand, there is a need for formalized methods to aid the design process; on the other hand, there is a need for “innovative” tools outside the usual toolbox of the OR practitioner. As regards the decision aiding methods, the thesis reviewed the philosophy and the main methods to structure the problem, and to deal with multiple actors (stakeholders, decision-makers, clients, ...), multiple and possibly conflicting points of view, and major uncertainties. The thesis outlines the significant similarities and differences between design and decision aiding, in the theory and in the practice. The thesis take into account the vast differences concerning the theory, the practice, and the expertise of people dealing with the two disciplines, and at the same time articulate and elaborate the nature of the common aspects they share. The objective is to explore the possibility to integrate and exploit methodologies of

decision aiding into the design of mobility services and systems; and vice versa, to understand if design can support and improve decision aiding practices and methods, taking advantage of the “designerly way” of the design community to face wicked problems. The practice side of the thesis illustrates and discusses projects concerning the design and in some cases the implementation and test of mobility services and systems (Figure 1), i.e. travel demand management, intelligent transport systems, demand responsive transport systems, car sharing, car pooling. Moreover, one of the projects concerns the identification of priorities for the EU funding as regards climate-friendly research on technological and soft mobility measures. The nature of the projects developed is very diverse, ranging from the implementation of local services to the priorities of international research. And diverse are the experts, stakeholders and decision-makers I interacted with. For each project, the strengths and weaknesses of the application of decision aiding methods in the design process are identified, providing insights useful for the development of the theoretical part. Causal mapping represents an

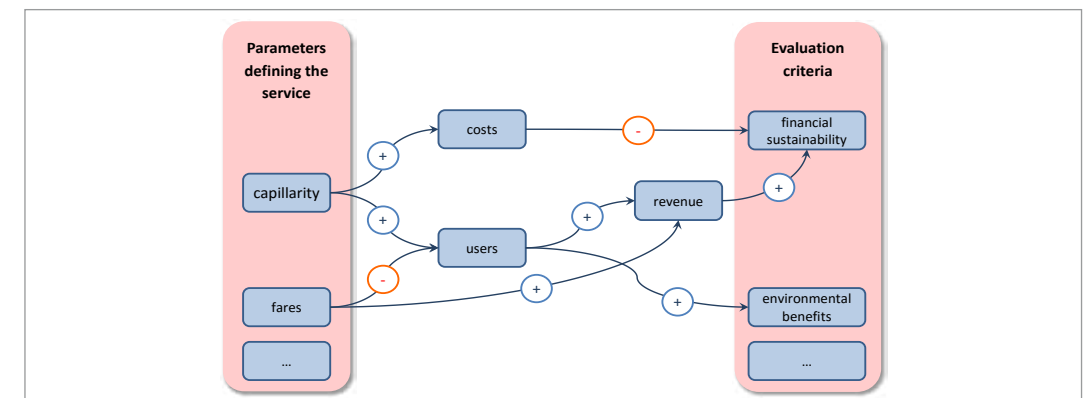
example of the decision aiding methods discussed in the thesis, used in the structuring phase of the decision-making process. Causal mapping allows graphically

representing the ideas of an individual through a network of interrelated concepts and building a shared vision of the decision problem in a group of persons.

Figure 2 depicts, as an example, the use of causal maps for design of a car sharing service in the Green Move project.

Project	Topic	Mobility measures	Decision aiding methods			
			Structuring	Multiple criteria	Group decision	Optimization
REACT	A European Strategic Research Agenda for a climate-friendly transport	EU research funding priorities for technological and soft measures	●●	●●	●●	
Green Move	Design of an electric vehicle sharing service for Milano	Car sharing	●●●	●●●	●●	●●●
Ayas	Conflict analysis for the assessment of transport systems in a tourist area	Travel demand management Demand responsive systems	●●	●●●	●●●	●●
Hazmat DSS	A Decision Support System for hazardous material transport in Milano	Intelligent Transport Systems		●●		●●●
PoliUniPool	Algorithms for a car pooling service dedicated to university students and employees	Car pooling				●●●

1. The projects presented and discussed in the thesis, developed at Poliedra, a consortium of Politecnico di Milano.



2. Exemplification of the causal map used for the design of a car sharing service.

MEANINGFUL NEGATIVE EXPERIENCES WITHIN GAMES FOR SOCIAL CHANGE.

DESIGNING AND ANALYSING GAMES AS PERSUASIVE COMMUNICATION SYSTEMS

Ilaria Mariani - Supervisor: Maresa Bertolo

Co-Supervisor: Francesca Piredda - External examiner: Clara Fernández-Vara

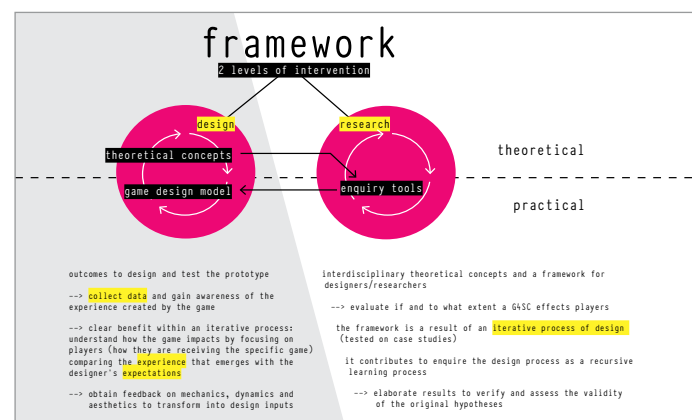
Does a game for social change contribute to move the social issue it covers forward? And the player's understanding of it? Does it represent a clear/unique perspective? Does it transfer the expected meaning? Is it likely to impact on player's attitudes?

But also: What makes a game for social change good in communicating meaning? Does it really work?

These are some of the questions that set in motion this research as an in-depth through-design enquiry on games addressing significant subjects of matters as wicked problems or social issues. Games for social change serve communitarian interests raising awareness, installing new social relations and triggering social improvements. They provide players with the opportunity to safely challenge themselves, explore civic, social, political, moral or ethical issues, encouraging an alteration of entrenched attitudes and sometimes even behaviours. As a consequence, when game design encounters and answers to social and civic purposes, designers have to go over and above the promotion of pure entertainment. The research extensively approaches and critiques the existent interdisciplinary literature (reaching out to game studies,

game design, anthropology, performance, educational theory and philosophy), including practical and analytical experimentations. Digging into elements and mechanisms to strengthen the experience of players, it introduces the concept of *meaningful negative experience*. The role of these experiences steamed from the encounter of negative feelings and failure during the game is investigated focusing on how designers can conscientiously include them as triggers that push players to acquire new meanings and reframe knowledge. Hence, exploring the potential for games to promote and instil pro-social attitudes, it pushes the issue further. It proposes a practical combination

of quantitative and qualitative tools to enquire if, how and to what extent the game responds the designer' expectations in terms of experience generated and meaning transferred. In so doing, it is acknowledged and answered the actual, spread need of the community of practice and reference, of having strategies and tools for conscientiously designing, assessing and verifying the effectiveness of these games in terms of play(er) experience. As a consequence it introduces tools and models for both designers and researchers, connecting relevant notions from the diverse fields explored. To overcome the existing gap between the analysis of the game system and its mechanics in favour of the



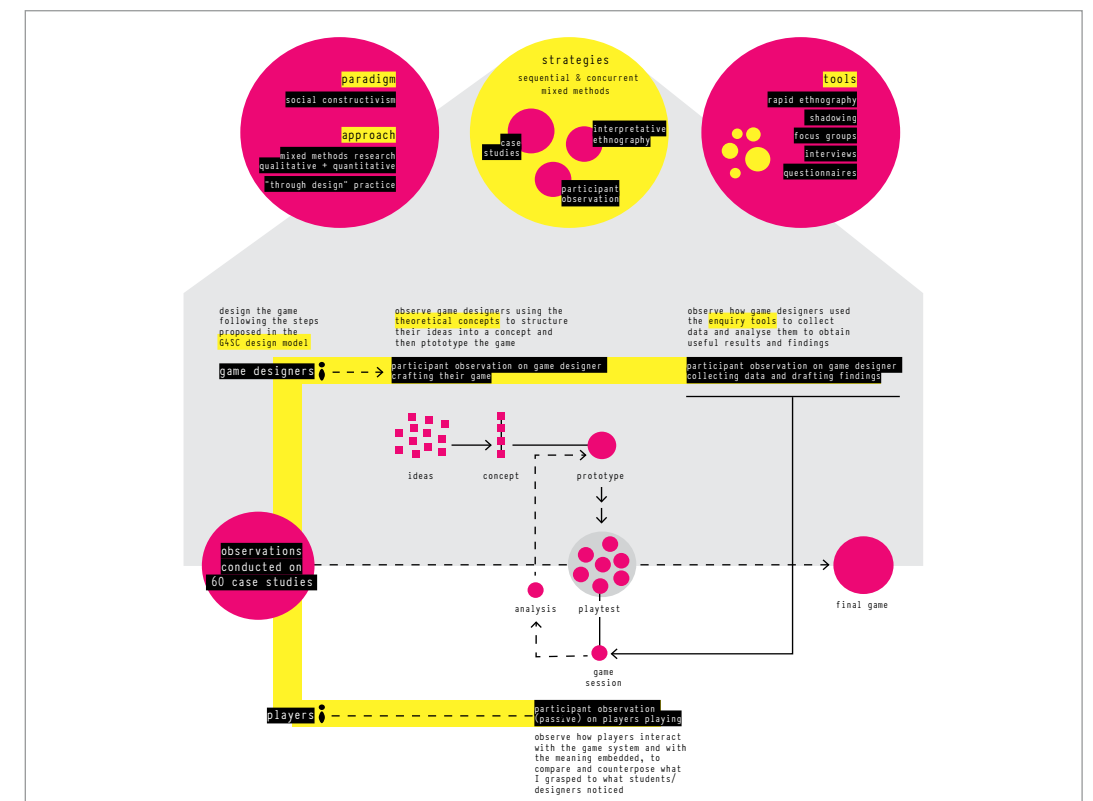
1. The two levels of contribution of the research.

understanding of the experiences it produces, the thesis identifies, explores G4SC in terms of design, communication, transmission of information on sensitive issues and socio-cultural practices, negotiation of meaning, and sense making. The result is a framework that provides a tripartite contribution: (1) a set of theoretical concepts to conscientiously design games for social change; (2) a set of practical, functional enquiry tools to enable designers/researchers to better comprehend these games effectiveness; (3) a design model largely based on the iterative design process that systemically includes the previous contributions.

As shown in Figure 1, the two levels of contribution consist in two processes running in parallel: **research activity** using the framework to assess and verify the game efficacy, and **design activity** on a case study using the interdisciplinary theoretical concepts and the research findings during the game design iterative process.

A central aspect of this study is its methodology that lies on the iterative process itself: its concepts, tools and methods, and the model itself have been developed and validated across an extensive experimentation that involved the design and evaluation of 60 case

studies. This research through design is developed through case studies and includes the practice of participant observation and interpretative ethnography as central activities of analysis, with severe methodological influences (Figure 2). Considering the broad amount of elements and interplays to craft G4SCs and assess them, it required the application of a mixed strategy with a combination of qualitative and quantitative research tools: rapid ethnographies, shadowing, questionnaires, semi-structured interviews, and focus groups conducted with both designers and students.



2. The methodology adopted (approach, strategies and tools), the application to 60 case studies observing and analysing both designers and players.

DESIGN FOR URBAN REASSURING SCENARIO. STRATEGIES AND TOOLS TOWARDS INCLUSIVE PUBLIC SPACES

Daniela Petrillo - Supervisor Prof. Agnese Rebaglio

This research thesis began within the DHoC - Design for Hospitable City - research group, a branch of the Interior Design section at Politecnico di Milano, School of Design.

The *urban safety* is the crucial topic of this work and the expected output merges in series of *guidelines* for the Municipalities actively involved in integrated projects related to urban regeneration and renewal programmes. The *integrated projects* indicates those projects that operate to solve several criticalities using a systemic approach, gathering simultaneously the diverse

dimensions of the problem.

In this work, the two main levers that sustain this approach are the *social cohesion* and the *public space*, this last one considered in its meaning of *urban interiors*.

The most relevant theories and applications related to the *urban safety* theme start from the prevention of antisocial or criminal behaviours through the design of the public spaces. In addition to these, the research starts from the *fear prevention* of these same behaviours. The perspective shift addresses the thesis to look at the issue from the side of the potential victims, designed with and for them a

set of activities that contribute to increase their *territorial and community awareness*.

The sense of territorial awareness and the sense of belonging to a community could be built - in their most *tangible* meaning - through different interventions focused on the places of everyday life. The design of these actions it must be supported in each phases by the local stakeholders, each of them with their own expertise and know-how, in order to tear down the emotions of fear and mistrust that come over definite urban areas.

REDESIGNING ORGANIZATIONAL PROCESSES

Azzurra Pini - Supervisor: Paolo Ciuccarelli

In the face of a world that is increasingly dominated by change and complexity, organizations are starting to interrogate, generate and store data related to their processual dimension. On the one hand, progresses in information technologies are providing organizations with large amounts of data and information on process behavior. On the other hand both executives and organizational scholars are exploring new ways to access, manage, interpret and make sense of this multiform stream of elements.

In this frame, design and organization can be seen as similar activities, considered as both nouns and verbs (designing and organizing), events or processes, both representing ways to come to grips with social complexity, shaping reality and defining behavioral patterns.

Historically graphical representations have been employed in organizations to arrange alternatives of choice, interact with stakeholders, and generally to support decision-making and the reproduction of organizational structures.

The more organizations become sensitive to environmental modifications and assume complex forms, gaining awareness of the multiform network of actors and perspectives to be addressed,

the more their processes that in the past could be represented by simple workflow diagrams, need new, scalable and flexible solutions. The recent shift towards automation in information systems goes in this direction, generating new opportunities for organizational process analysis and a wide range of frameworks and technological solutions are elaborated into business process research. At the same time the new technologies are creating an unexpected volume of process data to be managed and explored, resulting in a growing interest in process visualization techniques to support analysis activities and the communication of results to stakeholders.

Information visualization reveals a valuable source of methods and techniques to explore and make sense of large and heterogeneous data streams. Nevertheless, little research has been made up to now on process representation, linking the potential of visualization techniques to process analysis.

Recognizing the breadth of the research community on organizational processes, the thesis explores the different disciplinary approaches involved, ranging from social sciences to information systems, stressing the disconnection and the lack of

communication between them. The present research is therefore oriented towards the exploration of visual tools capable of relating and shaping the different perspectives of organizational processes. In doing so, communication design is intended to actively participate in process analysis and research, not only for the design of diagrams and interfaces, but also engaging its own expertise in drawing connections between the different research approaches at stake.

In this frame, the notion of process redesign, adopted from business process disciplines, has been reframed and exploited to describe the design approach employed in the research. This idea of "redesign" indicates the peculiar characteristics of designing in-the-making, based on the remediation of signs, objects and methods from different sources. A research process based on redesign is intended to enable the circulation of knowledge between management, information sciences and design to constitute a design-based research community on organizational processes.

Considering the disciplinary context the research is situated in the intersection between organization and management theory, information sciences and communication design. As a

fundamental part of both design and organizational theory the analysis has included also notions of complexity theory to set the general framework of inquiry. Business Process Management (BPM) discipline has been investigated as the most relevant and cohesive research community providing the theoretical framework as well as the operative techniques to compute, model and represent processes. From the representational point of view Data and Information Visualization disciplines constitute an important source of inquiry. Situated at the crossing between information sciences and data visualization is the new field of process visualization, which has been lately applied to process modeling in BPM.

The first part of the thesis sets the grounds of the reflection by acknowledging the pervasive and complex nature of organizational systems. The research has been focusing on the transformation occurring in these systems, revealing their multiple aspects and their inclination to change. A process vision of organizing focusing on flow and transformation, is opposed to an entitative one, focused on single static events.

The huge amount and the high variability of data and information made available by the advancements in information technology exposed a number of issues related to decision-making. The thesis therefore explores and exposes the limits and the potential of the different techniques that have been developed to manage

and make sense of organizational complexity, such as metaphors and visual devices, in pursuing ways to reintegrate some sort rationality into everyday work practices.

The second part focuses on the processual nature of organizing, describing the intersection of disciplines surrounding organizational research on the topic. In particular the concepts and modeling techniques related to the Business Process Management discipline are exposed, as shared by the largest and cohesive research community studying organizational processes. Multiple perspectives have been addressed as a specific feature of processes as complex phenomena, focusing on innovation, business and comparative perspective. Finally the different visual patterns and techniques applied to process modeling and visualization are presented.

The third part summarizes the experimental activities performed into two different contexts related to organizational processes. The first project has been carried out within the innovation environment, as a consulting research activity for a manufacturing company. The second project has been developed within the Business Process Management research stream focusing on the visualization of process comparison. Both experimental contexts are described by presenting first the research background, then the design approach developed by matching the background knowledge and the particular context; and finally the application

to a case study, where the motivations, data characteristics and visual solutions are described.

The fourth part constitutes a discussion of the observations and results emerged from the previous sections, which brought to the definition of the concept of redesign to describe the role attributed to communication design into the network of disciplines and established practices surrounding organizational processes. The section explores first the collaboration aspect by describing the differences in the interaction with stakeholders and scholars, observed in the two experimental contexts, finding in ambiguous representations a trigger to foster the creation of shared interpretations of complex phenomena.

The idea of process redesign is therefore exposed and reframed, together with some boundary concepts belonging to various disciplines, that are suggested in order to support the overall redesign process based on the circulation of knowledge between different curricula. Eventually a new scenario for communication design research into the organization one is suggested. Based on the recomposition of the different research perspectives by exploiting the potential of diagrammatic representation and visual interfaces, the approach proposes the constitution of design-based communities of organizational inquiry to support process modeling and design.

AFFECTIVE LOOPS IN INTERACTION DESIGN. EMOTIONAL-AWARE INTERFACES FOR HIGHER USER BONDING

Marko Radeta - Supervisor: Prof. Marco Maiocchi

The thesis investigates the verbal and non-verbal signatures of Panksepp's 7 primary process emotions. In doing so, the applicant argues that the emotion models used by the affective computing field are outdated and new approaches validated in neuroscience studies need to be used instead.

Through three studies, the thesis explores how these 7 emotions are expressed through body postures, differ in terms of physiological patterns and when and how these emotions coexist. The thesis also explores the use of new low cost technology to automatically detect these emotions. The long term aim is to create a system that is capable of recognising a person's emotional states and possibly regulating or enhancing them. As the words used to name these emotions partially overlap with the basic set of emotions already used in the affective computing literature, the candidate validate his results on other existing studies and extend those works by exploring the new set of emotions.

Skin Conductance. This parameter suggests that its intensity is the highest among the interactions with emotionally aware avatar for all emotions except for RAGE and LUST. While in former the intensity

is equally present throughout all triad group's tasks (16, 17 and 18) the latter shows higher volumes in first two tasks (19 and 20). For the former we suspect it is because the volume throughout the interaction with these tasks was constantly high for the purpose of inducing the RAGE while for the latter we suspect either that: (i) providing emotional-aware interaction on top of the potentially arousing LUST scene seems to be trivial, or (ii) the study participated more females (20) than males (5). GRIEF scenes shows the decline in skin-conductance while SEEKING, PLAY, CARE, FEAR (in accordance with this study by Klucken et al., 2015.) and LUST to have an incline which is in accordance with the study by Banks et al., 2012. of Skin Conductance with facial expressions and Anger (we correlated it with Panksepp's RAGE).

Blood Volume Pulse. This parameter is showing the increase in PLAY, GRIEF (in accordance with this study by Park et al., 2013.), RAGE and LUST where PLAY and RAGE are in accordance with this study by Lakens, 2013. Similarly to Skin Conductance, Blood Volume Pulse parameters show an increase in all triad groups tasks except of Tasks 18 and 21 which could have the similar explanation.

Accelerometer. This parameter suggests that the total average movement in interaction with emotional-aware Avatar is higher than an interaction with responsive avatar. We find also interesting that if we compare the regular interaction with emotional-aware interaction with Avatar, negative emotions (FEAR, GRIEF and RAGE) have less movement in latter.

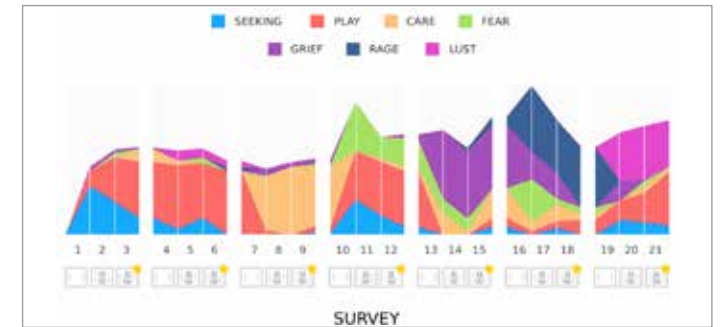
Heart-Rate. Due to the technical limitations this study is not able to deduce the correct correlation of HR across tasks as the data seem to be inept. Further statistical analysis and signal processing should be performed. However, if we assume the sum of all Heart-Rate, we find that Heart-Rate is increased for PLAY (in accordance with this study by Yoshino et al., 2011.) and LUST which should make sense as the persons would be using more his hands.

Temperature. This parameter suggests the similar pattern as in Blood-Volume Pulse. We find that the temperature sensor was the most sensitive from all as it needs to heat up in the case if the bracelet was left at the table in pause for waiting the next research participant.

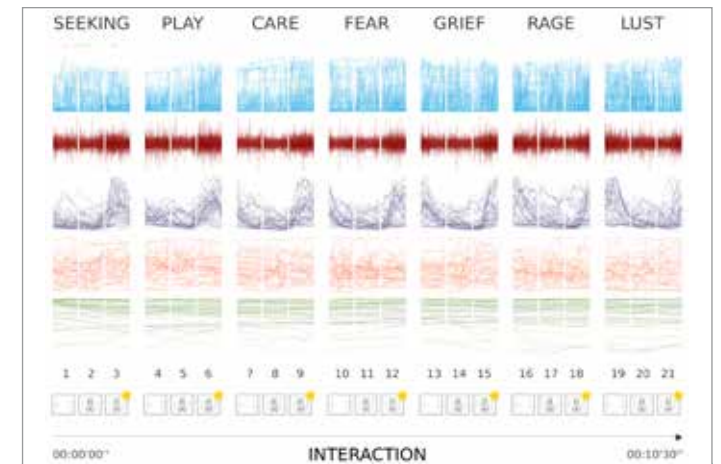
Survey Results. Subject were asked to choose the most dominant emotion for each of 27 tasks (SEEKING, PLAY, CARE,

FEAR, GRIEF, RAGE, LUST) and to rate them from 1 (low intensity) to 7 (high intensity). Picture below suggests that discriminating the dominant emotions per tasks corresponds to our previous findings and suggests that we used correct emotional video media to induce the emotion in user. We can observe this in the first tasks per emotion (1, 4, 7, 10, 13, 16, 19) where the most dominant emotions were respectively SEEKING, PLAY, CARE, FEAR-PLAY, GRIEF-PLAY, RAGE, LUST). Task 10 FEAR has the similar intensity with the PLAY and SEEKING, however this is due to the fact that the moment in which the user interface scares the user is during the task of escaping the labyrinth which should stimulate both SEEKING and PLAY.

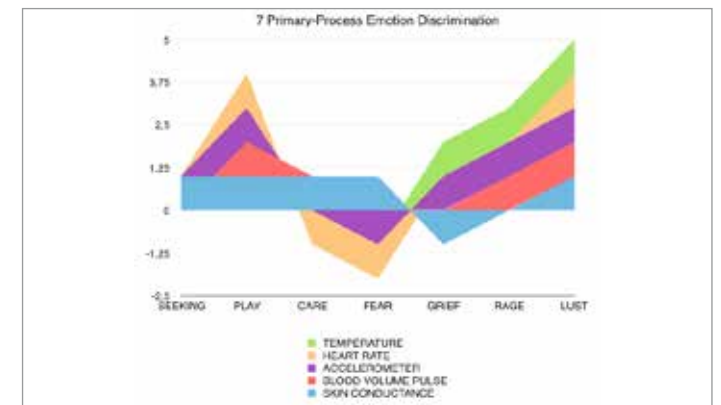
Conversely, Task 16 in particular suggests CARE increased as we believe it might be due to the neocortical interpretation of the Task itself (e.g. one of the subjects asked: "Is it important to select what I felt or how the scene looked like?" for which we gave them an ability to choose what they thought to be for themselves). Most importantly, these survey results depicts that It also shows that in most of the tasks an initial emotion was changed with the increase of PLAY. We also find that the LUST scene in Task 21 with emotional-aware Avatar provides no great interests and perhaps this is due to the very trivial representation of soft-core.



1. Participants' Survey comparison in discriminating 7 Primary-Process Emotions. Tasks 1, 4, 7, 10, 13, 16 and 19 are Interactions without an Avatar. Tasks 2, 5, 8, 11, 14, 17 and 20 are Interactions with an Avatar which follows the postural joints. Tasks 3, 6, 9, 12, 15, 18 and 21 are Interactions with Emotional-Aware Avatar.



2. Comparison of physiological data Skin Conductance (SC), Blood Volume Pulse (BVP), Accelerometer (ACC), Heart Rate (HR) and Temperature (T) across 21 tasks (3 per each emotion) measured in 10'30"



3. Discrimination of average sum of physiological data Skin Conductance (SC), Blood Volume Pulse (BVP), Accelerometer (ACC), Heart Rate (HR) and Temperature (T) per each emotion.

AFFECTING EMOTION THROUGH DESIGN

Zhabiz Shafieyoun - Supervisor: Marco Maiocchi

1. STATEMENT OF THE PROBLEM

Have a quick look in patient journey and the overall experience of the hospitals reveals that waiting area is one of the most stressful parts of the hospital. Environmental and behavioral effect are not separable and their influence on people are undeniable.

1.2 Research Aim and Objectives

How design has emotional impact on waiting time.

1.2.1 Aim

To affect on emotion through design in waiting areas of healthcare centers.

1.2.2 Objectives

How design can affect on:
 Increasing positive emotion
 Reducing negative emotion
 Increasing satisfaction with overall quality of care
 Improving environmental and behavioral interaction in the waiting areas
 Improving experience of wait
 Breaking icy atmosphere of the hospital

2. BACKGROUND AND HISTORY

2.1 Waiting area

Waiting area is the most stressful part of the hospital and one of the key parts of healthcare centers, which can have a

considerable impact on the experience of users attending the healthcare centers.

2.1.1 Physical Attraction in waiting areas

Environmental objects include light, noise, temperature, view of nature and windows, sizes and shapes, privacy, colors, textures, furnishing layout and patterns on the wall: each of these elements can have a strong effect on patient senses. Attractiveness of physical environments influence the perception of time, and hence the perceived quality of care.

2.1.2 Interaction in Waiting area

Patient in wait interact with environment and other's behavior in the same time and all make the atmosphere of waiting areas. Relationship between patient and healthcare provider has a strong effect on the atmosphere of the hospital.

2.2 Waiting time

Magiority of the research in this area primarily revolves around three factors: actual waiting time, perceived waiting time, and the gap between them The perceived waiting time is often different from actual waiting time . Waiting time refer to the time of staying in queue between entering till leaving.

2.3 Recent Solutions to Reduce Patient Perception of Time

Physician can decrease the negative effect of waiting time by spending more time with their patients. Make more interaction in waiting room can change passive wait to active wait. Preparing information helps patient's education and decrease their stress. Informing about the time is another way to give the control of time to patients.

2.3 Emotion

We have a variety of definitions for emotion in different fields such as psychology, neuroscience, design. We chose the Panksepp category of emotions. Panksepp defines seven fundamental emotions, fear, rage, grief, seeking, care, play and lust. In fact, we ignored Lust in the Hospital.

3. RESEARCH METHODOLOGY

3.1 Ethnographic approach

Observation starts by being in a hospital during day and night. Almost 300 hours in a month spent in INT hospital in Milan to know users. (Figure1)

3.2 Method and procedure: Interview

Interview with 100 patients during waiting time for radiology in INT and Ospedale Maggiore in Milan-Italy. To know: The feeling of people in waiting time.

Their recommendation and complaining about waiting time and waiting area.

Find the relation between the length of wait and user's feeling. Effect of physical attractions and distractions on perception of time. (Figure2)

3.3 Method and Procedure in Physical Attraction in Waiting areas

Using Kansei Engineering type I to know patient emotion in 4 waiting areas in INT and Besta Hospital. Warm color and cycle furniture layout and warm textures was with positive emotions. Flow Kansei Engineering proposed to test in the positive selected waiting area.

3.4 Method and Procedure in Effect of visual Art in Waiting area

Following a painting exhibition in INT in Milan and San Camillo hospital in Rome and ask patient to fill questionnaires during and after the exhibition to know and compare their feeling. Result shows the character of paintings and installation has a major effect on patient emotions. In these two case studies in INT patient were more active and agitated during the exhibition and in San Camillo that was not a big difference between patient emotion with and without exhibition.

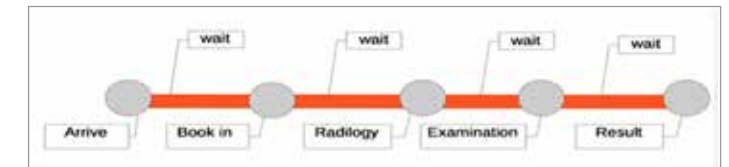
4. CONCEPTUAL DEVELOPMENT

Recording emotion of patient in every step of the journey to know the overall user experience. (Figure3)

8. DISCUSSION

This study focused on both

waiting time, waiting areas in healthcare centers. I proposed a new method based on my experience in all surveys in PhD. In this method recording patient Act, event, emotion and perception of time and actual time in the whole journey by a from filling questionnaire. Then, open structure inreview with coding verbal components. Validity of this method is in the process. Obviously result make User Experience in every step clearer.



1. OPD Patient Journey



2. Patient emotion in every step of patient journey based on Observation



3. A sample of theoretical Framework of user Experience in the Hospital

HOW CAN WE DESIGN THE BEHAVIOR OF INTERACTIVE OBJECTS?

Marco Spadafora - Supervisor: Prof. Margherita Pillan

External examiner: Prof. Wendy Ju

How can we design the behavior of interactive objects?

The research path described in the following dissertation represents a possible answer to the previous question. Indeed this research through design describes and evaluates a theory and a method to help designers design the behavior of interactive objects.

Nowadays, thanks to the information they share on the web, their sensors and the evolution of AI, interactive objects are no longer isolated, and their behavior can be increasingly dynamic by responding to a certain degree of autonomy and proactivity – in a certain way they are smart. Given so, the behavior of an object and the way this behavior is expressed—i.e. motion, audio, etc. - becomes extremely relevant in the definition of the overall experience that a user has interacting with the object. It is a design responsibility to design the behavior in order to create a conversation between the user and the object. Interactive objects are no longer only tools to augment people abilities, but actors in everyday scenarios; the interplay between the actors – people and objects – influence each other performance, determining the success of the communication.

In order to have an effective communication, object should first have a strong characterization.

Traditionally the interaction design realm uses a paradigm based on “efficiency” to drive the design process, but recently the community went beyond this approach. Nowadays we are conscious that efficiency is a necessary condition for the functioning of the interaction, but it is not sufficient to create a conversation and a relationship between people and objects. For this reason the community is fostering a more holistic approach integrating concepts such as aesthetics and ethics as a way to design the behavior from an experiential, rather than a functional, point of view.

Embracing this approach, and considering previous research and methodologies, this dissertation posit that the use of metaphors, within the design process, is the appropriate tool to control and to design the different variables involved in the design of an interactive object’s behavior.

The first part of the dissertation explores the concept of aesthetics of interaction focusing on the formal attributes of the interaction

and their impact on the user experience; next it analyses the characteristics of nowadays interactive objects and the variables involved in the design of their behavior. Successively it considers theories around the design of interactive objects’ behavior and it hypothesizes a theory and method to design it based on metaphors. In this case metaphors are suggested as a tool to facilitate the design process and not as a way to convey objects functionalities to the final user. The last part the dissertation reports the evolution of the design method through the use of it in different design groups, diverging according to people’s backgrounds and years of experience in the design field. It describes several experimental design activities in which the method was applied to design different kinds of interactive objects. Thanks to this effort and to the collection of qualitative feedbacks, from designers involved in the design process and from user of designed objects, we are able to demonstrate the value of the theory and its implication in the design of interactive objects’ behaviors.

According to Bill Verplank vision on interaction design, the evolution of this discipline has a relationship

with the different ways a person interacts with the world according to his/her age (Verplank 2009; Verplank 2015).

His thinking can be summed up as follows. In the early stage of our life we know how “to do” things thanks to a kinesthetic knowledge - such as to grab something - we have an enactive thinking. Successively we learn how “to see” things, we have a visual interpretation of the world; therefore for example we assume that a tall and thin glass is bigger than a short but large one, using iconic thinking. In the last step in the adult phase, we learn how to use symbolic thinking, we are able to interpret symbols – such as mathematical ones - and to use them to communicate.

The history of interaction design explored these three phases in the reverse order. At first our interaction with computer was based on a symbolic language, few people were able to type on keyboards those symbols in order to create commands lines and to communicate with computers through a dialogue. According to Verplank computers were build on a human metaphor, and the goal was to create intelligent computers that can substitute people. This kind of interaction is at the base of computer science and evolved into artificial intelligence. In a second moment people interaction with computer evolved into a visual one with the use of icons. Icons representing folders, printers and other kind of objects made their appearance and people started interacting with computers through graphical interfaces. The metaphor behind this step of interaction design is “computers

as tools”, therefore those interfaces are built to help people accomplish a task, and they are built under principles of usability. This is where actual interaction design started, and it was build according to the action-reaction paradigm, according to which in order to accomplish a task a user does something that provokes a computer reaction (Nielsen 1993). By analyzing nowadays evolution of interaction design Verplank claims that we are exploring a new phase, based on enactive thinking. Indeed we are involved in the design of tangible user interfaces that enables a kinesthetic knowledge in doing something. In this phase of interaction design computers are no longer tools to accomplish a task, but media related to communication and entertainment. As envisioned by Weiser (Weiser et al. 1999), computers today are part of everyday objects, they augmented everyday objects that are no longer just tools to accomplish a task but media that are expressive, through which we interact with other people and objects, that engage with us and that we enjoy. These interactive objects have a certain degree of autonomy and proactivity.

According to this definition, nowadays interactive objects can be considered and are perceived as actors in a everyday life scenario (Reeves & Nass 1996), the tangible and embodied interaction with them and through them affects our behavior (Dourish 2001). [image 1]

One example of the impact of this prospective is the work of Lanske (Laschke, M. Hassenzahl,

M. Diefenbach 2011; Laschke et al. 2013). With their research on “*Transformational products*”, they designed objects that require a certain kind of tangible interaction; this interaction is build to force the user into an action that change their behavior or at list creates a reflection moment about their behavior. One example is “Forget me not”, it is a reading lamp with the shape of a flower that opens up and switches on when the user touches it, and that slowly closes down and consequently switches off. To keep it on the user has to touch it again and again, this interaction creates a moment of reflection that influences his/her behavior and understanding toward the energy consumption. This work can be placed within the realm of persuasive technology, but it is also fundamental example to understand how things that have an “attitude” and require a certain kind of tangible interaction can have an impact on our behavior. [image 2]

This dissertation takes a step back from the design of interactive objects that have the goal of changing people’s behavior, and looks at the problem from a wider perspective. The goal of this research is to provide designers with a method to design interactive objects’ behavior, given that the design of their behavior is a fundamental step in order to design a fruitful conversation between the user and the interactive object, and therefore a meaningful user experience in the interaction with the object itself.

MEASURING PRODUCT EXPERIENCE A METHODOLOGY BASED ON A MULTIMODAL APPROACH TO ASSESS EMOTIONAL RESPONSES ELICITED FROM HUMAN- PRODUCT INTERACTION

Carlo Emilio Standoli - Supervisor: Prof. Giuseppe Andreoni

We daily face a multitude of products, either physical or digital. Sometimes they make our life easier: they are functional and aesthetically pleasant. We experience satisfaction and pleasure in using them. Some other times products are complicated and difficult to use and they can cause unpleasant and frustrating feelings.

The aim of the research is to investigate the interaction between user and product, underlining the aspects that elicit positive and negative experiences.

For this purpose, we developed Methods and Tools for monitoring such interaction and related emotions. The final goal of the research is to provide designers with guidelines and tools useful for the evaluation of products and product experiences.

A crowded Market

To date, the mobile apps market is huge and still significantly growing. Although many apps available in the market could have the same functionality, they also achieve a high response rate just right after the purchase. Their popularity and use decrease with time as they reveal as “replicas” of something already existing; moreover, they are not proposing any aesthetic or useful added value in comparison with other similar apps.

Their use is short because they meet (sometimes superficially) just basic needs. They can be functional, usable and even aesthetically pleasant, but the lack of a message to communicate does not allow any interaction to generate the individual emotional experience. This experience is the key factor that bring the user to prefer and to use a product over time. To develop an appreciable product, the designer should definitely consider its communicative and emotional aspects.

Artefacts communicate through form, color, material, and their sensorial properties, which provoke and engage the user and build the product personality.

Product Experience

The research deals with the concept of “Product Experience” formulated by Desmet and Hekkert.

Human-Product Interaction can elicit affective experiences, related to either the individual's characteristics, such as personality, cultural and social values, or product characteristics, such as shape, material and colors. Experience is also influenced by the physical, social and cultural environment. Beyond functionality, usability and pleasure in use, Designers have to think of the affective experience they want to

elicit.

Designer's role

In this context, the designer must define products that combine functionality and usability with technological, economic and social aspects.

Besides, he/she must deal with the users' emotional expectations. As mentioned, in a wider market, with a fierce and fast competition, companies and design teams have to develop products that can differentiate and be appreciated in the long run.

Designers must overcome the limitations of functional and usable product. Users no longer seek for products functionality; they seek and prefer products that can generate positive affective experiences. Man is a “wanting animal” (Maslow, 1970), an animal that is always looking to fulfil his needs and that hardly reaches a full satisfaction. In fact, the achievement of a goal or the fulfilment of a wish is always replaced from another goal or wish. Functionality, usability, shapes and materials are no longer sufficient to ensure the success of a product. Something more is needed.

Scope of the work

The research has various targets: first of all getting knowledge of human-product interaction

features: way to perceive objects, outcomes of the connection that establishes between the two, information obtained and how such information is managed. Starting from interaction, we get to experience the product. Second target of the research is to define a method to assess emotions rising from the product experience. Third target, developing methods, tools and models that designers and experts can implement in projecting and valuating products and interfaces.

The research does not end just in reaching those targets, but also in assembling a consideration pattern for a study field complex and stimulating at the same time. Tests were done either in lab or in real life, trying to explore interaction with digital products. More specifically, test of the Interactive WhiteBoard were carried out, the empirical activity was driven by the research and development of “affective wearables” and, to a lesser extent, of “affective toys”.

Research Output

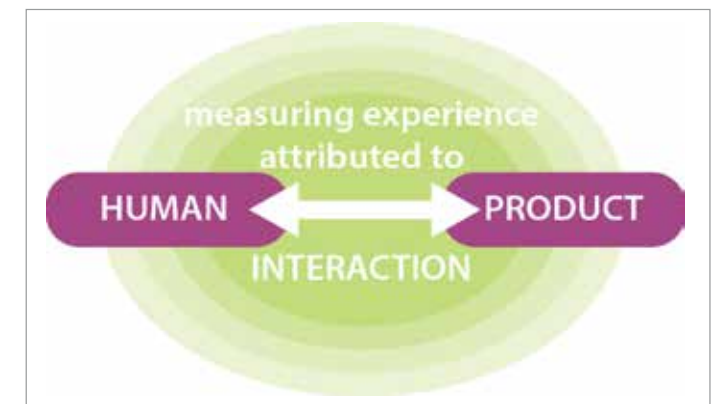
Expressed target of the research is the development of a Product Design approach that takes into account emotional experience arising from human-product interaction. To do so, a method to detect emotional states was

defined and applied so to give the designer a way to valuate products. More in depth, the research resulted in:

- Methodological contribution – Knowledge. Designing a methodology to measure emotions. Designing a physiological way to assess Product Experience means, first of all, obtaining answers not influenced by particularities or variety of individual points of view. It is advisable to bear in mind that every experience is deeply influenced by specific characteristics of either the user or the product, as well as the valuation process, being it conscious or not. The method proposed does not affect subjectivity of the experience,

instead it propose an objective measure of it.

- Analytic Contribution – Development of monitoring instruments. Guarantee user's comfort in use. Realizing a physiological system to monitor emotions, not obtrusive, comfortable and not restricting user's movement.
- Proactive Contribution – Development of tools supporting Designers. Possibility of use also outside the typical lab environment. Final goal of the research was developing a method and tools effective also in real life conditions (i.e. other than lab ones). Target is letting designers utilize tools capable of accurate measures also in real life.



1.

DESIGN FOR COMPLEMENTARY ECONOMIES. RESILIENT SERVICE MODELS AS STRATEGIES FOR LONG-TERM RESISTANCE IN TIMES OF SOCIO-ECONOMIC CRISIS.

Ida Telalbasic - Supervisor: Prof. Anna Meroni

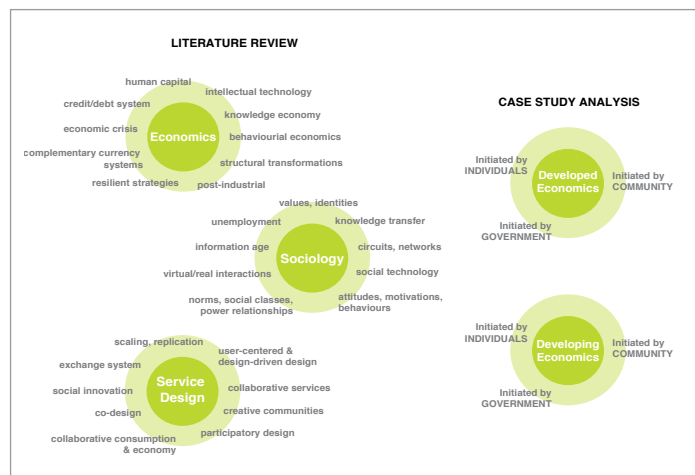
External examiner: Prof. Ken Friedman

The main motivation to conduct this doctoral dissertation was drawn from an altruistic standpoint of seeing young professionals affected by the 2008 socio-economic crisis and falling to the sidelines of regular job markets. The fact that many skilled individuals (young entrepreneurs, free-lance professionals etc.) had not been able to operate and offer their skills on the market was the main driver for conducting this research. The urgency for this research was triggered by statistics that stressed lasting consequences that are still present today and how this contributes to the numerous struggles within employment in Europe.

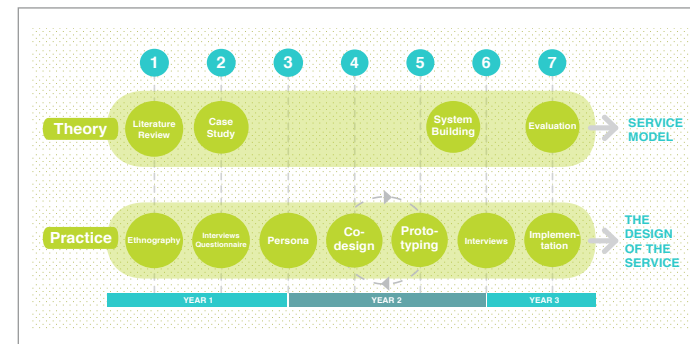
The theoretical framework was based on three distinct, yet complementary disciplines: economics, sociology and design. The economic landscape gave an analysis of postindustrial failures in income distribution and their root causes. Structural diversity through complementary currency systems was presented as one promising proposal of alternative monetary eco-systems that could act as mechanisms for territorial and social cohesion. The sociological landscape gave more profound considerations on social interpretation of money in diverse cultural contexts. Service design set the disciplinary framework that aimed to explore the potentials of an emerging discipline, especially

in terms of fostering collaborative participation and consumption towards design-driven innovation. Open innovation and user-driven innovation approaches were discussed in relation to the creation of collaborative service models that could sustain service co-designers and co-producers in an emerging collaborative economy. The designer's changing role was analyzed through co-designing services, re-conceptualizing products, re-designing of interconnections between technology and people, and its correlations to social innovation. The case study analysis was structured according to two main interpretation angles: best practices in reference to their contextual economic development and initiation determinants. The intention was to understand motivations for creating new currencies as a reputation mechanism as well as the main purpose of injecting complementary capital across global locations.

The aim of this research was to explore how service design could have a leading role in economic transformations and contribute to new ways of practicing democratized economics. This was done through mapping



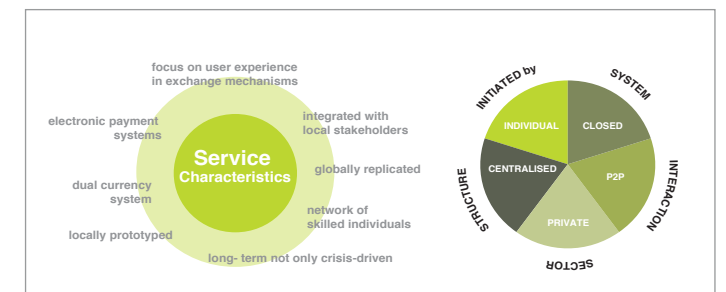
1. Theoretical Framework of PhD dissertation



2. Methodology of Participatory Action Research (PAR) Project

existing alternative economic models, developing design tools, co-designing collaborative service models that could be replicated and scale up as diffused social innovations. The main objective was to understand how service design contributed to the creation of resilient and democratized economic models that could act as a facilitation mechanism for coempowering and transforming idle capacities of skilled individuals into social capital and collaboration opportunities. The participatory action research (PAR) part of the dissertation showed the complete on...field research process with established collaborations such as co...working spaces, namely Impact HUBs in Milan and London, that provided the infrastructure and community for setting up a number of design

research strategies, including interviews, co-design and prototyping sessions etc. The results included four contributions: 'Credita Social Currency' service model as a co-designed collaborative service that relied on an emerging collaborative consumption mindset as a resilient strategy for long-term resistance. The theoretical contributions provided reflections



3. Credita Social Currency' Service Model Characteristics and Typologies

on the developed model for both evaluation and testing. Replication and scaling opportunities included customization possibilities of the model across diverse territories. The role of being both a researcher and designer included personal reflections on the research journey and how this shaped a new contribution of the design role. The novelty in approach was presented through the application of design knowledge and methodology to co-design complementary economies as resilient strategies in socio-economic conditions.

AN EXPERIMENT-BASED FRAMEWORK OF EVALUATING INTERFACE USABILITY IN INDUSTRIAL CONTEXT

Jing Zhao - Supervisor: Prof. Monica Bordegoni

Users have become more important than ever in the human computer interaction process, with systems being developed to be more and more powerful. However, in complex systems in industrial contexts a major concern is still lingered on operators' performance. Concerned with the interaction process quality through the industrial interface, the usability concept is adopted to measure the interface. There are different understandings about usability concept through different groups of researchers. Generally speaking, it has gone through the periods driven by performance-concern but later becomes more concerned about the user. Although subjective aspect is also considered such as satisfaction by prior studies, some researchers referred that it is more an attitude, rather than the inner state of user. So the emotion concept is employed to depict the accurate state of the user. As a result, in this study, the usability has been renewed to a version that concerns both the performance and the emotion of the users. Ecological Interface is selected to be the object in this study as it is a typical interface designed for complex systems and acclaimed by many researchers to be promising.

However, it also has overlooked users' perspective, neither paid attention to the interaction process as well. After reviewing and redefining the concept, it comes to the question how to measure the interface usability. While there are lots of studies discussing how to measure the emotion by exploiting bio-signal, also there are a handful of studies trying to combine the physiological measurements into the usability study. However, there are quite few studies focused on usability evaluation including emotional dimension. A framework has been put forward based on this insufficiency to help practitioners, designers, evaluators to conduct this evaluation process. Starting from the usability question, group of users, the selected evaluated part, and the context would be defined, and further the usability concern including aspects of performance and emotion are considered. Then it comes to the step to specify usability goal and also the measured dimensions. Then it falls into the pool of available experiment measurements to choose the appropriate methods. Following the objective and subjective methods combination principle, different methods

would be selected from the pool. Then different experiments were designed to apply the methods and after analyzing the data, conclusions are achieved. An iteration cycle has been completed. Three experiments have been conducted in this research to evaluate the DURESS interface usability. The first one has used questionnaire to compare the traditional interface with the ecologically designed interface. The fatigue, confidence and stress situation has been compared and only stressful degree of these two types of interface has shown significant difference. The second one has compared the interface with and without visual alarms. It is shown that these two kinds of interface have different influence on the physiological response of the users, which is another way to indicate the emotional states. It has found that the visual alarm could greatly arouse operators, which might mean they are more stressful. In the third experiment, different alarms and their combination have been compared by employing subjective methods as questionnaire and Self-Assessment Manikin, objective method as physiological measurement. Different kinds of methods have been combined

as they all have advantages and disadvantages. The first experiment has established that the Ecological Interface could help greatly decrease the subjective stress level. The second one showed the visual alarm could greatly arouse operators' physiological response, and decrease the time used to complete the task at the same time. The third experiment has combined different methods. It has shown the physiological aroused skin response is significantly different between visual alarm and visual&tactile alarm, also between sonic and sonic&tactile alarm. It could be referred from the information that the tactile alarm makes the difference. What's more, this result is not detected by the subjective methods. It has proved that the combination of subjective and objective methods does make sense. There are two parts of conclusion. For one thing is the interface evaluation. The concept of usability has been renewed. The emotional aspect in industrial interface usability evaluation is highlighted. Emotional states of the operators in complex system are considered as important components of usability, and they can be influenced by different design solutions; a detailed

route that researchers could follow to measure the emotional dimension of usability is offered, including the emotion and the performance. Examples are given by three experiments to show how the evaluation could be carried out; compared with the major trend using questionnaire in the emotion measurement in usability studies, both subjective and objective methods, verbal and non-verbal methods are suggested in the framework in order to get deeper insight of the users; it's important to complement the subjective measures with objective ways in the usability study, as differences could be beyond the subjective sensations, but are influencing the users' actual response. For another is the feedback to interface design. The blank area of neglecting the users' perspective in ecological design has been considered; further development of ecological interface design has been explored, in this study the alarm design of different sensations are explored and different forms are compared; human are found to be more aroused under the visual alarm situation compared with scenarios without alarms; the tactile alarm could be used to enhance the physiological arousal level of human operators in the

interface design. The present work has some limitations also. There are some future directions indicated. The correlation between emotion and performance should be considered further in order to better understand the interaction process while using the interface; further studies of side report from more redundant measurement such as behavior is needed; other measures (such as eye tracking) should be called into the framework to have deeper insight about the interface usability; a larger scale of subject number is in need in future experiments, enlarging the number of participants could better exclude some disturbing reasons that might be due to the scale of subjects' number and further find the underlying principle; this framework could also be applied to other interfaces that are used in industrial context.

DESIGN SCENARIOS. APPROACHES AND TOOLS FOR BUILDING THE FUTURE WITHIN THE DESIGN PROCESSES

Danila Zindato - Supervisor: Prof.ssa Manuela Celi

The strong relationship between design and the future is related to the tools used for creating and narrating possible alternative futures. In design as well as foresight, one of the most important tool is scenario building. In this phase a set of inputs are mixed and match in an abductive sensemaking process to develop possibile future alternatives in terms of products, services or contexts. During the scenario building process, designers organize, evaluate and filter data, producing new knowledge in different ways according to their target, tools and the available resources. The study explores the use of the design scenario as a 'bridge' between the analytically oriented planning and the creatively oriented vision.

The first part of this research sets the general theoretical framework to explore the different definition of scenarios in the literature and to pose the interpretative keys for understanding the multifaced soul of scenarios. In terms of tools, the literature review is focused on the analysis of the scenarios origins in the military field, the actualization into the design literature, and to answer to the questions "what are the

scenarios features into the design process after their formalization (in 2000)?" This second research layer has its starting point in the analysis of the work of a research group based in our polytechnic culture (E.Manzini, F.Jegou, S.Maschi) to identify main points and open issues in matter of design scenarios. A synthesis map represents the main issues identified in the literature review.

The first layer of desk analysis provides the research questions, that act as a *fil rouge* during all the research. They are related to four different themes:

- Objectives / Target | How is the scenario building process used in the design field today? When it is developed?
- Building Process | What is the building process? Is there a codification in terms of approaches and tools?
- Participatory Dimension of Scenarios | Who is involved in the scenario building phase (in addition to the design team)?
- Instrumental Dimension of Scenarios | What are the different tools for narrating possible scenarios in the design field?

The second part is focused on the scenario positioning in the

design process. The crucial point is a selection of product-based case studies in design-oriented companies to compare the different building process, the actors involved, and the scenarios' variables. For each case study, there is a process model to identify common point and differences among the enterprises and to provide a synthetic interpretative model of a general design process. The two layers of desk research provide insights related to the gap presented within the literature: the lack of a classification in target and approaches for building scenarios and the lack of tools mapping and clustering within the scenario building process. The hypothesis derived from these assumptions and aims to provide an interpretative matrix for creating a potential classification approach, and to define a potential classification for the instrumental dimension of scenario building.

The research results are both theoretical and practical. There is an overview of the scenario building process into the design field, with an actualization in terms of sources and new functional consideration. This work provides a current state

of the art and a model for the classification of approaches. Since scenarios are multifaceted, there is a need to define an interpretative model for the required intermediate steps. The first complexity coefficient is due to the lack of a univocal method and, at the same time, to the presence of many different approaches. They change according to the researchers group or to the field (strategic design, product design, HMI). This creates the need for a classification by target. The research presents a matrix for clusterizing the approaches according to the aim for developing a set of scenarios and provides a definition for each and a classification of the different building process. The matrix aims to synthesize a system of complex information to yield an understandable framework about design scenarios.

The knowledge systematization is able to solve one of the open issues identified during the early 2000's regarding the formalization of scenarios not just as a visualization tool but as a tool for supporting the whole design process in many ways (external and internal communication, business model analysis, strategic planning,

concept definition, solution generations and alternative testing).

The conceptual process model identifies six different positioning of scenario building into a possible design process, each with different aims. Each of them is synthesized with a name (explorative scenarios, strategic scenarios - a / b, concept scenarios, focalization scenarios, evaluation scenarios) and with definition and a set of features related to the target (internally use, externally use, sharing with the stakeholders, etc). The model could be used to identify the scenarios' purpose according to the different process step and for choosing the best tools for each position, to focus and optimize the whole process. The tools have different targets and are generally used in a combinatorial way: exploration tools, narrative tools and visualization tools are combined according to target, actors and available resources. Therefore, the last result is focused on the possibility to cross-pollinate approaches and tools for developing a specific toolkit adaptable according to the different situations for optimizing process and resources.