Grow: Generative Responsive Object for Web-based design

Methodology for generative design and interactive prototyping

Davide Ventura[1], Matteo Baldassari[2]
[1]Sapienza Università di Roma [2]ONL, Hyperbody research group
[1]www.cenosarc.org [2]www.matteobaldassari.eu
[1]davide.ventura@uniroma1.it [2]matteobaldassari86@gmail.com

This paper is part of the research on Generative Design and is inspired by the ideas spread by the following paradigms: the Internet of Things (Auto-ID Center, 1999) and the Pervasive/Ubiquitous Computing (Weiser, 1993). Particularly, the research describes a number of case studies and, in detail, the experimental prototype of an interactive-design object: "Grow-1". The general assumptions of the study are as follows: a) Developing the experimental prototype of a smart-design object in terms of interaction with man, with regard to the specific conditions of the indoor environment as well as in relation to the internet/web platforms. b) Setting up a project research based on the principles of Generative Design. c) Formulating and adopting a methodology where computational design techniques and interactive prototyping ones converge, in line with the principles spread by the new paradigms like the Internet of Things.

Keywords: *Responsive environments and smart spaces, Ubiquitous Pervasive Computing, Internet of Things, Generative Design, Parametric modelling*

FROM GENERATIVE DESIGN TO INTERACTIVE PROTOTYPING

The design process (Figure 2) is based on the principles of Generative Data-Driven Design. The interactive prototyping is based on the current techniques of 3D printing and laser-cutting. It is implemented, specifically, by using electronic boards (Spark) equipped with micro-controllers and devices which incorporate sensors-actuators and so on. The paradigm of the Internet of Things, instead, is implemented through the use of Wi-Fi boards, inserted in the electronic circuit inside the object and interconnected with web platforms by the encoding of specific scripts.The three general objectives converge on the idea of developing a smart object capable of special performances in terms of Pervasive/Ubiquitous Computing. Specifically, the study focuses on finding experimental solutions for designing new objects which can interact with the external inputs, being interconnected to the web. The search for formal "non-standard" solutions, which is carried out using the above methods of digital morphogenesis (Kolarevic, 2000), is linked with the techniques of integration of innovative sensing systems in order to con-

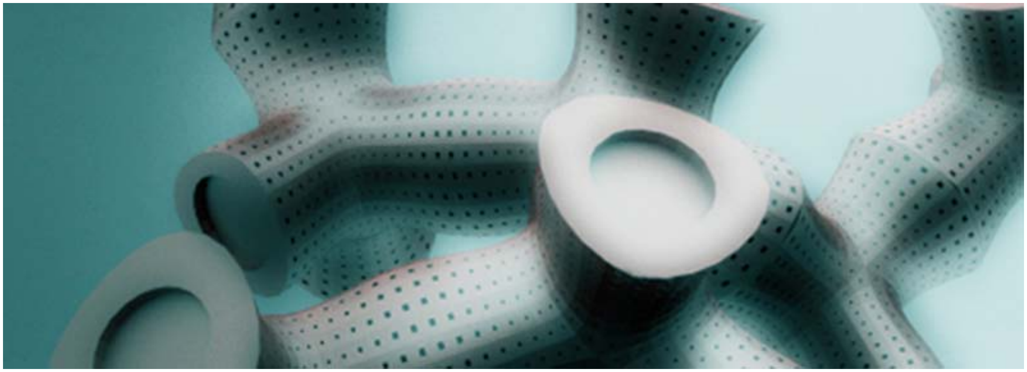


Figure 1
Render of the project

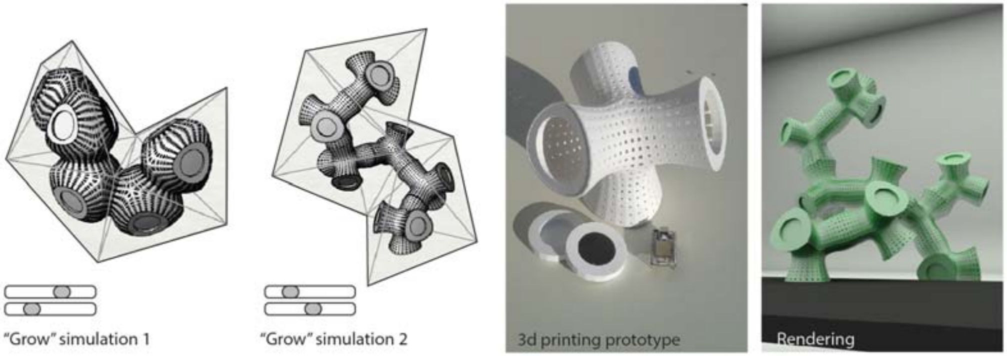


Figure 2
The design process: from generative design to interactive prototyping

trol and optimize the real-time performanceThe idea is to reformulate the traditional character of everyday household objects, adapting them to the new information and communication technologies.The investigation ultimately aims to assign to our everyday objects a new "genetic heritage", whose code does not only correspond to its "canonical" function but to the combination of different features and behaviors in terms of interactivity.The result is a "hybrid phenotype" in which the digital information pass through the matter and where architecture and design are interwoven with electronics and Information Technology. In this sense, the digital information is considered as a real material (Kuniavsky, 2010) which inspires and guides the design experience. This outlook brings in new questions about their ability to assume interactive behaviours towards the specific conditions of the context.

THEORETICAL INTRODUCTION

In 1993 Mark Weiser introduced the concept of "calm technology" describing the occurrence whereby technology is hidden behind the visible sphere of space and things. He embarked the paradigm of "Ubiquitous computing", the information technology separates itself from personal computer becoming integrated in objects and devices commonly used. After two decades, as Gregory Wessnerm has underlined, low cost of hardware solutions and increasing computational skills of software products allow to implement digital intelligence of machines. Furthermore the quality of design becomes an ephemeral and intangible value based on the computational capabilities. As Mike Kuniavsky underlines, nowadays architects and designers have the opportunity to experiment and shape with the new tools of information technology throughout several hardware and software solutions suitable for all. Do we have, today, examples about the impact of information technology in design? Are they leading to impressive outcomes? Before dealing with products in the market it's interesting to focus on the approach of artists picturing new scenarios within this field of research. For instance the domestic-city of Keiichi Matsuda (Figure 3) represents an exciting and truthful scenario. He employed information not as a medium to rebuilt a virtual dimension but, on the contrary, he altered the physical dimension around us overlapping reality with digital tags and information: the data became interactive and dynamic amplifying the objects meanings and functionalities. This idea resumes and follows the concept of "augmented reality" firstly explained by Manovich.

Figure 3
Keiichi Matsuda, Domesti/city

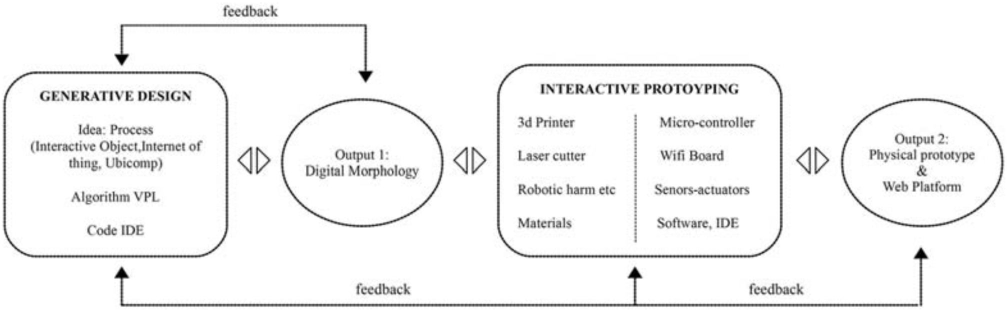
Examples and references

Artists like Matsuda suggests a process of innovation achievable in a long term although some companies have already undertaken a market strategy for this kind of products, showing the increasing potential of the products related to the internet of things as a real clue for the technological innovation and cutting edge design. The Fitbit company, for instance, released a series of smart wearable accessories able to track the diet and the physical activities of the users. In the other hand the belkin company promoted a smart pan controlled by distance throughout an App for mobile devices, furthermore "Sen.se" built a doll able to record and communicate events in a room. Kolibree it's also a remarkable example concerning products able to gather information about hygrothermal features, it verifies and communicates to the user the effectiveness of the oral hygiene . Italian design studio Digital Habits created a modular lamp that encourages human interaction. Called Dragon, the lamp consists of interlocking triangular modules filled with tiny LEDs that can be arranged to provide a variety of lighting effects. A fractal chandelier from the future, Dragon can be controlled with a simple smartphone app. It is the World's First Remote-Controlled LED Bulb that Can be Turned On Via a Smartphone. Some students at the MIT invented Twine, a device with external and internal sensors, wi fi connection and an application to connect and communicate environmental conditions. The product send emails and warnings according to the data collected. Researchers at the IAAC in Barcelona developed an akin device able to monitor environmental data. The device is connected to the web platform (smartcitizen.com/net) storing data in real time and sharing with other users of the platform. Even though forrester Research poll affirmed that the 53% of the Americans are not concerned to control devices through a smartphone, it's really difficult to deny the remarkable potential of an object able to interact with man, environment and the web at the same time combining several functionalities. Besides that all those kind of experimentations can be considered attempts to absorb the impulses of the new computational culture of the 21th century. Nevertheless today the most convincing inventions are the DIY (do it yourself) products where users can assemble components by themselves, in fact, instead of being a passive actor, the consumer participates actively to the process behind the mere fruition. Furthermore the challenge is to introduce products able to solve real issues and to improve life of people. The opportunity given by the communication between objects and people represents the breaking point of a consumerist society toward a democratic one, where devices will control and track environmental changes in an accessible, free and decentralized network. This research aims at underlining a methodology based on the intent to create a network of relations between object Computer environment and people. This scenario implies the capacity to manage and gather data throughout languages of the computational design culture.To achieve these goals was fundamental to approach the computational tools available today, five years ago these tools were reserved to an elite inner circle of researchers. Today architects and designers have easy access to these tools throughout an active open source community and low costs of machines and hardware solutions. The algorithmic and associative design allow in this case to establish dynamic relations through virtual models, physical models and software products using a small amount of resources.

ANALYSIS OF THE RESEARCH

The analysis of the research is structured as follows: a) description of the main steps of the generative design process carried out using algorithms developed with VPL: Grasshopper-Rhino and with Python programming language:The first step consists of describing the particular objectives with respect to the idea of the process: a free-form element subjected to an action of "recursive aggregation", then it follows the description of the generative algorithm and of the main parameters which define the process, then the results are analysed and selected. During the analysis of the results, it is evaluated the relation of emerging morphologies with the assumptions of functionalities, with the level of integration of electronic systems and also with the materials and prototyping techniques. The final step is the choice of functionalities, scale and of the most appropriate size and morphology.b) manufacturing and interactive prototyping process.After selecting the most suitable geometry, it follows the prototyping phase which consists of two main parts: the first is the actual construction of the object, while the second corresponds to the activation and integration of electronic devices-During the computational design stages, 3D printing has been chosen as the most appropriate prototyping technology. This alternative has determined a particular attention to detail within the virtual model that will be exported later as a stereo-lithographic printing. This stage will be improved using sustainable bio-plastics The second phase involves the programming of Spark and the setting of the connections with sensors (photocells) and actuators (LED or speaker).The whole system is powered by a rechargeable lithium battery and the physical aggregation of multiple components (in accordance with the digital recursive-aggregation) is obtained through the use of round magnets fully integrated in the geometry of the printed article. In the process of morphogenesis, in fact, one of the main objectives was to achieve the integration between shape and electronic devices.c) connection of the object to web platforms through Wi-Fi cards and appropriate software. The next step is to connect the object to the Internet. Over the last few years, there has been a spread of different web platforms able to store and manage data in real time (smartcitizen.me, xively.com, openenergymonitor.org). Through the sharing of API addresses and Feed URL an interconnection between smart objects (equipped with microcontrollers and Wi-Fi cards) and the web can be started.The environmental parameters received by the sensors, which are embedded in the object, are converted into digital information, edited in real time by web platforms or managed by appropriate software installed on the PCs or smartphones. In addition, since the early stages of design, specific plug-in for VPL (Grasshopper-Rhino) are used to manage virtual models, using real-time data acquired directly from the external environment or from the internet. It is therefore possible to represent, through digital simulation, the behaviour of a smart-object before its actual prototyping.

Figure 4
The methodology



METHODOLOGY

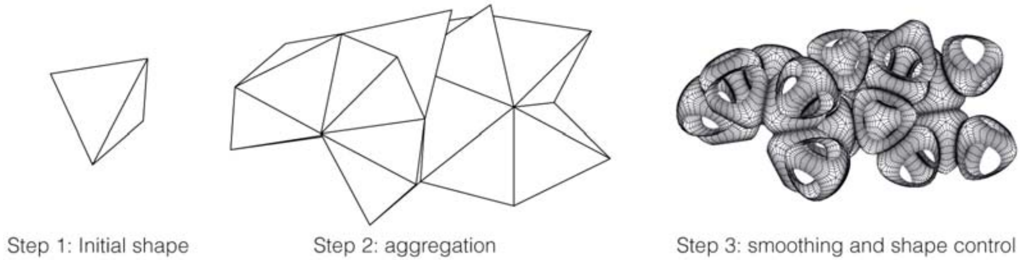
The methodology (Figure 4) adopted has a loop structure, this method allows to go back to previous steps and to easily redefined the logic for a different project. The methodology recalls a computer science logic of functions and loops to facilitate and readapt the design process depending on outputs, inputs and tools available.The process is formed by five different phases:

- Generative design
- Output 1: Digital morphology
- Interactive behaviour
- Prototyping
- Output 2: Physical-Interactive output

The generative design process

The starting formal idea is to set an iterative process in terms of "recursive aggregation" (Figure 5, step 2) starting from the definition of a core component.The initial concept does not correspond neither to a precise function nor to a predefined shape, it rather reflects the idea of an "open" morphogenetic process. The morphology of the core component is defined algorithmically: according to the principles of Associative Architecture, geometry has variable properties related to the definition of specific parameters and calibrated within appropriate ranges. Once you have defined the variables of the core component, it is replicated according to the rigid-geometric movement of the rotation, iterated n times and algorithmically checked through an appropriate function.At this time the general rules underlying the process are encoded in the generative algorithm.During the

Figure 5
The digital outcome



process of morphogenesis, hypotheses are evaluated with respect to the functions of the design product concerned. Considering the intended use of the object at the design stage (indoor), the various functions are: lighting systems, monitoring of indoor environmental conditions, sound systems (speaker) and kinematic systems.While evaluating the hypotheses of the performances that the object shall exhibit, the most appropriate scale and size is considered. Accordingly, the most congenial prototyping techniques are examined as well as the materials and electronic devices to be used for the construction of the physical prototype.All these choices entail certain conditions which guide the process of morphogenesis towards certain directions more than others. The geometric parameters are then calibrated in line with the choices made during the process.The simultaneous, interactive variation of parameters guides the evolution of the shape towards the achievement of the aims and objectives which are gradually defined. The formal result at the end of the path does not correspond to the representation of a pre-determined shape, but rather to a population of "emerging" geometries which best solve the simultaneous combination of multiple requirements.At this time the general rules underlying the process are examined more in depth: other aspects are involved within the generative algorithm. It takes on more complex configurations following the encoding of conditions and parameters which control in greater detail the evolution of the shape.

Digital morphology

The first digital outcome (Figure 5) is the mesh model realized using computational advanced techniques, mixing grasshopper and custom functionalities in Python. In this step we evaluate the morphologic features adjusting several parameters in the software. The generative algorithm has been constantly readapted during the creative process throughout continuous adjustments and feedbacks to formulate the rules of the design methodology. The same process has been driven by functional choices to achieve the maximum amount of possible interactions with the environment and the users.This fundamental step will also facilitate the translation of the software for mass customization into the web-site, allowing the users to personalise the shape according to personal requirements and tastes.

Interactive behaviour

The interactive behaviour of grow is the starting point of the research,. The device represents the natural connection between real and computational world, the design itself suggests the transition between biological and digital realm. The behaviour is characterized by four different hardware components: a lightning system, an environmental control system, speakers and the spark wireless core. The object has three different kind of behaviours depending on the mood and needs of the user.The biological behaviour transforms grow in a living organism. It will respond to environmental conditions expressing his emotive state to the surrounding. Like a coral it will bleach or change colours depending on environmental factors giving warnings to the users about climate conditions, changings or pollution raisings. At the same time this behaviour will interact with human proximity, changing the intensity of light according to the distance from the user, the presence of light in the room or the location of the device. Furthermore it will change his colour and conduct adding new components. This kind of interactivity represents a breakthrough to the human to artefact interaction and vice-versa, the fruition of the device is not just considered as a materialist and consumerist occurrence but as a more complex interaction within an ecological system where human artefacts and environment communicate responsibly. On the other hand the customizable behaviour allows to personalize the conduct throughout an App. The behaviour might also be customized depending on the needs of the users, lights gradient, intensity and functionalities can be personalized depending on the requirements using a software running on tablet or Smart phones. The system also connects to the internet over wifi with sparks and communicates information about environmental conditions.The two main behaviours can be easily switched and the design provides several functionalities related to different kind of activities and moods.

Prototyping

The stage of interactive prototyping consists in the physical construction of the object. During the earlier stages of design we evaluated different strategies of manufacturing. In fact, parameters define the digital-algorithmic model. Besides that they are established and adjusted with respect to the techniques of digital manufacturing chosen and compared to electronic cards, micro-controllers and input-output electronic devices already taken into account during the stages of parametric modelling. This phase requires the knowledge of both modern manufacturing techniques, based on new digital technologies, such as rapid prototyping 3d printer, as well as new electronic prototyping platforms based on the use of micro-processors, micro-controllers, wifi cards and various sensor-actuator devices. The period of widespread use of these devices allows to chose a great range of different solutions at reasonable prices. The interactive prototyping allows you to determine a connection between the virtual object, its computational makeup and modern techniques to build prototypes: 3d prints, laser cutter, etc. .. The choice of prototyping techniques implies the choice of materials and the definition of constructive details. For instance, 3d printers allow to use a range of materials (ceramic, plastic, synthetic resin)) that implies different kinds of finishes. Similarly, the laser cutting and other digital manufacturing techniques include or exclude the choice of some kind of materials and finishes rather than others.The next step consists in the programming of the electronic card (or micro-controller). It manages the performance of the object in terms of interactivity. At this stage you can use Apps already programmed for specific uses (as in the case of Spark.io, the used platform), in other cases you need to write code programs through specific IDE language (integrated development environment) to customize particular performances. However, it is possible to program the Arduino board using the same VPL (visual programming language: Grasshopper) used during the parametric modeling stage: some plug-ins like Firefly are useful to set a connection between the Personal Computer and the Arduino board by translating the Arduino IDE in algorithmic components of VPL.Furthermore nowadays the Internet allows to undertake innovative projects in the realm of industrial design and provides platforms Iot (internet of things) to control the devices and facilitate prototyping. The most common Iot platforms can be classified in two kinds.The first (smartcitize.me , Thingspeak.com) are platforms where users can collect data worth to share, for instance , environmental data or activities. The second kind of platforms provide hardware solutions and electronic devices (microcontroller and wifi boards) and software solutions which allow to build a real interactive prototype (IDE systems and apps).During the design process we used LilyPad XBee to test the interactive system but afterwards we choose to work with Spark (Spark io) a more flexible and tiny device with a better software development. Spark allows to control the device throughout a set of customizable apps depending on outputs and inputs established to achieve a specific purpose.Ultimately you can control with Sparks by remote controller, every kind of analogic or digital output.

Physical interactive output

The last step consists in the evaluation of the final prototype with respect to the performances to be achieved. After building the object and after implementing all electronic devices is possible to verify the efficiency and the degree of attainment of the objectives previously fixed. This is the stage where information is exchanged between the physical phenomena that occur around the object, the microprocessor inside it and the wifi network. In the example described the wifi network represents only the means through which the input signal is sent by the smartphone to the microprocessor integrated in the object. The Leds (output) are connected to the digital-analogic outputs of the card inside the object and receive the input signals in order to regulate the light intensity and the lighting effects of the prototype, managed by the smartphone's app.The next development consist in the implementation, within the object, of environmental sensors, like photocells or temperature/humidity sensors, in order to translate, into numerical ranges, the surrounding environmental conditions. Once selected a list of inputs it is possible to activate a series of output by means of actuators like speaker, that communicate specific signals, or led, whose light intensity, for instance, is adjusted according to the light level present on site and so on. Moreover, a web platform may receive and store the data exchanged between the object and the surroundings translating them into graphics templates useful to monitor and manage, through the web, the performances fixed in relation to the environmental conditions with which the object interacts.

CONCLUSION

In 1991 Mark Weiser published an article entitled: The Computer for the 21st Century, in which he predicted that when the technological innovations would become cheaper, smaller and more powerful they would begin to "recede into the background of our lives" integrating and blending into the objects around us.This research is trying to translate that vision into one of the possible methodology, in which the current parametric-computational design techniques and the recent electronic platforms, for the interactive prototyping, encounter the web.This methodology may also be used for the design of "smart" architectural components of greater complexity, such as, for instance, the housing of new buildings or upgrading of the facades.The next developments of this research, in fact, will be aimed at the following objectives, which are also among the main themes of the European Programme Horizon 2020: Integration of innovative sensing systems to control and optimize the real-time performance of the envelope, b) advanced building control systems to control the active envelope. (Horizon 2020, 2013).The next developments of the research will evolve, in fact, in two different directions. On one hand, as was mentioned earlier, the research will focus on further development of Grow in order to deepen its characteristics of interactivity with the environment, with the man and with a web platform specifically developed to monitor and manage the performance of the object. On the other hand future developments of the research aim to introduce these concepts in the field of technological innovation of envelope architectural systems to improve the performances of architectural skin in terms of interactivity thanks to the implementation of modern technology ICT (Information and Communication Technology) and in terms of adaptivity with respect environmental conditions.

REFERENCES

Kolarevic, B 2000 'Digital Morphogenesis and Computational Architectures', *Proceedings of the 4th Conference of Congreso Iberoamericano de Grafica Digital, Sigradi*, Rio de Janeiro, pp. 98-103

Kuniavsky, M 2010, *Smart Things: Ubiquitous Computing User Experience Design*, Morgan Kaufmann Pub, Burlington,Massachusetts

Manovich, L 2006, 'The poetics of augmented space', *Visual Communication*, 5, pp. 219-240

Matsuda, K 2010, *Domesti/city The dislocated home in augmented space*, Master's Thesis, http://www.bartlett.ucl.ac.uk/

Weiser, M 1991, 'The Computer for the 21st Century', *Scientific American Special Issue on Communications, Computers, and Networks*, 265(3), pp. 94-104

[1] http://www.sentientcity.net
[2] http://www.digitalhabits.it/dragon.php
[3] http://supermechanical.com/twine/
[4] http://www.smartcitizen.me/
[5] http://www.forrester.com
[6] https://thingspeak.com/
[7] http://lilypadarduino.org/
[8] http://www.arduino.cc/
[9] https://www.spark.io/