Life Lamp
Connecting Design and People Through Emotion

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Nowadays it is possible to use technology to achieve emotion-oriented products related to the user experience. The aim of this paper is to address a design exploration that combines the use of algorithmic modeling in order to create a design that seeks to express meaning through emotional bonds with people. Life Lamp was created to represent a life cycle as a sensitive object consisting of three layers and a unique shade that produces a complex image, expressing the paths and surprises of our existence. The design process is a hybrid between top-down and bottom-up approaches. The designers worked both with a predefined heart-like 3D model as the design base and with agent-based modeling, widely explored by Craig Reynolds in the 1980s. Life lamp is a product that emerged as a result of Estudio Guto Requena’s research that investigates the impact of digital culture through design by seeking to merge technology and affection.

Keywords: 3D Print Design, Agent-based System, Algorithmic Modeling, Emotional Design, Digital Design, Mass Customization

INTRODUCTION
Only recently, aspects of emotion have become a major issue in the design research field (Desmet and Hekkert 2009). These emotional aspects can orient the design process (emotion-oriented design) by seeking a meaningful conceptual message and can predict or influence user behavior in interaction with these products. Therefore, it is able to guide an individual towards a more conscious consumption by making design goods less disposable (Chapman 2015).

This paper reports a design process that resulted from Estudio Guto Requena’s research focused on the first emotional aspect elicited by Chapman (2015). This process seeks to design and produce objects carried with meaning to an individual or a small group of individuals. According to Hekkert and Mcdonagh (2003), designers should develop products that use deeper and richer levels of emotional experience rather than just taking a short emotional response such as that generated by aesthetic or functional characteristics.
Chapman (2015) also states that we seek to consume meaning instead of matter. In other words, when customers make a choice between two similar products, they choose the one that has more existential mirrors allowing them “to view and experience our dreams and desires in real-time” (Chapman 2015). This meaning, however, can be ephemeral or long-lasting depending on a combination of individual experiences and product features.

Diderot (McCracken 1988 apud Chapman 2016) first described our relationships with products and their instability. According to the author, consumers are driven to purchase products that reflect their personalities, which means that people usually project themselves into their belongings and in the products they choose to acquire.

In this sense, we need to understand how it is possible to integrate emotional aspects into the design process by creating a relationship of identity between the product and the individual. By doing so, we allow an object to stand out from others because of its personal meaning.

While the first two levels are more primitive and immediate cognitive responses, the third level is deeper in terms of emotion and cognition. Nevertheless, a product intended to be a good emotion-oriented design must well perform through the three levels of cognition and emotion.

Thus, the self-projection alleged by Chapman (2015) could be achieved through the emotional design experience described by Norman (2004) manifesting itself in the aesthetic and functional characteristics of the product as well as in the manufacturing process, the personal meaning that it carries and/or in the philosophy of the company that produces it.

However, by analyzing current mass production culture it is possible to notice that it is extremely difficult to design and manufacture an object that takes into account individual emotional aspects, capable of creating more personal bonds between consumer and product.

The ongoing breakdown of paradigms in the design and in the production phase, on the other hand, may favor the use of particular characteristics of an individual or group of individuals in the design process. In addition to this, it is also possible to materialize this individuality in a personalized product without harming its productive and economic chain.

Currently, it is possible to rely on the use of technology to develop emotion-oriented products related to particular characteristics of a given individual (Hekkert and Mcdonagh 2003). However, personalization by itself is not enough to create emotional bonds. It is necessary to develop some sense of ownership by creating the notion of individuality or by developing some kind of emotional link between customer and product (Norman, 2004).

Desmet and Hekkert (2009) by their turn, argue that emotion-oriented design can be facilitated by bringing users to the center of the creative process. In this sense, it is possible to collect personal data that expand the capacity to generate a deep symbolism between the user and the developing product. To bring the customer into such a creative process may seem an obvious strategy, nonetheless, when the conventional productive and design chain is taken into account, it’s possible to realize that several obstacles inhibit a personalized production approach.

This occurs because the conventional production chain is oriented towards a mass production system, as a way of maximizing production efficiency and, consequently, profits. On the other hand, the production chain influences the conventional design method as much as it orientates it to the “logic of repetition” (Oxman, 2006).

Having that said, this correlation makes a different design approach unfeasible. Thus to develop an emotion-oriented creative process that takes into account users’ individual characteristics, it is necessary to review the productive chain system as well as the traditional design methods so that both customization and large-scale production becomes viable.
EMOTION & TECHNOLOGY

The design of the Life Lamp was developed in such context. It was an attempt to bring an answer to these problems with innovative methods both in the design process as in the product manufacturing phase. Life Lamp’s design was developed by the Brazilian architecture and design studio Estudio Guto Requena [2]. It aims to represent three main life cycles of human beings. The studio has an industry-oriented design investigation that aspires to merge technology with emotion. Furthermore, the studio features several other products that deal with the interpretation of unusual inputs of information to generate emotional value to the product. As an example, we can mention the vase collection “Once Upon a Time”, which its shape emerges from audio files of a grandmother telling bedtime stories or the “Aura Pendant”, in which its final shape is defined from collected personal users data, such as the tone of voice and people’s heartbeat obtained from the users while telling their love story.

The approach of capturing the user’s mood through sensors and then processing this data as a means of manipulating space and objects is not a novel idea. The Life Lamp design process developed by Estudio Guto Requena’s research is similar to the explorative aspects of many installations developed by the architectural studio Coop Himmelb(l)au through the late 1960s. Moreover, the use of heartbeat data to express or generate form appears in numerous works of Coop Himmelb(l)au such as Astro Balloon and Hard Space (del Campo, 2016).

In the case of Life Lamp, it is a unique rhizome-looking object, made of three volumetric layers and a singular shade that produces a complex image, expressing the paths and surprises of our existence. The design process is a hybrid between a top-down and a bottom-up approach where designers worked both with a generic heart geometry as a surface model, as well as former knowledge about digital design using agent-based modeling.

Thus, Life Lamp seeks to tackle visceral levels of design experience by using the shape of a heart, an image usually connected to the idea of emotion, to make the first initial bond between customers and the product. On the other hand, the behavioral level is taken into account by the multiple shadows created by the three layers of rhizomatic heart shapes, generated by the agent-based modeling.

For this, parametric and algorithmic design techniques were used to define a form generation strategy. The morphology aspects of the lamp were parametrically linked to specific heartbeat sound data collected from a group of three individuals and converted into numerical information. In this regard, the heartbeat audio file was used as a means to interpret a physiological phenomenon as the symbolic expression of a human feeling. Therefore, it was possible to materialize this interpretation of emotion creating a direct link between product and individual.

By using such personal data as design inputs, the reflective level of emotional design was carried out by strengthening the relationship between the individual and the product. It creates the possibility to evoke good memories of the participative design process. If the individuals from whom the heartbeats were collected are friends or members of the same family, it is expected that these memories will have a greater impact as it may evoke good feelings.

According to Rivka Oxman (2006), digital design is a non-standardized, non-normative, and non-repetitive approach developed primarily in the computational environment that contrasts the normative productive logic of industrial modernism. To this author, digital design challenges the productive demand for repetition or standardization (Oxman 2006). Thus, digital design proves to be an appropriate approach to develop a design strategy that seeks to create a deep emotional link materializing a product that incorporates individual and sometimes intangible affective characteristics.

Concerning a broader and more participatory process by the consumer in the creative process, David Benjamin (2012) believes that digital design, supported by the use of parameters and algorithms, has the potential to democratize design. It allows
the participation of other individuals involved during the creative decision-making process. This is possible due to the nature of digital design that seeks, with an algorithmic description of the process, to determine the relationship between different characteristics of a design. Since the characteristics of a design piece are described this way and are linked in an algorithmic process, it is possible to test several design possibilities without the need to develop a new design from scratch at each iteration. Thus, it is also possible to describe a single design process that uses data from different people and resulting in a unique product for each data received.

The ability to make design artifacts that meet individual demands at a competitive price and production time is called mass customization (Phua at al 2007; Tseng et al. 2017). In this paradigm, each customer must be considered individually, providing personalized products and services based on an agile, flexible, and integrated process of the product's life cycle (Tseng et al. 2017). Thus, in the manufacture of the “Life Lamp”, in order to personalize the product according to the individual’s characteristics, a file-to-factory fabrication process was used. Once the virtual modeling of the lamp was completed, the file was sent to a 3D printer capable of printing the product in its morphological specificities. Both design and production processes were able to collect personal characteristics from different individuals and manufacture a customized artifact without harming their production chain.

SYNTHESIS & REPRESENTATION

An existing computational method for data and information processing is the agent-based modeling (Gilbert 2007). This method is capable of integrating material organization, design tools, and contextual environments as guidelines in a bottom-up design process in which the self-organization of the processing devices generates adaptive behaviors to explore emerging and unpredictable complexities (Baharlou and Menges 2013). Used in several other scientific fields, the agents are usually taken as autonomous and adaptive elements (Baharlou 2017) that are capable of computing the environment and are used to process and synthesize several natural phenomena. They are mostly used in computational simulation of events of the physical world and are capable of representing phenomena or systems for experimentation or construction of scenarios (Gilbert 2007).

This computational method considers the adaptive interaction in a collection of several autonomous decision-making entities (Bonabeau 2002) that follow simple local rules and interact with a given environment (Gilbert 2007). The emerging collective behavior is different from the behavior of individual parts (Holland and Miller 1991), thus, the global behavior arises from a set of rules that defines the agents’ strategies in recurrently new environmental conditions (Holland 1995). Such a set of rules also defines the behavior of agents and guides decision-making processes, where agents are able to modify the previous set with new data acquired from the
environmental context, altering and devising new rules (Baharlou and Menges 2015 and Casti 1997), which promotes the occurrence of dynamic adaptations (Baharlou 2017). Therefore, a behavioral system emerges from the organization and adaptation of individual and collective behaviors, in which the agents mediate the process of form and material synthesis (Baharlou and Menges 2015).

The agent-based modeling was used as a means to process the emotional data with a form-finding digital approach over three predefined concentric heart shape geometries that were scaled up according to the different life stages of three individuals: a newborn, a 30-year-old person and a 70-year-old elder. Considering the heart rate difference among them, their heartbeat sounds were collected individually, resulting in three different audio files. The volume peaks from the audio files were extracted and converted into binary data. They were taken into the design process as input parameters of the behavioral algorithm of the agent-based system. The control of the behavioral parameters by the audio files was a design strategy that allowed variation, non-deterministic occurrences, and integration and synthesis of the sound data as a geometric representation during the form generation process.

In addition, the feature of data processing with an emergent design approach, the Agent-based method was chosen due to the similarity of the observed design applications to natural branching systems, such as the vessel system that carries blood throughout the human body.

DESIGN METHODOLOGY

BASE GEOMETRY

The lamp design was defined on top of this briefing that guided the whole development. From this framework, the aim was to somehow interconnect three different heartbeats and the three concentric heart shapes in such a way that the heartbeats would dynamically change the final output.

There were six main steps in this process, first, the geometry of three hearts were modeled using traditional form-making digital techniques. The small one with a bounding box measuring approximately 46 x 47 x 55 mm, the medium-sized one with 110 x 118 x 142 mm and a large with 146 x 157 x 187 mm, although the medium-sized heart was the only one close to the dimension of a real heart (Figure 1).

HEARTBEATS

The second step was to record three different heartbeats and then denoise the recorded .mp3 file using the software Adobe Audition to achieve a sharp heartbeat sound separated from breathing noises or, in the fetus case, all amniotic fluid noises.

AGENT-BASED SYSTEM

The next step was to deploy a generative system using the Grasshopper add-on called Culebra 2.0, inside Rhinoceros 3D modeling software environment. This system used the same algorithmic steering behaviors like the ones developed by computer scientist Craig Reynolds in the late 1980s (Reynolds 1999). The final geometry, however, used only the trail created by the agents’ paths, and not the agents themselves.

Culebra 2.0 was essential in this step as it already had many pre-configured behaviors with a user-friendly interface from which four of them were used: the “Mesh Crawl” behavior that constrained the agents to move only on the surface of the heart geometry; the “Weaving Wandering” behavior that made the agents weave around its established direction giving a weaving pattern to the resulting trail; the “Flocking” behavior which made the agents interact with each other in a similar way to how birds interact in a real flocking; the “Stigmergy” behavior that made the agents interact with the trail produced by other agents. All of those data behaviors configured Culebra 2.0’s main component “Creeper Engine”.

Apart from the steering behaviors, the setup also had a hierarchy of two groups of agents, the parent-agents and the child-agents. The parent-agents stayed the same through the whole process of design, while the child-agents spawned from the parent-agents and had a short lifespan controlled by the heartbeat sound.
INTERACTION

The interaction of the agents with the input sound of heartbeats was achieved using a speaker that emitted the recorded heartbeat sound and the Grasshopper add-on for interactive prototyping Firefly (O Payne 2013). Through Firefly’s component Sound Capture, it was possible to receive the signal of the computer microphone and directly analyze its volume. Additionally, using a simple if statement inside Grasshopper environment, the algorithm checked each time the volume was higher than an established threshold, consequently, it was possible to create a true and false boolean data type that followed the rhythm of the analyzed heartbeat (Figure 2).

When the boolean data type is set true, the algorithm sends the location of the parent-agents to a second Culebra 2.0 Creeper Engine with different values for the aforementioned behaviors, releasing child-agents from the same place where the parent-agents are located. Those child-agents, however, survive for only one complete cycle of a heartbeat. As the first group of children dies, their paths are recorded and then a new group of children spawn and so on. Consequently, the child-agents created short, secondary paths.

With the environment and behaviors defined, 57 parent-agents were released at the same location, the highest point of the smallest heart geometry. Then, the heartbeat sound of the fetus activated the spawn of child-agents.

As all the agents interacted, their behavior made them avoid proximity with each other and all formed trails, while at the same time they were gravitationally bound to the geometry. Thus, it created distinct paths on the surface of the geometry that seldomly overlapped, creating a vessel system appearance to the final design.

HUMAN-MACHINE COLLABORATION

As the parent-agents converged at the bottom of the small heart geometry, the algorithm had to be paused for the designers to change the heartbeat sound from the fetus to the adult and also the heart geometry from the small to the medium size. As a design decision, the number of parent-agents was decreasing, going from 57 to 36. This process was repeated in the next iteration, and the number of parent-agents was reduced again, now from 36 to 27. Although the parent-agents had their number reduced in each iteration, the remaining ones created seamless bridges between the heart geometries, which made it possible to have one continuous path for the whole lamp (Figure 3).
Figure 3
Trail paths diagram:
a. Spawn location;
b. Bridges connecting the small and the middle geometries;
c. Bridges connecting the medium-size and the big geometries;
d. End of agents trail paths. Section:
e. LED Lamp Support was given by Decimal [1].

**MARCHING CUBES**
The parent-agents generated 23.7 meters of trails, while the child-agents generated 30.5 meters, adding up to approximately 54.2 meters. The next design step consisted of thickening the resulting trail paths. To do so, the most appropriate method was to use a Marching Cubes algorithm by the Grasshopper add-on, Cocoon. This algorithm was initially developed to process 3D medical data such as computed tomography (CT) and magnetic resonance (MR) achieving inter-slice connectivity and generating a surface reconstruction (Lorensen and Cline 1987). This algorithm was crucial to producing a single watertight mesh geometry ready for 3D print, which was the final step of Life Lamp design.

The variation in thickness was achieved through manually inputting custom values into Cocoon, aiming to have a slender path in the small heart, and a thicker path in the biggest heart. It was also really important that the paths had a tapered shape with a smooth transition (Figure 4).

**MATERIALIZATION**
As digital tools provide us with a four-dimensional space-time blank sheet, the gap between reality and digitally constructed concepts has to be linked. Such a link is possible to be achieved using digital fabrication processes. Powerful tools capable of turning binary codes into physical spaces are bridges that bring us closer to the images that we create in our heads.

To bring Life Lamp to reality, a range of possibilities inside the digital fabrication domain was possible to be used. Starting with Fused Deposition Modeling (FDM) - a common one in digital manufacturing. However, due to its intricate geometry, too many supports would be necessary to structure its rhizomatic branches. It would demand an extra manual step into the production process to remove these structures and clean up the object, which would certainly interfere with the product viability.

On the other hand, considering a Digital Light Processing (DLP) production approach, it would be possible to print the entire piece using less support compared to the FDM process. However, some supports would still be needed to structure the object. This dependency would make the manufactur-
ing process more complicated since accessing the central layer - the one that represents the newborn heartbeat - without damaging other parts of the object would be practically impossible or too difficult to manage.

These production and viability constraints had led to the choice of the Selective Laser Sintering (SLS) process. Similar to the DLP process, in which liquid resin is cured layer by layer, this method uses a laser to cure plastic powder, layer by layer, to build its parts. As each cured solid plastic layer lies over the reminiscent powder, there is no need for support (the reminiscent powder works as a structure) and this complex rhizomatic object with its multiple strati could be produced and printed at once. Without the addition of a manual process, it was possible to give more freedom for design exploration and fabrication.

CONCLUSION
By analyzing Life Lamp design process it is possible to state that the use of novel technologies can favor the creation of emotional bonds since it is capable of bringing personal characteristics from individuals into the products. This way, by stimulating the reflexive level of the design experience process, it is possible to create a longing-last relationship between user and product by creating a sense of ownership when projecting a user's self-image on the design process.

As a product that communicates a symbolic message, Life Lamp reveals itself as a dialogical object, translating graphically parameters that every single human being presents during its lifetime. It is a draft in essence. A three-dimensional geometry based on an interpretation and symbolic representation of human emotions as numeric parameters, carefully organized to form an object/icon, which ultimately conveys a meaning. The message (the human life cycle, the complexity of its layers, and the beauty of its finitude) and the medium (the object - lamp) are merged into a single element. In this way, the lamp becomes the means of propagating this message.

Considering the reason for the object's raison d'être, which is the propagation of the message, Life lamp is an experimental design object in its initial phase. Employing parametric design and algorithm modeling techniques, it is possible in further developments to add new parameters to this to evolve this design process. As long as the design research keeps on moving into the field of human emotions discovering how to measure them (and transforming this information into input data), it will be able, to physically materialize them or, in other words, sculpt emotions. Like a genealogical tree that describes the connection among members of a family, Life Lamp may become the symbol of a family's affection.

That opens space for mass customization in the material sciences field, simply because every single human being could have their own Life Lamp, each one with its particular features, special shapes, and scars. In the digital age, mass customization means that this customized product will be produced through digital fabrication, which in turn allows the decentralization of production. The result would be a customizable product that reinforces human iden-
tity as a species and can be produced independently by each community. This experience would not have an end in itself but could become a model for further experiences on how to spread affection across emotional consciousness around society.

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Figure 5
Life Lamp on.