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MAKING – GESTURES: CONTINUOUS DESIGN THROUGH REAL TIME HUMAN MACHINE INTERACTION

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Abstract. Design is "something that we do" that is related to our unique human condition as creative individuals, so as "making" is related to how we manifest and impress that uniqueness into our surrounding environment. As designers, the way we impress our ideas into the material world is tightly connected to a 'continuous creative performance' and with concepts often missing in digital design and fabrication techniques –yet present in analog processes - such as ambiguity, improvisation and imprecision. In this paper, a model of human-machine interaction is proposed, that seeks to transcend the 'hylomorphic' model imperative in today's digital architectural design practice to a more performative and reciprocal form of computational making. By using body gestures and imbuing fabrication machines with behaviour, the research seeks to embrace the concept of 'performance and error' as promoters of creativity and cognition about the things we create, installing human as the bond of the interrelations between designing and making.

Keywords: Human machine interaction; computational making; machine learning; digital design and fabrication.

1. Introduction

The early CAD implementations during the 1960 were based upon aspirations of using computers as informed, intelligent and cognitive machines. Moreover, influenced by cybernetic theories and artificial intelligence, CAD proponents such as Nicholas Negroponte and Ivan Sutherland, intended to augment the design enterprise in terms of creativity. To do so, they sought the implementation of interactive intelligent systems as 'creative enhancers' that are able to help designers to concentrate on the creative aspects of the design process by suggesting design options and taking care of tedious tasks such as project documentation, organization and elaboration of quantity takeoffs. Nonetheless, despite the constant efforts of early CAD proponents to frame design into a representational and generic model for production, they soon found themselves in contradiction to aspects of the creative process that cannot be codified as a meta-algorithm capable of grasping designer´s intentions.

According to Sutherland (1975), the major flaw of the early interactive digital tools such as SKETCHPAD, was related to the apparent freedom delivered by the interaction between designer and machine to produce a drawing. To him, a designer should be concerned with the "evolving logic" of the design itself, instead of the structure of the drawing material (p.75). It was clear to Sutherland, and later to Negroponte and Taggart (1975) that a computational approach to design in terms of 'augmentation by automation' was difficult to implement because of the differences between the constant evolving logic of the human brain and the structured logic of the computer that demonstrated its incapability to grasp designer's intentions. In other words, the conclusion of Sutherland was that the 'creativity' part of a design happened outside the machine. Moreover, the design augmentation enterprise through technology somehow failed, orienting the use of digital tools toward areas more related to the documentation, analysis and optimization of designs establishing a clear separation between design-ideation- and representation-making.

In recent years, the issue of enhanced creativity through digital tools has re emerged. As Kolarevic (2003) asserted, "digital technologies are changing architectural practices in ways that few were able to anticipate just a decade ago"(p. 3). This optimistic perspective about the future of Architecture can be related to the aspirations of technological improvement expected by early CAD proponents. The discussion has been oriented toward the emergence, unpredictability and unlimited possibilities of digital tools in terms of algorithmic geometrical experimentation though human - computer interaction. Nonetheless, by looking at CAD-CAM models applied in today's architecture and design practice, it is possible to identify the same problems that Sutherland described in early CAD applications. These problems strengthen the dichotomy between design and execution of an idea. This dichotomy has led to a sort of disembodied design practice in which the architect is permanently performing a set of translations - from idea to 3d model to code to machine to material- that eliminates the performative aspect of improvisation in the design process. This constant translation between representation stages has provoked the emergence of three fundamental problems that are addressed in this paper. The first one is the problem of the black-boxed processes that are embedded into software and machines. Such processes might bias the design processes into more representational efforts instead of the creative/cognitive aspects of design process. From this black-box concept it is possible to identify the other two. One is related to the use of generic operations - embedded into software and hardware- to impress a specific and non-generic design idea. The final one, is related to the creative gap that occurs as a result of the use of black-boxed generic operations in the mentioned transition from design idea to the fabrication of the prototype.

One can argue that, as physical modelling, gestures, and tools are mechanisms by which designers learn and think. Therefore, this paper discusses the idea that creativity emerges in the very moment of impression of the self onto the material world as an improvised choreography between humans and objects by using body gestures neither as action nor perception, but as the unity of both. If we are to extend our creativity and enhance the design experience through the use of digital fabrication tools, we need to reformulate the way we interact with computers and fabrication machines toward continuous design strategies. It is by the development of new models and strategies that are focused on the integration between human and machine that this could be achieved. In this paper, a cybernetic approach to CAD-CAM is proposed as an alternative model designing and making 'on the go', transcending from a model of 'operation' to a model of 'interaction'.

The hypothesis is that real-time interaction between designers and fabrication machines can augment our creativity and cognition, engaging exploration, speculation, improvisation, and knowledge production about designs through the use of gestures and interactive computation. To do so, 'Making Gestures: a personal fabrication system' is introduced, to explore real-time interaction between mind, body, and tools by using body gestures and imbuing fabrication machines with artificial intelligence. The goal is to propose and interaction model, that seeks to transcend the design-making dichotomy from current CAD-CAM applications to a more reciprocal form of computational making. 'Making Gestures' is proposed as a new paradigm for the use of digital fabrication tools, integrating the designer's 'unique gestures' into the digital design and fabrication process. This paper shows the integration of different technologies that go from machine design and fabrication, to the development of customized software through the application of different gesture recognition techniques base on machine learning. By using body gestures and imbuing fabrication machines with behaviour, adaptive and learning capabilities, the goal is to present a design methodology that embraces ambiguity and the unexpected. This way, the designer can engage into more improvisational and insightful design processes to freely impress his or her uniqueness in our surrounding environment.

2. Digital design and fabrication as a creative endeavor: three problems

From the beginning of CAD, the concerns about the relationship between humans and technology in design were based upon the assumptions of a symmetrical symbiosis between man and machine. Moreover, the development of 'intelligent' tools as "creative enhancers" was an enterprise that failed because of the naive assumptions of the human mind as an 'information processing' machine and the simplistic view of human skill and expertise (Dreyfus, 1986, p.xi) that could be translated to combinatorial and discrete operations of data processing and analysis. Furthermore, it is valid to assert that current use of digital tools somehow maintain this assumption by leaving 'the human' out of important and crucial moments of the process of the physical manifestation of an idea, leaving the "tedious and time consuming tasks" such as drafting or calculating tool paths in a CAM software inside the computer as black-boxed opaque operations to the designer embedded in software.

If we consider that design is "something that we do" which is related to our unique human condition as creative individuals, one can argue that "design and making" is related to how we manifest and impress that uniqueness into our surrounding environment. Hence, its is valid to assert that after more than 50 years of CAD invention, the possibility to impress that uniqueness through the use of software and digital fabrication machines is limited. Furthermore, because the machine is the one that determines the way something will be made according to predetermined structured procedures, the actual process of making, exploring and having feedback through seeing and doing is lost. Furthermore, why should designers accept that the physical manifestation of our ideas should be processed and expressed through this black box using generic operations? Plotting a drawing, 3d printing a model, or milling a piece of wood are processes in which the software calculates the "optimal" or "average" operation to produce the physical manifestation of our ideas. Nonetheless, unlike digital processes that occur inside software, designers don't 'make' according to calculations of optimal data. The creative process is the result of a continuous circulation of ideas and actions, through the interaction between body and its senses -primarily vision and touch- tools -pen, knives, scissors and so on- and matter -clay, paper, ink, wood. To Dreyfus (1986), it is clear that computers are indispensable for some tasks due to their intrinsic characteristics where they surpass human's capabilities such as precision or exhaustion (p.250). He asserts that computers are specifically useful in CAD applications due to their capacity to compute and process large amounts of information, improving efficiency by optimizing drafting, analysis and processing of tedious optimization, analysis and representational tasks (p.xii).

Nonetheless, What if in the process of designing and making a prototype the designer 'sees something else' and need to reformulate that design in real-time? How does this 'black-boxing' - which rarely happens in analog design processes - affects aspects of creativity and cognition of the design process? The design practice through technology is constrained by the imposition of an hylomorphic model by a constant imposition of predetermined ideas over matter by *"a violent assault on a material prepared 'ad-hoc' to be informed with Stereotypes"* (Flusser, 1991, p.43). Today's digital design technologies work by relying in an operation model that imposes a linearity of events to produce a specific outcome, hence, in the transition from idea to prototype, the designer is forced to pause the creation focusing on the representation of plans to express an idea, neglecting the interaction between action and perception present in continuous analog processes.

How to reconcile Design and Making through technology including the designer into more improvisational processes? How does the interaction between these antithetical worlds - the humans and machines - should happen in order to generate more insightful and creative designs? First, an understanding in the relationship between designers and digital tools must be achieved. According to Idhe (2003, p91), this relationship could be explained through the concept of "intentionality" and what he calls "middle ground" or "area of interaction" or "performance". He asserts that the only way to define or understand the relationship between humans and non-humans is through actionable situations that happen in a specific time and place.

3. From tool operation to tool interaction

In the design field, specifically in analog design processes, tools become almost invisible to us and act as mediated objects so the designer focuses in the specific action of 'making something'. Clark's (2004) interpretation about the relationship between humans and technologies according to degrees of transparency (p. 37) might be a useful perspective to understand why the three problems identified are relevant for today's design practice through technology. To Clark (2004) the difference between 'opaque' and 'transparent' technologies, relies on how well technologies fit our individual characteristics as humans (p.37). To Him, the more intricate the technology, the more opaque it is in relation to how it deviates the user from the purpose of its use. Suffice it to say that current model imperative in today's digital design practice is based on pure tool operation, neglecting the idea of real time interaction, leaving important parts of cognitive processes of design aside. Moreover, the many intricacies of digital tools (the black-box), lead the designer to engage and focus in the elaboration of plans for representation (the creative gap), that in many cases lead to rely in the software to solve a specific design problems (the generic) relegating the design experience to a initial effort later rationalized by a fixed structure.

Finally, in order to propose a model of interaction for design, we must explore real-time interaction between mind, body, and tools through a more reciprocal form of 'computational making'. It is by using body gestures and imbuing fabrication machines with behaviour, that we can establish a fluid conversation with machines, embracing ambiguity and the unexpected nature of error to engage the designer into improvisational, insightful and cognitive design processes.

4. Making Gestures: an interactive system for continuous improvisation and exploration in design

In this project, the first question to ask is, Why gestures? As it was discussed before in this paper, gestures have the capacity of embracing- beyond mental and intermediate representations- the moment of acting and perceiving. According to Flusser (1991), a gesture could be defined, as *"A movement of the body or of a tool attached with the body, for which there is no satisfactory causal explanation."* (p.3). This definition of gestures talks about how they are defined in relation to motion not only as intention -which refers to a backwards understanding process that require to decode the movement in terms of its results and the causal explanation for it - but with a meaning - which is related to a forward understanding of the unfolding processes of being in a specific moment. One can argue that gestures and the uniqueness of them as manifestation of the self are the result of a constant relationship between Action, Perception and Memory -which emerges from experience and learning. The uniqueness of every gesture can be explained by Schmidt's (1975) schema theory (figure 1) based in two concepts: *The Generalized Motor Program* (GMP) and the *Motor Schema*. While the *GMP* provides a motor pattern deposited in memory that posses different characteristics that are invariant in the desired gesture, the *Motor Schema* adjusts specific selected parameters of that motor response adapted to situational demands. Maldonato (2014) asserts that because of the relationship of these internal mechanisms, the repetition of a movement - a gesture- will never be identical (p. 61).

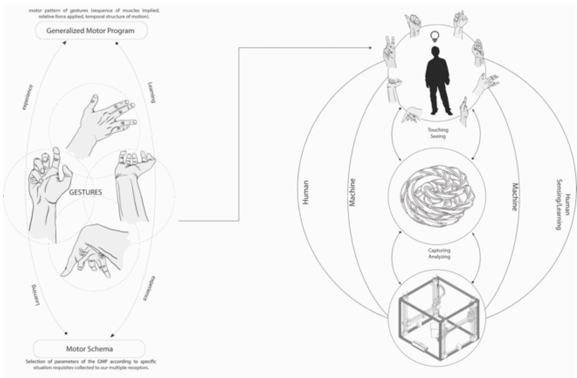

Figure 1. How action and perception works according to Schmidt's Schema theory and the Making Gestures Project diagram

Making Gestures is proposed as a specific implementation of a new paradigm for the use of digital fabrication tools integrating these 'unique gestures' as 'tool embodiment' into a cybernetic digital design and fabrication process. Specifically, the project was developed as a 5 axis hot wire cutter CNC machine that takes real time input from body gestures. By using motion tracking sensors it produces architectural designs prototypes through improvisation aided by machine learning algorithms while adapting to 'different ways of designing and making' in real-time.

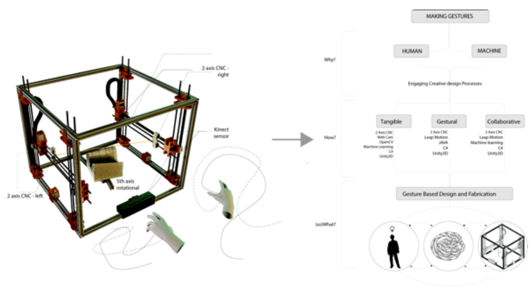

Figure 2. Hardware and Software working diagrams

On the hardware side, the machine was built using aluminum profiles and plastic 3D printed parts to integrate the 5 axis structure based on a timing belt motion system. A total of 5 NEMA 17 stepper motors connected to a *TinyG controller* board, which coordinates the motion of the 5 axes. The system was designed as a double 2 axis system - one for each hand- attached to a nichrome electrified wire. A 5th axis was implemented as a rotary base to hold the Styrofoam blocks to be cut (figure 2), adding one degree of freedom.

On the software side, the main controller was programmed using UNITY3D and C# connected through UDP protocol to the Gesture recognition software (programmed in C++) and also connected to the tiny G controller through serial communication. For the motion tracking, a Microsoft Kinect for windows connected directly to Unity 3D. In order to interact in a more fluid way with the five axes of the machine, the need of capturing a full body skeleton was crucial in the implementation of a more natural interaction with the machine in term of body postures. The interaction with the machine comprises two phases: Training and Making. In the training phase, the designer is encouraged to perform free movements to calibrate the machine in terms of speed, response and accuracy of movements. In this phase of the interaction, the designer performs the training of the symbolic gestures that the machine will perform as fixed operations such as “start motion”, “stop motion”, “go home” or perform specific fixed specific pre programmed geometric operations. (figure 3)

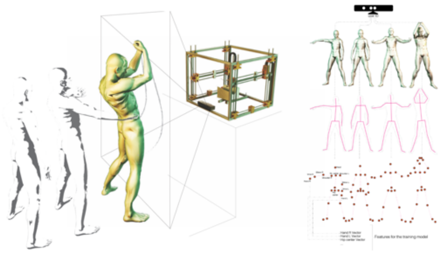

Figure 3. Training the machine and extracting motion data.

In the training phase, the software reads the skeleton model from human’s depth map data and blob detection. The skeleton model associated to a user ID, consists of several joints that have a position in space. The vector 3D data from the hands joints is used as features for the creation of the training model with the gesture recognition software. Furthermore, by repeating a specific gesture, the data extracted from the skeleton’s joints is transmitted through OSC to the Gesture recognition software (programmed in C++), which takes it as two 4 dimensional vectors adding them to a trained data file as positions related to a specific class (gesture). The data file is pre processed extracting the features applying a learning algorithm (Adaptive Naive Bayes Classifier). Finally, after the training model is created, the software is ready to perform the real time prediction phase, which in this case happens in the act of interaction with the machine by the designer. The use of auxiliary fixed movements, allows for a better integration in terms of controlling aspects of the machine that are constant in the act of performing fabrication operations such as "engaging motion" "stopping motion", "homing" or "rotate 5th axis in x degrees", or even performing pre defined geometric operations.

In the making phase, the designer is concerned with designing and making through improvisation (figure 4 left). Moreover, is in this stage of the project where the full integration between human and machine happens. Through the use of designer's gestures, the machine interprets the data and is able to determine from free improvisational and fixed auxiliary movements. The goal of the project implementation as an interactive machine, is to prove that creativity emerges in the very moment of impression of the self onto the material world as an improvised choreography between humans and objects by using body gestures neither as action nor perception, but as the unity of both (figure 4 right).

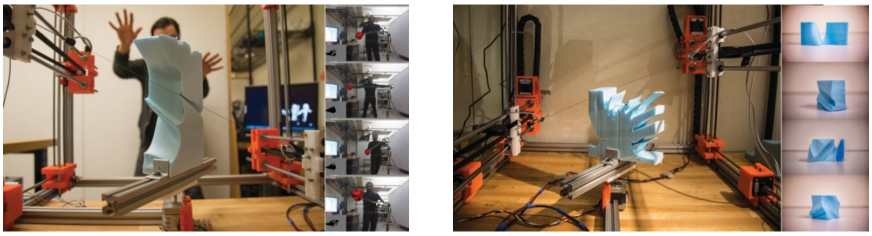

Figure 4. Different iterations and tests with users (left) and explorations results (right).

5. Conclusions

Is at this point where one can argue that by the development of gestural machines we can solve the three problems identified in the previous chapters - the black box, the creative gap and the generic. Moreover, in order to foster and promote the improvisational aspects of design as exploration, we need not only machines that emulate the movement of the designer but machines that by the use of sensors and actuators can enhance our experience by establishing a constant circulation of action and perception from both sides. Nonetheless by stating this, it's not the intention of this project to seek the development of neither 'Intelligent design machines' nor focus in solving the peculiarities and dead ends that early cad proponents found after a few years of implementing similar systems. The proposal here, is that we can take advantage of current developments on robotics, artificial intelligence, CAD and CAM in order to grasp in a computational way, the very aspects that make design a creative and original enterprise.

In the first place, by using interactive and intelligent design and fabrication machines, the problem of black-boxing can be solved. Moreover, by making tools capable of becoming transparent, the designer can focus and concentrate on the design and making in a similar way analog tools are used. A system that doesn't focus in the manipulation of intermediate artifacts to translate an intention into material but in one that participate seamlessly in a dance of agencies of designer, tools and materials was proposed. As a consequence of this seamless integration between designers and tools, the problem of the 'creative gap' could be avoided. Because the system is interactive and dynamic, capturing and performing according to the specific resistances and contingencies of participants, tools and environment, there is no gap between idea and designed object. The system eliminates the multiple translations -representations- present in digital design and fabrication processes so the designer can focus on the act of creation by seeing and doing-making in real time. Finally, the system solves the problem of the generic outcomes, by allowing the impression of the self onto our material word capturing designer's gestures and translating them as intentions in real time to the material, starting from the argument that the originality and the creativity emerge from the fact that no gesture is same as other, because of the ever-changing properties and characteristics of the participants (material, visual, psychological) of the interaction.

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