"TIME" IN ADAPTABLE ARCHITECTURE

Deployable emergency intelligent membrane

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Abstract. The term "Parametricism" widespread mainly by Patrick Schumacher (SCHUMACHER, 2008)is worthy of study. Developing the concept of Human Oriented Parametric Architecture, the need of implementing time as the lost parameter in current adaptive design techniques will be discussed. Morphogenetic processes ideas will be discussed through the principle of an adaptable membrane as a case study. A model implementing a unique Arduino[i] on the façade will control its patterns performance through an Artificial Neural Network that will understand the kind of scenario the building is in, activating a Genetic Algorithm that will optimize the insulation performance of the ETFE pillows. The system will work with a global behavior for façade pattern performance and with a local one for each pillow, giving the option of individual sun-shading control. Machine learning implementation will give the façade the possibility to learn from the efficacy of its decisions through time, eliminating the need of a general on-off behavior.

1. Introduction

A new global movement discussing the new definitions of matter, materiality and material within Architecture has arisen due to the importance Digital has acquired in those field discourses definition.

Meanwhile is worthy of study the reception, critical fortune and critical acclaim of the now ubiquitous term "Parametricism", widespread mainly by Patrik Schumacher. This term was already immediately contested when Bernard Cache was invited to publish about the obsolescence of the parametric reflected in "After Parametrics" (CACHE, 2009).

But, approaches have demonstrated to be as many as experts. It is within the architectural disciplinary debate where non-conclusive and non-allied ideas on post-humanism, matter, materiality and material are occurring, knowing that new materialism and post-humanism has demonstrated to be trans-disciplinary fields.

"Digital technologies have changed architecture—the way it is taught, practiced, managed, and regulated. But if the digital has created a "paradigm shift" for architecture, which paradigm is shifting?" (CARPO, 2011)

In that sense the idea of complex systems with intelligent components with emergent behaviours was proposed then as the base for form studies. It appears then to be a consensus about the requirements in design: continuous variation and intelligent emergence.

Post-human minds: The aesthetics of hybridization.

Being all digitally fabricated variable; this variability can be studied trough computation. This variability produced with emergent form finding methods implies new formal languages. At this point it enters the debate the idea of a natural adaptive "intelligence" with no consciousness awareness: But, should we study the nature adaptive "intelligence" processes instead of simulating artificially human mind processes? process that are the ones non related to human cells.

Human Oriented Parametricism (HOP)

Based on the study of the current implications of the Parametricism term, the current study considers *Dynamic Parametric Architecture* as an architecture which basic design inputs might vary during the building lifetime. It is defended the concept of Human Oriented Parametricism, HOP, which considers the idea of "Time" as the lost parameter in Adaptive Complex Architecture as the obvious evolution of the Parametricism idea. The current study will develop an example for this kind of design process implementation introducing the idea of buildings with morphogenetic behaviors.

2. The Emergency Health Deployable System, EmDeplo. Complex Systems. Morphogenetic Processes.

EmDeplo is a parametrically designed health system composed of an Intelligent Deployable Membrane. Morphogenesis (from the Greek *morphê* meaning "shape" and *genesis* meaning "creation") is the biological process that causes an organism to develop its shape. Artificial Intelligence is currently proposing processes based on biology as a solution for intelligent performance even in Architecture.

2.1. EMDEPLO SYSTEM DESIGN

The "body" of the system will be a multilayer deployable membrane with a factory interface customized fabrication. Its "brain" will be developed with an Arduino and its "mind" through an AI Algorithm.

Bottom-up robotics and evolutionary processes allow the existence of Artificial Intelligent Systems with quasi-intelligent behavior. That is, systems that simulate emergent and generative properties of natural processes, obtaining well-adapted and efficient forms.

Through an abstract model for the system and the presence/absence of behaviors the complex system that will configured.

3.3.1 The Emergency Customized Deployable Intelligent System.

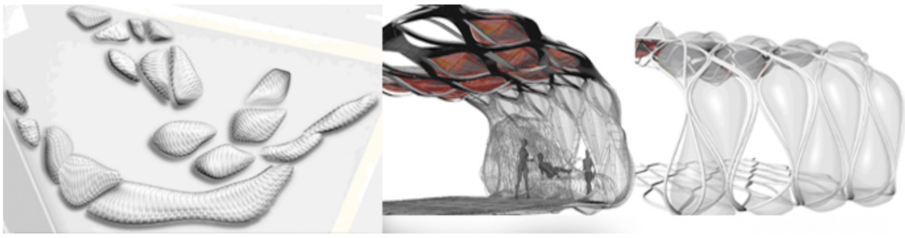

Figure 1. System deployability sample and triage sections.

WHO[ii] states that natural disaster and other unpredictable events are so common that it urges that architects to develop new kinds of high adaptable and rapidly deployable spaces for different emergency scenarios. The system proposed will be able to satisfy most medical needs in the shortest time in any scenario. (Figure 1) Deployable 3D structure from a flat surface, able to arrive directly from the factory to site, it is perfectly packed and ready for easy and quick employment. A multi-layered membrane will be designed so a 2D patterned deployable surface expands into a complete 3D space.

The factory interface[iii]

In recent decades the notion of time-based design has increased the architectural practice's interest to explore new kinds of design processes more linked to biology, philosophy and other disciplines.

When an emergency occurs, WHO will work through the interface at the factory that will fabricate the membrane system perfectly customized for the emergency scenario ready for deployment. The interface will design some compulsory parts for every particular scenario but also will offer to the client the option of some non-compulsory parts and units. This membrane customization through the interface will be the main strength of the efficiency of the Emergency Units. The clear properties of the material and some basic real controlled parameters will perform the unit, helping us to create a real transformable, transportable and customizable space.

Membrane Material System

The patterns of the different layers, controlled in four different scales, will hold all the design's weight (Figure 3|4).

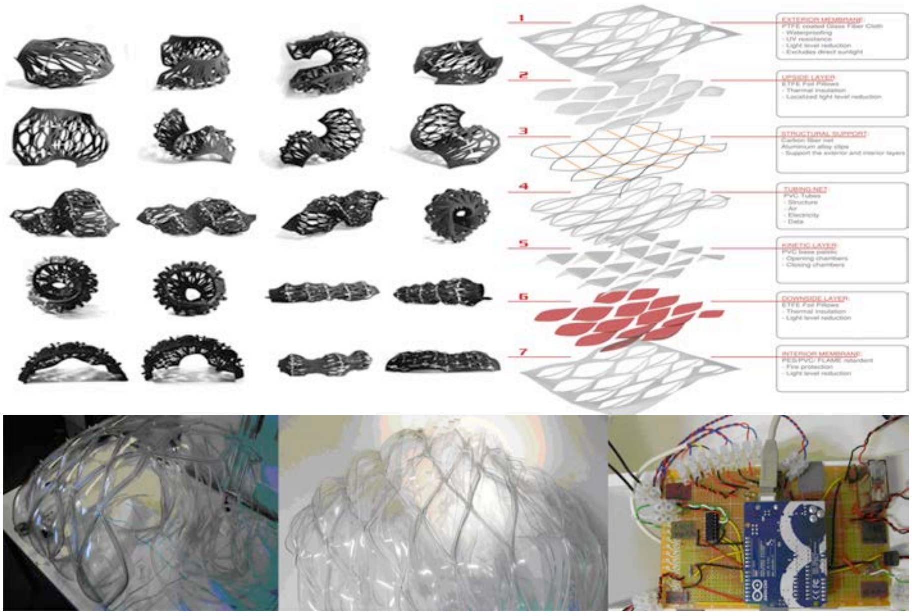

Figure 4. (a) Static models scale 1/20. (b) Circuit used for dynamic models 1/5
Figure 3. System layers and samples of performance.

3.3.2. System's mind algorithm: AI & ML Algorithms search

The Artificial Intelligence approach that will be used in the current study will be the one in which, in a continuous loop, an intelligent agent will receive data from the environment through some sensors, and will change or not its state, interacting with the environment through some actuators. It will be a perception-action circle benefiting the adaptability property of the system. AI will be studied as a method for uncertainty management and the aim will be finding actions for an agent (1).

$$\text{act} = \text{AgentFn}(\text{percept}) \tag{1}$$

Problem Solving vs. Planning

It was not considered as a valid method for developing the understanding and decisions related to the learning of the climate in which the system was in as the intention of the current study was to develop the system in a partially observable environment.

Markov Models
A Markov model will be still memory less but will provide more options in the next state to the goal calculation. In the case, Markov models were discarded, as they are not good algorithms for training memory.

Machine Learning Algorithms
Making the system learn from existing, artificial or new environmental data models will be the main goal of the system's mind.

Reinforced Learning.
Even though agent analysis has been a very effective learning technique, the idea of using EmDeplo as an agent, inside an unknown environment that has to take decisions for a goal and a reward, is clearly different to the learning process that our system must have, as the concept of reward function and goal might vary trough time during the existence of the building.

Unsupervised Learning algorithms: - Network; -k-means; - Spectral cluster.
After a study of the most common Clustering Algorithms unsupervised learning algorithms, it was concluded that unsupervised learning might not be the appropriate learning behavior for system's initial mind.

Supervised Learning algorithms: Linear Regression, Logistic Regression
Both models use Gradient Descent algorithm to find local optima. The problem with these algorithms appears when the size of the features array gets really big. The probability of over fitting increases and we will be dealing with an extraordinary number of parameters that makes this process clearly unreachable even if we are using only subsets of the training set.

Support Vector Machines (SVMs)
As non-probabilistic linear classifiers, they are a kind of algorithm that can be taken into account for the decision of EmDeplo's mind configurations. SVMs propose a much better error minimization as they are trained on the worst classified examples.

A Neural Network, on the other hand, will be likely to work well for most of these settings, but may be slower to train. Considering that real building implementation will be not developed at this stage, slow training speed was not considered a basic disadvantage. In this way an Artificial Neural Network seemed appropriate to start making the system work, not having to worry about the number of features and training set sizes.

Artificial Neural Networks (ANNs)

A Multilayer Perceptron will be able to deal with initially non-linear separable operations. In this way, inputs that were not linearly separable in the beginning became able to be mapped and classified. Therefore, loop networks with feedback and the idea of back propagation are the definitive alternative for adaptability. This kind of Machine Learning algorithm gives EmDeplo's mind the ability to distinguish between different kinds of environments and situations.

3.3.3. System's algorithm: Definition of the ANN & GA.

The process desired for the deployable system learning has to be a mixed one. It will need the power of neural processes for choosing and decision situations, and the performance of a genetic algorithm for optimizing the pillows pattern and adaptability. The combination of both sub-processes will generate a global behavior, where, since the very first day after deployment, the system will perform properly.

The system will be composed of: (a) An ANN for classifying and deciding the kind of situation we are in, which will learn through a series of labeled sets of situations for training. (Global Behavior) (b). A Genetic Algorithm optimizing the performance of the whole set of pillows creating a pattern for adaptability and improvement. Phenotype, genotype, fitness and mutation will decide and teach EmDeplo how to act in each situation. (Global Behavior) (c). An off/on behavior, for sunshade control, through the intermediate layer of a patterned ETFE Membrane not allowing the solar factor to be higher than FS 10. (Local Behavior)

Scenarios approach. Labeling Situations.

An analysis was therefore done of all the earth's climates and possible scenarios based on the three parameters that were able to be evaluated by the membrane: temperature, humidity and sunlight.

The Artificial Neural Network.

A supervised learning process will be developed consisting of learning training data based, data classified appropriately with known classifying patterns. We will consider ten different possible scenario situations for the system during its lifetime in a particular climate. These situations will be the outputs to decide and to choose by classification.

The proposed ANN, will have 100 neurons, (100 pillows), in the input layer, 150 neurons in the hidden layer, each one of these 100 neurons corresponding to the behavior and temperature of one pillow of the façade. The proposed outputs will be 10 different performances of the façade. So, depending on the output, one GA’s behavior or another will start. Testing the system with less than one hundred trainings was demonstrated unsuccessful.

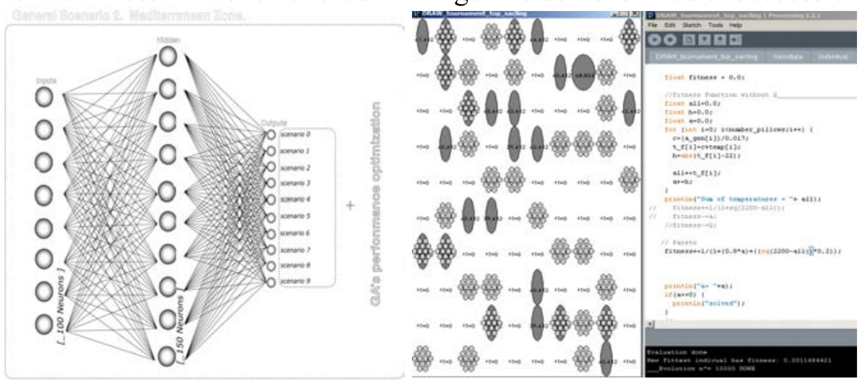

Figure 5. (a) Proposed ANN. (b) Digital model sample

The Genetic Algorithm.
Once EmDeplo has decided trough the ANN in which scenario it is located, it will generate the chromosome of the façade through an array that will be a sequence of all opening and closing possibilities for the 100 ETFE pillows. In that way, the genotype, will be an array of 100 elements that indicates the initial position of the pillows the system is starting with. The positions considered will be: closed, open or half-open.

Genes = new [100]; Genes [i]= [open/ close status] (2) (3)

Façade genotype = [c, o, c, h, c, c, h, o, c...] (4)

The general idea was to optimize the genes array of the façade for obtaining a desired temperature of 22º. Several simple fitness functions were implemented with a percentage of mutations between 0.01-0.05%.

Phenotype Definition
The thermal relationship between the pillows’ degree of openness and temperature variability was implemented as the fitness function. For the system, this environment in which our phenotype exists is the thermal relationship environment-material. After implementing the new relation genotype-phenotype, a new fitness function was included to avoid premature convergence and stagnation. This function will also be related to thermal behavior and it will be implemented in the phenotype for the pillows:

Δ Temp = (Q * thickness)/λ ; t_f[i]-temps[i] = G* genes[i]/ λ (5a) (5b)

This gene array will be the data needed to implement when the optimized result is sent to the Arduino. Starting with fitness smaller than -2000, stagnation appears with a fitness of -727 around evolution number 1000.

Selection method.

The method implemented initially was the Alasdair Tuner interpretation of the Rank Selection(TURNER, 2009). Maximum fitness obtained, -727 will try to be improved with different combinations. Roulette Wheel Selection will not be implemented due to the danger of premature convergence it generates if a clearly dominant individual exists. The implementation of the Tournament selection method improves the algorithm performance but only proved to increment fitness 0,98 %. On the other hand, when Top Scaling selection implemented, fitness decreases 1%. Tournament selection will therefore be the method used.

Multi-objective optimization. Pareto frontier

Considering necessary the optimization of two values, Q, the thermal flux, and t_f, the final temperature, a multiobjective optimization will be implemented.

Obj. A: Thermal flux min   Obj B: t_f = 22ºC   Weights Wa =0,2 Wb =0,8

Fitness function: f(x)= 1/ (1+ Wa*A + Wb*B) (5)

The results obtained in this final experiment showed a maximum fitness of 0,016. But due to the thermal properties relationship implemented,

t_f [i]= Q* genes[i]/0.017 + Temp [i] (6)

and to the constrains on the degree of opening of the pillows, and that is,

genes [i] = 0,   genes[i] = 0.5 or genes [i] = 1 (7)

That will be the maximum fitness that can be reached. Nevertheless, if we consider a free opening degree of possibilities, from thickness 0 to thickness 1, being all floats between 0 and 1 allowed as possible degrees of opening. A different code with a non-constrained genes array of opening was run. After a certain time working, the code reached the maximum fitness, a fitness of 1.

Conclusions, discussion & further research

The different façade patterns created by the learning of the system through the different scenarios and experiences, plus the local behavior for shading, optimizes the material insulation performance of the façade, maximizing material insulation properties. Even when a non-constrained opening of the pillows is allowed a maximum efficacy of the insulation properties of the façade is reached, the set of different layers proposed for the membrane configuration demonstrated not to be enough for a proper insulation and climate regulation.

A point that must be taken into account for further research must be a strict thermal calculus by proper environmental software taking into account the different curvature degrees of the pillows in each phase of the opening-closing procedures.

Considering the performance of the façade or the membrane as the performance of a set of autonomous agents improving its behaviour and adaptability in reaching their goal by practise and experience. Interpreting the possible behaviour of the system with a Q- Learning algorithm, look really a good approach for future developments. These agents, each of which, can be considered to be a pillow of the façade, can shape their behaviour according to the environmental context through the learning including a reward function. The proposed method will work in a diagram like the one proposed by Calderoni and Mancenac at the 12th Artificial Intelligent Conference in their paper *"MUTANT: A genetic learning system"*. The paper presented and demonstrated, in 1999, the efficacy of the application of Q- Learning to a similar situation that the one this thesis presented.

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[i] Arduino is an open-source electronics prototyping platform easy-to-use microcontroller.

[ii] The World Health Organization, WHO.

[iii] *Factory's Interface* is understood in this paper as the contact mechanism between the final customized physical system and the required needs for a particular emergency scenario. A factory integrated software that according to the different emergency scenarios, number of people involved or injured, will fabricate one physical system or another depending on the adequacy it considers for that particular emergency. Samples of that can be an extra foundation for strong winds, special designs for earthquake scenarios, desert special insulation layers, number of triage units or operating theatres, etc.