[Em_Deplo] Morphogenesis

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Summary: Developing the concept of Human Oriented Parametric architecture, it will be discussed the need of implementing time as the lost parameter in current design techniques. Morphogenetic processes idea will be discussed through the principle of an adaptable membrane, as the thought solution for future architecture design processes improvement. A model implementing a unique Arduino on the façade, will control the performance of the façade patterns, through, an Artificial Neural Network that will decide the kind of scenario the building is in, activating a Genetic Algorithm that will optimize insulation performance of the ETFE pillows. The final virtual model will be able to obtained the goal proposed, a homogeneous temperature in all the spaces of the building of 22ºC.

The EmDeplo System will work with a Global behaviour, pattern performance of the façade, but also with a local behaviour 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 an on-off behaviour for defending against the environment. Instead, the system will work with it, adapting to it, and evolving with its variabilities.

Keywords: *Membrane, deployable, Artificial Neural A.N.N., Machine Learning M.L., complex system, morphogenesis, adaptive.*

This research considers a clear division between <u>*Dynamic vs. Static Parametric Architecture:*</u>

Static P.A.: that obtains its form and configuration from several parameters used just to design its shape: FORMALISM

Dynamic P.A.: in which the basic inputs vary during the building life time: H.O.P.

This research defends a <u>*Human Oriented Parametricism. H.O.P.*</u>, that considers the idea of <u>*Time*</u> as the lost parameter in Adapative Complex Architecture. Understanding Architecture as a Complex System, this research develops an example for this kind of design implementation:

The Emergency Health Deployable System. EmDeplo.

EmDeplo is a parametrically based health system composed by an Intelligent Deployable Membrane. An emergency health system, complex & alive, which parameters basis are human & environmentally linked.

Complex Systems. Morphogenetic Processes

Morphogenesis (from the Greek morphê shape and genesis creation), is the biological process that causes an organism to develop its shape. Artificial Intelligence is currently proposing processes based on biology as solution for Intelligence Performance even in Architecture

Designed as a Complex System the system will work with the environment and NOT AGAINST IT. A perfect optimization of the system, with the intelligent behaviour implemented, will be able to be reached implementing the advantages of a global + local behaviour vs. the nowadays common stimulus-reaction performance

[EmDeplo System design]

The BODY: Multilayer deployable membrane + Factory interface customized fabrication

The BRAIN:Arduino chip microcontroller + circuit implementation

The MIND: AI Algorithm

Bottom-up robotics and evolutionary processes facilitates us today AI Systems as systems with quasi-intelligent behaviour that simulate emergent & generative properties of natural processes, obtaining well-adapted & efficient forms: A Complex System which is defined by more than the sum of its parts.

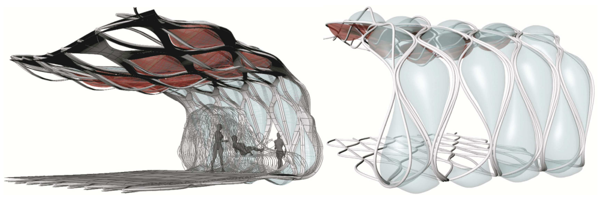
Through an abstract model for the system and the presence/absence of behaviours, the Complex system will have 2 goals in 2 different scales: Goal-state simulation (in Nature, survival) + local goals system interaction. The Complex System will be working in 2 scales, learning to survive through patterns of behavioural adaptability without external control.

The system's body, [Em_Deplo] Concept:

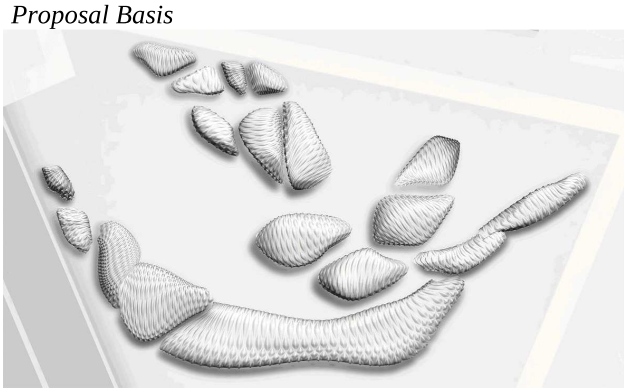
"EMERGENCY PARAMETRICALLY CUSTOMIZED DEPLOYABLE INTELLIGENT SYSTEM"

W.H.O. remarks natural disasters and other unpredictable events are so common today that urges that Architects to invent new kind of high adaptable and rapidly deployed spaces for these different Emergency scenarios. The Emergency Intermediate Health Deployable System, factory interface customized, will be able to satisfy most medical needs in the shortest time in any scenario.

Deployable 3D structure from a flat surface, able to arrive directly from the factory to site, is perfectly packed and ready for an easy and quick enablement. A Multilayered Membrane Intelligent System that will be designed through a 2D patterned deployable surface that expands into a complete 3D space. High adaptability and rapid deployment are highly requested in order to fulfill every kind of timely measures.



Proposal Basis



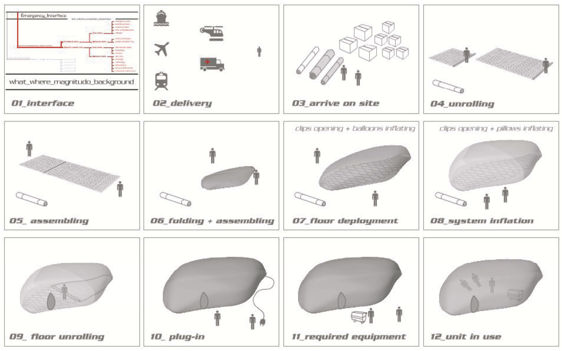
The factory interface

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 which main potential consider, a real application into contemporary process, to change the conventional architectural methods by diagramming, mapping and animation techniques.

The EMERGENCY INTERFACE will help us to decide quickly in critic situations how the Unit must be customized for any particular scenario and will carry us through the design in real time. When an emergency occurs, W.H.O. will work through the Interface. Connected to the factory , the complete fabrication process of the membrane system with be perfectly customized for the emergency scenario. The interface connected to the factory will fabricate the system, customized, folded and packed, ready for deployment by truck, plain or boat trough several containers.

The interface will design some compulsory parts for the case, already customized for the situation, but also will offer to the client the option of some non compulsory parts & units. The questions the interface proposed are those which help the customization of the system like the kind of emergency, expected number of patients, kind of diseases, etc

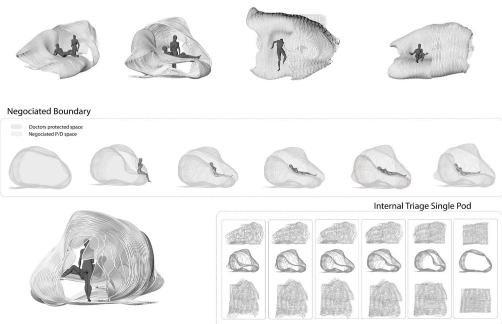
So, in the Emergency Health Deployable System, the parameters are the characteristics of the scenario and the kind of disaster. The parametric customization of the membrane system through the Interface factory connected is the basic idea of the efficiency of the Emergency Units.



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. Developing the pattern in some different scales, it will arrive to its final development.

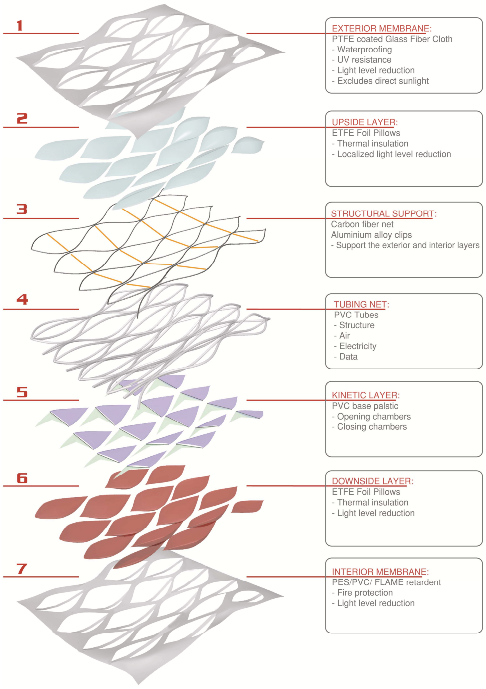
Basic Triage Pack

The triage proposed consist in a negotiated mixed space where the interaction between doctors, nurses and patients takes place only in the moments that is completely compulsory. The "sensor-ized" pod will react to the patient weight and movement making a complete adaptable cellule, but being always within the positions allowed for the doctor to the patient. Maximum number of patients will be attended with a minimum numbers of doctors and nurses.

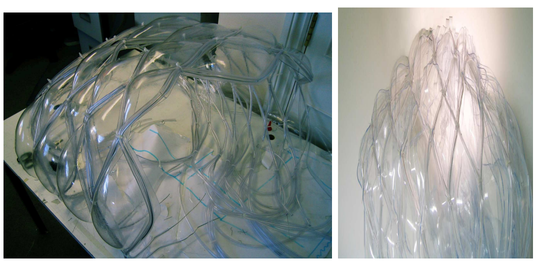


EmDeplo Material System

The patterns, controlled in four different scales will hold all the design weight. Controlling some basic parameters, it is possible to order the material how to behave, to tell the hospital what to do, considering this kind of behaviour to be the basis of the future adaptable customizable architecture.



So that the system is not only an envelope for a space, it is not a space that after you can fix with the medical equipment. It is a fully integrated system. It will be design including water, electricity and oxygen supplies as well as the necessary medical equipment. Also, the adaptable floor system will adapt to several range of different floor conditions.

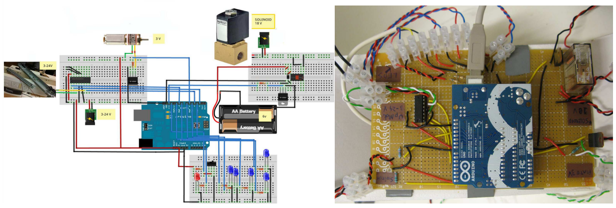


The system's mind, [Em_Deplo]'s algorithm:

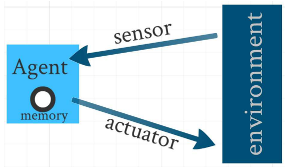
AI & MACHINE LEARNING ALGORITHMS SEARCH

The approach that will be used of AI in this research 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.

The intelligent agent in this case will be the EmDeplo material system and its brain will be configured through and Arduino chip.



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.



act = AgentFn(percept)

Basic problems of AI applicable to EmDeplo's mind design will be,

1- Micro worlds. The sum of restricted domains will never be a real environment. the systems should work in a real environment.

2- Lack of scalability. Emdeplo should be scalable.

3- Robustness. Cannot fail in a novel situation.

4- Operating in real time.

5- Bottom-up design & Embodiment

Through the search of an algorithm for the system the parameters related to which its adequacy was establihed where: *Fully Observable vs. Partially Observable Environments; Benign vs. Adversarial Environments; Deterministic vs. Stochastic systems;The actions of the system being discrete vs. a Continuous set of actions, meaning by that, infinite.*

Problem Solving vs. Planning

Problem Solving as a method, has demonstrated its efficacy with a fully observable environment and with a discrete, deterministic and known domain.So that 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 research, was to develop the system in a partially observable environment.

Markov Models

A Markov model is still memory less but provides more options in next state to the goal calculation.

States in a Markov Model can be subdivided and increased and used, in the case for example of Hidden Markov Models, in several complex applications as Robotics. Markov models were discarded as they are not a good algorithm for training memory. Nevertheless Second Order Markov Models consider a dependance not only on the previous state, but also, on the previous of the previous state, this kind of mathematical model resulted quite restricted for the learning that EmDeplo system will be suppose to be able achieve, so was discarded as a possible algorithm.

Machine Learning Algorithms

M.L. algorithms were considered a good starting point for the configuration EmDeplo's mind. Making the system learn from existing, artificial or new environmental data models,will be the main goal of the system's mind. Knowledge that will give the façade the possibility to adapt to the environment, learning from it and maximizing its efficacy.

A. Reinforced Learning.

Even though agent analysis has been a very effective learning technique, the idea of using EmDeplo as an agent, inside in 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.

B. Unsupervised Learning algorithms

- Kohonen Network; - k-means; - Spectral cluster

Unsupervised Learning consists in Clustering Algorithms which labour is to find patterns in unlabelled data. After a study of most common unsupervised learning algorithms, it was concluded that unsupervised learning might be not the appropriate learning behaviour for EmDeplo's initial brain. Nevertheless the will be considered for a future system behaviour more complex. Receiving plenty of unlabelled data from the environment, and trying to find patterns in it, for proposing new scenarios for acting, can be an extremely advance adaptability behaviour of the membrane.

C. Supervised Learning algorithms

- Linear & Logistic Regression; - ANN; - SVM.

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 is really big. The probability of over fitting increases and we will be dealing with an extraordinary number of parameters. For example for a medical prediction based in 100 parameters: x_1*= size;* x_2*= age;......; .*x_{100}*= wealth.* We will be dealing with approximately 170.000 features. That makes this process clearly unreachable even if we are using just subsets of the training set.

In this kind of situation, Linear Regression is highly not recommended.

Support Vector Machines

An alternative view of Logistic Regression are Support Vector Machines. As a non-probabilistic linear classifier, they are a kind of algorithm that can be taken into account for the decision of EmDeplo's brain configurations. SVMs proposes a much better error minimizationas they are trained on the worst classified examples, known as *support vectors.* A large margin around the decision boundary guarantees us an smaller error that in conventional Logistic Regression.

A Neural Network, on the other hand, will be likely to work well for most of these settings, but may be slower to train. According to that it results, a priori the best algorithm to try for EmDeplo's brain. Nevertheless it is considered that, for a real building implementation, the slow training speed can be a problem, but, for the development of this research this was not considered a basic disadvantage. In this way an ANN seem appropriate to start making the system working not having to be worried about number of features and training set sizes.

Artificial Neural Networks

An A.N.N. are normally adaptive to external environment learning from the data received from it. Modern neural networks are non-linear statistical data modelling tools trying to simulate the brain parallelism way of working and capability of learn by training and pattern recognition, by *feedforward* and *backpropagation*. The 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. So that loop networks with feedback and the idea of backpropagation 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.

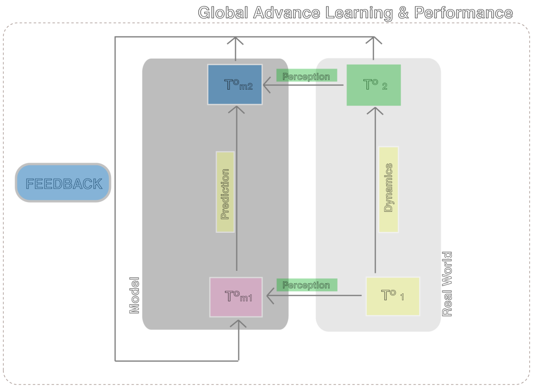
ARTIFICIAL NEURAL NETWORK & GENETIC ALGORITHM MODEL. Evolutionary computation for EmDeplo.

EmDeplo's brain has been designed as a complex system, non-divisible, and non-reducible in which, the only way to know its real behaviour, is to run the system as a whole. The process is proposed in 3 steps:

1. *To define the way of performing once the decision about what climate we are in is taken.*
2. *To be able to recognise after training and learning in which situation of Tº, radiation and sun-shade we are in.*

3. To define the dynamic process of the membrane once the training has been done and the decision about in which Tº/sun-shade situation we are currently in.

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 deciding 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 behaviour, where, since the very first day after deployment, the system will perform properly.



The system will be composed by:

- An *ANN* for classifying and deciding the kind of situation we are in, that will learn through a series of labelled set of situations for training. (GLOBAL BEHAVIOUR.)

-A *Genetic Algorithm* that will optimize 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 BEHAVIOUR.)

-An off/on behaviour (LOCAL BEHAVIOUR) Sun shading through the intermediate layer of a patterned ETFE Membrane, can be decided as a stimulus-reaction response depending on the light meters readings,not allowing the solar factor be higher than FS 10.

Scenarios approach. Labelling Situations.

One of the main aims of the implementation of Emergency Deployable in natural disasters will be its customization and adaptation to the different situations.The customization to the different emergencies is based on different performances and designs.

- The design customization will be done through the interface used for factory fabrication.

- The performance customization will be done at site though the internal environmental control.

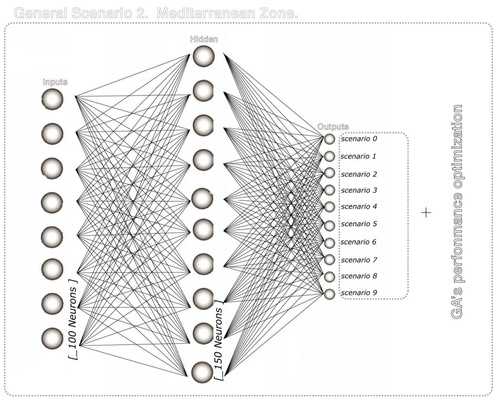
The first idea of the learning behaviour was, to make the membrane able to decide in which scenario it was, not speaking about kind of disaster but about kind of weather and environment. So that, it was done an analysis of all the earth climate possible scenarios, study based on the 3 parameters that were able to be evaluated by the membrane: temperature, humidity and sunlight.

EmDeplo's Artificial Nerural Network.

ANN can learn association between patterns so, it will be used as a tool for making the membrane understand the situation through different patterns of temperatures and data recorded by the sensors.

We will work with a sample of 100 pillows and developing a supervised learning process consisting on a learning based on training data, classified appropriate with classifying known patterns.

We will consider 10 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 A.N.N. will have 100 neurons in the Input layer, 150 neurons in the hidden layer, corresponding, each one of these 100 neurons to the behaviour and temperature of one pillow of the façade. The proposed outputs will be 10 different performances of the façade, optimized for the G.A.s previously run. So, depending on the output, one behaviour or other will start.

The decided testing time, checking the input temperatures pattern will be each 30 minutes. Period during which, the A.N.N. will re-decide again in which scenario it is in , and, will re-apply the G.A. Then, in case some pattern of opening and close pillows is found to be more efficient than the current one, the façade will be readjusted. Once a minimum amount of training has been done, we can test the learning of our system, testing the system with less that 100 trainings was demonstrated unsuccessful.

Emdeplo`s Genetic Algorithm.

Once we have decided trough the A.N.N. in which scenario the system is in, 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 our genotype will be an array of 100 elements that indicates the initial position of the pillows we are starting with. The positions considered will be closed, open or half-open.

Genes = new [100];

Genes [i]= [open/ close status]

Façade genotype = [c, o, c, h, c, c, h, o, c...]

The general idea was to optimize the genes [ ] of the façade for obtaining a desired temperature of 22º. Several simple fitness functions were implemented, based on the idea of obtaining an ideal temperature for each pillow of the façade. The trials were done with percentage of mutations between a 0.01-0.05%, basically: *Probability of mutation = 1/chromosome length.*

Phenotype Definition

The thermal relationship between the degree of openness of the pillows and the temperature variability was implemented as the fitness function in the algorithm. In EmDeplo, this environment in which our phenotype exists is the thermal relationship environment-material. Once implemented the new relation genotype-phenotype, a new fitness function should be included to avoid premature convergence and stagnation. This function will be also related with the thermal behaviour: *Δ Temperature = (Q * thickness)/λ* It will be implemented in the phenotype for each of the 100 pillows:*t_f[i]-temperatures[i] = G* genes[i]/ λ* (Being genes[i], the thickness of that pillow). T_f[ ]are the final temperatures and Temperatures[ ], are the input temperatures at the beginning of the optimization performance. This genes array will be the data needed to implement when the optimized the result is sent to the Arduino. Possible configurations of different temperatures and spaces will be able to be programmed in the future. Also, it can be considered that different solar factors can be needed depending on use and timing.

Starting with a fitness smaller than -2000 stagnation appears with a fitness of -727 around evolution number 1000.

Selection method.

Trying to improve the genetic algorithm performance it was carried out the study of the implementation of different selection methods. The method implemented initially, was the Alasdair Tuner [1] interpretation of the *Rank Selection.* Maximum fitness obtained, -727 will try to be improved with different combination of selection methods and variations of the current fitness function.

The Roulette Wheel Selection, will not be implemented due to the danger of premature convergence it generates if it exists a clearly dominant individual. The methods considered will be , *Top Scaling* and, as a second option, *Tournament selection*. The implementation of Tournament selection method improves the algorithm performance. With the experiment finished it only proved to increment the fitness an 0,98 %. On the other hand, when *Top Scaling* selection was implemented, the fitness decreases a 1%, due to the variance decrease that it uses to produce. *Tournament selection* will be finally the method used.

Multi-objective optimization. Pareto frontier..

As the fitness function should improve after choosing the more effective selection method, a serial of extra experiments of its definition will be done. The first step will be to implement Pareto frontier. Considering necessary the optimization of two values, Q, the thermal flux, and t_f, the final temperature, it will be implemented a multiobjective optimization.

Obj. A: Thermal flux minimum Obj B: t_f = 22ºC

Relative Weights: Wa, Wb, Wa =0,2 Wb =0,8

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

The results obtained in this final experiment showed a maximum fitness of 0,016, optimizing the maximum insulation properties of the material and ETFE pillows. An homogeneous controlled decrease of temperatures has taken place in all the façade as desired in the inputs of the programme.But due to the thermal properties realationship implemented,

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

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

genes [i] = 0, genes[i] = 0.5 or genes [i] = 1

this is the maximum fitness that can be reached. Nevertheless, If we consider a free opening degree of possibilities, from thickness 0 to thickness 1, so, *genes[i]=random (0,1),* being all floats between 0 and 1 allowed as possible degrees of opening, maximun fittness will be achieved.

After implementing the thermal relationship of the material in the façade performance, a complete process through the ANN and the GA, is carried out for each scenario possible and, particularly focused on the one chosen by the ANN, obtaining, a much more efficient thermal performance.

The different façade patterns created by the learning of the system through the different scenarios and experience , plus the local behaviour for shading, is more effective nevertheless when a non-constrained opening of the pillows is allowed.

[1] Turner, A., (2009). Ann in open processing. Retrieved 20 July 2011.