KINE[SIS]TEM'17

A methodological process for a Nature-Based Design

Maria João de Oliveira[1], Vasco Moreira Rato[2], Carla Leitão[3]
[1] Instituto Universitário de Lisboa (ISCTE-IUL), Dinâmia'Cet-IUL, Lisboa, Portugal [2] Instituto Universitário de Lisboa (ISCTE-IUL), ISTAR-IUL, Lisboa, Portugal
[3] Rensselaer Polytechnic Institute, Troy, NY
[1,2] {mjoao.oliveira|vasco.rato}@iscte-iul.pt [3] leitac@rpi.edu

Architecture is the mediator between the Environment and Humans. Nature maximal performance and minimal resources creations are Humanity inspiration that led us to exceed structural, material, mechanisms, tools, systems and methods boundaries (Oxman, 2010).Nature are the Architect of the most reliable and sustainable systems. Looking into Nature's lessons, this paper presents a Nature-based design methodology conducted during Kine[SIS]tem'17 Shading Systems International Summer School, held by the ISCTE-Instituto Universitário de Lisboa, Portugal, between 19th - 30th June 2017. The methodology encompasses two main stages, one before and other during the Summer School. From a pre-definition of context constrains, a nature based design strategy, to a planning of the manufacture and construction still during the phase of development of the design, conducted the Summer School participants through a defined biomimetic process that achieved the construction of 1:1 scale prototype.

Keywords: *Kinesis, Shading, System, Nature-based design*

BACKGROUND

Architecture could be no more static. Our environmental context, our social responsibility and our true natur(al)e condition as Humans are conducting us to (re)new building mutable capacities, dynamic and automatic response, to internal and external environments and to different patterns of use. Our constructions are now seen as bridges to transform needs or use sustainable resources between Humans and the surrounding environment. These bridges could filter the solar radiation, change the air temperature, storage the solar heat transforming it into light energy, among many other functions. These ideas speculate and inquire on reciprocal relationships between users, spaces and environment. This means that the three before mentioned factors have direct consequences on each other, affecting reactions, sensations, configuration and behavior. (Kolarevic, 2014). In the realms of fiction and science fiction, several examples compel the imagination on this topic. In 1962 James Ballard, a British novelist, described a 'psychotropic house' a mood sensitive house that responds and learns from its occupants, made of a new material called 'plastex' - a combination of plaster and latex - that enables the house to change its configuration and form. Addressed with sensor cells, the 'psychotropic house' could interpret its occupant's mood and position, in a way that could change its configuration and environment, fulfilling the needs of the users. In the same decade, in interdisciplinary and design fields, Gordon Pask starts setting the foundations for interactive environments through the 'Conversation Theory' cybernetics concept, which integrates processes in electronic, mechanical, and biological systems. 'Conversation theory' proposed human-machine interaction as a form of conversation - a dynamic process, in which the participants learn about each other. Influenced by Pask's cybernetic principles, Cedric Price worked on the 'anticipatory architecture' of the "Fun Palace", an unbuilt 1962 design project for a flexible, open-plan structure integrating space, media, change in time, and collective virtual elements of decision making, into one structure. Later in 1975 Negroponte started working on 'architecture machines', incorporating computational analytical and synthetic processes into buildings, developing several novel concepts such as evolutionary mechanisms and augmented and assisted reality. In 1987, Jean Nouvel had completed the Institute du Monde Arabe in Paris, building the first large scale building with an adaptive envelope (From Natur(e) to Architectural Matter, 2017). In *Flexible: Architecture that respondes to change*, Robert Kronenburg, argues that for a building to be flexible, "it must be capable of: Adaptation - responding to several functions, uses and requirements; Transformation - being capable of alterations of shape, volume, form and appearance; Movability and Interaction - internal and external to the building. This Flexible capacity is induced by environmental factors" (Kronenburg, 2007).

INTRODUCTION

Having Nature has a starting point, Kine[SIS]tem'17 Shading Systems (SIS'17) was the first International Summer School held in Portugal, that aimed sharing and debating research and develop design work related to the integration of biomimetic design processes applied to the scale, function and aesthetics architecture. Kine[SIS]tem was divided into two different moments: two days of conferences with four sessions leaded by internationally guest keynote speakers - Alberto Estévez (ESARQ, Barcelona), Alex Haw (Atmosstudio, London), Bob Sheil (Bartlett School of Architecture, London) and Manuel Kretzer (Braunschweig University of Art), and eight days of design studio, that have integrated four fundamental masterclasses - Sustainability and solar radiation, Nature-based parametric patterns, Essay and simulation by Ladybug and Digital fabrication, mechanics and electronics. Kine[SIS]tem'17 was hosted by ISCTE - Instituto Universitário de Lisboa, 19th-30th June, 2017. SIS'17 International Summer School methodology and scientific strategy were defined in two main stages, (1) Creation and analysis of a context - choice of place of intervention, observation of the local inhabitants and they type of space occupancy, local environmental analysis and diagnose of solar radiation, design, fabrication and construction of a base structure of intervention for the SIS'17 participants. This stage was conducted by the tutor's team before the SIS'17 event; (2) Design studio - creation, development and analysis of three nature-based passive low-cost shading system solutions, fabrication and assembly of the solutions by the SIS'17 participants, during the SIS'17 event.The goal of SIS'17 International Summer School, was to develop passive low-cost shading system solutions for a pre-defined and constructed structure.

SIS'17 METHODOLOGY

Stage 1 - Creation and analysis of a context (before the SIS'17 International Summer School)

The local of intervention choice was related with the architectural characteristics of the ISCTE-IUL campus. A solar challenge was needed, as well as frequent inhabitant's usage. And so, a second level 100m2 terrace, informed by two white seven level façades coated by lioz marble, where students only occupy the terrace margins due to the discomfort caused by the excess of heat and incident solar radiation, was the elected location. In order to provide shelter and shading comfort in the middle of the terrace to its inhabitant's, a canopy (Figure 1) was projected as the base structure for the SIS'17. Using Ladybug, an open source environmental plugin for Grasshopper, the first step that lead us to the canopy design were a wind-rose diagram and a sun-path analysis of the terrace. Context scenario influence also irradiance, reflection and refraction results. With this first analysis, implantation and design decisions were taken, occupancy and pedestrian patterns and wind were also considered and analyzed through diagrams and graphics. The design of the canopy was loaded with three concepts. The canopy needed to be material sustainable, reusable and low-cost. The elected material was Coretech (thermal and acoustic panels, made from the by-product recycling of the automotive industry), sponsored and off course, limited to sixteen boards 2200X1200X16mm. Beyond limits of material, we assumed that the canopy would be constructed without the use of other materials - screws, glue or others - and so de canopy was all assembled with its own material. A connection and self-support system was conceived, designed, planed, and fabricate. The designed canopy, was constituted by four triangular frames and a bench. The triangular frames and the bench were autonomous modules, that were pre-assembled, and after transported to the ISCTE-IUL terrace. Once in the terrace, the triangular frames and the bench were connected to each other through his locking and sealing system. The canopy was positioned in the terrace with one frame facing West, two frames facing South/Southwest and the last one on the horizontal plane.

Stage 2 - Design studio (during the SIS'17 International Summer School)

The second stage, was based on Lisbon and ISCTE-IUL terrace site specific conditions, the canopy location, implantation, design and its surrounding constrains and function. Participants had access to the environmental analysis essays and canopy model, in order to informed them of all the pre-determined constrains. Divided in three groups, participants were encouraged to subdivide the presented problem - structural constrains, material availability, nature inspiration, its relevance and major input for the system, and then focus in only one problem - shading effects, system performance, system responsiveness to its environment and/or its inhabitants, human comfort, etc. During this process some data bases were presented so they could find some possible solutions, examples and strategies - Biomimicry 3.8, AskNature, Diffen, among others. The design process was supported by environmental analysis, allowing the diagnosis and improvement of the solution. Considering the construction of physical prototypes, questions related to assemblage, support, planning parts for fabrication, mechanics, electronic, among others, emerged in an early stage during design process, shaping the design and also the system performance.

Figure 1
Kine[SIS]tem'17
canopy skeleton

THE PROJECTS

Mechanical Leaves

From the main structure canopy weather and environmental ladybug analysis, the rooftop module of the canopy was the one that was diagnose with the less necessity of shading. The ladybug radiation and sun path first analysis revealed that for the triangular surface, the South/Southwest edge, if totally exposed was the one that could induce some sensation of discomfort to the canopy inhabitant. Considering, from the previous analysis, that a partial shading would not induce any improvements to the system, the idea for this canopy surface, was to design an autonomous shading system that enable full exposure or total blackout, according with sun exposure intensity. The decision of closure and opening were meant to be decided by the canopy inhabitants.Based on the Palm trees leaves, this project finds its basis on the interactive movement that occurs between the natural leaves by overlap. In nature, these movements occur during the leaf growth and during the leaf exposure to sun and wind. A reinterpretation of their natural movement and a mechanical design conducted to the Mechanical Leaves system solution. The Mechanical Leaves system was composed by two symmetrical groups of leaves, composed by five blades (leaves) each. Those groups were attached to opposite faces of the canopy substructure, and the first blade of each fan was static. These static blades were positioned to the South/Southwest edge of the system, preventing the canopy inhabitants of any type of solar radiation. The material choice, intended to prevent flexibility and improve the sliding ability of the blades. A red wood fibre with eight millimeters thickness was chosen for the system of the symmetrical fans. How can we do a symmetrical double fan system with only one linear motor? The challenge was all about how to draw the mechanical system. How could we produce a closed circuit that could produce a symmetrical movement in two independent fans? Most animals have bilateral symmetry. Peacock took the sexual selection theory to an extreme level, developing a too heavy tail for its body proportions, only with the goal of increase its chances of mating. The tail produces and up movement, followed by a symmetrical fan movement. Butterflies wings are another classic nature symmetry example. When Butterflies fold their wings upward, they are perfect matches in size, shape as well as patterns. On both previous examples the movement of the elements begins on a center axis of the animal and moves to on near 90º angle. To introduce the idea of overlap on the system, we pick the *Lemniscata* (Latin for a geometric curve in eight - also known as the infinity symbol). The symmetrical element that only needs one input direction movement, and on the same path distributed it in two directions. The parametric model was essayed, in a way that could provide us info related with the physical constrains of the two blade systems, helping us to prevent eventually crashes between the elements and the preexisting structure. A ladybug analysis revealed a neutral condition for the canopy structure, being the inhabitant the determining element in the movement of the Mechanical leaves.

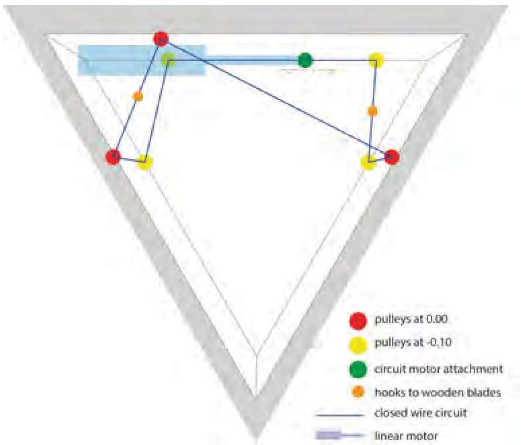

Figure 2
Mechanical Leaves – Movement circuit diagram.

The construction of a 1:1 mock up model was necessary to calculate the strength and the material resistance, as well as the assembly constrains between the blades, between the fan and the structure. The system was developed using a single linear motor, and a *Lamniscata* pulleys circuit (Figure 2). A continuous lashing wire rope closed circuit, was attached to the motor and to the first blade of each fan. The blades, fibre wood were cut by CNC machine, and were assemble/connected to each other's by cotton rope - providing softness to the closure movement of the fan and preventing rope relaxion, keeping no more than the necessary and calculated gap between the blades, for them to slide over each other. A power supply was used to provide electric energy to the system as well as a switcher was attached to the structure to provide the canopy occupants the open and closure option of the rooftop canopy.

The Lotus Project

Ladybug environmental analysis, diagnose the West module of the canopy with a prior necessity of protection against wind and sun exposure. The ladybug radiation and sun path analysis revealed that the south edge of the surface needed to have larger areas of sun entrance, and the north corner of the surface needed to be more protect and so, opening need to be less and smaller.The idea was to develop a system that enable sun exposure through the façade, allowing the possibility to block intensive wind. So, the intended essence for this system, it's the possibility of block its openings that have rhythm and autonomous dynamics created between the system and its surrounding environment. This project finds its basis on the life cycle of the lotus flower. Associated to several meanings, such rebirth and purity, lotus flower lives on a daily cycle marked by two events - the lotus retraction into the water at the night, and its emergence in the sun the next day. The idealize system must allow an autonomous cycle to the canopy, enabling it to have its own rhythm, but also providing its inhabitants the ability to interrupt that cycle in order to improve its occupancy comfort. The Lotus Flower Project, produce several openings on the West canopy surface. These openings all had different sizes and proximity relations, according with the sun and wind analysis. To provide an internal order and dynamic to the shading system, all the openings were filled by smaller turning elements. These turning objects produces filtered sun effects inside the canopy and had the ability to filter the direct wind. Considering that this was the most volatile façade of the canopy, in terms of temperature fluctuation, expanded agglomerated cork was the primary material to be consider for this shading system (Figure 3). But agglomerated cork it's a light material, with no structural skills. So, to thirty millimeters agglomerated cork, an eight-millimeter offset grey fibre boar was added. This double skin enables us to hide the blocking system and to hold the metallic axis of the spin elements. The blocking systems were design as Y elements, giving the possibility to lock the three spin elements on the radius of the Y axis. They were positioned between the cork and the fibre wood. A left-right turn bottom enables the inhabitant of the canopy to lock and unlock the spin elements and so interrupt the 'natural' spin system. So the main focus was to conceive a passive dynamical shading system, engaging form, material and environmental conditions, enabling users to interact and intersect the natural behavior of the system without breaking it. *Codariocalyx motorius* known as the telegraph plant. Each leaf is equipped with a hinge that permits it to be moved to receive more sunlight. To optimize its movement, each large leaf has two small leaflets at its base. These move constantly along an elliptical path, sampling the intensity of sunlight, and directing the large leaf to the area of most intensity. Another hypothesis has been offered that the rapid movements are intended to deter potential predators. *Nelumbo nucifera*, known by Lotus flower (aquatic specie) and *Ipomoea nil*, also known as Morning Glory Flower both daily perform to expose their petals to the sun and closes them at sunset. Their routine could only be broken by an external event or a third element. After the environmental analysis and diagnose, it was important to analyses and evaluate what were the sizes and proportions of the subtracted openings on the shading façade and their relationship with the spin elements. The proportion of the openings were determined by the graphic analysis of the radiation and wind canopy impact and human hand reference. The spin elements establish the trilogy relationship between light, void and surface of the system. These elements were proportional to its corresponding opening. The void space between the spin element and the corresponding opening, range between the 25% and the 99% depending of the angle position of the spin element.Both cork and fibre wood panels were cut by CNC machine. The spinning elements were attach to metallic axis that were placed between the two panels in a way that the spin element was 'fluting' on the void opening. To sustain the axis a three-millimeter engraving were made on the fibre wood surface. The 'blockers' were Y-shaped MDF elements that had the ability to turn 60º and when not needed were completely hidden between the panels. The 'mechanism' was very simple, the Y was attached to a cylinder that served as an axis for the rotation movement and for the user interaction.

Figure 3
The Lotus Project – assembly stage (photography by João Sousa).

Bioshading - A Performative Mockup

Facing Southeast, South and Southwest sun light exposure, the two triangular modules attributed to this group, had the most extreme levels of radiation. From the initial analysis, the major sun incidence of radiation crosses the southwestern panel of the canopy. However, ladybug analysis also reveals that the passage of some controlled radiation from the modules could benefit for its afternoon inhabitants, increasing its comfort values. Revealing to be the most critical and determinant area of the canopy structure, it was necessary to consider far from only form - movement and material. So, the idea was to develop a system that was capable to produce a relatively fast open and close movement, and yet enabling always a filtered light through the system. The system its autonomous, driven by wind. However, it's a mechanical system that enables inhabitants to interact with it, through the possibility of inducing velocity to the system. In nature one of the most flash open/close happening it's the eyes movement. Particularly amphibious eyes, open/close a geometric membrane, producing a retracting moment. To produce an open/close movement, and create a prominent/retraction moment, a tridimensional structure was designed. Based on triangular modules, these eyes were composed by two not complete pyramids and attached by two common edges that establish a structural rotation axe. The rotation movement produce a fast change of state of the system: a closed and pyramidic shape or an open diamond frame. The system needed to cover two modules of the canopy, and yet work somehow individually at different levels and in different panels. The idea was to introduce hierarchy to the system by regulating the area of voids in the panels, using the intensity of shade and radiation as a proportion measure.The group projected a tridimensional passive shading system, completely autonomous in its behavior, that increases the canopy inhabitants comfort. The natural movement of the system enables inhabitant's participation, as a momentary intervention in its natural cycle, and regulate it finding its natural rhythm, in a matter of short period of time. Considering nature references, different pupil shapes seem to be an adaptation to different activity patterns during a day. The eyes of most terrestrial vertebrates have slit-shaped pupils. Pupil plays the key role as the adjustable opening that controls the intensity of light allowed to enter your eye just like the aperture on a camera. Human pupils dilate to allow more light in and contract to allow less light in. Canines, felines, (some) snakes, geckos and some birds have vertical slit pupils, and in common they all are nocturnal predators. Other species like some frogs, octopi and humans have horizontal slit pupils. Predators eyes on the sides of their head with lateral they get and extremely wide field of view, nearing 360º degrees. The two-module façade faced sun exposures between 110º to 230º degrees. Panel openings cover 75% to 85% of the area. However, the shading system openings, by each unit enables a conditioned solar rays passage between 50% to 20% of its total area. These low percentages of direct exposure enable to manage a fulltime controlled and filtered system. It was also very important to establish the relation of progression of the panel openings. Starting from the ladybug analysis, crossing it with a triangular grid it was possible to design a progressive hierarchic grid structure. By integrating these solution into the canopy structure, the shade benefit control increases between 2° to 3° celsius degrees, which translates in an 20% to 25% of comfort improvement. Each shading panel was composed by two MDF parallel boards. Aligned inside the main skeleton structure. Panels openings follow a bottom-up direction, from bigger to minor area, respecting the evaluation of proportion between the several elements and conditions. For the cut and subtraction of the openings we used the CNC machine. The 'eyes' were transformed into plan sheets and cut with laser cutter. The 'eyes' were equally proportional aligned in horizontal lines by threaded rods, defining a simultaneous rotational movement per line (Figure 4). These threaded rods worked between the two panels, sustained by a wood pulleys net. The eyes were produced in a translucent colored polypropylene, attached to the threaded rods with bolts and nuts. These primitive bolts and nuts system help us also to fixed determine space between the eyes, as well to constrain the final geometry.

Figure 4
BioShading Mockup Prototype – assembly stage (photography by Filipa Osório).

COMBINE - MECHANICAL LEAVES, THE LOTUS PROJECT AND BIOSHADING

The combination of Mechanical Leaves, The Lotus Project with Bioshading, occurred in a very natural way. All project started from an initial environmental and local weather analysis. Thus, from the diagnosis of the ladybug we can extract that from its West side, the canopy was mostly exposed to strong winds and intense rays of late afternoon sun; the canopy South/-Southwest façade was exposed to strong solar radiation, making it necessary to control and mediate the entrance of light, regulating the shade, and improving the interior comfort of the canopy. Being passive systems, human intervention was a common ingredient that the three groups considered essential. The three systems are open to human intervention and interaction, assuming it in different degrees of relevance in the well-functioning of the systems. Mechanical leaves let inhabitants to determine its state - open or close; Lotus Project it constituted by an autonomous system, that could be blocked - closed by the canopy inhabitant's intervention; while Bioshading accept inhabitant's intervention by enabling time limited blocks or system acceleration but yet, when inhabitants stop interacting, the system, reorganizes itself, returning to its natural dialogue with environment.

INSIGHTS

KINE[SIS]TEM'17 challenge was overcome. The canopy was in its whole efficient.The three developed shading systems solutions revealed to be up to each specific challenge, designing strategies that driven into valid solutions. Mechanical Leaves, the less site/position constrained element of the structure lead into a mechanical passive strategy approach. Lotus faced the thermal dynamic issues using manual mechanisms and engines. Bioshading, conceive a system completely integrated in its formal essence - growing form, structure and material as a cyclic consequence. A brief SWOT (Forces, Weaknesses, Opportunities and Threats) analysis of the projects is presented in Table 1.

CONCLUSIONS

During SIS'17 we have analyzed and put to the test the way that nature could inspire design. For that we prepare a gauge that encompasses the climate analysis, how to interpreter and (re)design a natu-

	Mechanical Leaves	The Lotus Project	BioShading
Was there any conditioning by the context premises: 1. local solar geometry and orientation 2. pre-defined canopy	1. This project was designed for the horizontal surface which was the one that had the less impact in the solar radiation incident inside the pre-established canopy; therefore, this was the design that had more freedom in dealing with solar angles. 2. This design had to be installed at the top of the pre-established canopy. Therefore, a special care had to be taken about the weight of the system.	1. The system was designed to be applied in the West-faced panel of the canopy. In this way, the guiding geometry for each shading element had to be in the vertical direction. 2. The triangular geometry of the canopy conditioned the size of the shading elements that decreased towards the South edge of this panel to assure the adequate shading levels inside the canopy.	1. This group reached a final design for the shading elements that was not conditioned by local solar geometry, which is one of the interesting aspects of this project. The rotation based on a horizontal axis allows for effective functional performance in different latitudes. 2. The triangular geometry of the canopy' panels conditioned the parallelogram shape of the shading elements.
How it was conditioned by the fabrication premise (materials, processes, assembly)	In this case, the most important challenge was related to the idealization of the mechanical system itself, rather than to the fabrication process. However, in order to have operable parts in a mirrored system, the selected materials had to assure mechanical strength, adding extra weight.	The need to optimize material usage conditioned the geometry of the rotational shading elements. These had only variation of size within the same shape.	The volumetric geometry of the rotational shading elements required foldable materials in order to considerably reduce the number of joints. Therefore, this system had to use four different materials, adding extra complexity to the fabrication and installation process.
Weaknesses	The self-weight of the system was to high. Besides the fabricated coloured MDF leaves, the mechanical parts of the system added considerable weight.	The morphology that was defined for the shading elements, together with the need to assure operability so that the system was dynamic (shading, non-shading), prevented the possibility of a complete blockage of the solar radiation.	In each horizontal row, the respective shading elements rotate on the same axis. Because of this, the dynamic rotation was hampered and not always functional by the wind force.
Strengths	This was the most successful design from the biomimetics perspective because it emulates the dynamic superimpose effect of palm trees. Autonomous system, working with a PV panel energy supply.	The fact that the system does not allow a complete sun block creates interesting light patterns inside the canopy as a result of the wind-induced movement of each shading element.	This was the only project that was able to comply with all the established objectives.

Table 1
Diagnosis and analysis of the projects.

Figure 5
KINE[SIS]TEM'17
Shading System
Final Prototype
(photography by
Vasco Costa).

ral element or mechanism, how to analyze environment and inhabitants comfort and finally how could we materialize, fabricate, build and develop these solutions. Pre-SIS'17 stage reveal to be essential, not only because of the time consuming of this preliminary analysis and design strategies, but also for the design, fabrication and construction process. The pre-constructed canopy not only 'frame' the shading systems solutions, it also combined them into a unique system (Figure 5). During the Summer School, we also guide our students through an unconscious but strategical script defined by: Analyze; Structure; Subdivide; Focus; Brainstorm; Evaluate; Combine and Prototype. This methodology revealed to be an important tool to help define and lead the projects to an end. The main methodology proved to be effective. Developed solutions, faced material, system and mechanical problems, but in the end, all of them were succeeded.

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