EMMANOUIL VERMISSO
Florida Atlantic University
Design Portfolio
teaching + research integration

Design Computation & Biomorphic Design 1
Architectural Robotics & Smart Materials 2

The work presented here tries to discuss an evolution of pedagogy which considers integration of both Analogue and Digital tools as complementary. My primary interest is that of adopting technologies and theoretical practices towards the establishment of a bottom-up design methodology. The "Emergent Form" course lies at the core of this intent, and is supported by earlier teaching research seminars and design studios which allow the refinement of such technologies and their eventual implementation into a course on Design Computation that is not relying on specific software/hardware but rather on the realization that Architecture can directly borrow rationales from external disciplines like Engineering and the Sciences at large.
Design Research integrating research & teaching

Biological Analogy / Design Computation / Robotics

Self-Organization: Synthetic Landscapes
Emergence & Self-Organization: Computational Design Methods

Smart Material Systems

Shape Memory Alloys: Passive Responsive Building Facade System
Carotid Thermo-Regulator: Responsive wearable clothing
Responsive Habitats: Hammock Veil

Soft Grids: Conformal Mapping Deformations
Wet Grids: Minimal Path
Elastic Grids: Force-Active Structures
Layered Grids: Hybrid Laminate Materials
Drained Grids: Aggregate Casting
Adjustable Casts: Analogue Algorithms

CNC-manufacturing
Ornament: Design of Affect on Plywood (Material Surface Consideration)
Prototyping: Formula SAE open-wheel race-car
Shape Optimization: Design options

Integration of simple motor: Bio-inspired LEGO machines
Nature & Technology: Vessels of Consilience
teaching + research (Computational form-finding)

EMERGENT FORM: Computational Design Methods
[3 credit course/duration: 6 weeks]

Can we ‘design’ bottom-up processes?

[Diagram showing various design processes and methodologies]
These morphological studies involve the mapping of a shape or geometry within a Cartesian coordinate system. Subsequent controlled deformation of this system aims to establish quantifiable continuities between known states of evolution of the original subject or identify successful mathematical rules for developing further stages of evolution.

It is important to assess both the subject of deformation (shape) but also - if not primarily - the notational vessel for this deformation (grid) separately. Interesting observations can be made by studying these “soft grids” that can frame more experiments. In “On Growth and Form” (1917), D’Arcy Thompson sought to mathematically deform “instances” of evolution on paper; we have decided to enlarge the potential of the system by physically defining it. A separate, physical vessel should be accounted for in our case, that of material - this provides specific constraints which affect the system’s performance. A fourth parameter/element in the system is the contraption which regulates the material behavior and implements the analog rules for deformation.

Paint studies: we have either used latex as an elastic agent to allow the grid to soften, but gone further to ‘laminate’ the latex with paint/gypsum in order to visualize/manifest the forces under which it’s subjected and try to empirically understand the refinement of the rule/Algorithm.

In the case of D’Arcy Thompson skull studies the mathematical rule for achieving the deformations is not listed in “The Theory of Transformations”. Based on further investigation which made clear the complexity involved, we questioned the suitability of 2-Dimensional deformation relative to the prospect of a 3-Dimensional one in capturing these extremes (human to chimpanzee to baboon).

Another context was proposed, that of deforming these within a Non-Euclidean frame of reference: Hyperbolic Geometry. A formula for inversion was used, where the coordinates of the subjects were inverted in reference to a circle (2D) - this is also known as using the Poincaré disk model (also known as conformal disk model) - or a sphere (3D). The results were much closer to the original studies conducted by Thompson and fellow scientist Heilmann, thus raising the question of method in D’Arcy Thompson’s work: Did D’Arcy Thompson employ Non-Euclidean geometrical references in his “Theory of Transformations”? 

Latex Studies
Manual shape deformation
Wet Grids: Understanding of Minimal Path logic and its potential applications [case-study: Frei Otto]

These studies explore the concept of the "minimal path" by assessing the behavior of 'wet grids' using soap water in various temperatures and consistencies. A hypothesis is sought which could drive a design application - a possibly promising scenario to further examine is deriving optimal routes for the London Underground.

Convergence Studies:
Testing of various type of thread fabric

Optimal scenario: convergence of 3 threads

Influence Studies
Testing of neighboring conditions on convergence

Hypothesis: Train Route Optimization using Minimal Spanning Tree logic

FORCE: SURFACE TENSION

MINIMAL SURFACE: SOAP FILM

WATER

WATER+SOAP

AT A MOLECULAR SCALE, SOAP IS COMPOSED OF SUBRENCENTS: WATER ONE AND ALKYL, THIS MEANS THATS ARE BOTH POLAR AND NONPOLAR, WHERE THE WATER MOLECLUES ARE AT THE EXOTHERmic PHASE OF THE INTERFACE AND THE ALKYL ARE DECOWAS.

THE MINIMAL SURFACEV IS THE COMING ELEbENT BETWEEN THE WET GRID MINIMAL PATH AND THE SITR SURFACI ENERGHS.

THE FLEXIBLE GRID ALLOWS FOR THE MOVEMENTS OF THE POINTS, WHICH RESULTS IN TENSION AND CONTRACTION OF THE SURFACI.
This fast-paced workshop studied elastic fabrics' ability to portray and engage the phenomenon of emergent, self-organizing and unpredictable form. It was essential to understand emergence as the natural, decentralized, non-hierarchical phenomenon of self-organization of form as yielded by the development of manual algorithms and logical processes via analog computation, and as influenced by material properties, context and other factors. MIT's "Silk" pavilion experiment (N.Oxman 2013), a precedent which stimulated questions on the parameters of emergence, is a peculiar case study where natural agents that don't seem to display the survival-guided social behaviors of animal groups -such as the ant colony- create emergent complex form when introduced to a man-made medium. Initially, the experiment aimed to allow free agents to determine the fabrics' points of attachment, hence allowing form-making though a bottom-to-top approach, and starting with self-organizing, basic, independent and computational agents working together in a decentralized fashion. Live silkworms were introduced to the study aiming for this approach, resulting in a system that expresses the juxtaposition of the form made by the agent-as shaped by its natural, goal-oriented reasons- with elastic fabric media. The silkworm (Bombyx mori) does constructs more flexible in form under different spatial conditions not limited to two-dimensional or planar designs (more so than the spider, for example). The fabric media was initially meant to be interposed after the agent acted. Ultimately, however, experimenting with digital representations of algorithmic functions of natural growth determined the attachment points of the fabrics, and hence, their forms, after which, the agents were placed to observe their constructs. The fabric media was initially meant to be interposed after the agent acted. Ultimately, however, experimenting with digital representations of algorithmic functions of natural growth determined the attachment points of the fabrics, and hence, their forms, after which, the agents were placed to observe their constructs. The fabric, thread and wood media, or HUBs (hybridity | unfoldings | bluntings) re-quired parameters which would determine some of the agents behaviors (i.e. discouraging corner weaving), undermining totally decentralized emergence. Differing from the silk pavilion, the experiment was not attempt to express future possible material applications, but to express possible organic interactions between parameters of emergent form-making and man-made materials. The juxtaposition of and the interactions between natural and artificial elastic fibers was secondary. The results were organic, with most agents successfully completing their life cycles after spinning on both intended and unintended surfaces. Limitations were observed in controlling the agents' spinning behaviors, but closely observing patterns, and opening questions about further media and the wide range of possible unpredictable results, as well as about the feedback of natural systems on artificial ones became a tangible source of interest. This is a system with potential for complexity and further experimentation, and despite not fully achieving a bottom to top approach, it offers a close look at the influence of constructed spaces on natural behaviors.
 teaching + research (Computational form-finding)

EMERGENT FORM: Computational Design Methods
STUDENT WORK: Design by M.Siles, L.Rodriguez, C.Calderon
[duration: 4 weeks]

Layered Grids: Examination of laminated structural configurations with SOFT & HARD materials

The objective of the final experiment was making a flexible vault-like structure with an initial rigid material by altering its design through a particular notching technique, while keeping it structurally intact and able to absorb shock forces through composite techniques. A mixture of analogue and digital techniques were used to apply certain composite materials, towards attaining a lightweight optimized form. Digital simulations in Rhino-plugins Millipede and Scan & Solve were conducted to identify vulnerable areas of maximum stress. In those areas, Kevlar and/or Liquid Silicone Rubber were applied according to the location and performance requirement (i.e. liquid rubber works better in compression, absorbing force).

Short-term hypothesis: If a 1/8” offset symmetrical notching is made in a 1” depth piece of poplar wood and have the notching transition to a 30 degree cross notch, then the structure becomes highly flexible, yet vulnerable to failure, and therefore requires subsequent reinforcement with rubber to absorb compressive stresses, and Kevlar used to achieve greater tensile strength in areas prone to deflection.

Long-term hypothesis: If the base material of the vault (wood) is modified or simply eliminated, how will the hybridization of Carbon Fiber, Kevlar, and Silicone Rubber alter the Form, Structure and Layer Logic in order to achieve flexibility? Will the topology resemble a barrel vault or is a new one likely to emerge?

2D Hybrid Material Studies: BEAM
Prototypes A B C D: Straight vs. Cambered beams

3D Hybrid Material Study: VAULT
Prototype E: Reinforced Panel (bottom)

Prototype X: CNC-routed Poplar

Rubber Reinforcement

1-directional bending

2-directional bending

Soft: Silicone Rubber

HARD: Kevlar

DESIGN: PROFILE VARIATION
PROFILE 01
PROFILE 02
PROFILE 03
PROFILE 04

PERFORMANCE: BENDING
structural optimization: hybrid material laminates ➔ Soft & Hard

This investigation considers Sand Angle of Repose as a material factor for form-finding. Aggregates consist of finer particles which set up the behavior of the material when looked at larger quantities. Sand as the product of weathering and erosion on the smaller scale acts as a crystal of a mineral. In nature, the bigger amounts of sand like dunes, pits and landslides act to find an optimal shape to resist gravity, wind, water and earthquakes. We herewith explore sand as an agent that delivers structural simulation and juxtapose two projects between 1898 and 1960, the Sagrada Familia by Antoni Gaudi and Sydney Opera House by Jørn Utzon. Observing the absence of beams in the Sagrada Familia -accommodated by hyperboloid vaults instead- the working hypothesis considers the integration of a parametric rule of varying profiles within a vault structure following a self-organizing process.

In works of Jørn Utzon like the Sydney Opera House, Kuwait National Assembly and Zurich Theatre, the idea of adjustable geometry is connected to structural performance. Virtually, the structural roof modules of these projects consist of infinite numbers of structurally sufficient profiles to explore the full capacity of the system. Although an infinite number of options is impractical, the application of associative rules on a virtual level can provide endless results. Using profile succession from 'T' to 'c', from 'γ' to 'U' and from '_-' to 'γ', Utzon explored the arrangement of material over applied force, space and time. These precedents establish an understanding of a bottom-up approach, although stylistic misconceptions of their time could become an obstacle during form-finding. Both the work of Utzon and Gaudi address design beyond their authors' lifetime and challenge temporary stylistic dogma. Understanding form as a result of structure and material, both architects used analogue experiments to embed mathematical rules within a structural pattern language.

Is the application of digital methods valid compared to the analogue ones? Can we call the first virtual and the later real? Both of systems [Analogue/Digital] are inclusive and self-sustaining, but they differ in the output information. The analogue system uses the advantages of the natural agent (sand in our experiments) when the digital ones perform through the simulation of agent established by physical rules (gravity, friction). The discovery of system potential in digital way by inheriting 'supernatural' qualities of material is of the same importance as experimenting in analogue ways. The first can explore the expanded system capacity and the second test the material to achieve the desired result.

Silicone Rubber Mold extracted from Sand Draining; Plaster Cast

Drained Sand Studies: Transition from '+' Grid to 'X' Grid
**teaching + research (Computational form-finding)**

**EMERGENT FORM: Computational Design Methods**

STUDENT WORK: Design by J.Bernal, M.Mandra, S.Sipahi

[duration: 4 weeks]

**Adjustable** Casts [case-study: Sydney Opera House Concourse Beam, Jørn Utzon]

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**Beam Studies**

Prototype I: Sydney Opera Moment Beam (concrete)

**Mold Studies:**

Adjustable Mold for Casting

**Prototype II: Sydney variation >> Bifurcation (concrete)**
teaching + research (non-trivial machines)

Digital Fabrication: The Indeterminate Canvas
STUDENT WORK: Design by A.Wright, L.Turek, R.Downing & E. Vermisso

* This work has been presented at the TEI 2011 WIP workshops: Conference on Tangible, Embedded and Embodied Interaction

This project examines the interrelationship of moving assemblies of a familiar geometrical shape from which unfamiliar patterns gradually emerge. An installation creates a series of 'paintings' by visually mapping the trajectories of the joints of a grid assembly. The grid joints - submerged in a mix of graphite and engine oil - come in contact with a blank canvas to produce a “drawing”. The machine is triggered by subsequent users, producing a unique drawing every time. The installation addresses design from a cybernetic (as “feedback”) and architectural perspective (as “ornament”).

On an architectural level, the machine can operate in the form of an assembly rolling over a blank canvas, spread along the walls of a room (similar to an Entablature). Considering the machine’s end product in isolation, the sequential nature of the drawings creates a relatively continuous output that may be viewed from an aesthetic perspective as a type of “ornament”. Although early rationalist cybernetic theory regards Architecture independent from the user, more recent views embrace the phenomenological aspects of experiencing space. von Foerster's distinction of machines into “trivial” and “non-trivial” identifies the simplicity or complexity that a construct can manifest to an external observer.

The kinetic nature of the project relies on the use of simple (Lego®) or programmable (Arduino-servo) actuation. By integrating responsive technologies, the reciprocity between user and the installation output allows for a shifting cognitive appreciation: time is critical in the performance of the machine, as it allows one's perception of the system to change through the insertion of pieces that affect the machine's operation: such elements can change its behavior from a system of unexpected output to a more predictable one. The process itself can change from “trivial” to “non-trivial” and the final drawn canvas is essentially a product of a non-trivial process, with specific identifiable elements that make its operation trivial for certain periods. Considering Philip Ursprung's discussion on the importance of both the Outcome and Process of a design (Ursprung 2008), ongoing work will consider if the machine’s process should be internalized (hidden) or externalized (exposed), as this can radically influence one’s experience. Furthermore, assessment of intuitive versus rational user response towards the machine needs to be examined.

Can a 'technically augmented system' enhance our phenomenological perception of the space it inhabits? We believe that people with higher activity on the left brain hemisphere may relate to the "process", while those with dominant right hemisphere may instinctively prioritize “appreciation of the outcome”.

Prototype function
>create 'painting' by mapping point movement

Designer's intention
>allow observer to make familiar associations
teaching + research (biomorphic design)

Fabricating Interactions Exhibit: Kinetic Prototypes


Prototype exploring flexibility during rorqual whale feeding

Fruit Fly Robot Installation within 2nd Avenue Gallery

Expanding skin prototype

Introduction of Actuators [LEGO® motor]

Venus-fly trap machine
teaching + research (biomorphic design)

Morphallaxis: A process of structural growth

STUDENT WORK: Design by M. Elder & E. Vermisso

* The project was presented during the CAAD Futures 2011 Conference in Liège, Belgium

The conceptual premise for this project lies in an ancient Greek myth which involves a serpent (Lernaean Hydra) that could regenerate and multiply its heads once they were severed by “Hercules”. The marine organism ‘Hydra’ uses a similar process as a defense strategy: it can restore tissue due to loss or death of existing one, through a process known as ‘morphallaxis’. This biological property is the guiding principle towards designing a structural system that manifests regenerative behavior to remedy structural failure. The responsive aspects of the project are still under consideration, while we have established a “growth logic” that can be applied as a design guide: A speculative structure has been designed (grown) within a designated shape (context). Relating to the behavior of the Sea Hydra, the morphogenesis was affected by two spatial layers, what is referred to as ‘inner’ and ‘outer’ context (endoderm & ectoderm).

The possible advantage of such a system is the improvement of a structure’s behavior as a result of its tendency for failure. Every time a break might seem likely, the damage component will break off, and that joint will grow into multiple, subsequently scaled members, affecting the formal qualities of the overall system in this way. Within a biological context, we wish to consider the analogy of the programmed death of mitochondrial cells, known as “apoptosis”. Specific cells in the organism commit suicide to avoid likely cancerous mutations, thereby protecting the overall integrity of the system (similar to Hydra’s behavior).

The design process began by developing a manual algorithm that relied on a sequence of actions that were triggered by the use of topological “thresholds” along a linear direction. This project will assess the resulting structures derived from this process, examine the process itself, discuss current development and propose a course of future evolution. Considering the tight integration of formal, structural and material properties present in natural systems, we would like to improve the growth algorithm based on prior performance analysis (CFD or FEA simulation). Using quantitative results we could affect the early stages of growth and develop the algorithm based on material properties and contextual behavior. These results could subsequently be compared with the original algorithm of growth based on thresholds. We believe that a growth process relying on previously acquired data may yield a more honest approach that approaches the integration that yields the robustness of natural systems.
Bio-Prototypes: The Fibrous Structure Machine

**STUDENT WORK:** Design by M. Rega, A. Steffen, D. Arenobia & E. Vermissop

*This work has been published in the International Journal of Architectural Computing (issue 03, vol.10, Sep.2012)*
PERFORMATIVE PARAMETRIC DESIGN: Passive SMA-controlled facade system
STUDENT WORK: Design by A. Martinez, J. Bernal, J. Llampay & E. Vermisso, co-instructor: M. Thitisawat
[duration: 4 weeks]

This study investigates exchanges between digital and physical computing platforms, assessing possible workflows for kinetic responsive design using physical computing platforms like Arduino, and smart materials like Shape Memory Alloys. Various configurations were considered for integrating the SMA into a physical panel system, to control the movement and augment the resultant motion caused by the wire’s contraction of nearly 5% of memory strain under 15,000 psi (103 MPa) during cooling (Dynalloy). Mechanisms which allow translation of movement from one plane to another (i.e. linear motion to rotational, folding, lifting, shrinking, etc.) were also examined. The final proposal features a triangulated shape made up of squares which are connected at the ends with nylon and attached to an SMA spring at the fulcrum point in the centre. This enables maximum deflection of the material with minimal actuation of the spring. We propose to use this system for an inclined facade which uses solar gain to trigger opening and closing of the panels.

PHYSICAL COMPUTING & SMART MATERIALS
- Control: Arduino micro-controller
- Non-Mechanical Actuation: Shape Memory Alloy Spring
- Environmental Response: Passive Strategy

Simulation Scenario
- Analogue input ↔ Kinect Motion Sensor: Body Movement
- Digital output ↔ Grasshopper/ Firefly: Facade Panel Rotation

Real-Life Scenario
- Analogue input ↔ PV Panel: Solar Radiation (Heat)
- Analogue output ↔ Shape-Memory Alloy: Contraction (Movement)

* The project is scheduled for presentation at the Advanced Building Skins 2015 Conference in Bern, Switzerland.
The human cervical region has been celebrated in one way or another by historical and contemporary fashion trends alike. Either through concealment or elaborate exposure, tailored garments and accessories like the “Ruff” or “turtleneck” have been used since the 16th century. While some versions of the former denoted an aristocratic provenance, the latter has been associated with certain radicals, academics, philosophers, intellectuals and politicians. This project aims to re-imagine this area of the body through a prosthesis which extends aesthetic preoccupation to consider thermal comfort scenarios and their visual expression. Our premise stems from the traditional Ruff, which evolved from a small neck piece to high ruff or collars during the Elizabethan era. Throughout history, ruffs have been shrunk or enlarged transforming into cuff and skirt through multiple evolutions, even incorporating wooden support in some of its iterations (Hughes 2011).

Our proposed carotid prosthesis embraces physical computing and anatomical expression to create a dialogue between technology and nature. This proposal considers garment as a vessel for human thermal adaptation. Interestingly, body temperature amplitude and patterns correlate to standard biophysical incidences such as the heart and respiratory rate as well as emotion (Nummenmaa, et al. 2013; Davies and Maconochie 2009). The design includes a microprocessor, sensor, circulation control system, heat regulator and wearable enclosure. A pulse sensor’s reading from the Carotid artery is used as control logic for a peristaltic pump. Fluid medium is circulated in a closed loop tubing system with an inline heat exchanger that can either collect heat from body or environment. The integration of these components within a wearable item carefully considers minimum weight and non-disruptive presence on the user. Soft materials like silicone rubber and flexible resin are employed, combining laser-cut and 3d-printed pieces to achieve geometrical complexity.

The silicone rubber serves as a primary (inner) layer holding a ‘soft’ 3d-printed layer which in turn secures the liquid-tubes. To ensure skin breathability, a pattern of holes is cut from the silicone surface using a parametric definition which translates color data from thermal IR imaging of users’ cervical area into a gradient pattern. The effect resulting from the transformation of thermal data into graphic becomes an inherent quality of the piece. It provides a clear reference to the internal blood vessel network of the neck; this component secures the heart rate sensor and tubing and is attached on the silicone piece via a number of ‘buttons’ and feather-like barb ties. The pump is integrated into the 3d-printed layer in order to remove attention from that area to the higher part of the neck where the sensor is located. The shape and arrangement of tubes follows the diagram of blood vessels and hot spots in infrared reading. The prosthesis serves as a fashion statement, celebrating the importance of the cervical area as a liaison between the central body organ (heart) and the body’s processing unit (brain).
The work discusses the stage of architectural and spatial intelligence in the near future by looking at the relationship between Nature and Technology, through the co-habitation of organic and robotic agents which demonstrate the ability to self-organize into variable spatial constructs, thus transforming our conventional experience of a 3-dimensional terrain. The agents’ inter-dependence but also their rivalry in the evolutionary process is examined.
Architectural Design studio

Future of Knowledge: Mediatheque (Design 8)
- Design Optimization/Fabrication: Economy of Structure
- Concept Generation: Book Hacking

Ephemeral Structures: Modular Hotel in North Miami Beach (Design 7)
- Ease of Replacement: Crane Hotel
- Introversion of Material: Folding Skin
- Ease of Assembly: Inflatable Pods
- Environmental Performance: Massing from Wind Analysis

Detail Resolution: Design & Build Project for Modular Hotel
- Space Economy: Rotating Pods
- Shifting Experience: Moving Spider Pods
- Human Response: Magnetic Facade
- Moving Layers: Folding Balcony/Shading Screen

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**teaching (design & build)**

**Architectural Design 7: Modular Hotel Project**

STUDENT WORK: design by P. Rojas, detailing with M. Zapatta & I. Fomina

[duration: 1.5+1 weeks]

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**Instructor Commentary:**

This project negotiates issues of modular construction by looking at reconfiguring the conventional hotel typology for a proposal in North Miami Beach. The intention is to create some relative density by minimizing the surface area of hotel rooms which are replaced by 'pods'. The pods are configured as agents of multiple activities within a minimal space, by taking advantage of the overall volumetric capabilities of each pod; this happens by separating each pod into three parts: part A contains all service requirements and is fixed to the permanent part of the building. Part B is a rotating component which allows the occupant to use the space in **three configurations:** Sleep-Work-Lounge depending on the time of day and personal preference. Part C is a lighter construction of synthetic materials and provides a nosle type end that allows for shading and the introduction of a 'balcony' type space.

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**modular structure**

**prototyping**

**assembly**

**construction logistics**

**flexibility**

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**Sectional Diagrams indicating activities relative to the degrees of pod rotation**

**Exploded axonometric of the Pod components showing skin, furniture and rotating mechanism**

**Detail Section showing the rotating mechanism and pod interior**
Instructor Commentary:
The scope of Design 7 is to expose students to modular building construction systems while enhancing their presentation skills. It represents an important transition from manual to digital drawing, which is initiated in the previous semester. The semester begins with a series of short iterative design projects for a modular hotel, culminating in a design and build exercise that looks at the potential of detailing as generative design tool.

This project examines impermanence and mobility in public aspects of a mixed-use program like a hotel. Intimate spaces (pods) which can function as lounge areas are proposed to inhabit a vertical facade looking into an atrium. The pods are able to move along the vertical surface using spider-like legs and magnetic locks to secure themselves. This movement, albeit not intentionally relevant to the pods’ function causes a spectacle in the public lobby area, where the orchestrated movement of the pods is visible to the visitors checking in the hotel.
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This solution for a modular panelization facade system filters natural light based on human circulation inside the building, therefore integrating occupancy with local facade modulation. The diamond shape geometry allows for an aggregation of panels which pivot around a horizontal structural subframe. Each panel houses a set of neodymium magnets. A larger magnet, placed on a track situated on the ceiling space above the circulation corridor, maps human presence; this causes the magnet to move ahead of residents, therefore repelling the magnets in the diamonds panels and allowing sunlight inside the corridor space.