From material to material with new abilities

Performative Skin: an unfinished product derived through the organizational logic as developed through research on 'movement'

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Abstract

This paper presents the process and products from research on 'a movement behavior', transforming the initial surface from one state to other states. The study developed an initial model of material organization inspired by nature: the adaptable exoskeleton of the armadillium vulgare. Through geometric analysis of functional variation in the exoskeleton's unit shape, and physical model making, the underlying principle is translated into design & production rules. The generative model of 'an adaptable segmented system' is constructed through a geometric abstraction of the exoskeleton, achieving diverse functions such as variability in form, volume, porosity, flexibility and strength, through a distribution of 'material geometry' with the folding technique. The potentiality of this parametric physical model (based on simple systematicity) is questioned in relation to diverse situations that result in complex surface adaptations. This research shows the formulation of a design intention.

Keywords: Making for Digital Craft, Production Techniques and Methods, Folding, 3D Out of Flat Sheet Material, Material Computation, Informed Matter

Introduction

"Designer's experience tends to become divorced from the organic properties of materials and the skill processes used to make or even fabricate objects. These changes began to occur when production factories like Etruria opened in 1769. With such factories the division between concept and execution became marked. In later years it only became more acute as industrialization and automation increased. The result of all this was that designers tend to lose touch with the natural organic qualities of materials and how they can be worked." (Risatti, 2009).

'Architectural design is constructed as the result of conventional materials and building techniques' due to the separation of design and production, a gradual linear design process instead of synchronic thinking & Material / Making processes. Despite this, todays 'new' material and manufacturing languages – resulting from systematic investigations of Technique, Making and Material Properties – are becoming more common. Unique concepts and language for material systems and digital Manufacturing / Fabrication systems, are emerging from the Open Source Sharing / Making Culture. Developments in computational Science and Technology are allowing the Design Product to tease elements from the holistic integrative process and connect multi-phase design involving different disciplines. Thus, designers start to build integrative structures (systems) for processes in order to employ cutting edge technologies.

Today's architectural association with 'digital fabrication and production' results in the implementation of novel design and construction concepts. Oxman (2014) says that current impacts on 'materialization concepts upon form' become one of the main influences in contemporary design. Some of these novel system proposals are; Matrix Architecture of Sabin (2013); Digital Materiality for Robotic Fabrication by Gramazio & Kohler (1998); Bidirectional Modeling of Constraints by Killian (2006); Digital Craft of Thomson & Tamke (2013); Smart Materials of Addington & Schodek (2005). These design approaches involve 'materials and the way of transforming the materials' to guide the formation of the material systems, and consequently, the design objects.

Contemporary architecture consists of 'versatile' material systems that, as Menges (2013) says, "expand the architectural design repertoire and increase the performative capacity". Essentially, material systems involve the logic of transforming basic materials to materials with new abilities, resulting in the expression of form, structure and performance. 'Exploring the transformation of the material in a systematic way at the beginning of the design process' and 'the abstraction of this system' is vital to implementing and materializing these integrated design & fabrication systems.

Designers and Architects interrogate the relationship between 'Materiality' and 'Materialization' through different perspectives from the initial design conceptualization phase of the process. Rather than starting the design process with established contexts that limit the designer's mind, constituting familiar relations, today there is more focus on experimental design processes through exploration and research in performativity of material systems.

The computational mechanism of these production systems is developed by organizing relationships through experiments on the iterative changes on the way of Making; occurring as a result of the perpetual feedback between subject and object and two way transfer of information. 'Making' (production techniques) is 'performative' that changes designer ideation, and the idea changes the rule and the direction of 'Making' iteratively. In this paper, performativity of the Material and Geometry is investigated through the transformative impact of making a case study that transforms the existing one with new affordance. In this case study a material system was Designed, Prototyped, Interrogated and Fabricated.

The study aims to enhance the capacity of the 'Materials' and as such, the term 'material organization' is used to explain the association of Material and Geometric relations, allowing materials the ability to fold with different degrees of movement behaviors, different degrees of porosity and different degrees of structural support, for Designing & Producing differentiated forms. The performativity of the organization is explored via experiments on 'differentiated movement organizations'. The process started to focus the geometric organization for the movement in one direction to create curvatures, and continued with the assembly of different curvatures to extend the directions. The movement of the surface gets more complex step by step. It can potentially display any specific behavior through re-organization of 'the segmented bodies and their relationships'. Because of the organization of these curves and the derivative definitions of the secondary relationships, matter has a potentiality for unlimited movement and formation. In other words, it transforms into an ever-developing structure that has a potentiality to produce variable parametric end products in different scales.

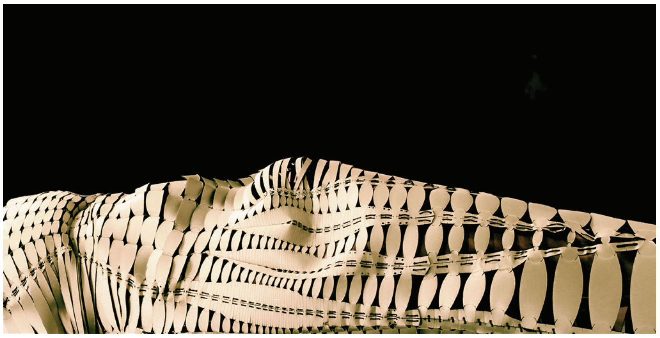

Figure 1. Example of 'Performative skin: foldable joint surface'. Bacınoğlu, S. Z. (2012). "A Model Proposal for Architecture of Potentialities, Master Thesis, ITU."

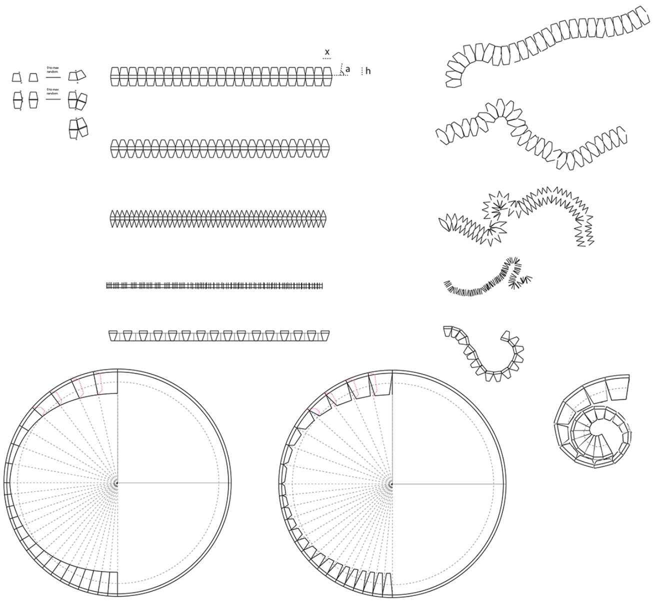

Figure 2. Section view of differentiated 'folding joint surfaces' results with a different curvature through enabling the movement behavior.

A Material System Proposal: Creating a 'Design & Production Language'

This paper presents the process and the products of research on 'changeability of material' that transforms the initial surface from one state to other states. The study developed an initial model of a material organization: a system inspired by nature: the adaptable exoskeleton of the armadillium vulgare. Through geometric analysis of functional variation in the exoskeleton's unit shape, and physical model making, the underlying principle is translated into design & production rules. The generative model of adaptable-segmented system constructed through geometric abstraction of the exoskeleton achieved diverse functions such as variability in Form-volume, Porosity, Flexibility and Strength through distribution of materials with the folding technique. The potentiality of this parametric physical model (based on a simple systematicity) was questioned in relation to the human body, especially as wearable, to fit complex surfaces and adapt diverse situations of the human body, which were not anticipated at the beginning.

Material & Production / Fabrication Techniques as Layouts / Tools for Design Thinking & Exploring

Mostly, production techniques and materials are considered after the design conception is finalized. However, this study claims that the way of transforming material (as Production & Making technique) is also shaping the design process (of itself). After Material & Making experiments, a language for an adaptable 'folding' detail is created.

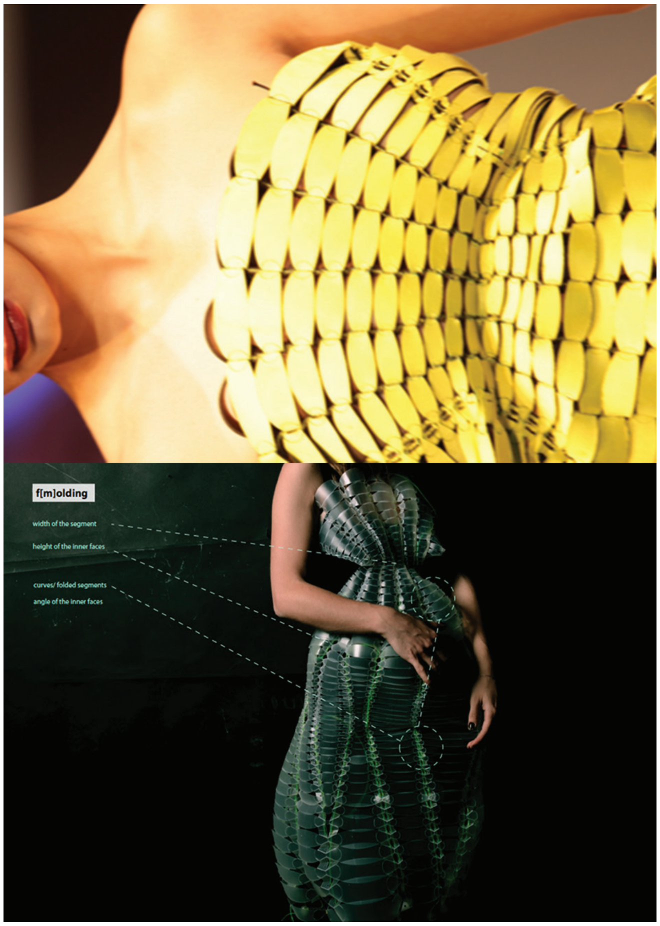

Figure 3. Example of a fabricated product. Bacınoğlu, S. Z. (2012).

Methodological Procedures

Research began by questioning 'performativity of the matter' through folding experiments on the formation of a movement; resulting in an adaptable detail and a fabrication method proposal. This process re-defines and transforms 'flat material' consisting of variable geometric relationships and rules. Besides this, an embodiment of movement by folding is interrogated and the exploration of the relationship between the Materiality and Materialisation which, finally, creates an integrative 'material organisation'.

This exploration process, as a reflective and growing process, comprises interactive reciprocal ever-increasing relations. The exploration-experimentation process of the material organisation comprises three interrelated-reciprocative cyclic phases:

1. Definition of the topological relationships between movement and geometry (rules for folding and design intention).

2. Definition of the relationship between movement and geometry, to fabrication constraints (folding rules and fabrication & assembly constraints)

3. Definition of the relationship between physical material and developed geometric organization (folding rules and required performance)

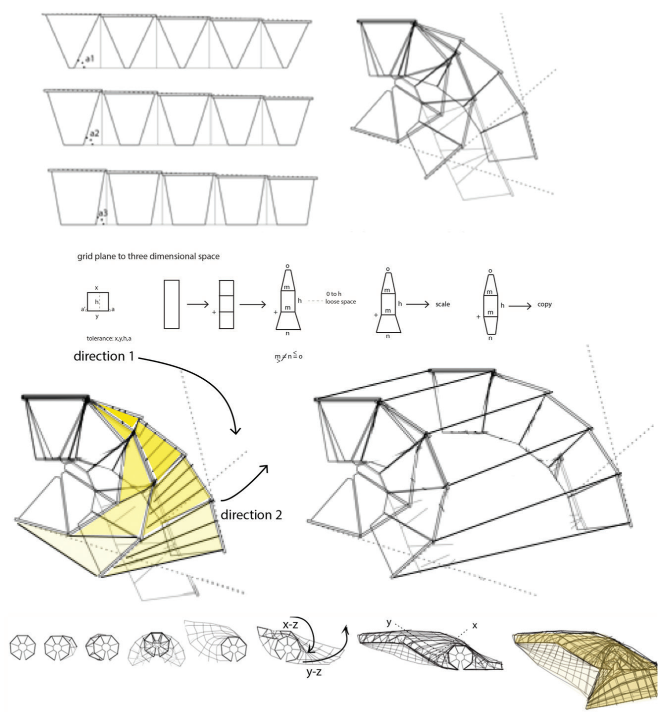

Figure 4. Initial rules for folding.

The study focuses on integration of Design and Making in the process. It starts with the analyses and abstraction of a natural system that translates these insights to a production-fabrication method through physical model making. The fabrication method potentially embeds differentiated curvatures into flat surface through a folding technique. The initial underlying rule is refined and gets complex through physical and digital models in an iterative process. Thus, the developed organization gains an ability to transform any planar surface to non-standard forms with varying behaviours.

A single materialized organization is investigated through different folding experiments in various ways. Four different states of the matter are exemplified as Folded Shell, Semi-Folded loose Surface, Bended (upper) Surface, and Unfolded Plane. Iterations of the organisation are experimentally produced to create various effects for different degrees of Expanding / Stiffness / Stability / Patterning (as folded state), Wavy free-form surfaces (semi-folded state) and for Plane Surfaces with different degrees of Permeability (unfolded state). As it is produced, intentional different effects relate to the Static and Dynamic part of the human body. Experiments on assembling different movement behaviours also create surprising differentiated surface effects.

Description of the Process

During the materiality (organisation) and materialization (physical folding form) cyclic process, performativity of the organization is interrogated in relation to the movement of differentiated curvatures and the potential resultant surface-

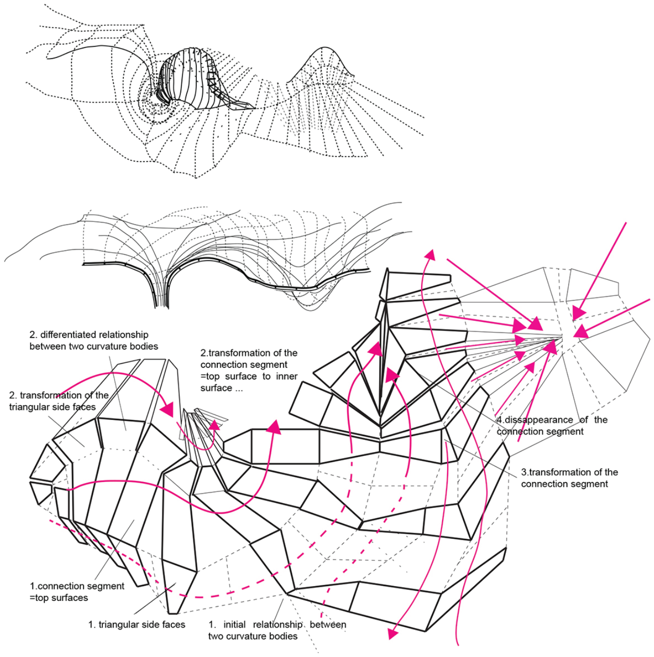

Figure 5. Results of differentiated behaviors through iterated rules.

volume effects. As a result of multiple experiments, with folding, interrelated topological relations of the 'material system' are defined (as shown below).

'Folding geometries between triangular faces' to create curvatures from flat surface; 'connection between triangular faces' to connect different curvatures; 'different degree of curvatures and different size of segmented top surfaces' to create differentiated 3D space from flat surface.

This process generated a customizable and adaptable method for fabrication. The developed organisation allows us to transform the flat surface to an intended space structure via movement (folding) ability. The density, of U & V points on the surface, determines the folding axes and segment sizes, respectively. In other words it determines the degree of the curvature. The inner triangular foldable pieces are determined based on the U & V points and the curvature of the form. Indeed, the system allows designers to implement their fabrication process by designing their own fabrication tool.

The developed organisation is transformed to 'a design tool' (a potential open-ended and flexible / adaptable skin system) through the exploration of its materiality. This abstract geometric organisation's adaptation and relation to the human body is exemplified with differentiated products.

The developed logic of the organisation: Performative skin is derived for body proportions. It is formed with various degrees of Curvature, Porosity and Thickness according to specific parts of the body. The composition of the 'material organisation' is produced to meet specific performance criteria in relation to parts of the human body; and structure is manually adapted to the human body.

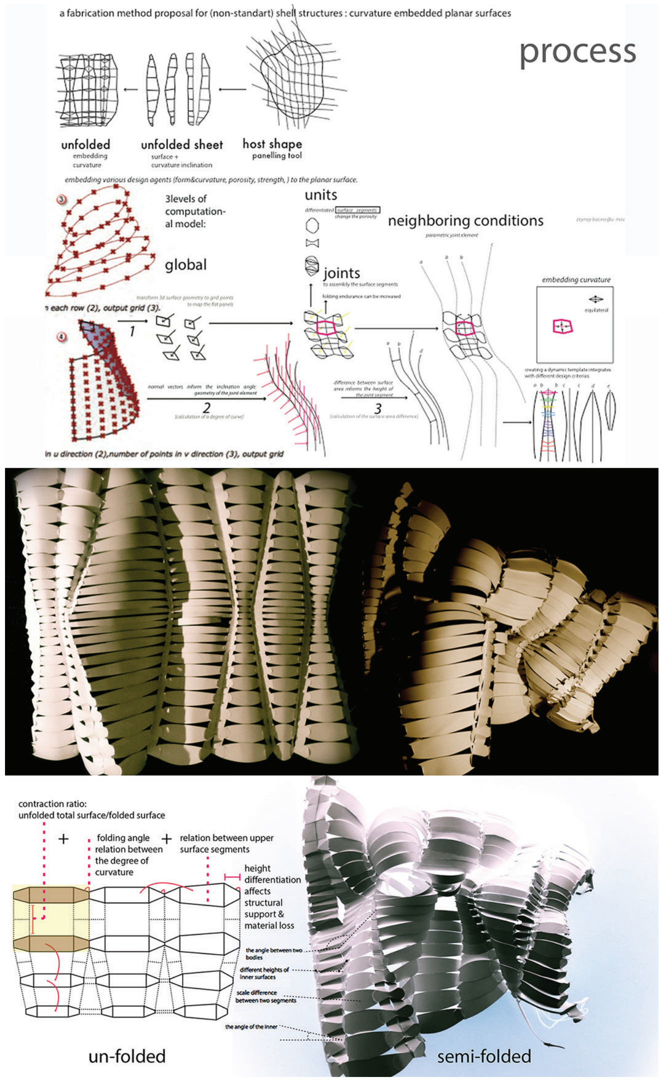

Figure 6. Different states of the 'planar surface' material. Bacınoğlu.

The Material

Tested materials were paper, 'Tyvek', polycarbonate, polypropylene, leather and various other textiles.

The Cutting

The computer-generated layout pattern is applied to the material with a laser cutter. Once the pieces are cut, they are folded and assembled as planar or 3-dimensional forms.

The Performance

The overall material system is composed of the topological relationship between upper segmented surfaces and inner foldable surfaces. While the properties of upper segments relate to Porosity, Smoothness and Strength; the Density, Shape, Height and Direction of the inner faces relate to the surface effects of Thickness and Stiffness of the structure, as shown in the Figure 9.

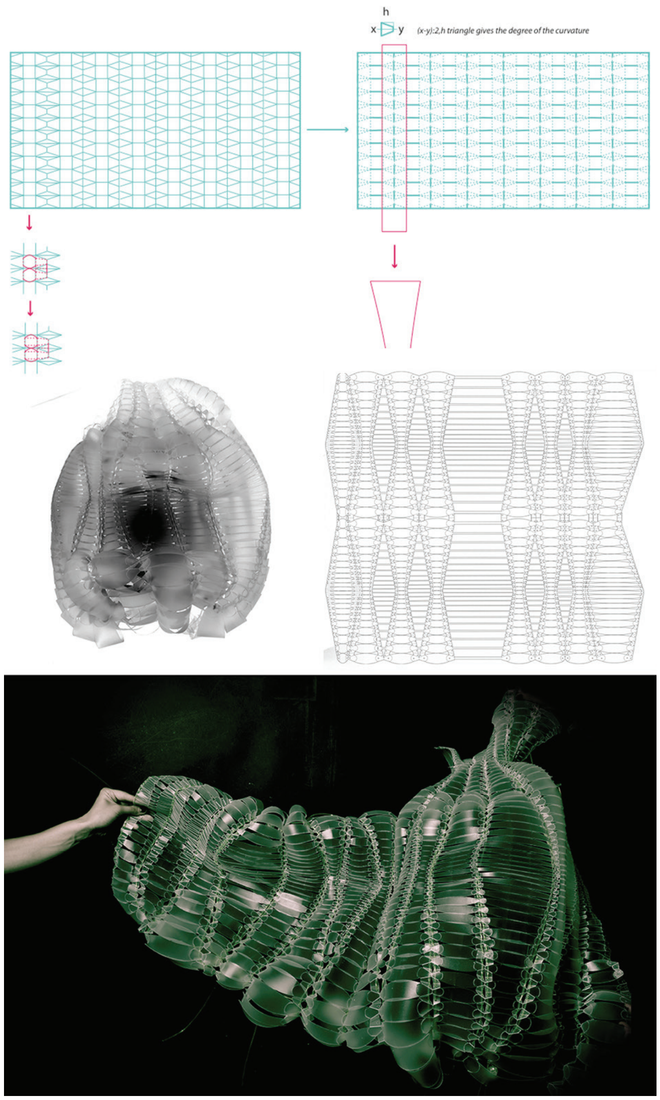

Figure 7. Fabrication file of a semi-folded segmented surface.

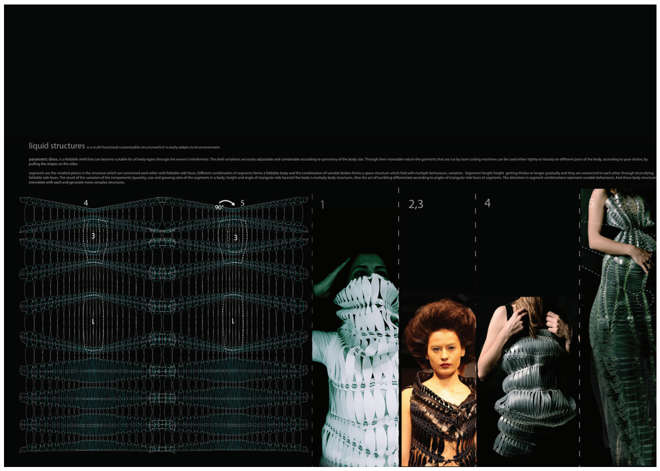

Figure 8. Adaptation of a pattern.

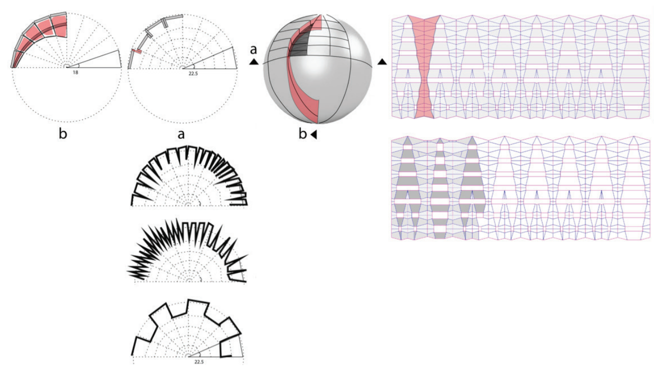

Figure 9. Different sections of a sphere, made of segmented foldable pieces, show different performances such as variability of thickness, strength & structural support, softness, continuity and surface effects.

Result

" The materialized structure, an adaptable skin, is a folding shell which is capable of covering the intended shape and reshape through the different behaviors of the constitutive segmented bodies. Segments are the smallest components in the structure, having foldable side faces. Different combinations of segment form a foldable body and the combination, of variable bodies, form a spatial structure which folds with multiple behaviors. " (Bacınoğlu, 2012).

The model is termed a 'Performative skin' which has the capacity to create various Effects, Volumes, Movement behaviors and differentiated degrees of Porosity and Structural support, by controlling the materialization of its organization.

This customizable structure is suitable for all body types and can create various surface effects through the owner's interference. The skin potentially exhibits any specific behavior through the ability of Folding, Bending and Expansion or Contraction. The shell variations can be organized according to symmetry of the body size. Through their moveable nature, garments that are tailored by laser cutting machines can be used either tightly or loosely on different parts of the body.

Discussion

This study advocates the exploration of the 'new' architectural knowledge on-through 'transforming materials to materials with new abilities' (in terms of various production-fabrication techniques / layouts). In the last 10 years, this approach has become widely accepted in architectural practice and education. Hence, it transforms architectural Conventions, Definitions, Interpretations and Knowledge. The result of 'the new architecture' is not needing to be built on established elements such as Wall, Insulation, Door & Window. 'Performative formations' are substituting these well-known concepts that have the potential to transform 'everything'.

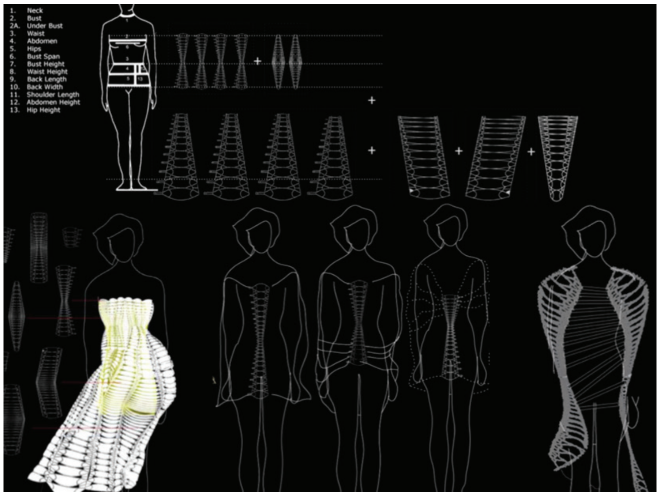

Figure 10. The composition of a material organization is produced to meet specific performance criteria in relation to the parts of the human body.

In this research, multiple constraints are defined to the implementation of this design & fabrication system. The constraints explored in this system, through folding procedures, is planning to be interrelated with the concept of 'graph-based dependency links' (Aish, 2013) in terms of defined logical relationships in the exploration process.

This study explored many relations between materiality (organization) and materialization (fabrication) which formed the differentiated results at different scales but it could not experiment the entire potentiality and definitely missed many parts in this unlimited open system.

This experimental, intuitive design formation and materialization process is capable of being extended for many adaptable incomplete architectural products through the logic of the 'material organization' as a design tool. Besides, incomplete products produced by this 'design tool' can further the design process. It is open to the user's participation and creativity at different levels by reinterpreting and seeing or changing and combining the parts and wholes. It allows us to create more responsive customized products by adapting them to the context of their environment.

An experiment of a model proposal for a 'performative skin' which informs and guides the design process of the future mass customized solutions for new product and building design. The proposal of this fabrication method will create non-standard geometries through curvature embedded planar surfaces that may have a contribution to building industry.

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