Towards a Semi Living Materiality: Biomaterials and Sensing for Wearable Interfaces

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Abstract

Bacterial living tissues operate in a symbiotic ecosystem with the external environment. This research question Can we draw inspiration from their behavior to design and manufacture body skins that can adjust to variations in internal metabolic processes? This project investigates the use of bacteria cellulose with 3D printed bodily anatomies literally grows a series of 'body architectures' developing a framework for architecture as an interface and extension of the human body achieved through the implementation of biofabrication processes and sensing technologies that utilize and integrate internal body signals and atmospheric flows in determining body-machine-environment relationships.

Keywords

Wearable Design; Physical Computing; Bio Fabrication;
3D Printing;

Introduction

Several technologies are converging to drastically change local and global spatio temporal relationships, including autonomous robotics, cyber-physical systems, ubiquitous sensing networks, and synthetic biological systems. These technologies provide architects and designers with opportunities to redefine models of human-machine-environment interactions that encompass more complex methods of simulated intelligence and nuanced response across a range of scales from the micro to the macro. This project explores the physical territory between the body and the environment—exploiting definition of 'spatial skins' (Figure 1) that are designed from inside-out of the body using the following design process:

1. Biofabrication Process_This research uses bacterial cellulose,as a means of growing biomaterials for architectural membranes. This provides opportunities to calibrate ecological systems that reduce the waste of local resources.

2. Sensing Technologies_We propose potential wearable applications that utilize and integrate biometric data (heart rate, electro dermal activity, brain electrical activity) and atmospheric flows (temperature, light) in determining body-machine-environment relationships.

Background

Many designers and artists have explored the notion of augmentation, projection or expansion of the human body skin (Cruz and Spize, 2005). This project is informed by a rich artistically and filmic lineage, ranging from the hybrid forms of 16th century Bruegel, Louise Bourgeois, Patricia Piccinini's and the visceral aesthetics in David Cronenberg work, most vividly the flesh formations of the game-pods in the 1999 film eXistenz. A visionary artist, Stelarc has studied different ways of altering the body (Teyssot 2005) in order to adjust and extend 'its awareness to the world'. The amplified body thus calls for remapping the body, by remapping, reconfiguring and redesigning the body by building on their work considering the expansion of human skin as a living landscape without a true limit or contour, and instead, part of a symbiotic ecosystem between the body's internal organs and the external environment.

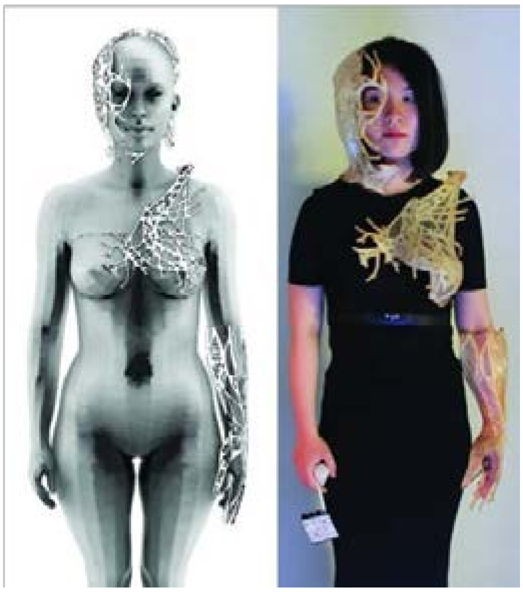

Figure 1: From left to right: Rendered image and photo of 3 Wearable Devices

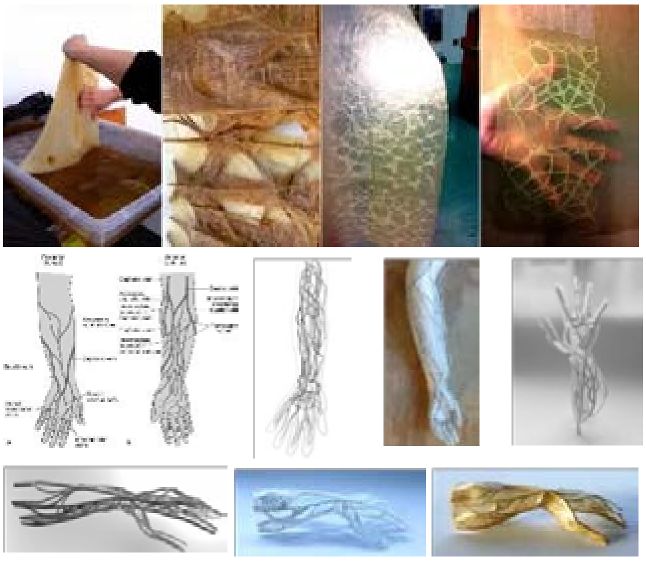

Figure 2: Stages of the fabrication process, bacterial cellulose growth and harvest; drawings, 3D doodle prototypes, 3D PLA plastic print, and a photograph of the bacterial cellulose clad prototype.

Design Approach

This project draws inspiration from the behaviour of bacterial living tissues, and our question is: can we grow, harvest and manufacture body skins as responsive layers that can adjust to variations in internal metabolic processes as part of a symbiotic ecosystem between the body's internal organs and the external environment?

The design process start by literally growing the material and materializes three 'body architectures' (Figure 2) developing a framework for architecture as an interface and extension of the human body achieved through the implementation of biofabrication processes and sensing technologies that utilize and integrate internal body signals and atmospheric flows in determining bodymachine-environment relationships. This project presents a novel architectural design research into machinic instruments that emerge as morphological responses to biotic and abiotic phenomena at the interface of bodies and spatial ecological systems across a variety of scales. This includes the design and production of a series of small scale wearable devices that operate as liminal mechanisms, creating a dynamic boundary between the body and the environment through the use of biometrics and environmental data. In this scenario, inhabitants of buildings are not treated solely as users acting within a static built environment, but as stakeholders that hold agency, and act as catalysts for an architecture that can adapt to changing materials, environmental or ecological demands. These technologies alter our ability to imagine constructed systems in highly nuanced relationships between internal bodily signals and surrounding atmospheric data, requiring an expanded view of networked and object oriented relationships between bodies, designed devices, and regional and global environments.

The Material and the Biofabrication Process

This research utilizes bacterial cellulose, as a means of growing biomaterials for three wearable devices. Microbial cellulose has proven to be a remarkably versatile biomaterial and can be used in a wide variety of fields, to produce for instance paper products, electronics, acoustics, and biomedical devices.We experimented with the strains from *Acetobacter*, in particular *Acetobacter Xylinum* bacteria being the most common and efficient type to use for a series of experiments and material testing samples. This particular strain is used to make Kombucha tea. The ingredients necessary for biofabricating the bacterial cellulose, are water, tea, sugar and vinegar. The spinning of cellulose is achieved through the fermentation process of bacteria, glucose, and oxygen within water.Nanofibers of cellulose are spun by bacteria into layers, forming a mat on the surface of the water, the material sheets grow on this aquatic environments in iterations of 3 weeks which can be removed and dried to produce a translucent sheet of material. Synthetic biological processes offer the potential to grow materials into specific forms and shapes for the biofabrication of architecture. (Figure 2).

Mapping, Modeling and Fabrication of the body devices

We have adapted a strategy of creating form from the inside-out, mapping and projecting body internal processes that would materialize into second skins connected with different biometrics sensing on each piece. We decided to couple the following body parts with biometric relationships:

A – Arm piece: Cardio vascular system with Heart-rate sensing

B – Chest/Back Piece: Organs and Muscles Anatomy with Dermal Activity (Stress Levels)

C – Head piece: Cardio vascular and organs with Brain Activity

Each piece senses bio-data in realtime and actuates it differently through the user interaction with it.

Drawing the Body

We started by developing analogue filament wired models by using a matrix of points, developing anatomical scaffolds and placing them in the selected body parts (Figure 3) In the second stage of form finding, we mapped in 2D body systems like cardiovascular, nervous, muscular and organ systems into a full body mannequin and with a 3Doodler pen we drew the 3D body shapes into three wearable pieces. (Figure 2). The 3Ddoddler prototypes were then modelled in Rhino and the digital models were generated using NURBS and Subdivision modelling techniques in Rhino and Maya, beginning with a series of curves that were based on biological information of bodily organs, as a means of creating the primary exoskeleton structure. A secondary structural pattern geometry was computationally generated by developing a script in the node based algorithmic editing software, Grasshopper (Figure 3). The script is designed to emphasize the primary structure by using the initial curves to create the boundaries of a dense, secondary set of curves. The control points of these curves are distorted using a series of attractor points located along the primary curves. This results in a curve network pattern which functions to provide additional volume and space for embedding sensors and hardware, while creating a range of densities and enhancing structural support. These curve networks were used to create NURBS surfaces which were combined into a single mesh using ZBrush. This allowed the geometry to blend together as a single, continuous polygon mesh surface, for visual continuity, as well as rapid prototyping various models using additive layer manufacturing technologies.

Sensing Technologies

The project integrates physical computing methodologies through the use of code, microcontrollers and sensors, that measure biometric information, including heart-rate, thermal activity, and brain activity. This includes the use of coding in Python and Javascript, Ardunio and BITalino microcontrollers, and Electrocardiograph (EKG) sensors, Electrodermal (EDA) sensors, and Electroencephalography (EEG) sensors, respectively. Each of the three prototypes are embedded with hardware and focus on a specific biometric by allowing users to connect the sensors to specific locations within their bodies (Figure 3). Biometric data is sensed and output through lighting, sounds and digital patterns that visually and auditorily express this invisible ephemeral phenomena.

Future Work

This is an on-going research that presents the potential architectural applications that utilize and integrate biometric data (heart rate, electro dermal activity, and brain electrical activity) and atmospheric flows (temperature, light) in determining bodymachine-environment relationships. In this scenario, inhabitants of buildings are not treated solely as users acting within a static built environment, but as stakeholders that hold agency, and act as catalysts for an architecture that can adapt to changing materials, environmental or ecological demands. These technologies alter our ability to imagine constructed systems in highly nuanced relationships between internal bodily signals and surrounding atmospheric data, requiring an expanded view of networked and object oriented relationships between bodies and designed spatial devices. Future development will aim at combining and merging the material and sensing components of the project. For example, instead of growing the material and then cladding it in a synthetic structure, we will look at a synchronous process of growing and form making of the morphologies. Bio-printing technologies combined with bio sensors will allow a more seamless integration of living material and synthetic matter.

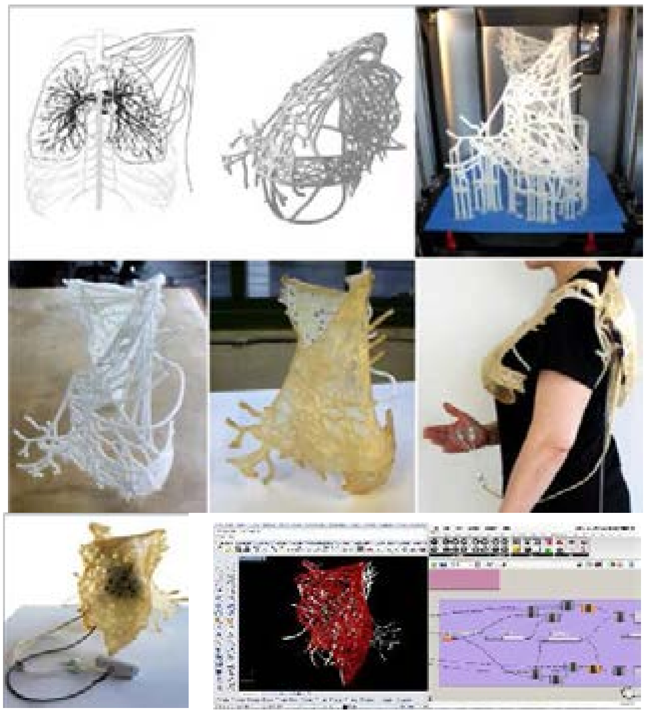

Figure 3: Design and fabrication process of the chest piece wearable device: anatomical diagram, digital model, 3D print on the MakerBot Replicator Z18 printer, final 3D print, bacterial cellulose clad prototype, and final prototype of wearable device with sensors and hardware integration. Photograph of the physical prototype consisting of 3D printed parts, bacterial cellulose, sensors, and hardware. Screenshot of the script generated pattern.

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