Nature of the Research and Significance

This proposal is about the design and prototyping of a Living Wall System (LIWAS) as a test bed for integrating concepts from biology into architectural design. The Living Wall is a new way of interpreting a wall system that we use in architecture and building. We try to integrate characteristics of living organisms into the wall design to harness some of the intriguing qualities of life into our built surroundings. Living Walls may include flows of water; they may move, adapt geometry, and change appearance; they may be inhabited by algae, plants and other organisms and in general be “alive.” The framework of the proposal is the overlap between architectural design and biological research, using biomimicry as a methodology for information transfer between the fields (Image 1).
The comparison between the so-called “signs of life” as defined in biology literature and on different architectural scales (urban design, building, element, materials) reveal a biological paradigm underlying current architectural research. This paradigm generates a vision of architecture as a dynamic, adaptable, sensing, reacting, and self-organizing entity with embodied smartness or even intelligence. Within this framework and together with international interdisciplinary groups of scientists and designers, I have in recent years investigated patterns from nature, and specifically biological growth as concept generator for a new, living architecture. Those projects, and the related publications, have gained broad acknowledgement. The concept of living architecture has since been taken up by different research groups worldwide, for example the Living Architecture Systems Group (LASG) with Philip Beesley in Toronto, Canada, and the Living Architecture (LIAR) project initiated by Rachel Armstrong at the University of Newcastle, United Kingdom.

Walls are especially interesting. They are borders between an interior environment designed for human habitation and a dynamic and changing environment of the exterior. Active and multifunctional wall systems, as proposed in the 1980s, can negotiate between the inside and the outside, integrating functions like energy management, light management, mechanical protection etc. The integration of a set of those functions into technical translations that can finally achieve the users’ comfort requirements is the ultimate goal of the proposed research in contemporary building facades using a biomimicry approach.

Contemporary wall systems are also increasingly providing additional functions to the classical provision of shelter from other people, animals, elements, managing of light entry to the inside, and provision of privacy.

5 Gruber, Petra and Barbara Imhof. 2017. “Patterns of growth - biomimetics and architectural design.” In Special Issue Biomimetics in Sustainable Architectural and Urban Design.
6 Living Architecture Systems Group http://livingarchitecturesystems.com
7 Living Architecture LIAR http://livingarchitecture-h2020.eu
Today’s building facade should deliver energy (solar and photovoltaic systems), customizable transparency (according to the wishes of the user), and signal to the outside (media facades) etc. Many of those systems are available on the market as single-function products that actively control inputs and outputs on the base of computation, relying on mostly centralized digital models that are not integrated, made of unsustainable materials and have a high energy demand.

In order to harness the embodied intelligence of biology, not only the functionality from biology has to be translated, but so do some deep omnipresent principles of design. such as hierarchical structuring of materials, anisotropic characteristics, multifunctional and integrated systems, use of passive mechanisms, local resource harvesting, and fine-tuned adaptation to the environment.

In a previous research project, the potential of biomimetics for future building facades was investigated, and a database of role models was generated. This research suggested that energy management and subsequent metabolic activity would be specifically interesting aspects to be translated into design. In the current proposal, the technical approach taken in BioSkin shall consider an experimental and artistic approach for integrative design and prototyping, as carried out in follow up projects, for example “Growing as Building” (GRAB) (Image 2, 3).

Current research on thermodynamics of plants will be a starting point for translating morphological principles into spatial structures and for establishing a system to integrate flows of water and humidity layering into wall systems. Further concepts will concern hierarchical material systems on different levels of scale, integrated efforts to use locally available materials and upcycle waste materials, as well as the integration of biological organisms like plants, algae, fungi, and microbes into the system.

At the University of Akron, the field of design research is now being developed by the Biomimicry Research and Innovation Center located at the Myers School of Art, in biomimicry design classes, and within the IB program and PhD Research Fellowships in Biomimicry. The research will take place in my current lab at the Department of Biology, in collaboration with two PhD students in Integrated Biosciences.


During the research and design phase, colleagues from the Biomimicry Research and Innovation Center, the Department of Biology as well as Myers School of Art will engage in exchanges and discussions. For design and production phase, there will be a collaboration with Drew Ippoliti, Assistant Professor in Ceramics at Myers School of Art. A funding component for the LIWAS is also to establish and maintain exchange with other external
researchers for reviews and discussions. The prototype of the research will be implemented at the University of Akron’s Biology Fieldstation at the Bath Nature Preserve (BNP) for long term exposure of at least six months to environmental conditions. Lara Roketenetz, the field station manager of the Department of Biology, will support the implementation and presentation activities on site.

The results of this project will generate an important example for a research-based design prototype that can be used to visualize the potential of biomimicry in architecture, and also in subsequent grant proposals with external funding organizations. As an experimental design concept, the final project represents a potential solution for the defined outset of design interests and parameters. In addition to the public presentation, the results will become part of the publishing activity of the lab, including papers produced by PhD students with their own approaches to the topic.

Goals and Objectives

The goal of this research proposal is to generate a collection of case studies in the field of living architecture in order to create a variety of design proposals presenting new approaches to translating sets of life criteria into design, and to create and build a prototype of a living wall system at the University of Akron BNP as a test bed for furthering design research in this field.

Objectives of the proposal are:

1. Furthering research and development of “living architecture” as an application field for biomimicry research and development.
2. Generating design proposals for living wall systems integrating new signs of life such as metabolic activity etc.
3. The main objective of the proposal is to build a prototype for a “living wall system” at the University of Akron’s Department of Biology field station at BNP as a long-term installation to serve as proof of concept example.
4. Long-term monitoring of the installation and hands-on presentation of the research field.
In addition to the biomimetic approach, important design goals are sustainability and integration of biology into the systems.

Broader impacts of this proposal are:

1. Visible and tangible results from the design research implemented at BNP will promote the University of Akron, STEAM approaches, and biomimicry to an audience based in the surrounding community and regional schools hosted at the BNP field station.
2. LIWAS will serve as a proof of concept example to further the intersection between art, architecture, and science.

Procedures

The project’s research methodology includes literature reviews, expert discussions, biology literature research, abstraction of basic design principles from biology, biomimicry information transfer, ideation and creation of concepts, architectural design, and experimental prototyping in the following phases:

1. Literature and case study research
2. Selection of biological role models for specific signs of life, and abstraction of their principles
3. Creation of designs that translate the principles into a technical system of a living wall
4. Evaluation of designs, and selection of a transferable concept
5. Building an experimental prototype installation
6. On-site implementation and presentation of the prototype
7. Long-term observation and monitoring of the system within PhD research beyond the funding phase of the University of Akron grant

Phase 1 will research the literature and interview relevant researchers in the field. Phase 2 will take on existing datasets from previous projects as well as current research on the thermodynamics of plants conducted in my lab. Phase 3 will be a series of creative design sessions and workshops with PhD students and collaborators from the University of Akron. Phases 4 to 6 will be in-lab design and prototyping sessions bringing together undergraduate design and biology students.
Facilities in the lab (3D printer, laser cutter etc.) will be used for production, as well as the ceramics lab at the Myers School of Art for larger scale productions.

Table 1 shows the schedule for the research. Research, design, and prototyping will be carried out over the summer and fall of 2019 from May to October. The final installation will be created in October and introduced in a public presentation at BNP.

Expected Results and Data Analysis

The expected research outcome will be a review of current living architecture systems, a set of design proposals taking on a biomimicry approach, and a tangible prototype installed at the University of Akron Biology Fieldstation at Bath Nature Preserve (BNP). The installation will serve as a proof of design concept, creating a tangible example of the potentials of biomimicry as an applied field. In the long term, the installation allows for monitoring of functionality and physical parameters (for example humidity and temperature), as well as observation of long-term behavior, colonization by organisms, and durability of the system.

Publication or Presentation

The results from the research will become a review paper about living architecture systems, and the design process and the prototype will be exhibited at the BNP for a public research presentation. The audience will consist of students, academics, and the public who are interested in biomimicry and experimental architectural design. The BNP hosts hundreds of pupils during organized visits each year. Having the installation there will be a great outreach to potential future STEAM students. The progress of the project will also be published in a blog and on social media. The research will also be part of the publications from participating PhD students.
Image 4  Overview of the Living Wall Systems prototype  
Work by Thibault Houette  
© Petra Gruber

Image 5  South Face of the mycelium section  © Petra Gruber

Image 6  South Face of the ceramic section  
Work by Ariana Rupp  
© Petra Gruber

Image 7  Fruiting bodies thriving on the mycelium panels  
© Petra Gruber

Image 8  Detail of the ceramic panels  © Petra Gruber
Feasibility of the Project

As discussed in the introduction, this proposal is based on a body of previous research in experimental architectural design (see bibliography). The materials from those projects are a starting point for the proposed research, as well as contacts to relevant researchers in the field in order to generate reviews. Two previous projects included large-scale spatial installations that were part of the design-based research. They opened to the public at the University of Applied Arts in Vienna, Austria, and later traveled to Hong Kong, Brazil, and Australia (Image 2, 3). In 2017, we organized the exhibition BIOSCOPE at the Emily Davis Gallery at Myers School of Art with design proposals created in the Biomimetic Design class.

The proposed project is highly experimental and still far from production stage. As a proof of concept, the project would be instrumental in getting external grants to continue researching in the field of biomimicry in architecture and design, and to accelerate establishing the research field at the University of Akron with follow up projects.

Team

Petra Gruber, Assoc. Prof. at Biomimicry Research and Innovation Center BRIC at the University of Akron (UA)

Ariana Rupp, PhD student in the IB program at UA, Biomimicry fellow (Engineer and designer), research, design and production

Thibaut Houette, PhD student in the IB program at UA (Architect), research, design and production

Brian Foresi, Biomed student at The University of Akron, research and production

Drew Ippoliti, Assistant Prof. Ceramics, UA Myers School of Art, design and production support

Lara Roketenetz, Field Station Manager BNP, UA Department of Biology, on-site support

Jeff Spencer, Lecturer and Lab coordinator at UA, prototype building support
Funding Status

The project was funded by The University of Akron with a Faculty Research Grant.

Dr. Petra Gruber is an architect with a strong interest in inter- and trans-disciplinary design. In addition to her professional work as an architect, she holds a PhD in Biomimetics in Architecture from the Vienna University of Technology in Austria. She also collaborated as a research fellow at the Centre for Biomimetics at The University of Reading, UK. She taught Biomimetics in Energy Systems at the University of Applied Sciences in Villach, Austria, and held lectures and workshops at universities worldwide.

As a visiting professor for Architectural Design and Building Science, she set up a Master’s program in Advanced Architectural Design at the Addis Ababa University in Ethiopia. Her research spans from projects for the European Space Agency on lunar base design informed by folding principles from nature to arts-based research on the translation of growth principles from nature into proto-architectural spatial solutions.

Dr. Gruber is based at the Myers School of Art and the Department of Biology for the Biomimicry Research and Innovation Center or BRIC at the University of Akron.