GRADUATE AND POSTDOCTORAL STUDIES
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OF

MERCEDES GARCIA HOLGUERA

DEPARTMENT OF BIORESOURCE ENGINEERING

ECOMIMETICS: AN ECOSYSTEM-BASED BIOMIMETIC DESIGN METHOD FOR INNOVATIVE BUILT ENVIRONMENTS

July 17th, 2018
9:15 A.M.

Raymond Building, Room R2-045
McGill University, Macdonald Campus

COMMITTEE:
Dr. K. Manaugh (Pro-Dean) (Geography Department)
Dr. S. Prasher (Chair) (Bioresource Engineering Department)
Dr. G. Clark (Supervisor) (Bioresource Engineering Department)
Dr. S. Gaskin (Co-Supervisor) (Civil Engineering Department)
Dr. D. Covo (Internal Examiner) (Peter Guo-hua Fu School of Architecture)
Dr. M. Cerrutti (External Member) (Materials Engineering Department)

Dr. Josephine Nalbantoglu, Dean of Graduate and Postdoctoral Studies
Members of the Faculty and Graduate Students
are invited to attend

ABSTRACT

The practice of biomimetic design, defined as the application of biologically inspired design for the advancement of technology, is ancient; however, the organization of the field as a scientific discipline is recent and ongoing. For example, biomimetic design was present in Leonardo DaVinci's drawings of flying machines based on the observation of birds' flight in the fifteenth century, an in 1955 when George de Mestral patented the Velcro after studying how burrs attached to his dog's fur. One thing these two examples have in common, beyond the emulation of nature, is their spontaneity or lack of structured methodology that led to their use. In the past two decades, more disciplines are embracing biomimetic approaches as a successful way to stimulate innovation in their fields, one of these disciplines is architecture. Biologically inspired design in architecture has, in addition, the potential to address present anthropogenic environmental challenges, some of which are directly or indirectly caused by the built environment. In this context, nature is perceived as a vast database of design solutions from which to learn and obtain inspiration. However, systematic methods for accessing nature's designs and successfully transferring them into architectural objects are still incipient. Reliable and reproducible methods are fundamental for the dissemination of biomimetic design in professional and academic environments and constitute the cornerstone to building the discipline of biomimetic architecture.

In order to address this gap, this thesis presents a novel ecosystem-based method for biomimetic design in architecture, the ecomimetic method. Biologically inspired design can mimic one organism and its parts or the behavior of a group of organisms, but it is also possible to mimic the multiple and complex interactions that occur in ecological systems. It appears that ecosystems and buildings share some interesting features; for example, they both are open thermodynamic systems that need a constant inflow of energy to maintain a steady state. Buildings, like ecosystems, are made of numerous different components that interact in non-linear ways, therefore producing complex dynamics. However, unlike ecosystems, most buildings still rely on non-renewable sources of energy for their design, construction, maintenance and demolition. Learning from ecosystem dynamics can help optimize resource use in buildings and generate innovative designs.

Challenges to the development of biomimetic design methods are manifold. They include, but are not limited to, the identification of a biological system in nature's extensive catalogue, the selection of transdisciplinary language and tools to transfer knowledge from biology to architecture, the coherent abstraction of the lessons learned from nature, and the successful emulation of those lessons in architectural designs. The ecomimetic method presented follows a problem-based approach and displays distinctive characteristics in each one of its design phases. The first phase requires the definition of an architectural design goal using thermodynamic language and the second phase suggests how to select an ecosystem that fits that design goal. In the third phase, two transdisciplinary tools (the Energy System Diagrams and a system dynamics software) are introduced to abstract the qualitative and quantitative organization of the ecosystem. In this phase, non-ecologists gain a deeper

understanding of the ecosystem's functions and processes so that, in the following phase, they become capable of establishing functional correlations between ecosystemic and architectural components. During phase five, a building system is designed that reproduces some aspects of the ecosystem's processes and, finally, its performance is assessed during the last design phase.

Three case studies were developed to evaluate the ecomimetic method. The first one studied the regulation of temperature and humidity in the ecosystem of a leaf-cutting ant, which inspired a breathable building envelope as a design solution. The second exercise focused on freshwater marshes and mimicked their water quality improvement processes to design a modular building block for wastewater treatment. The last case explored a variety of processes in maple forest ecosystems to produce three mimicked solutions. Several lessons were learned from these cases. Although the ecomimetic method is highly transdisciplinary and requires that participants receive some basic technical training in disciplines complementary to their own, this was not a major obstacle for the participants. Improvements in meeting energy and water use goals were proposed in the three case studies. The ecomimetic building models reduced considerably the estimated energy use when compared to actual and benchmark building designs, and in all cases the solutions proposed included innovative architectural components.

The ecomimetic method is here shown to be a reliable tool for building design with great potential for addressing environmental challenges. Its implementation in academic and professional environments can be further broaden through the development of workshops and university-level courses, as well as a comprehensive software tool to facilitate the design process.

CURRICULUM VITAE

UNIVERSITY EDUCATION

2018	**Ph.D. in Bioresource Engineering** McGill University, Canada
2005	**Certificate in Sustainable Architecture** Pontificia Universidad Catolica de Chile, Chile
2003	**Master and Bachelor degree in Architecture** Universidad Politecnica de Madrid, Spain

EMPLOYMENT

2014-2018	**Tomlinson Graduate Teaching Fellow** McGill University, Canada
2013-2015	**Teaching Assistant** McGill University, Canada
2013-2014	**McGill Net Positive series Project Manager** McGill University, Canada
2009-2010	**Architect Associate** TEN Arquitectos, Mexico
2008-2009	**Preconstruction Assistant Manager** Grupo GA&A, Mexico
2005-2006	**Project Architect** Self-employed, Spain
2003-2007	**Architect Project Leader** Jose Cruz Ovalle Arquitectos, Chile

AWARDS

2018	**BLUE Fellowship** McGill University, Canada
2014-2018	**Tomlinson Graduate Teaching Fellowship** McGill University, Canada
2013-2015	**Teaching Assisstant** McGill University, Canada
2011, 2012, 2014	**GREAT Award** McGill University, Canada
2012	**Graduate Excel Fellowship** McGill University, Canada
2013-2015	**Teaching Assisstant** McGill University, Canada

2011-2013	**Caja Madrid Foundation Scholarship** Spain
1999-2000	**Erasmus Scholarship** European Union

PUBLICATIONS

Refereed Publications

Garcia-Holguera, M., Clark, O. G., Sprecher, A., & Gaskin, S. (2015). Ecosystem biomimetics for resource use optimization in buildings. Building Research & Information, 1-16.

Garcia-Holguera, M., Clark, G., Sprecher, A., & Gaskin, S. (2015). Approaching biomimetics: Optimization of resource use in buildings using a system dynamics modeling tool. Conference proceedings. Symposium on Simulation for Architecture and Urban Design (SimAUD), Washington, DC.

Garcia-Holguera, M., Clark, G., Gaskin, S., & Sprecher, A. (2012). Ecosystems Biomimetics: Ecological Systems Diagrams for Characterization of Environmental Performance of Buildings. The International Journal of the Constructed Environment, 3(2), 147-164.

Conference Proceedings

Garcia-Holguera, M., Zisa, A., Clark, O.G. (2016). An Ecomimetic Case Study: The Ecosystem of the grass-cutting ant for building retrofitting. Conference proceedings. CIB World Building Congress WBC16

Garcia-Holguera, M., Clark, G., Sprecher, A., & Gaskin, S. (2014). Ecomimetics: Ecological engineering tools for resource use optimization. Conference proceedings. ASABE Annual International Meeting, Montreal, Canada.

Professional Presentations

Armin Yazdani, Valerie Bourassa Dan Petrescu, Wagner Souza-Silva, **Mercedes Garcia-Holguera,** Chris Bailey, Benjamin Keenan, Cassidy Vander Schee, Faygie Covens, David Harpp. (June 2018) The Tomlinson Project in University-Level Science Education (TPULSE) and knowledge translation for improved future STEM teaching and learning. SALTISE Conference. Disruptive innovations: Changing educational landscapes. Montreal, Canada.

Garcia-Holguera, M., Coelho, S., Varela, B., Yazdani, A., Chouinard-Thuly, L., Covens, F., Harpp, D.N. (July 2017). Training graduate students and postdocs in

course design: A workshop to bridge the gap between new professors' pedagogical background and institutions' teaching requirements. Oral presentation. The Western conference on science education. London, Ontario. Canada

Garcia-Holguera, M., (May 2017). Ecomimétisme: comment concevoir des bâtiments qui se comportent comme des écosystèmes. Oral presentation. ACFAS Conference. Montreal. Canada

Garcia-Holguera, M., Clark, G., Sprecher, A., & Gaskin, S. (2015). An Ecomimetic methodology: Buildings that mimic ecosystems for climate change adaptation and mitigation. Poster presented at the International Environmental Trade Show and Conference Americana 2015. Montreal. Canada.

Garcia-Holguera, M., Clark, G., Sprecher, A., & Gaskin, S. (2014). An Ecomimetic methodology: Ecological engineering tools for building resource use optimization. Poster presented at the First Annual Trottier Symposium on Sustainable Engineering, Energy and Design, Montreal, Canada.

Garcia-Holguera, M. (2013). Ecomimetics: Buildings that mimic ecological systems. Oral presentation. McGill University. 9th Interdisciplinary Graduate Student Research Symposium.

Garcia-Holguera, M. (2012). Ecosystems Biomimetics: Ecological Systems Diagrams for Characterization of Environmental Performance of Buildings. Third International Conference on the Constructed Environment. Vancouver, Canada: Common Ground Publisher.