Bio-Cyber Physical Architecture

Optimization of Green building strategies for Self - Sufficient Buildings

Introduction

The world around us is rapidly changing and evolving. In a recent report by the World Green building council, Together, Building and construction are responsible for 38.8% of all carbon emissions globally, with operational emissions (from energy used to heat, cool and light buildings) accounting for 28% [1]. Our structures depend upon many resources during the construction phase or operational phase. So it is clear the design decisions we make now for our built environment have a significant impact on the future. As the population grows, the need for freshwater, electricity, and other urban infrastructure grows exponentially. It leads to much pressure on the existing human-made and natural systems needed to run our cities smoothly. Self-sufficient buildings can be a crucial solution to urban problems like increasing energy demands and poor air quality, which we face today. It is less dependent on active means of energy sources and more inclined towards passive energy sources. Self - Sufficient buildings as a concept have been existing for quite some time currently and have made significant impacts giving us a new vision to move towards a sustainable future. Integrating vegetation into the built environment has proven in many instances that it increases the self-sufficiency of the users' buildings and well-being, according to R.Hassell, 2017[2].

The built environment has replaced the previous natural environment as man's "normal" surroundings. Often, greenery has become a mere add-on to any design project rather than integrating them within the design process. Integrative design solutions are the key to solve a number of our building-related problems[3].

A green building is a high-performance characteristic that considers and reduces its impact on the environment and human health. It is designed to use less energy and water and reduce the life-cycle environmental impacts of the materials used[4]. Self-sufficiency index rates the success of a development's energy, food, and water production, the amount of its surfaces allocated to the solar collection and urban farming, and the extent of its systems for recycling and harvesting natural resources [3].

Nature has always been giving us inspiration and ideas for the field of innovation. It has always helped us provide new ways of living and green solutions for the future and provide us with environmental, economic, and health & community benefits. The integration of green vegetation into the buildings has proven to have various psychological and physiological benefits over the users[5]. More than its aesthetic advantages, it also helps absorb excessive solar radiation on the roofs, which reduces indoor temperatures up to 4 - 6°C[2]. It absorbs excessive stormwater runoff, which is used for various functions in the building. Kampung Admiralty, Singapore, was awarded the title of the building of the year 2018 by W.A.F. is one of the projects that integrate vegetation not only for its aesthetic purposes but also to improve the self-sufficiency index of the building. The lush green step gardens seamlessly flow into habitable spaces, improving the users' psychological and physiological state[6].

Nevertheless, to understand the impact of the green building strategies in self-sufficient buildings on its future, we need data and statistics from predated green-built projects to speculate it holistically. Calculating all the parameters and testing multiple iterations for a design solution to postulate its impact is quite complex. Computational optimization methods can help solve complex calculations and assess their holistic impact on the built environment.

To summarize, integrating green building strategies can increase the self-sufficiency index in our structures. The research will explore various computational optimization methods used in the past for similar contexts and relate them with green building strategies to design a self-sufficient habitat.

Research Question

The research question mainly revolves around developing a design process that explores computational design strategies in green buildings and landscapes. After careful deliberation, all investigations are moving towards understanding different aspects and find the overlaps between these two emerging fields because innovation and new ideas can be explored in that overlap. To summarize, the research question is "How to optimize green building strategies using computational optimization methods to design self-sufficient buildings."

Theoretical Framework

The design framework is an amalgamation of 3 different aspects, such as Bionics(Ecology/vegetation), Cyber(Computational optimization methods), and Physical (prototyping). Each plays an important role where it aims to achieve a symbiotic relationship between these different aspects. Each sub-section caters to the diverse needs of the user. The research needs to dive into various aspects of the framework in order to achieve a holistic design.

1. The research will investigate what Self-sufficient buildings proposed by the International Living Future Institute consisting of seven petals of self-sufficient design. My research takes inspiration from it by decoding its elements into a new framework for integrative design and building processes. Based on this thesis's research and ideas, Fig 1 proposes a framework for integrating it into the current design process.

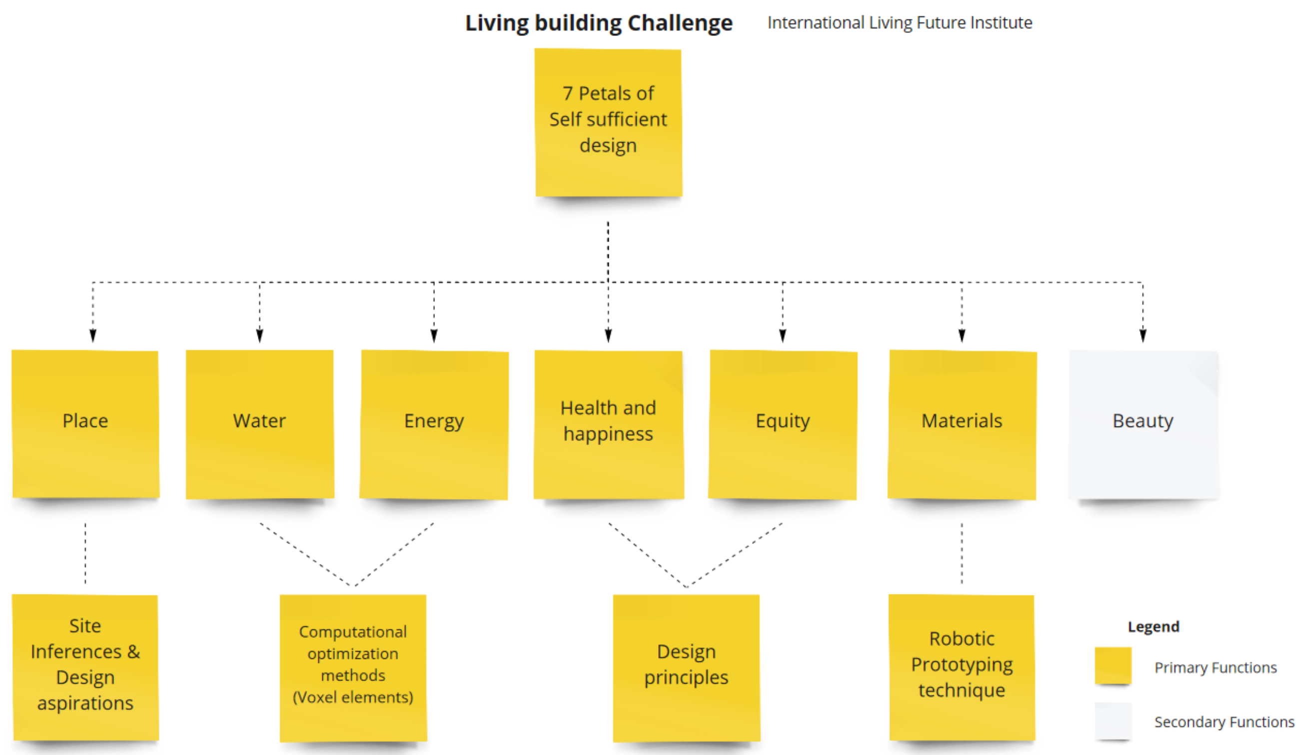

Fig.1: 7 Petals of Self Sufficient Design by International Living Future Institute

2. The research will investigate few questions like what are green building strategies? How can it improve the design's self-sufficiency index and the designer's current challenges are a few of the tasks of the research design. Biophilic design is one of the strategies which is incorporated in the design principles. It is a concept to increase occupant connectivity to the natural environment through the use of direct nature, indirect nature, and space and place conditions. The term 'biophilia' was first coined by social psychologist Eric Fromm (The Heart of Man, 1964) and later popularized by biologist Edward Wilson (Biophilia, 1984)[7]. The strategy is to study existing precedents where biophilic design has made a significant impact on its environment. Furthermore, Green Dip is a research project under the thinktank of The Why Factory, T.U. Delft. The project proposes a new way of living in cities that look and feel different from the concrete jungles we live in today. It is a tool that allows the user to test Green implementation strategies tailored to

any project, measure in real-time the positive benefits, and mitigate our urban urgencies with dynamic solutions, new possibilities, and new visions. Nevertheless, it could not optimize the strategies to find the optimal solution for a specific area in the entire design. It can be used to speculate solutions for schematic design, but it needs more research to integrate in order to encompass a nourished design. The research analyses the project and finds the missing links and data required to realize this thesis's goals.

3. Which computational optimization methods will comprehend in integrating green building strategies for the design framework? What are the past precedents where computation is integrated with ecology? There are multiple calculations required when it comes to integrating green building strategies into our built environment. Many of these calculations are done by manual methods and are quite complex. Computational design strategies aim to bring efficiency in designing, fluidity in design, testing multiple hypotheses in a short time, and many more. The research will analyze past precedents like the Green dip and flora robotica[8] to find an existing strategy supporting the design.

An existing theoretical framework such as D2RP&O- Design to Robotic Production & Operation - is a design process that aims to optimize material and energy efficiency to achieve adaptive and reconfigurable robotic building components and buildings for customizable and sustainable use. Traditional construction can be a slow and inefficient process; Robotic Building has the potential to revolutionize the way we build. Before building the design, several simulations can help us understand its real-time effect in the built environment. When the design comes into the operation stage, sensor actuators give constant feedback to the design completing the process and making it can closed-loop system[9]. This framework will enable to prototype of the proposed design to understand its real-world implications.

The amalgamation of all the above frameworks will help develop a symbiotic approach to explore integrative solutions towards designing self-sufficient buildings.

Methodological Reflection

The overall formulated design process consists of three parts- Bio, Cyber, and Physical. These elements are quite broad spectrum topics; hence we need to understand their various aspects. The research started with testing different possibilities together and then taking a deeper dive into the selected topics.

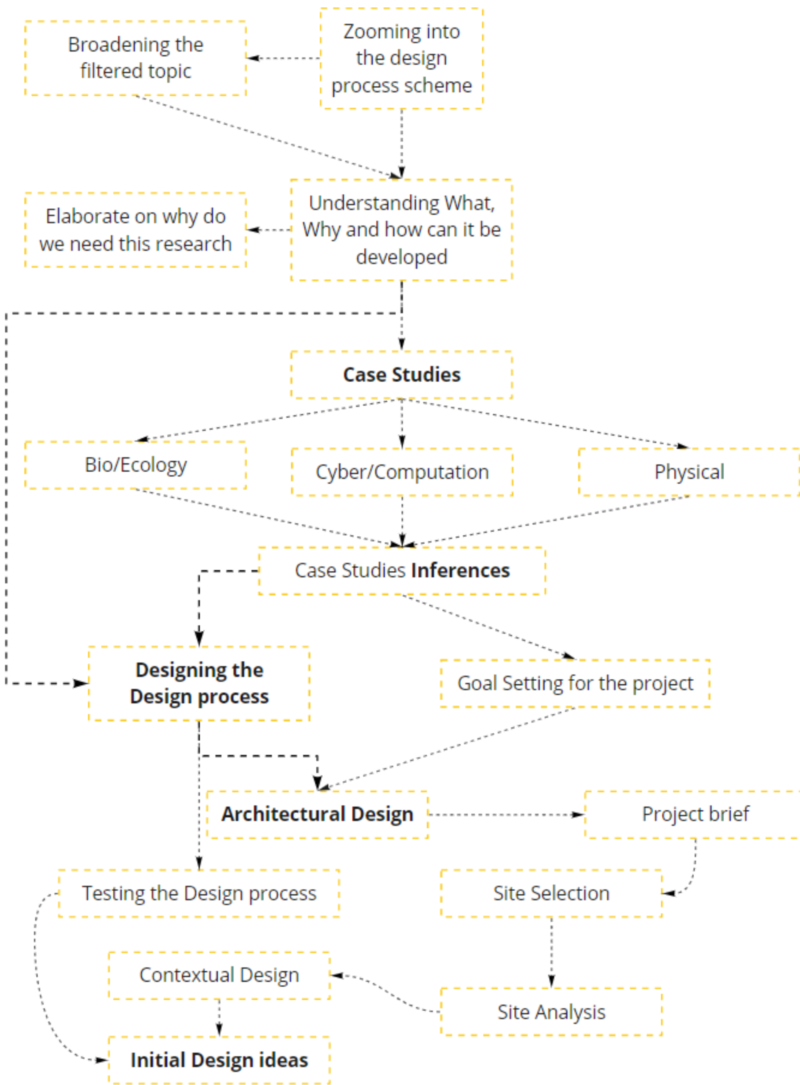

Fig.2: Methodology

In this research project, the methodology was always to look at relevant case studies, and its analysis would help formulate the different aspects of the project. Streamlining the thoughts into a flexible research framework creates a non-rigid process that keeps room for more improvement at every stage. Having a flexible research framework keeps room for innovation and, at the same time, does not let the researcher move too far away from the topic.

Several topics ranging from built architectural projects to innovative research projects will be explored to help formulate the design process and architectural design intervention. Figure 3 explains how the inferences from each project helped in formulating various sections for Architectural design intervention.

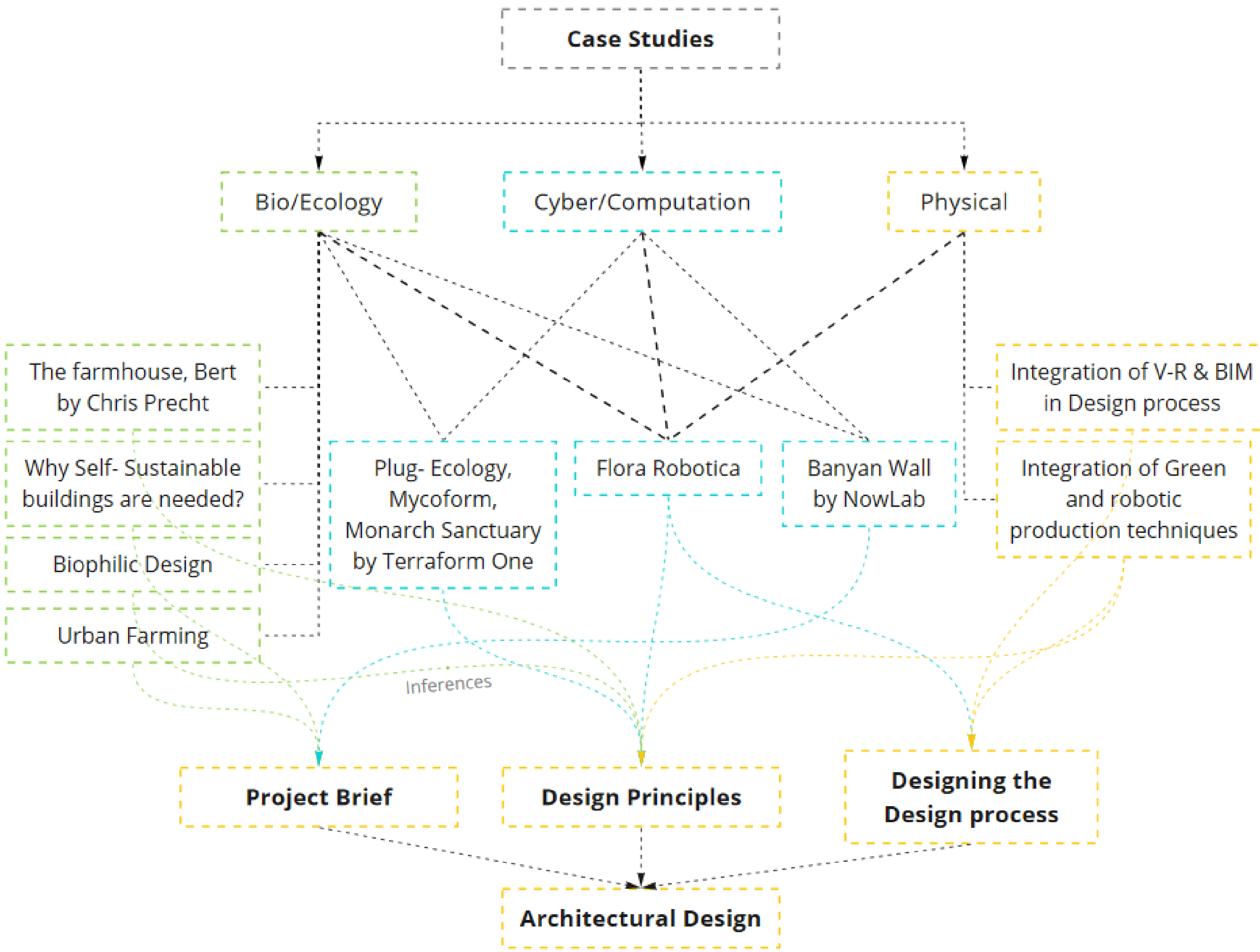

Fig.3: List of Case studies for the research design

Vision for the thesis project

Developing a complete Bio cyber-physical architecture (B.C.P.A) system is a lifelong project. The ideas are streamlined into testing a specific part of the design process, considering the Graduation timeline. The project brief is developed to design an innovation hub for emerging Eco-Tech. The results from the research will help in framing the computational workflow for the project. It can be later used to test the schematic design of the project to understand its workability. Voxels are used to create elements that will be populated on the schematic design based on the energy production goals set for the project. After analyzing the voxels' performance in the overall design, it will give the user the ability to understand the building's future impact on the built environment. Using Biophilic design as design principles, the attempt will be to create similar modules as design elements. These elements can be populated on the schematic design similarly. The architectural design aims to create a hub that will inspire its context to promote such green ways of living and newer technologies to have a sustainable future. Hence Mumbai, India, is chosen as the city for its context as it has a cultural and economic impact all over India.

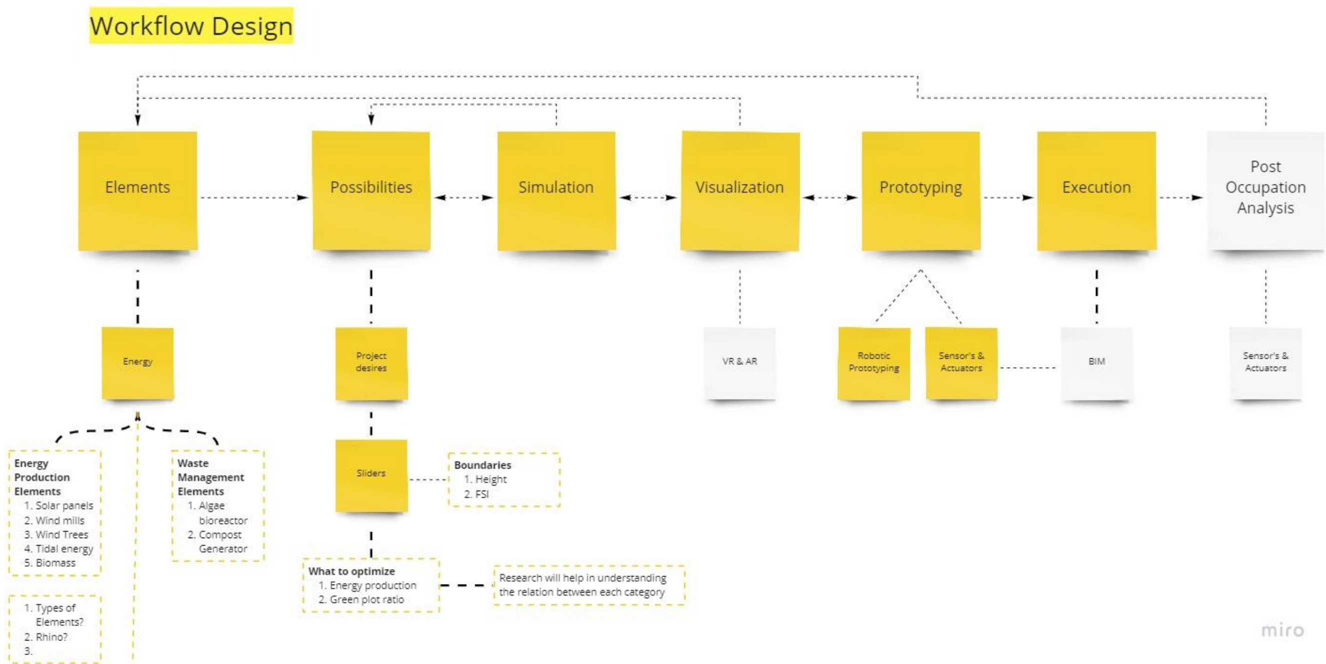

Fig.5: Schematic Design process- B.C.P.A Systems

Conclusion

To conclude, after doing many case studies that helped understand various aspects of B.C.P.A, the project envisions speculating and designing an Innovation Hub for emerging Eco-tech, allowing innovators to come from all over the globe and work together in the field of Ecology and Computation. This research will help develop a design process, which will act as the primary driver of architectural design. Biophilic design[10] and seven petals of self-sustainable design[11] will be the project's primary design principles. After understanding the project's need and the developed design process framework, Voxel theory was chosen as a part of computational design strategy, which will help populate the conceptual design with passive energy production modules depending on the project's goals. In this way, we can speculate on how the building will perform in the future and make better-informed design decisions for the project. Some secondary goals for the project are testing the design ideas on a prototype scale using robotic production techniques and evaluating the project's overall impact on the built environment.

Course Reflection

Considering our graduation project consists of extensive research, and can benefit from a research course running parallel to the main project. The lectures and the course's masterclass given by the tutors were good; however, it was unclear how it could improve or develop new research skills. In my case, I felt the lecture contents were too far from my research aims, and I could not find clear channels to adopt them into my ongoing research trajectories.

If the course could have been introduced sooner in the masters, it would have been much more beneficial to help us set up a research plan for our thesis since we would already be aware of the methodological approaches and scope of a plan.

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