DREAMHOME: A PERSONAL SPACE OF CORE HUMAN DESIRE AND AMBITION

A Thesis

by

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ABSTRACT

Dreamhome is a creative exploration of a prototype house designed with creative freedom using possible future technologies that may not be currently feasible. New and forthcoming technology in various scientific branches that could be applicable to architecture will be presented, and the applications discussed. Limitations of application to architecture of the reviewed technologies will be discussed. Prior works by architects and engineers who push boundaries to innovatively overcome technological limitations will be explored, as will examples in which advanced technology is applied to create unique architectural designs. Together these references will evoke inspirations to be translated into an architectural design and a virtual home. The house is desired to boast of a unique design with various aesthetic and functional features that are not usually seen in present day architecture. This visualization could be a glimpse of possible home design of the future.

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NOMENCLATURE

HVAC	Heating, ventilation and air conditioning
RCC	Reinforced cement concrete
CAD	Computer aided design
CAM	Computer aided manufacturing
SMP	Shape memory Polymer
SMA	Shame memory Alloy
PCM	Phase-changing material

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1. INTRODUCTION

During the timeline of human civilization, many a fantasy has been turned into reality. There are miraculous new inventions in fields such as medicine, telecommunications, and information technology that render old technology obsolete every few years. Every few months one reads in science journals about new discoveries that demystify many wonders of nature. Constant research efforts in these fields not only advance technology by leaps and bounds, but also make implementation cheaper and more affordable to the global society.

Building design technology, on the other hand, has not seen the kind of progress other fields of science have witnessed. Developments in other scientific fields have influenced architecture and construction, however slowly. After the stone, brick, and wood construction era came the industrial revolution in the 19th century which introduced structural framing systems that provided the possibility of high rise construction. To this day, the same structural frame systems with RCC components are used in architectural construction, in which a framework of slabs, beams and columns support the entire load of the structure and transfer it to a structural foundation under the ground. Since the structural frame bears weight of the entire structure, partition walls and external facade walls no longer need to be load bearing and can thus be built of lightweight materials with more surface area in openings. Development in environmental HVAC systems and high scale industrialization of glass making led to the proliferation of the glass curtain wall, widely used in modern architecture today. In a curtain wall system, the building facade is disconnected from the structural support system, creating an architectural skin. Advancement in CAD and CAM technologies allowed for design and precision manufacturing of curved glass, aluminum and titanium panels to be used as components of architectural skins, which ultimately lead to a wide range of building forms never seen before [1].

The scope of architectural design possibilities, though widened with the technologies described above; is limited with respect to the properties of materials that are employed by the particular technology. For example, the total load to be carried, depth of the beam, size of columns and stress bearing capacity of steel reinforcement would determine the distance between two columns. Even within technological limitations of any construction era, architects and engineers together have designed and built many a wonder on earth. The Egyptian pyramids and the Taj Mahal, for example, are monuments of load bearing stone construction. Frank Lloyd Wright has created timeless architecture with the use of RCC technology. Frank Gehry and Norman Foster have created modern architectural sculptures by using innovative curtain wall designs. Were serious research to be initiated towards the advancement of construction technology integrating advanced technology from scientific disciplines, it could mediate many design limitations and evolve many new possibilities. Architectural design could very well scale heights beyond imagination.

Many scholars such as Axel Ritter and Michelle Addington predict that we are on the brink of an architectural revolution**.** New research and development in nanotechnology points to functionally adaptive materials and technologies that may influence the next generation of buildings to have more functions and design expression. Restraining factors such as structural limitations of the materials and technology employed would no longer drive architects to compromise an original vision.

Slowly but surely, more and more architects and engineers are looking beyond standard construction practices and adopting new technology derived from research into other branches of science to realize hi-tech, speedier and greener construction. Inspired by such realizations, this thesis project shall borrow ideas from possible future materials and technologies to achieve a unique architectural vision. It seeks to illustrate a personal space of core human desire and ambition.

2. NEW TECHNOLOGY AND MATERIALS

2.1 Introduction

In this section are discussed new developments in other disciplines of science that have impacted architecture, or have the capacity to do so in the future. Some of the technology described is feasible in the present day, while others are future possibilities.

2.2 Augmented Reality

Augmented reality is a technology that enhances the real world experience of a person in an environment by introducing computer generated imagery, sounds, smells, or feedback systems in the existing environment; blurring the line between real and unreal [9].

2.2.1 Applications in Architecture

2.2.1.1 Changing Elevations

Still images or videos could be projected onto the facades or interior walls of buildings to give them a new look. One could create optical illusions with augmented reality. Projecting higher intensities of light to compensate for dark shadow areas on the façade would change how one views the actual 3d form of the building. (Figure 1) demonstrates the application of augmented reality to generate façade details on a plain white model of the Taj Mahal; the projectors being labeled as Shader Lamps [22].

(Figure 2) shows how changing the projected image can influence the perception of the form of the augmented structure.

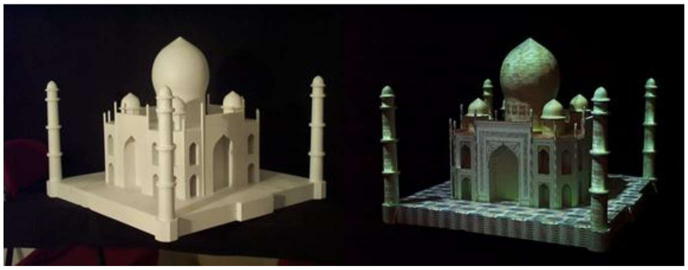

Figure 1. Illuminating the Taj Mahal with Shader Lamps

Fuchs, Henry. *The Underlying Physical Model of the Taj Mahal and the Same Model Enhanced with Shader Lamps.*2001. Shader Lamps, University of North Carolina. http://www.cs.unc.edu/Research/stc/Projects/shaderlamps.html. Web. 20 May 2009.

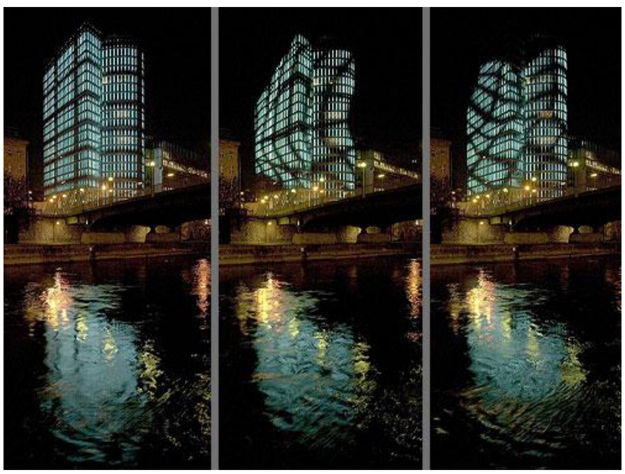

Figure 2. Changing Perception of Form

Massard, Herve. *Twists and Turns.* 2007. Uniqa Tower, Vienna. http://www.webblick.de/index.html. Web. 20 April 2012.

2.2.1.2 Controlling Interior Environment

Phillips Daylight Window is an example of a window system designed by Phillips Company that augments the actual view of a window with artistic silhouettes and shadow patterns, and is programmed to change colors and intensity of daylight passing through the window via hand motions registered on the window's touch surface [28]. (Figure 3) shows how evening scenery is generated on demand by application of augmented reality.

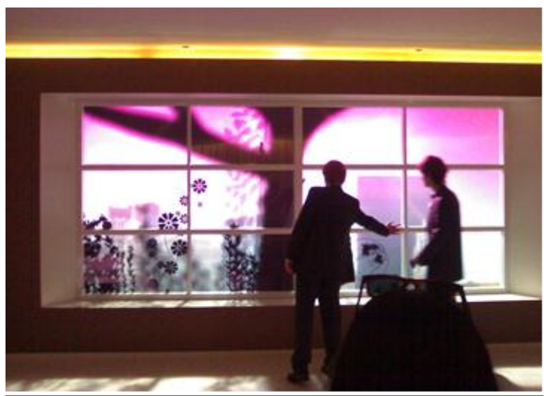

Figure 3. Scenery on Demand

Phillips Co. *Daylight Window*. 2007. The Concept Collection, Netherlands. http://techlun.ch/tag/daylight-window/. Web. 25 May 2011.

2.2.1.3 Interactive Art

Cameras inserted into the architectural environment could capture the position and movement of people present in the space. A computer program could generate art using the gathered information, which could be projected onto surfaces in the environment.

2.2.2 Limitations of Application

- The application of augmented reality to change building elevations would require precise mathematical and geometrical calculations to map the 2D coordinates of the projected image onto the 3D coordinates of the building's geometrical form. Any change in the placement of the projector, or its calibration would result in misalignment of the projected image on the 3D surface.
- The optical properties such as absorptivity, color, luminosity, photosensitivity, reflectivity, refractive index, scattering and transmittance of the building material would greatly influence the clarity and sharpness of projection cast on the material's surface.
- The environmental lighting conditions could interfere with the quality of the cast projection on the façade.
- The façade of the building could be composed of a combination of different materials with different finishes, such as wood, glass, paint. The projected image would look different on the different finishes, which might cause undesired discontinuity in the projected image.

2.3 3D Printing

3D Printing is a technology that uses a computer controlled printer to convert CAD data into physical objects, layer by layer.

2.3.1 Salient Features of 3D Printing

- Can build objects that other technologies cannot handle, e.g. continuous complex geometry. (Figure 4) is an example of an object with continuous edges, which can only be built through 3D Printing.

Figure 4. 3D Object with Continuous Edges

Grossman, Bathesba. *Borromean Rings*. N.d. Mathematical Sculptures, Boston. http://www.vubx.com/interesting-designs/impressive-mathematical-sculptures-of-bathseba-grossman.html. Web. 10 May 2009.

- Objects can be printed in a variety of materials. E.g. Plastic, plaster, wax
- Accuracy, as CAD data is directly translated to physical object, eliminating human error.
- Speed and cost effectiveness, as no casts or moulds are needed.

2.3.2 Desired Advancements in 3D Printers

- Ability to choose one's own printing material and binder.
- Ability to use multiple printing materials at a time.
- Ability to assign material identification numbers to the CAD model components so that when printed the model part will be of the designated specification. The aim would be to print a working model with an integrated lighting system inside it.
- Options to control the drying/hardening time of the print material so that the designer has time to sculpt and experiment with the form manually if desired.
- A printing material that, after printed, could be scaled though a chemical/physical process to the desired architectural scale.
- Increased printing speed
- Lower cost

2.3.3 Limitations of Application

- The size of the 3D printer will influence directly the maximum size of the object that can be printed with it.
- Currently available 3D printers offer limited choices of materials for printing; which would restrict options of the material choices for the 3D printed object. That said a 3D printer could be custom designed for specific needs. One example of a custom designed 3D Printer applicable to the building industry is discussed in section 3.3.

2.4 Nanotechnology

A nanometer is one billionth of a meter; a length smaller than the wavelength of light. It is a dimension so small it is only one hundred thousandth of the width of a human hair. As small as a nanometer is, an atom is even smaller. A nanometer is several atoms wide. Atoms are the building blocks of every element that exists in the universe. Groups of atoms bond to each other to form molecules; and molecules group to form cells that could be inorganic or organic. Cells group to form all matter that exists in the universe. The position of individual atoms within molecules and the force dynamics between them gives matter all its properties, for example color, mass, strength, and reflectivity. Development in scanning tunneling microscope technology allows scientists to view individual atoms at nanoscale. With the tip of the microscope, scientists can move and align individual atoms to desired positions and thus design materials from the 'bottom up'. This technology of manipulating matter at the atomic and molecular scale is called 'nanotechnology'. At this scale, the laws of quantum physics start to take hold which cause radical and dramatic changes to the properties of the material. By manipulating matter at this scale, it is thus possible to create new materials with extraordinary properties that never before existed in nature [2]. Billions of dollars are currently invested in nanotechnology research. These research efforts are envisioned to have extremely pervasive and profound impacts in the 21st century, which is already referred to as the 'Nano-century'.

Just as nanotechnology would deeply impact medicine, electronics, robotics, and other fields, it would also impact architecture. Architects and builders already have access to quite a few nano-engineered materials in the form of aerogels, carbon fibers, carbon nanotubes, self-cleaning materials, self-repair materials, etc. Nanotechnology is bound to transform architectural environments physically and functionally, and is likely to alter to a great extent how we as occupants interact with the environment.

As nanotechnology advances, it is perhaps beyond imagination at what scale it will revolutionize architecture in the far future. Nanotechnology might provide architects with unprecedented design flexibility, making available choices of materials that could fulfill any design whim.

The subsections that follow discuss present likely applications of nanotechnology in the field of architecture.

2.4.1 Carbon Fiber

Carbon fiber is a material composed of carbon atoms, bonded together in crystals aligned more or less parallel to the axis of the fiber lengthwise. Such an alignment gives the fiber an extremely high strength to volume ratio. The fibers are thinner than a human hair, with a diameter of about 5–10 nanometers. Carbon fibers have high stiffness, tensile strength, chemical resistance and temperature tolerance. In comparison with steel, carbon fibers are five times stronger, two times stiffer, and two-thirds lighter. Carbon fibers can be combined with other materials to form composites that can be designed to serve various purposes [15]. Carbon fibers could be woven together like a textile, and can be molded to desired shapes. Carbon fibers are a present day technology, and are suitable for a wide range of applications in the automobile, aerospace, architecture, and industrial design industries. They are only rarely used, for example in the BMW M6 luxury car, due to the high cost factor of the technology.

2.4.1.1 Applications in Architecture

- When used as reinforcement or a direct construction material, the high strength to weight and volume ratio of carbon fibers would greatly reduce the size and weight of a structure, making the architectural design less bulky.
- Supporting members such as columns and beams of a structure not only would be high strength themselves, but would require supporting less weight. Thus columns and beams could be greatly reduced in size and number. The distance between columns could be greatly increased, allowing larger continuous architectural spaces.
- The ability of carbon fibers to be molded could be directed toward creating various free flowing, delicate, yet strong architectural forms. (Figure 5) shows how Carbon Fiber is used by architect Peter Testa to create a conceptual design of a building without using steel for the structural strength of the building. The building would use a cross-hatched carbon fiber lattice woven around the building for structural strength. Carbon Fiber being extremely strong would eliminate the need of columns in the interior of the building [19].
- The strength and flexibility of carbon fibers makes it a perfect material for construction on sites that are prone to hurricanes and tornadoes.

Figure 5. Carbon Tower by Peter Testa

Testa, Peter. *Architecture Textile.* N.d. Uniqa Tower, Vienna.
Works of Peter Testa Architects, Los Angeles.
http://www.texbac.de/assets/images/ArchitectureTextile.jpg. Web. 20 April 2012.

2.4.1.2 Limitations of Application

- Carbon fibers though highly tensile, are brittle in nature and fail catastrophically at very low strains. To prevent failure, carbon fibers are combined with ductile materials such as polymers or metals to form composites. A carbon-fiber composite combines strength and stiffness of the carbon fibers with the resilience of the constituent material of the composite [10].

2.4.2 Aerogel

Aerogel is solid glass foam created by replacing the liquid portion of a gel with gas. Comprised of 99.98% air by volume, aerogel is the lightest solid on earth. The air bubbles that are saturated in the aerogel scatter light within the material, making it translucent in appearance and earning it the nickname ‘solid smoke’. Aerogel has amazing thermal insulation properties as its structure and composition nullifies all three methods of heat transfer: conduction, convection and radiation. Conduction of heat through aerogel is poor as aerogel mainly consists of gas, and gases are poor conductors of heat. The lattice structure of aerogel inhibits convection currents, reducing heat. Due to its nanostructure, aerogel is structurally very strong despite its extreme light weight [1].

(Figure 6) displays the transparent and translucent visual properties of aerogel. In the figure is also demonstrated the amazing insulation properties of aerogel. The heat generated by a Bunsen burner on the bottom face of the aerogel sheet fails to transfer the heat to the upper surface, leaving the flower on the surface undamaged.

Figure 6. Aerogel has Excellent Insulation Properties

NASA/JPL. *Flower On Aerogel Over A Flame*. 2009. Aerogel Photos, Texas.
http://upload.wikimedia.org/wikipedia/commons/4/44/Aerogelflower.jpg.
Web. 30 May 2012.

2.4.2.1 Applications in Architecture

- Aerogel allows for natural light to pass, but insulates the heat and thus helps energy efficiency in the building. Presently, aerogels in granular form are infused in windows and skylights as a super effective insulator.
- As a construction material aerogel would have a great aesthetic appeal due to its translucent look that resembles a glowing ice cube. In the future, entire walls may be constructed with aerogel, which would be see-through and also have high thermal insulation properties.

- Transparent walls would create openness to the ambience, connecting indoors with outdoors.
- As a highly strong and extremely lightweight material, aerogel would translate to an extremely strong, yet lightweight structure.
- Aerogel has high fire resistance, a desired quality in a building material.

2.4.2.2 Limitations of Application

- Older versions aerogels had high friability. Application of firm pressure would leave a permanent depression on the surface or would even cause it to shatter, which made structural applications of aerogels impractical for a long time. Modern versions of aerogels have overcome friability by modifying the aerogel structure through various processes such as liquid-phase crosslinking, vapor phase crosslinking, fiber reinforcing, and reduced bonding [5].
- Aerogels by themselves are hydrophilic, and have a tendency to dissolve in water. In humid weather, aerogel would suffer structural change and get degraded. To prevent this, the aerogel would have to be chemically treated to make it hydrophobic [4].
- Some aerogels could cause irritation to the eyes, skin, respiratory tract, and digestive system, making it essential to use protective gear whenever handling aerogels.

2.4.3 Self-Repair Materials

The inspiration behind self-repair materials is drawn from the human body, which has the capability to heal itself after a cut or bruise. Self-repair materials are smart materials that use nanotechnology, engineered to be capable of automatically repairing damage.

Damage in materials begins at a microscopic level and then grows to greater levels that may cause material failure, often without detection. Within the matrix of the construction material are embedded extremely thin capillaries, called nanocontainers. These nanocontainers hold within them active materials that have the ability to heal any damage that occurs in the material. When damage occurs, the capillaries break at the junction and the nanocontainers release the active material in a controlled fashion so it comes in contact with the damaged area and begins the process of healing the damage [13]. Refer to (Figure 7) for a diagrammatic representation of the working process of a self-healing material.

Figure 7. Working of Self-Repair Materials

McLeod, Kagan. *Self-Healing Materials.* 2008. University of Illinois. http://www.popularmechanics.com/technology/gadgets/news/4236607#slide-2. Web. 14 May 2009

2.4.3.1 Applications to Architecture

- Early detection and immediate repair would greatly enhance safety of the structure, and increase the lifespan of the structure.
- Physically inaccessible areas could be self-repaired without a need to be accessed by human or machine.
- Self-repairing materials would greatly reduce maintenance requirements, and save time and money.
- Human intervention is repairs would not be necessary. This would reduce cost, and eliminate human errors.
- Self-repair properties in external coatings and films would maintain the look and finish of the structure for a long time.

2.4.3.2 Limitations of Application

- Depending upon the amount of damage, and the chemical constitution of the self-healing material, the self-healing process could require a timespan ranging from a few seconds to a few months to complete. The time required for the self-healing process would be an important factor in choosing a self-repair material.
- The self-healing process is less efficient if damage is repeated on an area that was self-healed previously. This shows that self-healing materials have a fatigue life.

2.5 Internet of Things

The Internet of Things is a major trend that is projected for the future and is a field of active research and development for established brands like IBM, Microsoft, Cisco and Sun. The concept of the Internet of things is to enable everyday objects to interact with each other via physical mechanisms and computer controlled applications. Tiny nanosensors embedded in building materials and in physical objects that are part of the built environment would make it possible to track changes in the environment and trigger intelligent functional responses according to the occupants' preferences and attributes. This would change one's way of living, by eliminating timely human monitoring of everyday chores and activities, as well as various industrial processes [31].

Listed below are examples of the application of the internet of things. The technology could have innumerable applications in the future that would unfold as the technology advances.

- Internet of things could be adapted to design a smart living environment so that a house automates its ambience to suit the mood of the owner, by changing colors, lighting and temperature and other controls as programmed.
- Construction sites could be monitored remotely and data visualization from sites could help evaluate progress and setbacks.
- Building structural and service systems could have embedded sensors that would indicate with signals if at any point the health of the system requires attention. This could vastly increase the life of the structure.
- Sensors could be programmed to detect if the building is ever on verge of structural failure due natural or mechanical disasters, and designed to automatically trigger a disaster management system designed to minimize loss of life and property.

Some of these physical systems have already begun to be deployed. In the subsection below is an example of an innovative object that has been integrated with sensors, representing the first step to the revolution of the Internet of things.

2.5.1 Rust Tracking Device

Inclement weather conditions and salt (sprinkled to thaw snow) that leeches into steel reinforcement in structural components of bridges and other structures causes rusting, which eventually results in structural damage in the form of cracks, or worse, may result in collapse of the structure. Present methods of testing for corrosion are tedious, time consuming, non-conclusive for testing the exact amount of damage, and destructive as they involve hammering on the concrete and boring holes in search of cavities in the reinforcement. Experts at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg have now designed a cost-effective and reliable method for detecting rust corrosion at an early stage.

The device designed by the Fraunhofer institute consists of a sensor and transponder. The sensor continuously monitors the depth to which damage causing salt ions have penetrated into the concrete. The transponder conveys the measured data wirelessly to a reading device. The data helps determine whether or not repair work is needed. The transponder uses magnetic fields for its energy rather than a battery, and hence does not need to be replaced, thus it can stay in the concrete structure permanently [20]. (Figure 8) shows the components of the Rust Tracking Device.

Figure 8. Rust Tracking Device

Fraunhofer IMS. *Dem Rost auf der Spur*. 2010. Tracking Down Rust, Germany. http://phys.org/news189695036.html. Web. 16 July 2012.

2.6 Ubiquitous Computing

The idea of ubiquitous computing was first introduced in a paper published in the year 1995, 'The computer of the 21st century' by Mark Weiser. Ubiquitous computing is the concept of drawing computers out of their electronic shells and imbedding them in the human environment instead. The goal of ubiquitous computing is technology so woven into everyday life that it becomes indistinguishable from the natural human environment. Computers would vanish from sight but be very much present everywhere in different sizes and suited to different tasks.

Ubiquitous computing would create a high tech intelligent environment in which rooms would greet people by name, telephone calls would be automatically forwarded to wherever the recipient would be, computer terminals would retrieve the preferences of whomever is sitting at them, and appointment diaries would write themselves. Ubiquitous computing would become an important part of the modern future ‘smart’ home [30].

2.7 Metamaterials

Metamaterials are engineered to achieve material properties that may not exist in nature: the atomic and molecular structure of matter determines their properties. Metamaterials are formed by tiny repeating cell structures, the wavelength of each smaller than the wavelength of light. See (Figure 9). This can achieve a negative refractive index, a phenomenon never observed in nature. The negative refractive index causes this unnatural behavior. For example, metamaterials can theoretically direct light to flow around an object thus preventing reflection, making the object invisible. Similar behavior can be achieved for sound waves too [27].

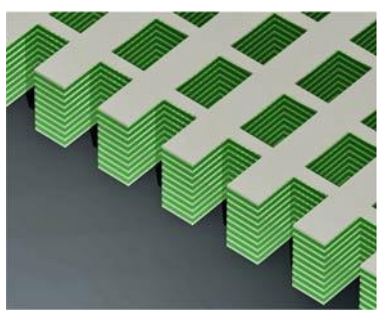

Figure 9. Metamaterial Formed of Repeating Cell Structures.

Valentine, Jason. *3D Fishnet Metamaterial*. 2008. University of California, Berkeley. *http://berkeley.edu/news/media/releases/2008/08/11_light.shtml*. Web. 10 May 2009.

2.7.1 Applications in Architecture

- Introduction of invisibility could result in many fascinating architectural designs. Making structural members completely or partially disappear could create an illusion of architecture that defies physics. See (Figure 10).

Figure 10. Invisibility in Architecture.
Photo manipulated by Hemali Tanna, 2010.

Original photo by Scheeren, Ole. *MahaNakhon*. N.d. Office for Metropolitan Architecture, Thailand. http://www.e-architect.co.uk/thailand/mahanakhon_tower_bangkok.htm#.UBaz_LSe7g0. Web. 3 May 2010.

- Metamaterials could be used to hide from view undesired structural elements such as unsightly water tanks or service pipes.
- Sound waves could be controlled with the aid of metamaterials to improve acoustics.

- Metamaterials could be used to channel sound waves to enhance immersive experiences in auditoriums, entertainment parks, discos and similar spaces.
- Metamaterials could be designed to deflect physical objects of certain properties, for example, to create bullet proof structures that enhance safety.
- Building units could be preassembled in factories and the invisible structures could be placed on site without anyone's knowledge or awareness of construction, thus aiding in defense.
- Seismic metamaterials is a term given to a class of metamaterials designed to counteract the adverse effects of seismic waves on man-made structures. This technology could help make buildings earthquake proof [7].
- Metamaterials can be used to create a 'superlens' to achieve resolutions beyond the capabilities of ordinary lenses. Superlenses can resolve features smaller than wavelengths of light. This property could be creatively applied in architectural design to create interesting possibilities in occupant experience [12].

2.7.2 Limitations of Application

- The working of metamaterials to achieve negative refractive index to creative invisibility presently works only in theory. There has been no practical demonstration of the phenomenon as it is presently beyond technological limitations to create a device that negatively refracts all the wavelengths of visible light.

- If the phenomenon of invisibility were made practically applicable, and if metamaterials were applied on the outer skin of the building, the light rays would bend around the building and not traverse into the interior of the structure. That would make it impossible to get a view of the outside environment from within the building.

2.8 Metabolic Materials

Metabolic materials are classified in a group of technologies that have some properties of living systems called 'living technology'. Metabolic materials are designed to possess the living property of metabolism. Metabolism is the set of life sustaining chemical reactions that occur in the cells of living organisms, in which one group of substances is transformed into another with the absorption or production of energy.

It has been envisioned by researcher Dr. Rachel Armstrong that metabolic materials would form the next generation of architectural skins that would not be merely decorative cladding, but would impart biological functionality to building exteriors, by offering a medium through which a chemical dialogue between the classical architectural framework and the environment.

Current research on metabolic materials aims at creating materials that would be able to grow, self-repair and respond to changes in the environment. They would serve in reducing environmental pollution by reacting with carbon dioxide in the environment, and creating a byproduct such as limestone that would deposit on the skin of the building. They would thus function as synthetic 'lungs' on the building's exterior [6].

2.8.1 Limitations of Application

The byproducts of the metabolic process such as limestone that would be deposited on the skin of the building might have an undesirable effect on the appearance of the structure.

2.9 Smart Materials

Smart materials are materials that are designed to significantly change one or more properties, structure or composition in response to changes in environmental stimuli, so as to serve desired functions in a controlled fashion. The stimuli could be application of stress, or a change in temperature, moisture, pH level, or electromagnetic fields. In many of the smart materials, changes could be reversed once the stimulus is removed.

There are various types of smart materials, which shall be described in this section. Smart materials provide an extremely wide and highly interesting range of aesthetic and functional applications in architecture. Smart materials are broadly classified under two types.

2.9.1 Type I: Property Changing Smart Materials

2.9.1.1 Color Changing Smart Materials

These are smart materials that change optical properties under external stimulus. A difference in heat, light or chemical environment alters the molecular structure or the molecular orientation on the surface of the material, which in turn changes the light transmittance, reflectivity and scattering of the material which is perceived as a color change. The color changes are reversible. The material reverts back to its original color upon removal of the stimulus. Depending upon the stimulus that causes the change of color, these materials are classified as:

2.9.1.1.1 Thermochromic Materials

These materials change color when there is a temperature difference in the environment. They absorb heat which induces a chemical reaction or phase change, which leads to a change in color at the determined temperature. These materials can be made in various forms such as semi-conductor compounds; as liquid crystals applied on films; or as metal compounds. (Figure 11) is an image of a Thermochromic material, in which a palm print is created by body heat on the surface.

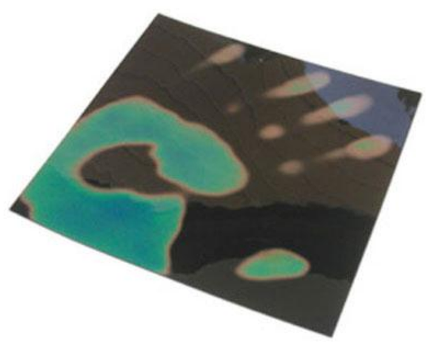

Figure 11. Thermochromic Material

Mindsets. *Thermocolor*. N.d. Smart materials, Herts. http://www.mindsetsonline.co.uk/product_info.php?cPath=418_627_464&products_id=548 .Web. 30 May 2010.

Thermochromic materials have found various design expressions in furniture design. The material of the furniture is designed to be sensitive to body heat, creating a colored imprint on the furniture piece, showing the past presence of a person who used the furniture. The imprint eventually fades as the heat is lost.

2.9.1.1.2 Photochromic Materials

These materials change color when exposed to light. The material absorbs radiant energy from photons in the ultraviolet spectrum of light. Depending on light intensity the materials enter different energy states, resulting in changing absorption qualities associated with the visible spectrum of light. The material is colorless until exposed to sunlight, when the material begins to selectively reflect or transmit certain wavelengths, thus different colors. The intensity of the color depends on the directness of light exposure. Photochromic colors could also be mixed with base colors to achieve changes from one color to another.

2.9.1.1.3 Mechanochromic Materials

These materials change color when a mechanical force such as stress or strain is applied to them.

2.9.1.1.4 Chemochromic Materials

These materials change color when there is a change in the chemical composition in their environment.

2.9.1.1.5 Electrochromic Materials

These materials change color when there is a change in the electric field in their environment, which could be achieved by applying a voltage difference. Depending upon the voltage applied, the electrochromic material can change several different colors.

Electrochromic materials have found an application in present day architecture in the form of Electrochromic windows, also called smart glass. Application of a voltage causes the glazing to darken, which results in reduction of the light and heat absorbed by the building. Removal of the voltage results in a lighter glazing. Depending upon the voltage applied, the glazing could be completely dark, translucent or transparent. Electrochromic glass preserves visibility even when in a darkened state, allowing one to maintain contact between the interior and exterior environment.

Recent development in electrochromic technology has resulted in development of materials that switch between completely transparent to mirror-like upon the application of a voltage [3].

2.9.1.2 Phase Changing Materials

Numerous materials can exist in different physical states, namely solid, liquid, and gaseous. Change of phase occurs at specific temperatures and pressure shifts, and involves absorption, storing or releasing of large quantities of latent heat. Phase changing materials seek to take advantage of the energy absorption and release actions, and apply them toward maintaining thermal environments.

PCMs make use of materials such as inorganic hydrated salts which absorb very large quantities of heat to change from solid state to liquid, and from liquid to gaseous. These materials also release very large quantities when they reverse from a gaseous state to liquid and from a liquid phase to solid. The material can undergo unlimited phase change cycles without degradation.

PCMs encapsulate the phase changing material in small pellets or microcapsules, and make use of solid to liquid phase changes to store latent heat [3][25].

2.9.1.2.1 Applications in Architecture

- The pellet technology has found widespread application in various heating and cooling systems.
- The pellets can be embedded in surfaces or textiles that would allow them to be responsive to heat in the environment. The PCM would absorb excess heat and store it as it turns to liquid form. As the surrounding environment starts to cool, the PCM would begin the phase change from liquid to solid, releasing heat into the environment. [3]

2.9.2 Type II: Energy Exchanging Smart Materials

2.9.2.1 Shape Memory

Shape memory effect is a phenomenon in which a material, after undergoing deformation, has the ability to revert to a memorized, preset shape upon receiving an applied stimulus such as a temperature change or an electromagnetic field. Smart materials exhibiting shape memory effect could either be polymers or alloys [3][24].

Shape memory polymers can retain up to three preset shapes, and the transition between these shapes is induced by change in temperature. Shape memory polymers have a high capacity for elastic deformation, low density, and can be associated with a broad range of application temperatures which can be tailored according to the purpose they are designed to serve [16].

Shape memory alloys are designed to display a one way-way memory effect or a two-way memory effect. In the one-way memory effect, the shape memory alloy can be deformed in any way desired, and it will retain the deformed state, until it is heated to the required transition temperature to achieve the preset memorized shape. In the two-way shape memory effect, the material remembers two preset shapes; one at a higher and one at a lower temperature [21].

Shape memory polymers and alloys presently have applications in the aircraft, automotive, telecommunications, robotics and medical industries. Mechanical processes that position motors or levers for movement could be replaced by a shape memory material that would regain a programmed shape upon heating, using only a fraction of the energy. The lower mass of the shape memory material adds lightness to the design. Shape memory materials also lead to new design possibilities, as they can be placed where a motor wouldn’t fit. (Figure 12) is an example where various SMA are placed to generate silent, fluid motion without the use of motors in an architectural installation [11].

Figure 12. Motion in Architecture with Shape Memory Alloys

Ley, Rob. *Reef*. 2009. New York Storefront for Architecture, New York. *http://www.sciarc.edu/news_archive.php?id=1665* .Web. 30 May 2012.

2.9.2.1.1 Limitations of Application

SMA actuators are typically actuated electrically, through resistive heat produced by the process of an electric current passing through a conductor. SMA used an environment where the ambient temperature is uncontrolled, may get unintentionally actuated by the ambient heat.

A large number of repetitions of the shape memory cycle may result in structural and functional fatigue of the SMA, and it may fail to achieve its preset shape.

2.9.2.2 Piezoelectric Materials

Piezoelectric materials produce a voltage when stress is applied. Reversibly, a voltage would produce stress in a piezoelectric material. Piezoelectric materials are widely used presently in mechanical systems that require sensors and actuators; the working of a simple electric bell is one such example. The mechanical force applied to push the bell is converted to a voltage, which completes the electrical circuit to ring the bell. Piezoelectric materials are also used in microphones, where acoustical pressure from sound waves is converted to a voltage [3][26].

2.9.2.2.1 Applications in Architecture

- Piezoelectric devices are also presently used to harvest electricity from mechanical vibrations on highways, bridges, railway tracks and dance floors.
- Piezoelectric materials can also be used to dampen vibrations on a structure, by dissipating the electrical energy developed across a shunting [3].

2.9.2.3 Thermobimetals

These are composite materials created by permanently binding, by plating or other methods, two or more metals with different thermal expansion coefficients. As changes in temperature occur, each component metal of the composite reacts differently, thus changing the form of the object [24].

2.9.2.3.1 Applications in Architecture

- Thermobimetals could be used in designing functional and/or aesthetic architectural skins.
- In hot temperatures the skin would open up due to expansion of a component metal, forming pores that let air in. In cold weather the pores would stay closed

to block cold air from entering into the building. (Figure 13) is an application of using Thermobimetals to create an architectural canopy that is responsive to the heat in the environment.

- The difference in expansion of the components could create very interesting banding patterns, which could serve an aesthetic purpose.

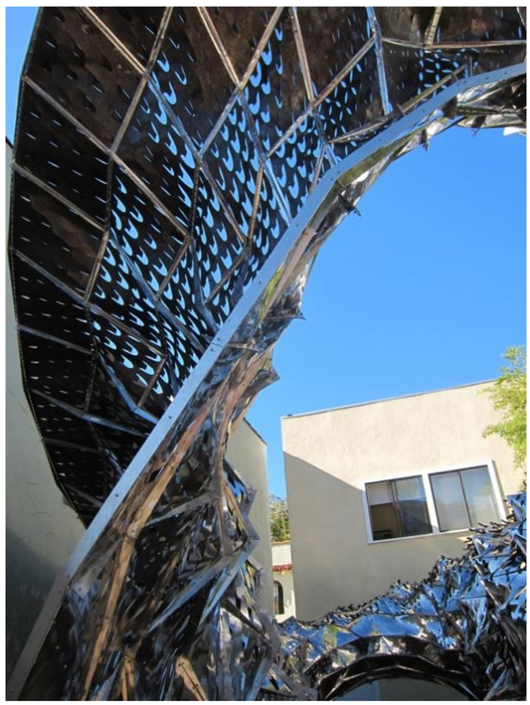

Figure 13. Thermobimetal Canopy

DOSU Studio Architecture. *Thermobimetal Canopy*. N.d.
Materials and Application Gallery, Los Angeles.
http://dosustudioarchitecture.blogspot.com/2011_11_01_archive.html.
Web. 30 July 2012.

2.9.2.3.2 Limitations of Application

- Oxidation, corrosion and degradation over time of the metals that constitute the thermobimetal may lead to functional loss.
- If the interior of the building is air-conditioned, the temperature of the interior environment may influence the working of the thermobimetal against the effect of the temperature of the exterior environment.

2.9.2.4 Light-Emitting Materials

Light emitting materials absorb energy in the electrical, chemical or thermal form, which causes the electrons of the material to elevate to a higher excitation state. The material then releases the absorbed energy in the form of photons of light to bring the electron back to the original energy state [3].

2.9.2.4.1 Applications in Architecture

Light emitting materials have found a widespread application in modern architecture in the form of light-emitting diodes, electroluminescent films, and chemoluminescent paints. These can be used to create surfaces and spaces of extreme visual interest. (Figure 14) shows the application of light emitting diodes to generate stunning visual effects on the GreenPIX building located at Beijing, China [8].

Figure 14. Light Emitting Diodes

Simone Giostra & Partners, Arup. *GreenPIX*. N.d. Zero Energy Media Wall, Beijing. http://www.archdaily.com/245/greenpix-zero-energy-media-wall/ . Web. 30 May 2010.

2.10 Hydroponics

Hydroponics is a technology in which plants are grown in artificially created nutrient solutions. The plants may be mechanically supported if required by an artificial medium such as sand, gravel or sawdust. This system thus eliminates the need of water and soil for growing plants [17].

2.10.1 Applications in Architecture

- Hydroponic systems are applied in architecture to grow plants and creepers on external facades of buildings and interior walls. See (Figure 15).

- These systems are also useful in creating indoor gardens. Since soil is not necessary, it greatly reduces the weight on the structure, and also keeps the interior environment more sterile.

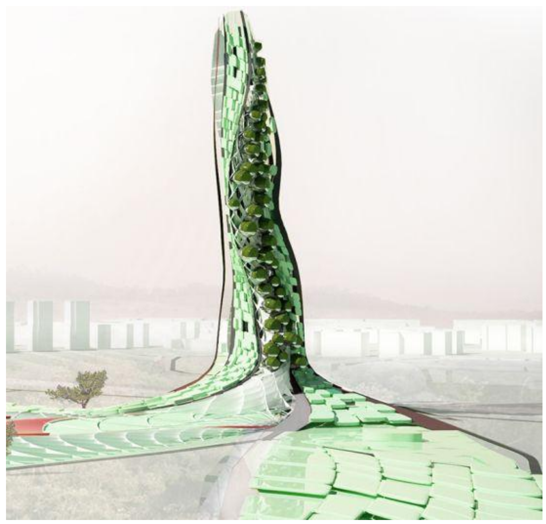

Figure 15. Vertical Hydroponics

Murray, James. *Hydroponic Tower*. 2010. Vertical Oasis, Syria. http://www.evolo.us/architecture/vertical-oasis-in-syria-is-a-hydroponic-farm/. Web. 11 July 2012.

3. CASE STUDIES

3.1 Introduction

There are a few architects and engineers who have forged new pathways in building technology. They have challenged old systems and have applied fresh and new concepts toward architecture and construction—the result has been stunning. Below are case studies.

3.2 Dynamic Architecture

David Fisher is the architect who designed Dynamic tower. Dynamic tower is a skyscraper in which each floor can be rotated separately around a central static core. Not only would the building exterior change form at any given time, but the inhabitants of the tower can enjoy different interior views too. See (Figure 16). Dynamic tower is also the first ever building to use prefabricated components in construction. Apart from the central core, the entire structure is made of prefabricated units. See (Figure 17). These units arrive on site from the factory, completely finished with flooring and service conduits, ready to be mechanically installed. The construction time is drastically reduced because of prefabrication. Reduced number of workers reduces site risks and costs. The skyscraper has wind turbines and roofs with solar ink, thus making it self-sufficient in terms of energy [32].

Figure 16. Dynamic Elevations

Fisher, David. *Dynamic Tower*. N.d. Dynamic Architecture, Dubai. http://www.archivenue.com/wp-content/uploads/Rotating-Tower-Dubai-UAE-Dr-David-Fisher-1.jpg. Web. 30 April 2009.

Figure 17. Prefabricated Housing Units Being Assembled on Site

Fisher, David. *Dynamic Tower*. N.d. Dynamic Architecture, Dubai. http://www.designbuild-network.com/projects/dubairotatingtower.Web. 30 April 2009.

3.3 Building Construction with 3D Printing

Enrico Dini is an Italian engineer who introduced Robotic Building into the world of building construction. He took the application of 3D printing to new heights: he designed a 3D printer in a warehouse to print actual life sized buildings [18].

See (Figure 18) for a view of the 3D Printer built by Enrico Dini.

3.3.1 Advantages and Applications

- In the 3D Printing process CAD data directly influences the construction on site, thus introducing extreme precision in the built construction.
- The building construction cost would not be influenced by the complexity or details of the building design. Requirements for moulds to cast design features such as architectural reliefs and curved structural components would be eliminated, saving time and money.
- 3D Printing is estimated to reduce time of construction to one-fourth of that required by traditional building methods.
- Advanced knowledge of required operating times would aid in accurate planning for organizing machinery and resources.
- 3D printing as a construction method would reduce human intervention substantially, thus enhancing site safety by reducing accident risks.

Figure 18. D-shape 3D Building Printer

Dini, Enrico. *Printing a New World*. N.d. D-shape Technology, Italy. http://weburbanist.com/2010/04/02/for-real-13-futuristic-3d-scanner-printer-designs/ Web. 20 May 2010.

3.4 Seed Cathedral

The Seed Cathedral was designed by Heatherwick studio for the UK Pavilion, also called the 'Seed Cathedral', at the 2010 World Expo in the city of Shanghai. It was built with the purpose of displaying the thousands of seeds collected by the Millennium Seedbank, Royal Botanical Society, from every plant in the world. 3D computer modeling data was used to achieve the extreme precision required to construct this design.

This unique structure is made up of a steel and timber composite, which is pierced by 60,000 slender transparent fiber optic rods, each 7.5 meters long. Each rod encases a unique plant seed at its tip. These fiber optic filaments sway with the wind, and draw daylight inwards to illuminate the interior of the structure. During the night, light sources inside the filaments create a glow in the exterior. See (Figure 19 and 20). The wooden diaphragm structure enclosing the interior is 1 meter thick. It is drilled with great geometric accuracy to precisely place aluminum sleeves within, through which the finer optic rods are passed. The accuracy was achieved by CAD data fed into a computer controlled machine [29].

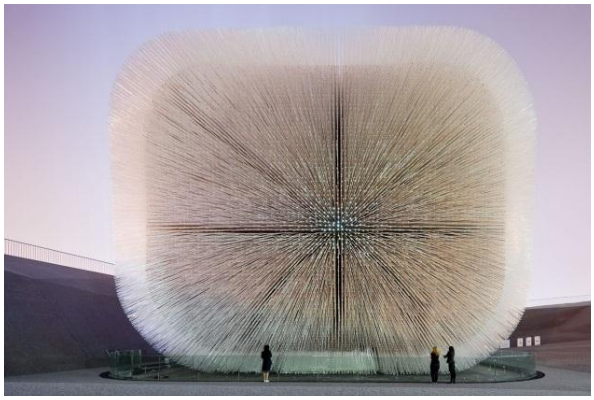

Figure 19. Seed Cathedral Exterior

Baan, Iwan. *UK Pavillion Exterior*. 2010. World Expo, Shanghai. http://www.heatherwick.com/uk-pavilion/. Web. 20 June 2010.

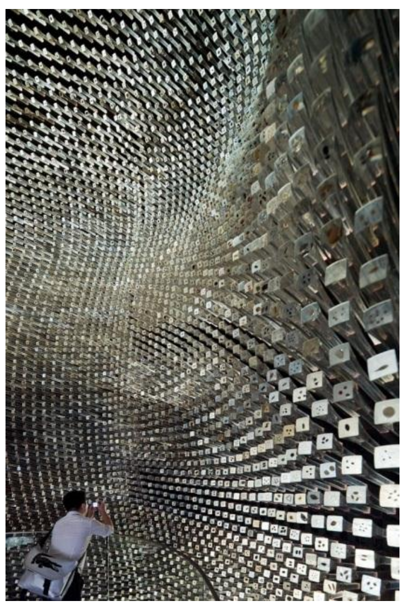

Figure 20. Seed Cathedral Interior

Baan, Iwan. *UK Pavillion Interior*. 2010. World Expo, Shanghai. http://www.heatherwick.com/uk-pavilion/. Web. 20 June 2010.

3.5 Water Wall

The digital water wall concept was initially developed in the Zaragoza Digital Mile class at MIT, led by William Mitchell and Dennis Frenchman, with Michael Joroff and Carlo Ratti. The Waterwall was designed in pursuit of creating ‘fluid reconfigurable architecture’ which implies spaces that can expand or shrink based on necessity and use. The Waterwall is made of water curtains, called ‘digital water’. The digital water can be made to appear and disappear through various control systems. The working design principle of the Waterwall is similar to that of an inkjet printer.

The Waterwall consists of a row of closely spaced solenoid valves along a pipe suspended in the air. The valves are controlled by a computer, and can be opened and closed at high frequency to produce a curtain of falling water with gaps at specified locations. This forms a pattern of pixels created from air and water; a one-bit-deep digital display that continuously scrolls downward. Waterwall can detect the approach of people through sensors, and it stops the water flow at the location to create a door.

Waterwall is a great exhibit of architecture in the digital electronic era which combines sensor technology, embedded intelligence, control software, networking and computer-controlled pumps and valves [23]. See (Figure 21) for a view of the Water Wall installation.

Figure 21. Water Pavilion

Ratti, Carlo. *The Digital Water Pavilion*. 2007.
MIT SENSEable City Laboratory. Zaragoza World Expo, Spain.
http://www.core77.com/blog/object_culture/mit_digital_water_pavilion_makes_a_splash_in_spain_10171.asp. Web. 20 June 2010.

3.6 Floating Bed

Dutch architect Janjaap Ruijssenaars was always consciously aware during his student years of the fact that architecture is dictated by gravity, and that building structures, fixtures and furniture always have a contact point to the ground. He had a desire to design a system so that the other physical forces supersede the force of gravity and dictate the position of the structure. In his quest to make objects float, he consulted with several specials for six years and accomplished creating a prototype of a floating bed, at a scale of 1:5. The prototype model of the bed can carry on it 80 kilos, and the true scaled bed would be able to carry on it a weight of 900kgs. The cost of the actual sized bed is one million dollars.

The bed floats because of the repulsive forces between extremely strong magnets embedded within the bed and the floor slab below. The bed is tethered with four cables from the ground to prevent it from flying off the roof due to the strong magnetic forces. The architect describes his design as a ‘reverse of reality’.

The magnetic bed is made safe by reducing the magnetic field at the top of the bed to zero by layering of steel and plastic and air. The bed is safe to use with electronic devices such as laptops. The technology makes use of the electromagnetic fields used in MRI scans, so one must avoid wearing anything made of steel while using the bed [14]. (Figure 22) is a photo of the prototype magnetic floating bed.

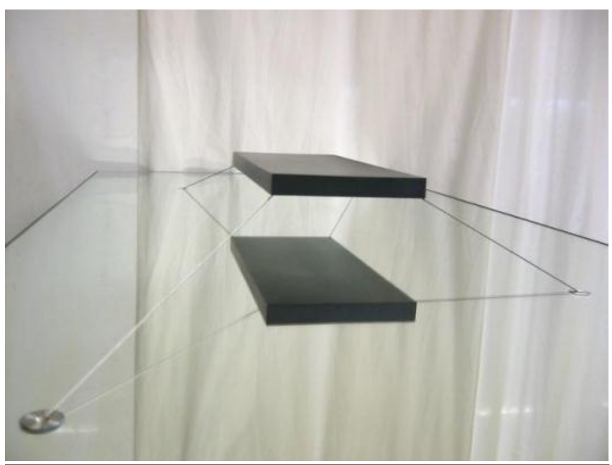

Figure 22. Magnetic Floating Bed

Ruijssenaars, Janjaap. *Magnetic Floating Bed*. 2006. Millionaire Fair, Belgium. http://www.gizmag.com/go/5824/picture/24663/. Web. 20 June 2010.

4. DESIGN AND DEVELOPMENT OF DREAMHOME

4.1 Concept

The dreamhome is conceptualized to have the form of an abstract butterfly alighting on grass. The massing of the structure is designed to mimic the delicateness of a butterfly, and yet convey a sense of stability. The structure is designed to blend easily into the surrounding landscape, and yet emerge from it as a striking architectural sculpture. The design of the dreamhome incorporates several dynamic features in its architecture. One such example is the dynamic roof system of the house, the motion of which resembles a butterfly's flapping wings.

The functional goals of the design were to have a well-planned layout with interior spaces that have highly impactful visual connections to the outdoors via large windows, skylights, and openings. While maintaining the visual connection with the outside, privacy concerns are addressed by providing high tech solutions that would not impose a visual barrier that blinds and curtains would. The interiors open out into semi-covered spaces such as terraces and decks, which lead to the outdoors. The house incorporates many green technologies, some energy saving, some energy generating, and cost effective with low maintenance. Advanced technology is applied to design safety mechanisms that would react in events of natural disasters such as earthquakes, and to send alert signals in case any attention towards maintenance is required.

The design process adopted is to keep the visual and functional goals paramount, and exercise creative freedom based on present high end and predicted future technology to fulfill the original architectural vision. It is also intended that most of the design features have functional value along with aesthetic qualities.

(Figure 23) demonstrates how various decisions of the form and design of the house were guided by the form of a butterfly.

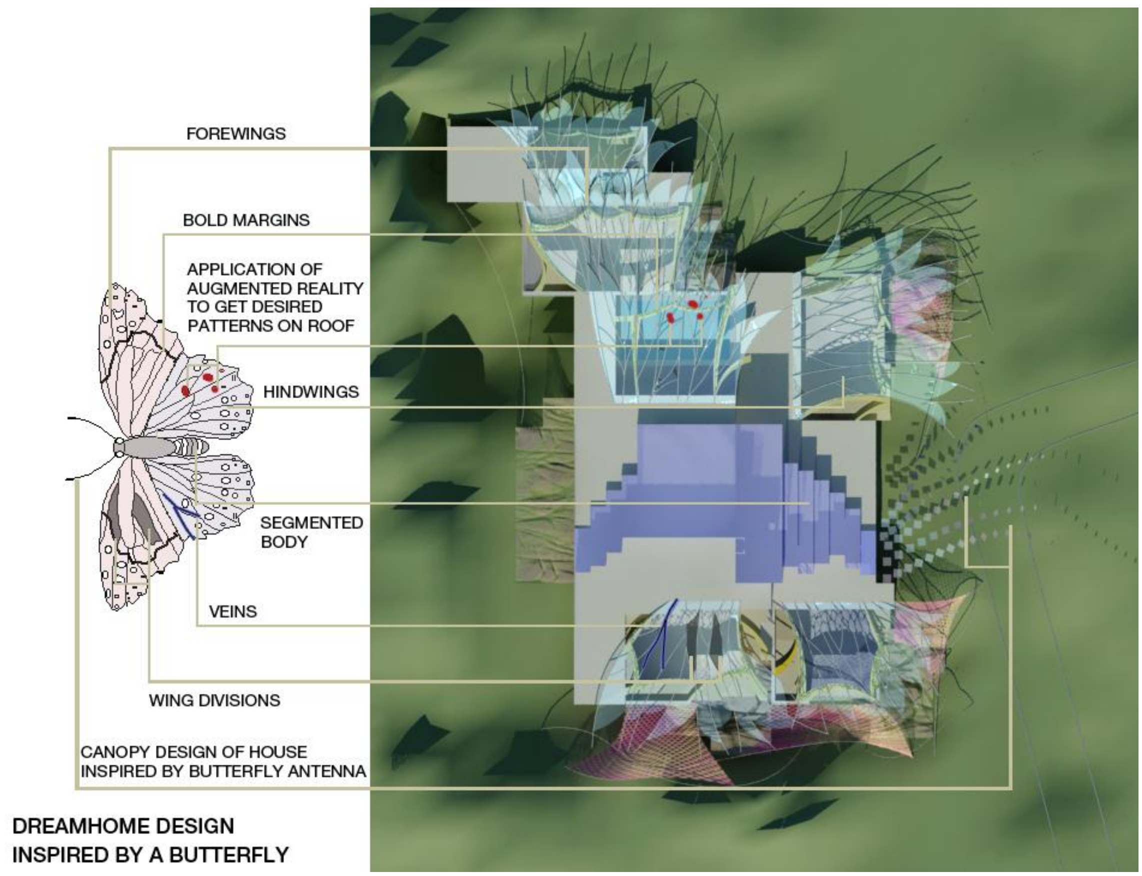

Figure 23. Design Inspiration

4.2 Design

The butterfly home lies on a sloping site. The layout of the house is inspired by the symmetry of a butterfly's wings on the two sides of the central body. The central body of the butterfly corresponds to common areas such as the entrance foyer, lift lobby and family room. The four lobes of the butterfly wings correspond to individual areas, such as the master bedroom and children's room on the upper level of the slope, and a guest room and living room on the lower slope. The roofs over the bedrooms and the living room are designed in the form of abstract butterfly wings, and have the mechanics to rotate around the axis parallel to the body enabling them to 'flap'. The master bedroom adjoins a large semi-covered pool area which opens out into a spacious deck. The master bedroom and the children's' room are connected via the family room at the upper level. The family room overlooks the entrance foyer at the lower level.

(Figure 24) represents the architectural drawings of the plans and sections for a graphic understanding of the layout.

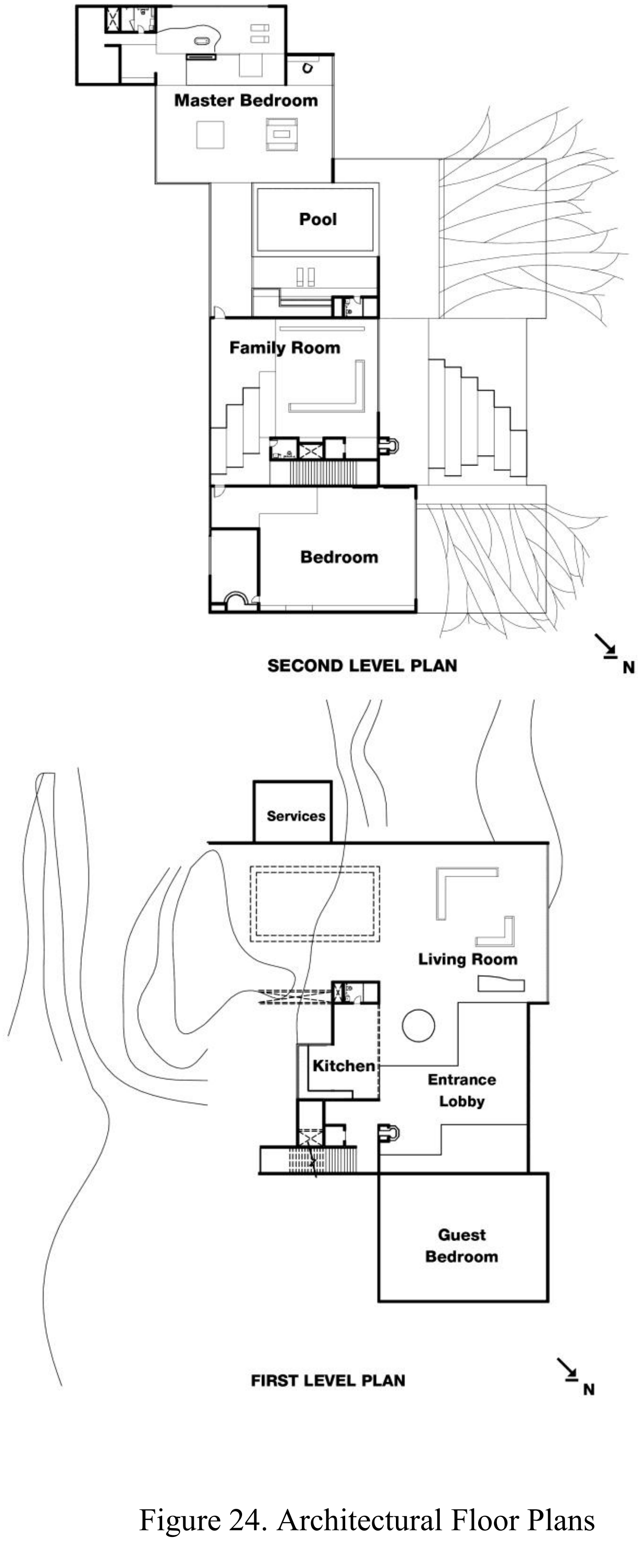

Figure 24. Architectural Floor Plans

4.3 Application of New Technology and Materials

4.3.1 Application of Carbon Fiber Composites and Aerogel to Create a Lightweight Roof

The butterfly wing roofs are designed to perform flapping rotational movements, and need to be lightweight and strong. The lightness of the roof could also be compared to the lightness of a butterfly's wings, which are as light as two rose petals. To achieve this, the framework of the veins on the roof is made of carbon fiber composites. The surface area between the veins is made of aerogel, which is light in weight, extremely strong and transparent. As a highly insulating material it will prevent any heat gain from the large surface area of the transparent portion of the roof. See (Figure 25).

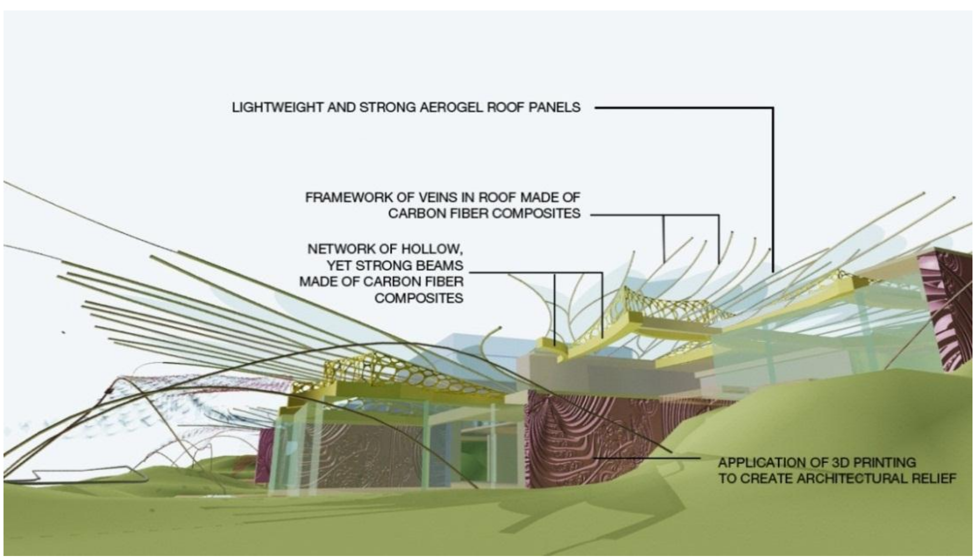

Figure 25. Applications of Nanotechnology and 3D Printing

4.3.2 Application of Carbon Fiber Composites to Fabricate a Strong Network of Beams

Extremely strong carbon fibers can be used to create paper thin structural components. In this design, carbon fibers are used to form a hollow structural network of beams that support the flapping roof system. Ducts for HVAC and lighting can pass within this framework; thus eliminating the need of a false ceiling. See (Figure 25).

4.3.3 Application of 3D Printing

The technology of 3D Printing discussed in sections 2.3 and 3.3 is applied in the project to print exterior and interior walls with architectural relief of floral fractal patterns. See (Figure 25). The choice of the floral fractal patterns for relief was inspired by patterns on butterfly wings and their association with flowers.

4.3.4 Application of Shape Memory Alloy

As the roof opens and closes in a flapping motion, the membrane between the rotating surface, and the beam below needs to stretch open and collapse. The deformation of the membrane as the roof flaps close, and the regaining of its shape as the roof flaps open makes use of shape memory alloy as described in section 2.9.2.1. It is proposed that small springs made of shape memory alloys with the one way shape memory effect be embedded into the shape memory polymer membrane at various joints. When a mechanical force is applied to the wing roof upon receiving the impetus of an electric current, the springs would deform out of shape and no longer stretch the membrane open, causing it to collapse. The membrane itself would be made of a shape memory polymer, which would have three shapes preset in its memory. The memorized shapes in the polymer could correspond to states of the membrane fully stretched, half-closed and fully closed thus retaining preset positions in the flap cycle of the wing. Upon receiving heat through an electric current, the SMA springs would regain their original shape, and give an impetus to the shape memory polymer membrane to stretch into its preset shape; enabling the roof to flap fully open. See (Figure 26).

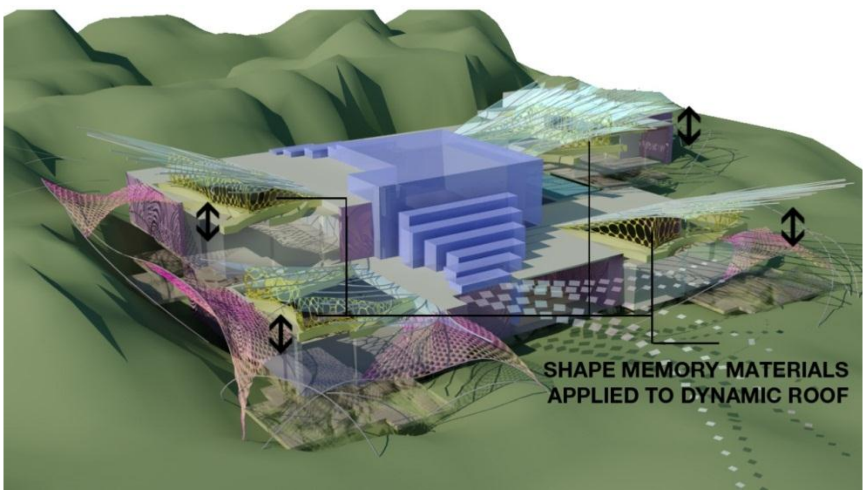

Figure 26. Application of Energy Exchanging Smart Materials

4.3.5 Application of Hydroponics to Create Vertical Indoor Gardens

The slope of the site forms the south wall of the living area. The hard rocky wall of the site juts into the living area, giving the space a natural rugged finish. Hydroponics technology is applied to grow plants onto the vertically inclined slope. Soft edges of the plants and the hard edges of the rocky site would create a visually appealing space in the living area. See (Figure 27).

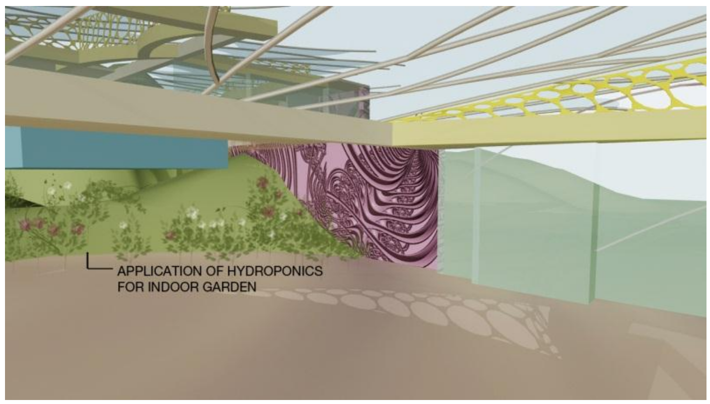

Figure 27. Indoor Landscape with Hydroponics

4.3.6 Application of the Concept of Internet of Things and Metamaterials to Design an Interesting canopy

The canopy of the dreamhome is designed so that individual facets of the canopy face the person walking underneath it. This shall be actuated by embedded nanosensors that would register motion of a person. The sensors would actuate a mechanical system that would rotate individual panels of the canopy to face the source of motion. Metamaterials are used to make invisible all the connecting parts and joints of the canopy, so that individual panels of the canopy appear suspended in air. In (Figure 28), the dotted lines indicate the direction line of the canopy facets facing the person underneath it.

The design of the canopy is inspired by the antenna of a butterfly, which are richly covered by sensory organs called sensillae and help the butterfly sense wind and scents.

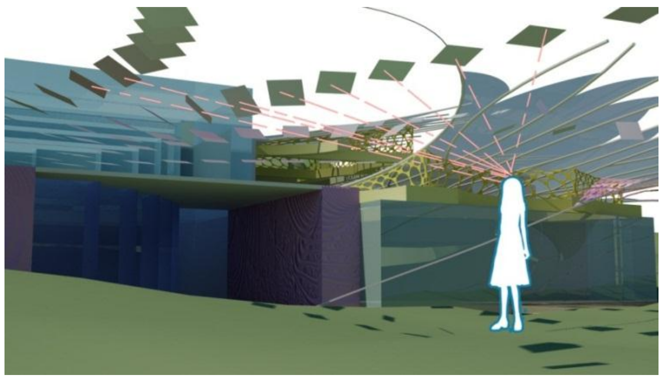

Figure 28. Canopy Facets Face Person Underneath

4.3.7 Application of Augmented Reality to Create Interesting Visual Effects

Projecting digital images and animations on the surface of the butterfly wing roofs generates interesting designs and patterns on the roof. It is thus possible to influence the look of the house to a great extent by changing the projected image.

Inspired by the Phillips Daylight window discussed in section 2.2.1, augmented reality is applied in the design to generate colorful and light blocking shapes on the window surfaces, to function as a curtain whenever desired.

(Figure 29) demonstrates examples of two different projected images creating two different visual effect patterns on the roof. The application of augmented reality could thus be used to have the house imitate different species of butterflies with different patterns on their wings. Augmented reality could be used to project images with colors that would help visually blend the structure with the surrounding site, like some species of butterflies that have wings which help camouflage them in their surrounding environment.

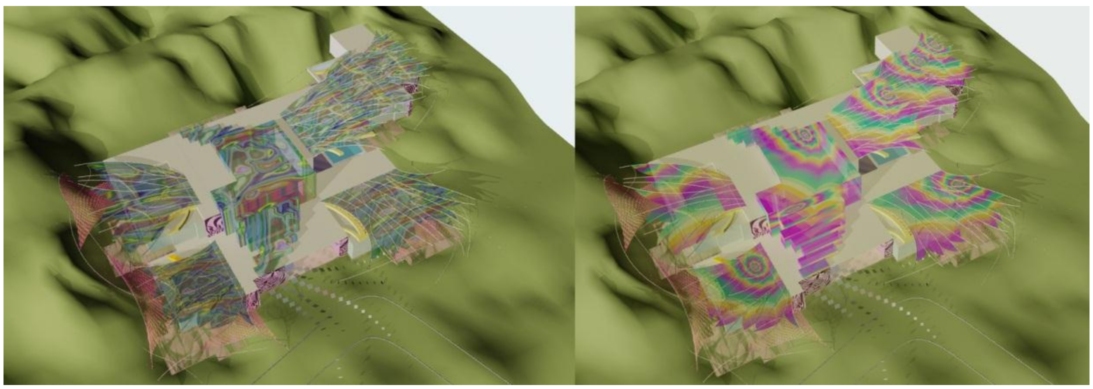

Figure 29. Augmented Reality to Create Different Patterns on the Roof

4.3.8 Application of Smart Materials for Color Variation

Several surfaces of the dreamhome, such as walls, the vein network on the roof wings, the network of hollow beams, and the freeform carbon fiber canopies around the structure are coated with thermochromatic and photochromic paint and films. These surfaces shall change color as the sun moves across the sky and the ambient temperature cools down toward dusk. (Figure 30) shows different color effects on the building at different times of the day.

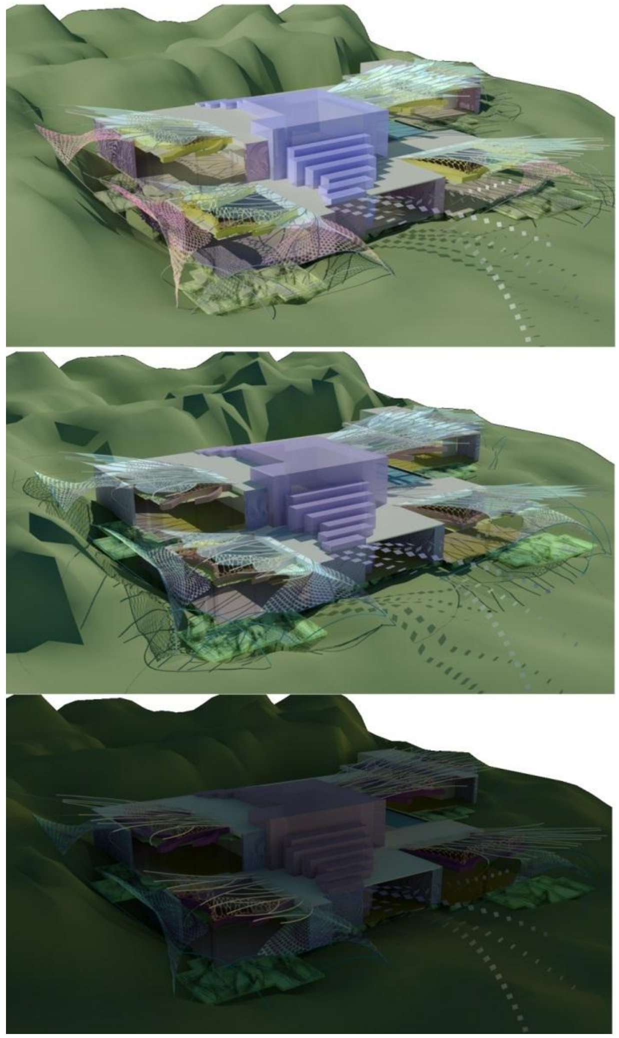

Figure 30. Application of Color-Changing Smart Materials

4.3.9 Fiber Optic Cables for Visual and Motion Effects

Inspired by the used of fiber optic filaments in the Seed Cathedral described in section 3.4 the design of the Dreamhome uses fiber optic rods that project out from the vein structure of the flapping wing roof. These filaments will sway with the breeze, and glow at nighttime to add visual interest via motion and light. See (Figure 31).

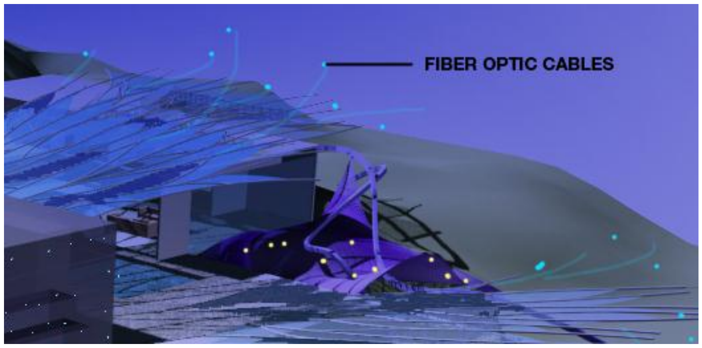

Figure 31. Application of Fiber Optic Cables

4.4 User Experience of Architectural Space

A person experiencing the architectural space would first be struck by the uniqueness of the design, which would generate in his mind a curiosity about the design. The interest level of the person shall be maintained throughout his experience of the design, as new and interesting features of the home reveal themselves over time.

When viewed from a human eye level, the form of the building shall draw attention though the sleek and delicate curves of the large spanning butterfly wing roofs and the freeform canopies over the decks around the house, balancing the straight planar surfaces of the walls. See (Figure 32). A person would start associating the form of the house with that of a butterfly from what he would see of the projecting wing-like roofs over him. When the person would climb at the top of the sloping site, the complete butterfly-like form of the house would unfold to him. See (Figure 33). Motion of the flapping roofs, and the fiber optic filaments swaying in the breeze would imply further similarities of the house to a butterfly.

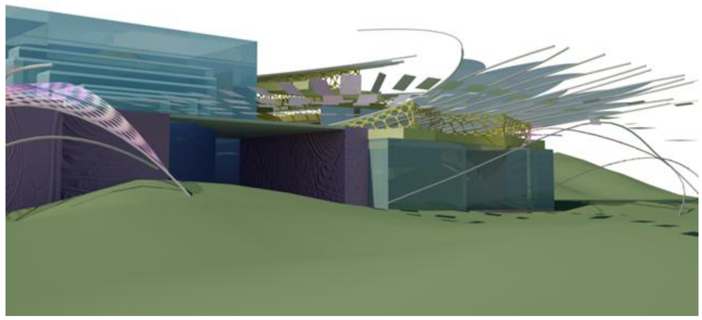

Figure 32. View from Human Eye-level

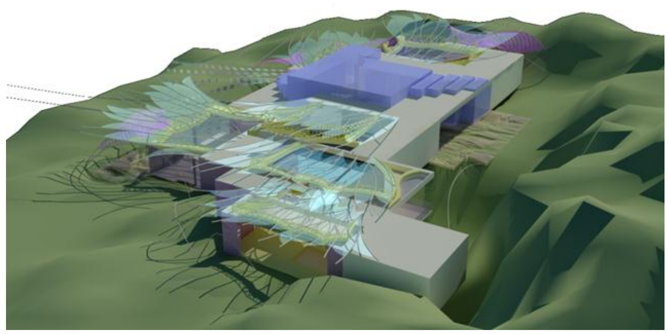

Figure 33. View from Top of the Site

The finish of the hi-tech materials used would be impressive. Large clear surfaces of glass would be well balanced with solid surfaces 3D Printed with floral fractals. When a person enters the house, facets of the entrance canopy would rotate themselves to face the person entering. The motion would generate a subtle soothing effect, like that of rustling leaves. The interior spaces would be inviting, with large spacious rooms and large floor to ceiling windows. See (Figures 34 and 35). The indoor hydroponics garden in the living room would bring nature indoors. The butterfly wing roof would cast interesting shadow patterns in the interior of the room. When the butterfly roof is augmented with projected images, the light transmitted through the roof would create interesting patterns of light and color on the floor. When the butterfly roof would flap, it would seem the room is breathing.

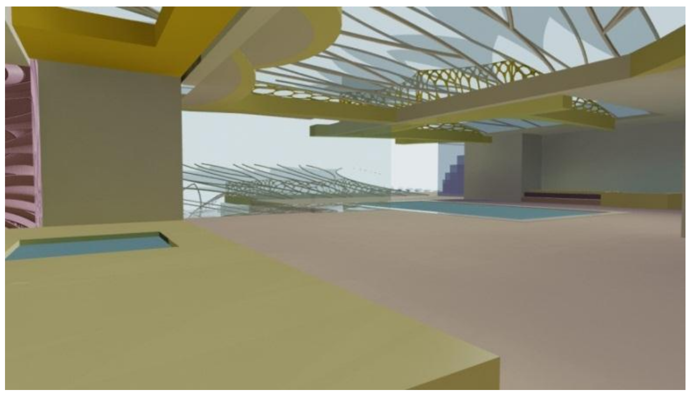

Figure 34. Interior View of Bedroom

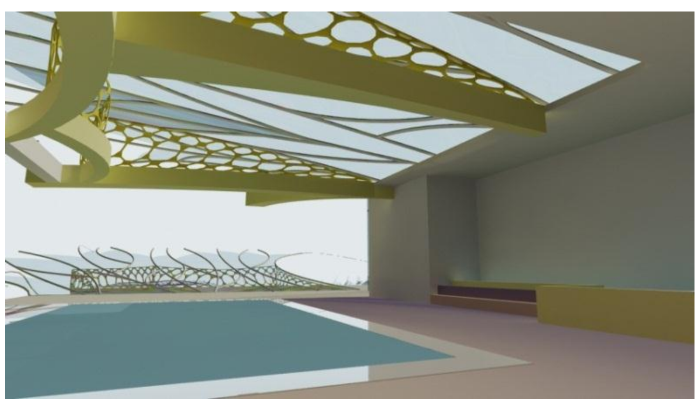

Figure 35. View of Pool Area

The rooms open out into spacious semi-covered decks and terraces that would invite a person to enjoy the outdoors, and appreciate how the structure fits perfectly in the natural beauty of the site. The site will be landscaped beautifully, and have exotic varieties of flora and fauna that would attract birds and butterflies. As the sun moves across the sky, and the day fades into dusk, the house would subtly change colors. At night the house would display interesting lighting effects.

5. FUTURE WORK

Future work could include development of new construction technology based on example ideas to produce techniques that would realize the virtual design. Ideas that are superficially discussed in this thesis could be developed into more detailed research and taken up by students in related fields. For example, a mechanical engineer could develop the mechanics of the unique dynamic roof system of the house. A materials science student could research a material that is extremely lightweight and highly tensile with high load bearing capacity, so that the sleek design of the house is structurally sound.

Future work could include extending the application of the technologies discussed toward designing the interiors of the Dreamhome, while staying true to the butterfly design concept that inspired the design of the exterior of the building.

A small scale prototype model of the design could be built, to study possible demerits of combing various technologies used together to create the design. Experts in related technologies could be consulted for their opinions regarding the viability of the suggested application of the technology on the design.

Continually keeping abreast of new developments of technology in various fields of science and researching their applications to the building industry could lead to updated designs for the Dreamhome.

The author of the thesis aims to apply the knowledge gained through this research toward a career as a consultant for application of new technology to create high tech, smart, sustainable architecture.

6. CONCLUSIONS

In this research paper we discussed the evolution of construction technology over the last few decades, and how present day RCC construction technology gained precedence over the earlier adopted stone, brick and wood construction. We discussed where future building technology may lead. We reviewed new technology in various branches of science, and how they could be applicable to architecture. Limitations of application to architecture of the discussed technologies were also reviewed. We looked at several examples of innovative architecture and engineering, which made creative use of new technology.

A unique home design was conceptualized that made use of several of the technologies reviewed in the paper. A 3D Visualization of the design was created. It can be concluded that advancing and embracing new technology and materials gives architects greater creative freedom. What would not have been possible to create with old technology and materials is made possible through advanced technology, for example paper thin walls, large span of beams, changing colors of the structure, and dynamic architectural components. Thus one could conclude that integration of multidisciplinary research with architecture could lead to very interesting living spaces and advance architectural technology by resolving technological limitations of more established construction methods.

Just as new technology inspired a creative architectural design, futuristic architectural design concepts could bring to light new topics of research interest in various scientific fields.

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GLOSSARY

Alloy

An alloy is a metal made by combining two or more metallic elements. The resulting alloy has a greater strength or resistance to corrosion than the component metals.

Electromagnetic Field

An electromagnetic field is a physical field produced by moving electrically charged objects. It affects the behavior of charged objects in the vicinity of the field.

Fatigue Life

Number of cycles of fluctuating stress and strain of a specified nature that a material will sustain before failure occurs.

Friability

Friability (or friable) is the ability of a solid substance to be reduced to smaller pieces with little effort.

Hydrophilic

Having an affinity for water; readily absorbing or dissolving in water.

Hydrophobic

Repelling, tending not to combine with, or incapable of dissolving in water.

Semiconductor

A semiconductor has electrical conductivity intermediate in magnitude between that of a conductor and an insulator. Conductors are materials that can transmit electricity. Insulators are materials that cannot transmit electricity.

Quantum physics

Quantum physics is a branch of science that deals with discrete, indivisible units of energy called quanta as described by the Quantum Theory. There are five main ideas represented in Quantum Theory:

- Energy is not continuous, but comes in small but discrete units.
- The elementary particles behave both like particles and like waves.
- The movement of these particles is inherently random.
- It is physically impossible to know both the position and the momentum of a particle at the same time. The more precisely one is known, the less precise the measurement of the other is.
- The atomic world is nothing like the world we live in.

Stress and Strain

When external forces are applied to objects made of elastic materials, they produce changes in shape and size of the body.

Strain

Strain is the relative change is shape or size of an object due to externally applied forces.

Stress

Stress is the internal force per unit area associated with a strain

Hooke's Law

Stress is directly proportional to strain.

Wavelength

In physics, the wavelength of a sinusoidal wave is the spatial period of the wave—the distance over which the wave's shape repeats.