How to exhibit architecture in a meaningful and effective way using AR technology

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This thesis project investigates the use of Augmented Reality (AR) as a tool for engagement and understanding in the architectural design exhibition. Communicating the complexities of building design and systems to a non-expert audience is challenging, AR provides a way to enhance the display of architectural innovations and features in a more interactive, effective and meaningful way. While AR technology is currently available and in use in a wide variety of fields including architecture, my argument focuses on the interrelationship between the architectural exhibition space and AR, and to make the invisible visible in terms of ideas, design narrative, and imagined possibilities.

The key to my project is the development of an AR application system that can be used and applied to all areas of design architecture rather than specific to one particular project. The end goal is to develop AR apps that can be used universally in any architectural design exhibition. My testing of prototypical applications (Cruess Hall and UC Davis Design Museum), demonstrated the functionality and creativity of AR. This project will be further developed and deployed at the U.S. Solar Decathlon in Irvine California in October 2015. The AR application will enhance the exhibition experience for the visitors attending UC Davis's Solar House by adding an interactive, virtual layer to the existing physical structure, as the technology allows the audience to see beyond the finished architectural component (wall, floor, etc.) and view materials of construction not visible by the naked eye.

In conclusion, I look to various artists and architects who have demonstrated that through the use of technology and augmented reality architectural exhibitions will continue to evolve and change, as we know it. It is architects like Pernilla Ohrstedt, who states, that in the future we will be able to travel to faraway places virtually, because the scans of places will be so precise.

Design and construction process for the final exhibition
in design museum at UC Davis design department

Outline

I.Introduction

A. Discussion of current limitations in architectural exhibitions.

B. Introduce AR as a creative interactive solution to these limitations.

II. Traditional approaches to architectural presentation and exhibition

A. Problem : No way to present an abstract idea in an interactive way

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C. Universalization of AR in all aspects of architectural exhibition from idea to market

VI. AR Application technology for the future of architectural design.

VII. Conclusion

Using augmented reality to exhibit architecture is still in its infancy stage, however, its potential for greater achievement in creativity and interaction is limitless.

VIII. Bibliography

"Seemingly immobile and durable, architecture remains a challenge in the modern world of collecting and exhibiting."- Wallis Miller

The challenge in today's architectural world exists at the level of exhibition. How can the designer effectively communicate the intricacies of design behind fixed structures—structures which appear to be "seemingly immobile and durable?" While, effective communication is a necessary component of any high quality service, achieving effective communication in architecture has been one of the challenges faced by designers in the world of exhibition. Presenting the varied levels and details of architectural design to audiences not familiar with the technical side of architecture is a crucial step in the communicative process, and yet this can be difficult when audiences are face to face with finished structures. Architects use a variety of techniques and materials in attempts to communicate their ideas, such as, physical modeling, printed versions of the schematic design, floor plans, sections, elevation and so on. However, in most cases these materials are immensely technical and challenging for the non-technical to fully understand the design narrative through a series of diagrams, floor plans, site analysis, etc., which require a high level of understanding of structural conventions. For the purposes of exhibition, these more technical structural elements are always hidden within the finished materials and cannot be observed by the naked eye, such as insulation systems, HVAC systems, framing, and so on.(see figure1)

My solution to these challenges is the use of Augmented Reality (AR) as a tool for engagement and understanding in the architectural design exhibition. Augmented Reality's potential for Architecture is huge. "AR" is defined as "any system that overlays, or 'augments,' the real world with digital information that seemingly co-exists." Augmented reality is used in architecture and construction by placing a 3D model of a proposed design onto an existing space using mobile devices and 3D models.

Figure1- The final thesis project first prototype on picnic day in design department at UC Davis

The applicability of AR in architectural exhibition creates a virtual world in which the previously unseen, unheard, unimagined comes to life for the viewer. For example, “virtual furniture may be overlaid in real time to check its size and appearance in a room; 'see-through' walls on a construction site .builders to view pipes and mechanical ducting behind; and overlays of past and future buildings render the city a canvas for virtual data.” The user-friendly nature of this technology is evidenced by the fact that it has already become a common interface in many other areas and fields including education and gaming. It is predicted that “the number of worldwide users consuming AR via portable media devices is expected to exceed 1 billion users by 2020.” Given this information, the implications for AR's success in architectural exhibition is noteworthy.

In addition, in most architectural presentation and exhibition, by maximizing the level of interaction between the audiences and design, architect enhances the understanding between them to convey the right design message to her audience. Interacting with form, color, shape, scale of a building will make a significant impact on audience in terms of understanding the design concept. The use of materials in making design decisions is heavily influenced by the results of human interaction on their surfaces. The ability to control and position architectural components and elements to reveal and celebrate these interactions.

Furthermore, Sustainability is another issue that need to be considered in architectural presentation. Materials used by architect to present their idea are often are not environment friendly, so there is always a way to reduce the amount of hazardous material and find the alternative.

Traditional Architectural Presentation Methods

Traditionally, architecture has been presented by following 3 basic steps with each step having its own deliverable materials.

A) Schematic design:

This phase is recognized as the first phase in the architectural design process. During this stage an architect commonly develops study drawings, documents or other media that illustrate the concept of design including the special relationships, scale, and form for the owners to review. This phase is also recognized as the research phase of the project when zoning requirements are addressed. This phase produces the final schematic design to which the owner agrees after consultation and discussions with the architect. Costs are estimated based on overall project volume.

Deliverable:

Schematic design often includes a site plan, floor plans, sections and elevations, computer image renderings or physical modeling (optional). Drawings include overall dimensions, and construction costs are estimated.(see figure 2)

Figure2- Schematic design for Mubarak project in Tehran-Iran 2007

B) Design development

DD services use the initial design documents from the schematic design and take them one step further. This phase lays out mechanical, electrical, plumbing, structural, and architectural details. Typically this phase results in drawings often specifying design elements such as material types location of windows and doors. The level of details provided in the DD phase is determined by the owner's request and the project requirements. This phase often ends with a formal presentation and is approved by the owners.

Deliverable:

Design development often produces floor plans, sections, and elevations with the full dimensions including doors, windows details and outline material specifications.(see figure 3)

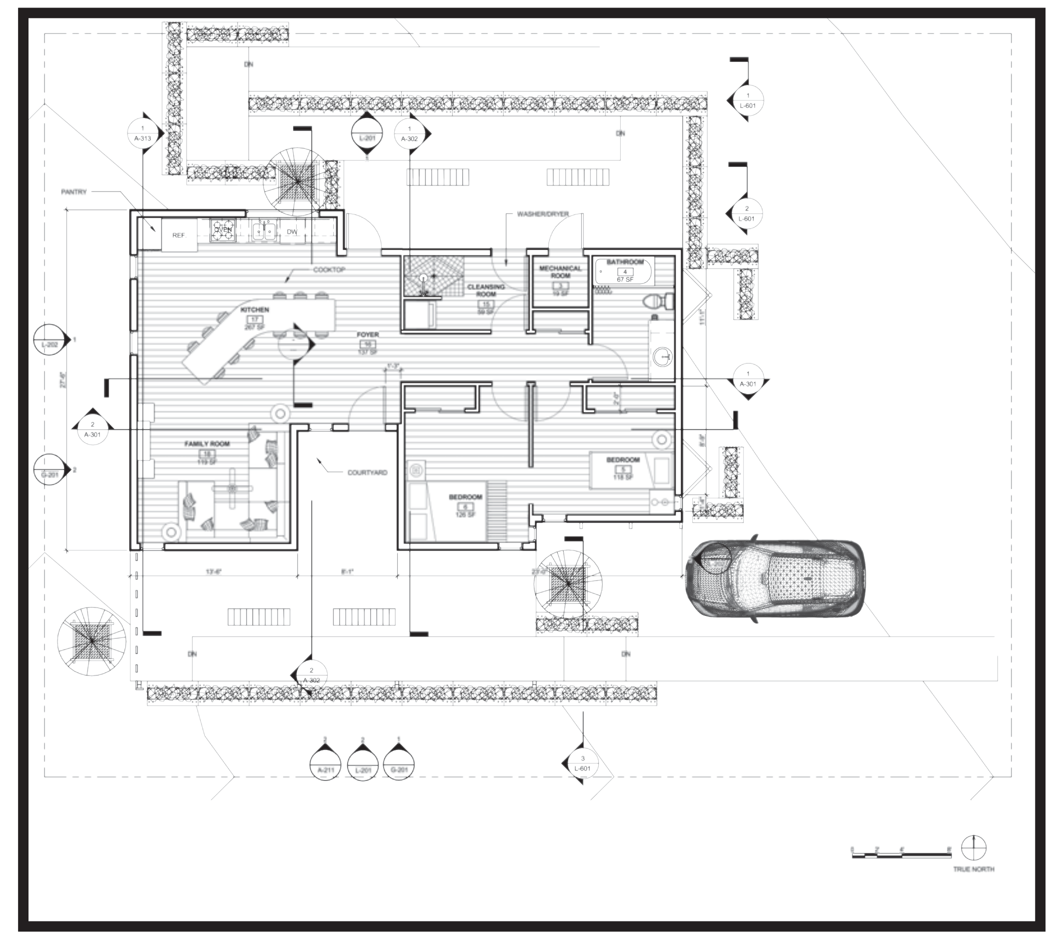


Figure 3- Design development phase for UC Davis solar decathlon project

C) Construction documents

The next step is the construction documents (Cds). When the architect and the owners are satisfied with the documents produced during DD phase, the architect moves forward and produces drawings with more details. These drawings typically include specifications for construction details and materials. After this phase is completed, now it's time to send the drawings to the contractor for pricing or bidding.

Deliverable:

The construction document phase involves a set of drawings that include all relevant requirements for the contractor to price and build the project.

While this method described above has sustained architectural presentation for years, the problem is that there has yet to be an effective way to present abstract ideas like floorplans, elevations, sections, etc., in a visually interactive way. I believe the use of my AR technology provides a revolutionary solution to these traditional limitations. (see figure 4)

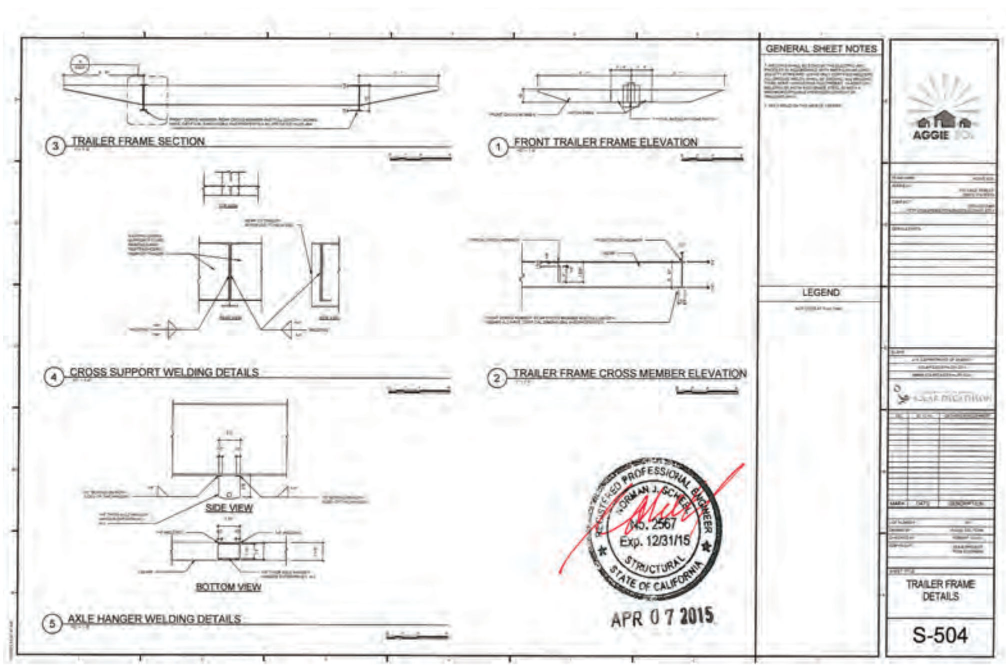


Figure 4- Construction document for UC Davis solar decathlon project

Augmented reality (AR) and its application in the field of architecture

AR has been used in the video gaming and media entertainment for a much longer period of time to show a real image interacting with one created from computer graphics. Its utilization has matured in the AEC industries in the past five years when contractors such as Seattle's BNBuilders began using it to show clients proposed designs in the context of existing conditions using iPads and other mobile devices on a construction site.

An oft-cited use of augmented reality came in the aftermath of the 2011 Christchurch earthquake in New Zealand. The University of Canterbury released CityViewAR, which enabled city planners and engineers to visualize buildings that were destroyed in the earthquake. It gave planners a great reference to what used to be there while also letting them gauge the devastation the quake left behind. Since then, it's been used as a tool throughout Australia for construction and earthquake investigation.

Augmented reality technology in architecture has potential to bring to life unbuilt designs to look at ways to reduce building footprints. Augmented reality will definitely be used in the future as a tool for designers to show clients what the design might be like. Through AR, it is possible to see a building virtually in its real position before it is built.

The other useful aspects of the technology is the fact that the interiors of a house and apartment can be easily explored in 1:1 scale allowing clients to see the quality of the finishes, and to understand the scale of the rooms as they walk through them. In addition, designers can overlay virtual motion graphics and animations using smart devices with static printed material.

When it comes to architecture, AR is a contemporary way of thinking about sustainability and architecture. For example, in the future with smart glass technology, a meeting room could be designed in augmented reality where people from different parts of the globe could sit inside the virtual space as if they were experiencing being in the actual building, and having a meeting with people in different parts of the world. Taking this a step further, the future of AR promises the creation of virtual, habitable spaces which can be custom designed to fit the aesthetic and functional needs of its users.

Solar Decathlon Project

Working as the architectural manager in an architectural competition called Solar Decathlon, I had the chance to visit France where the Euro solar decathlon 2014 was taking place. The U.S. Department of Energy Solar Decathlon is an international competition that challenges 20 collegiate teams to design, build, and operate the most attractive, effective, and energy-efficient solar-powered house. The winner of the competition is the team that best blends affordability, consumer appeal, and design excellence with optimal energy production. The competition has since occurred biennially in 2005, 2007, 2009, 2011 and 2013. The project is open to the public and free of charge, and gives visitors the opportunity to tour environmentally efficient houses. Here, viewers can find ideas to use in their own homes, and learn how energy-saving features can help reduce power bills. The competition is presented by the U.S. Department of Energy and organized by the National Renewable Energy Laboratory (NREL). The Solar Decathlon has been presented in Europe in 2007 as the result of an agreement between the United States and Spain. (see figure 5)

Figure 5- Euro Solar decathlon 2014

China also established a Solar Decathlon in 2011 with the signing of a memorandum of understanding between the U.S. Department of Energy, China's National Energy Administration, Peking University, and AppliedMaterials.

[1]www.solardecathalon.gov

Having attended the Euro Solar Decathlon 2014 in Versailles, France, and interviewing several presenters, I noticed that each building performs as an exhibition booth to educate the public about their respective unique ideas and design narratives. Each team had opportunity to:

- Educate students and the public about the money-saving opportunities and environmental benefits presented by clean-energy products and design solutions
- Demonstrate to the public the comfort and affordability of homes that combine energy-efficient construction and appliances with renewable energy systems available today
- Provide participating students with unique training that prepares them to enter our nation's clean-energy workforce.

Each team were responsible for communicating their design and engineering ideas through several daily public tours. Each program represented at least one unique design or engineering idea that needed to be communicated effectively and efficiently to the audience.

Each tour lasted no more than 15 minutes, so it was crucial to the house owners to do it fast, be concise, and make it understandable to the public. They were also taking advantage of environmental graphic design such as outdoor posters and signage as a vehicle to communicate their message to their audiences, while at the same time make their houses a provocative and attractive space for the audiences. (see figure 6)

Figure 6- Swiss house in Euro solar decathlon.

My thesis project; theory and practice.

This thesis project investigates the use of Augmented Reality (AR) as a tool for engagement and understanding in the architectural design exhibition. Communicating the complexities of building design and systems to a non-expert audience is challenging, AR provides a way to enhance the display of architectural innovations and features in a more interactive, effective and meaningful way. While AR technology is currently available and in use in a wide variety of fields including architecture, my argument focuses on the interrelationship between the architectural exhibition space and AR, and to make the invisible visible in terms of ideas, design narrative, and imagined possibilities. The key to my project is the development of an AR application system that can be used and applied to all areas of design architecture rather than specific to one particular project.

The end goal is to develop AR apps that can be used universally in any architectural design exhibition. My testing of prototypical applications (Cruess Hall and UC Davis Design Museum), demonstrated the functionality and creativity of AR. This project will be further developed and deployed at the U.S. Solar Decathlon in Irvine California in October 2015.

The AR application will enhance the exhibition experience for the visitors attending UC Davis's Solar House by adding an interactive, virtual layer to the existing physical structure, as the technology allows the audience to see beyond the finished architectural component (wall, floor, etc.) and view materials of construction not visible by the naked eye. (see figure 7)

Figure 7 - The final thesis project prototype exhibited in design museum at design department

Station 1: Overall description of the project

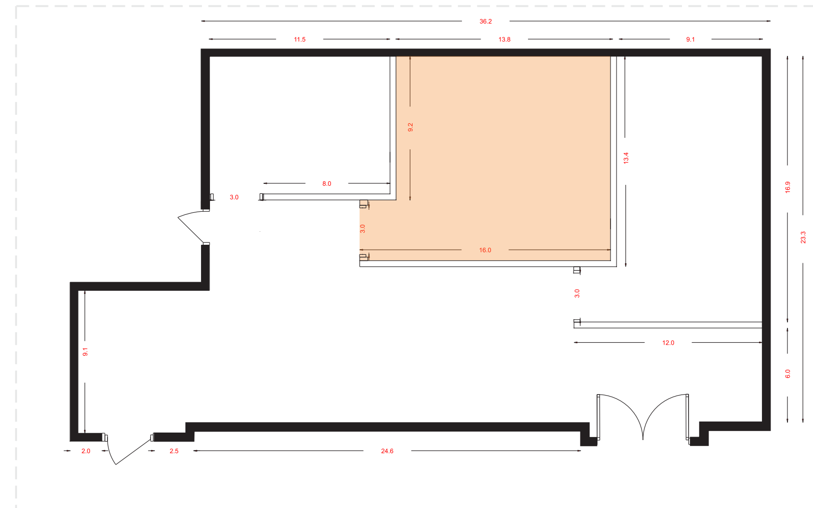
For my final thesis project in UC Davis design museum in Cruess hall, I have implemented the floor plan of the Aggie Sol building on the floor to define several architectural spaces in order to give a better understanding of the design to the visitors. This structure is the avatar of the 1000 sq2 building which is exhibited in a 208 square foot exhibition space. The overview shows four stations where the audience can learn about different aspects of the UCD Solar house. Each station has been dedicated to at least one sustainable idea that the Aggie Sol team has developed to make the house sustainable. (see figure 8,9)

Station 1 is presented in two sections:

A) Overview of the house (house description)

Aggie Sol is a student-led project at UC Davis to design and build a prototype, zero-net- energy home for the underserved farmworkers of America. The two bedroom, 1 bathroom home is factory built for easy transportation and construction. The floor plan provides a large common space with living, kitchen and dining rooms that open onto the decks, with sleeping and service rooms off the hallway. The home features in-line framing and an innovative radiant floor system that utilizes the night sky to reduce cooling loads. This Strong architectural and engineering concepts makes our sustainable home affordable available to the masses of California.

(see figures 8,9)



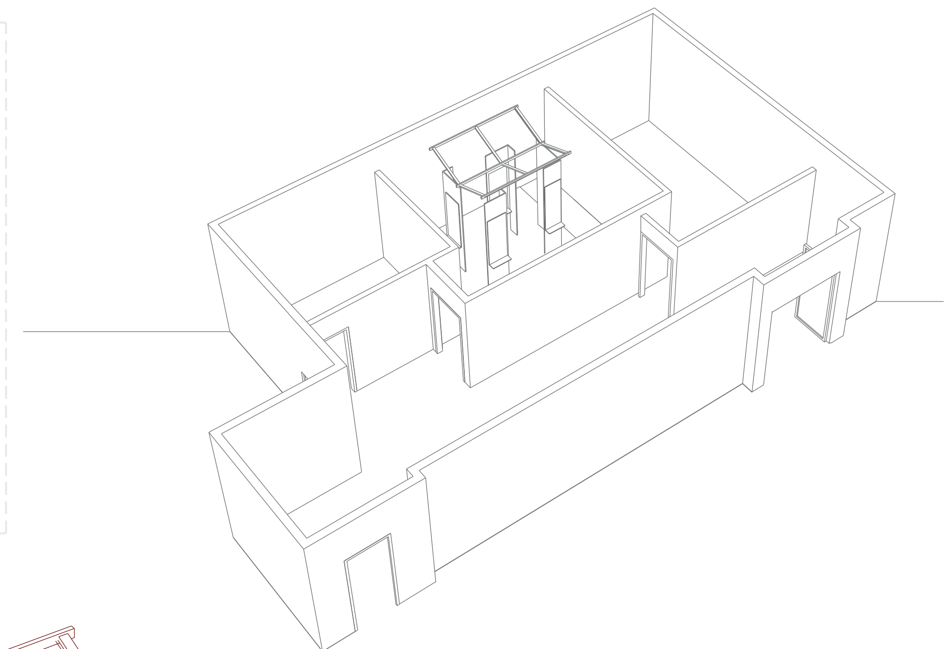


Figure 8- Design museum in Cruess hall floor plan
With the detailed dimension.

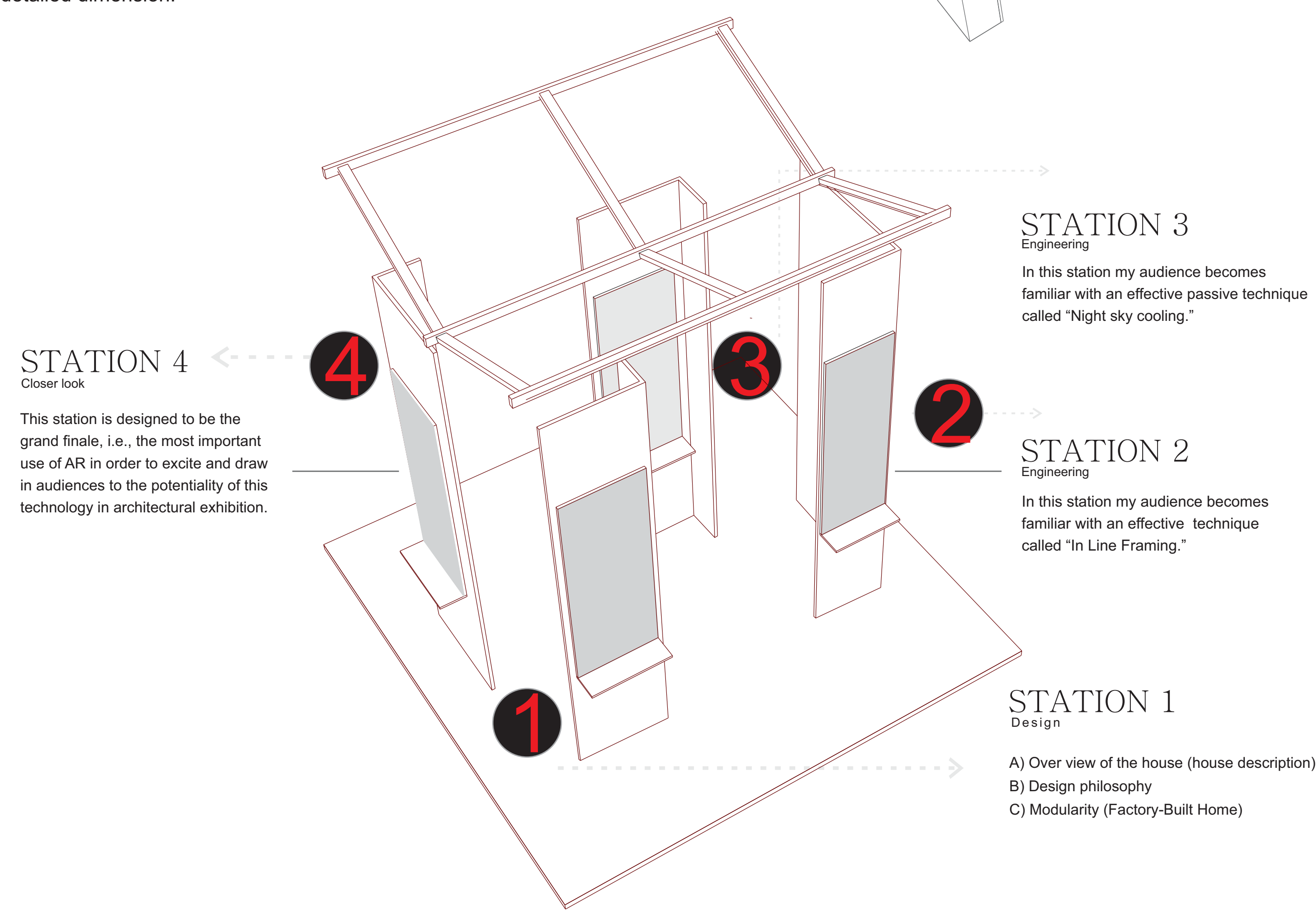


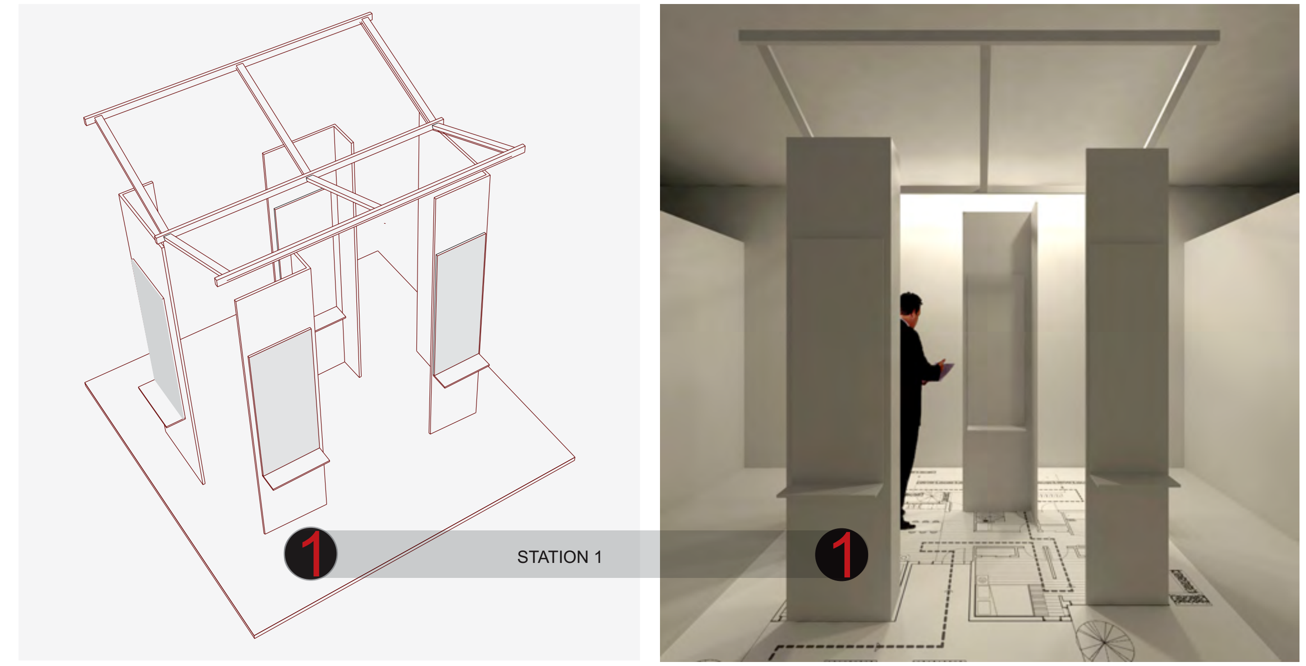
Figure 9 - The final thesis project prototype exhibited in design museum at design department

B) Design philosophy

Team Aggie Sol's goal is to design an affordable zero-net-energy home that provides comfort, safety, and a better quality of life for farmworkers and other underserved workers. Our design addresses numerous health, living, and cost concerns associated with current farmworker housing conditions, including inadequate heating and cooling, poor air quality, work-related debris, affordability, and an absence of sustainable, energy efficient housing options. Our team has designed a zero-net-energy home that will serve workers at a price that public and private housing providers can afford. In our mission to develop sustainable housing at the lowest possible price, we have incorporated low-cost energy-efficient technologies pioneered by the cutting-edge research from UC Davis. Our work has focused on designing a "smart home" which innovations the energy collection systems, the heating and cooling solution, and the unique concerns of the farmworker. As well as reducing the cost of the home, these technologies have the potential to make well-designed ZNE housing available to communities of all income levels.

C) Modularity (Factory-Built Home)

By using a double-wide, factory-built home divided into Northern and Southern halves, the Aggie Sol home can be constructed and transported quickly and cost-effectively. The halves are then reconnected on-site in order to have a livable home in a matter of days after delivery, demonstrating that the house we design is a modular house with two distinguished modes.(see figure10)



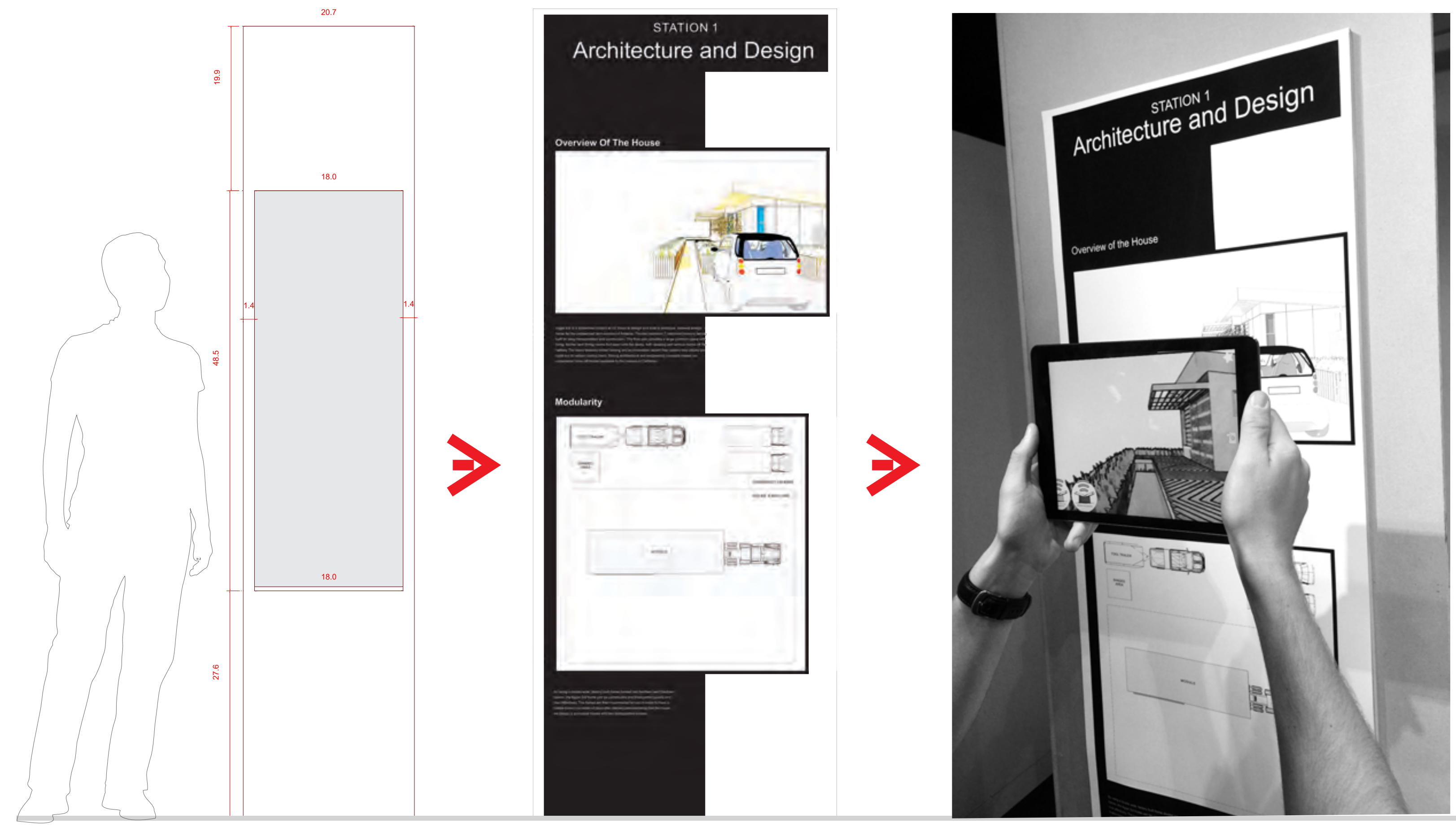


Figure10 - First station's stand and poster

Method of Presentation using AR

Station 1

In this station, viewers are presented with a physical layer of information about the contents that need to be covered on a poster, as well as a tablet with my augmented installed reality application. With the integration of the informative virtual layer to the printed diagrams, my audience will be able to receive more information about the design philosophy and overview of the house through two 3d animations which run when the audience face the tablet toward the first and second images (trackers) on the poster. The walk-through animation describes two audio narrations. While the audience is watching the walk-through animation, they can tap on two icons at the bottom left side of the tablet screen to trigger two audio narrations educating them about the overview of the house and design philosophy.

The second section of station one communicates modularity as an important characteristic of the house. The second image (tracker) on the poster represents an architectural diagram showing how two modules of the house come together on-site to form the house. This 2D animated diagram then turns to a 3D animated building uncovering several views of the house. As one faces the tablet toward each section, individuals will be able to see a virtual layer, which includes sound, animation, video, and pictures appearing on the interface of the tablet. The AR technology functions to further educate the viewer about the modularity of house. For example, in terms of the larger picture of modularity, viewers will see specifically operational diagram showing how two large modules of the house come together to form the structure of the building on site. (See Figures 11-13)

Figure11-AR application features shown on the tablet's screen

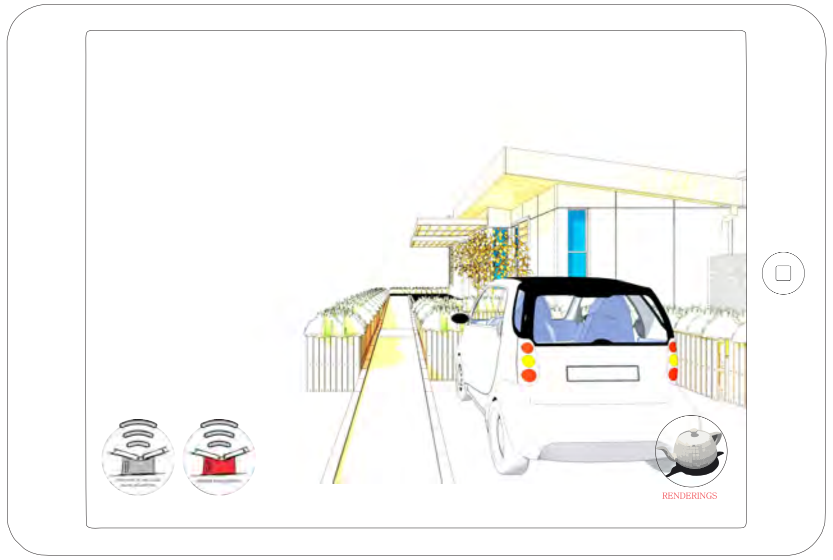


Figure12-First section walk through animation

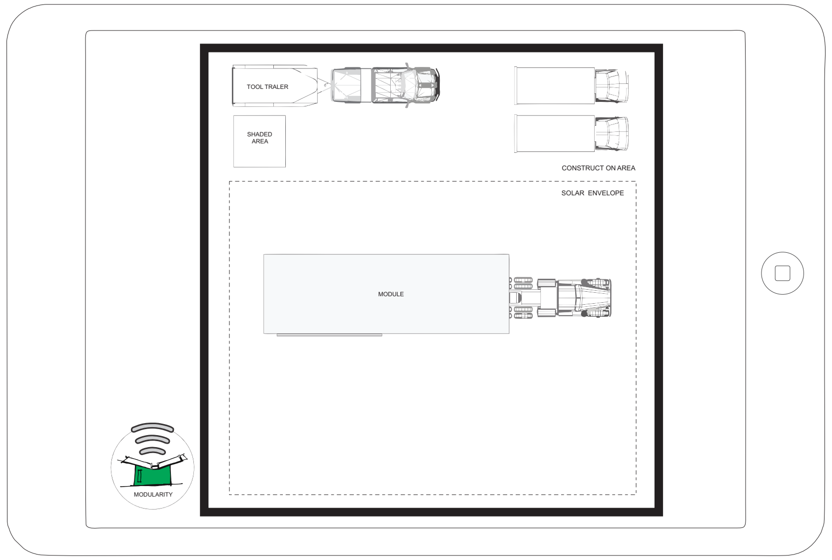


Figure13- Second section Animated operational diagram representing the modularity of the house

Station 2

In this station my audience learns about an efficient construction method called in-line framing in two sections. The first section reveals the overall feature of in-line framing through 3D animation. While the audience hold the tablet toward the first tracker, they see the AR detecting the image from the poster overlaying a fly-through animation on the tablet's screen uncovering beams and columns of the house under the façade material. There is an icon at the bottom left side of the tablet's screen that can be tapped by the visitor to trigger the visual narration while the animation is running to enhance the learning process for the audience. The audience will see and hear the following narration:

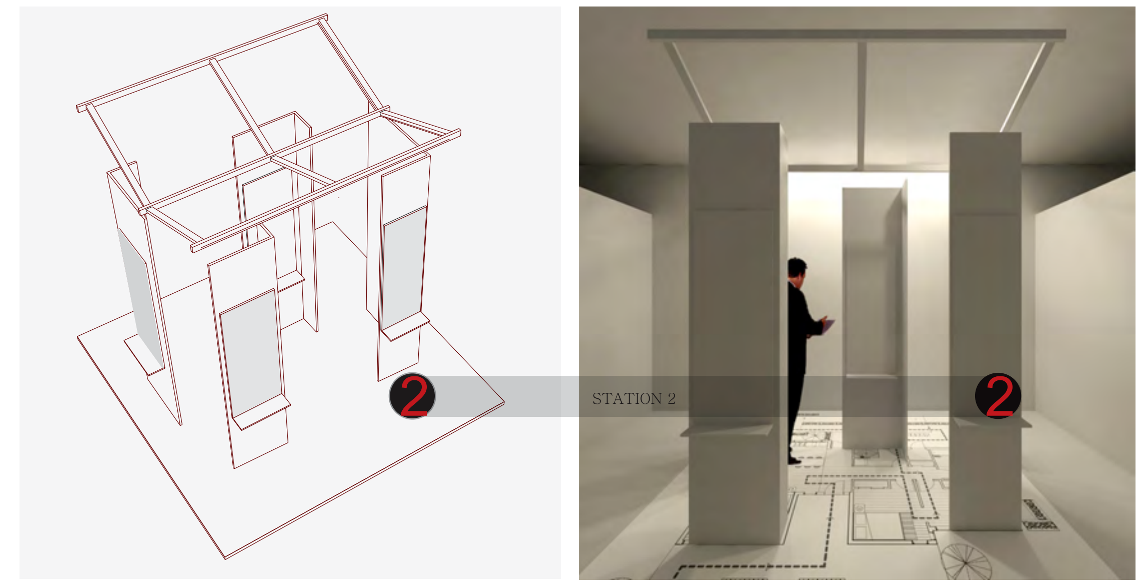
In-line "Balloon" Framing

Through the use of in-line balloon framing, the Aggie Sol home uses 30% less lumber than conventional framing methods. This method uses 2 x 6 framing 24" on center, providing us a sustainable advantage in cost, design and materials resource. Our wall cavities have more insulation and less thermal transmittance through the studs. In-line balloon framing makes our home environmentally friendly and efficient, by being built better with less materials.

Station 3

Reduced Solar Heat Gain

In this station my audience learn about the radiant cooling system and its functionality during the daytime and nighttime (night sky cooling system). The Aggie Sol home is designed with minimal use of windows, and features operable exterior window shades, and a light-colored exterior to reduce solar heat gain. This passive design technique reduces the cooling loads on a single valley, reducing the amount of gutters and simplifying rainwater collection. (see figures14-16)



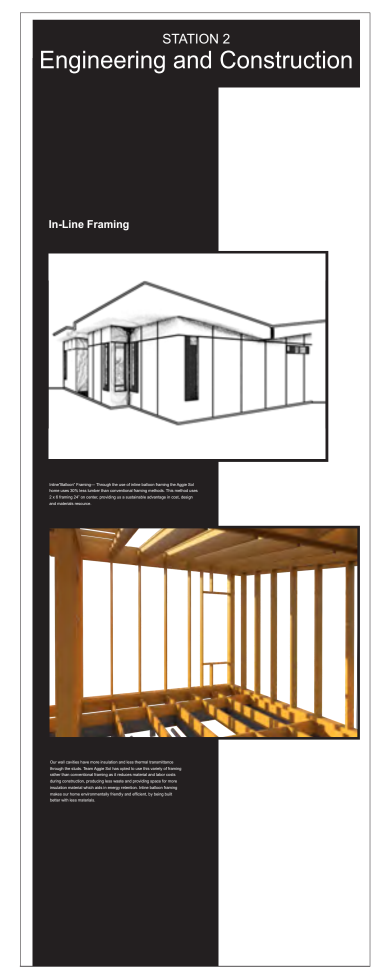


Figure14- Second station's poster

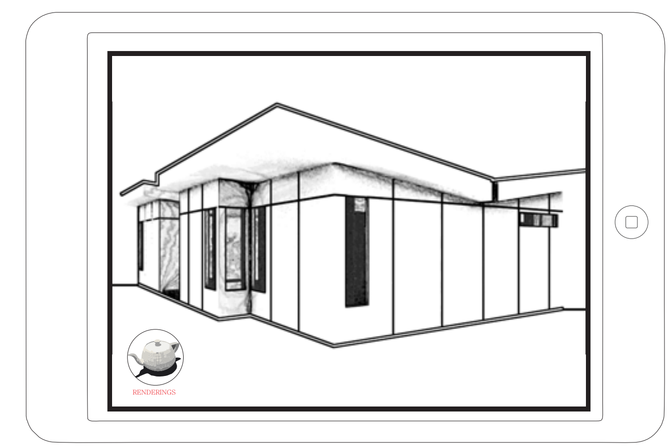


Figure15- First section on the poster represents In-Line Framing technique through a walkthrough animation.

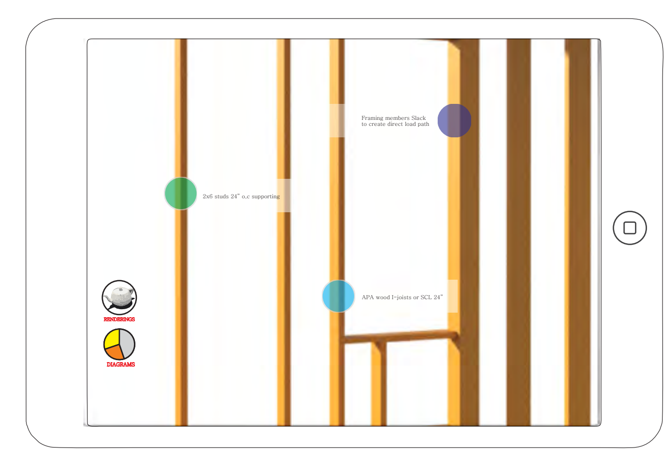


Figure16- Second section, offers more detailed information regarding In-Line Framing

Furthermore, this makes an architectural statement, i.e., a home that is beautiful as well as sustainable. In this station my audience becomes familiar with an effective passive technique called Night Sky Cooling.

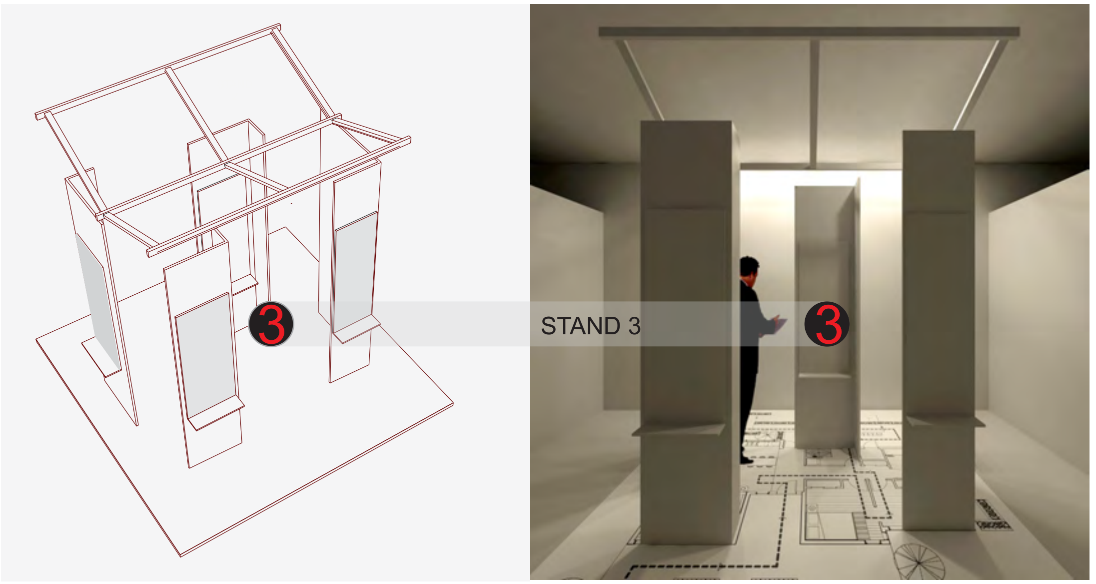
Method Using AR

In this station my audience will learn more about the radiant cooling system in two sections. In the first section, the AR technology describes the daytime process of the radiant cooling system. By facing the tablet toward the first tracker on the poster, my audience will see a 2D style animation overlaid on her tablet's screen showing how cold water flows out of the Eastern water tank to cool off the building by moving under the floor to absorb the heat generated by the building and flow back to the water tank to be cooled later through the night sky cooling system. There is an icon at the bottom left side of the tablet's screen that runs the audio narration to help the audience to learn more about the system in a visually informative way.

In the second section, my audience learns about the night sky cooling system by seeing an overlaid animation on top of the second tracker on her tablet's screen when she holds the tablet toward the second tracker. There is also an icon at the bottom left side of the screen that triggers the audio narration when the audience tap on it. The narration for both is presented in the following description:

Radiant System

The Aggie Sol home features a unique radiant cooling and heating system that leverages the unique geographical features of the West coast of North America. The solution utilizes a large rainwater reservoir which is cooled by exposing the water to the air during the during the chill night hours through a sprinkler system on the roof.(see figures17-19)



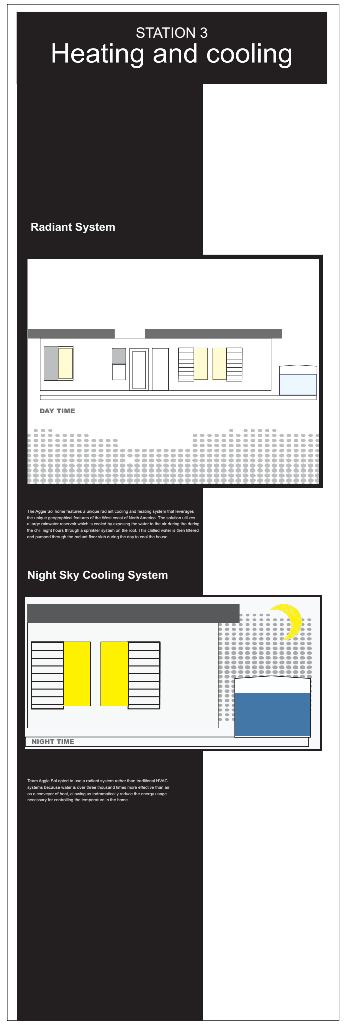


Figure18- Second section, offers more detailed information regarding In-Line Framing

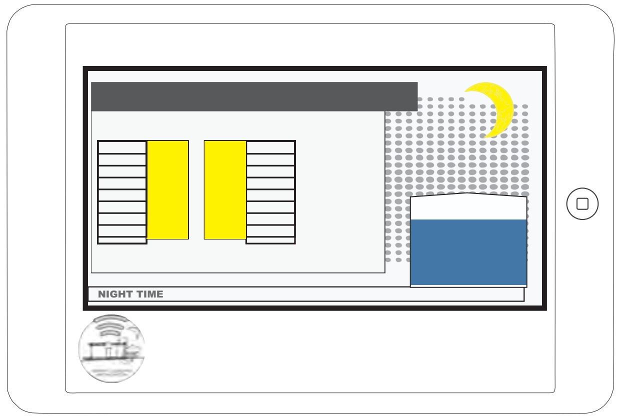


Figure17- Third section, offers more detailed information regarding Radiant system during the day times.

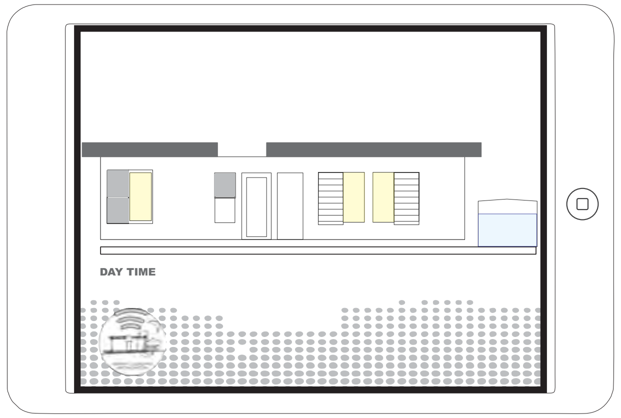


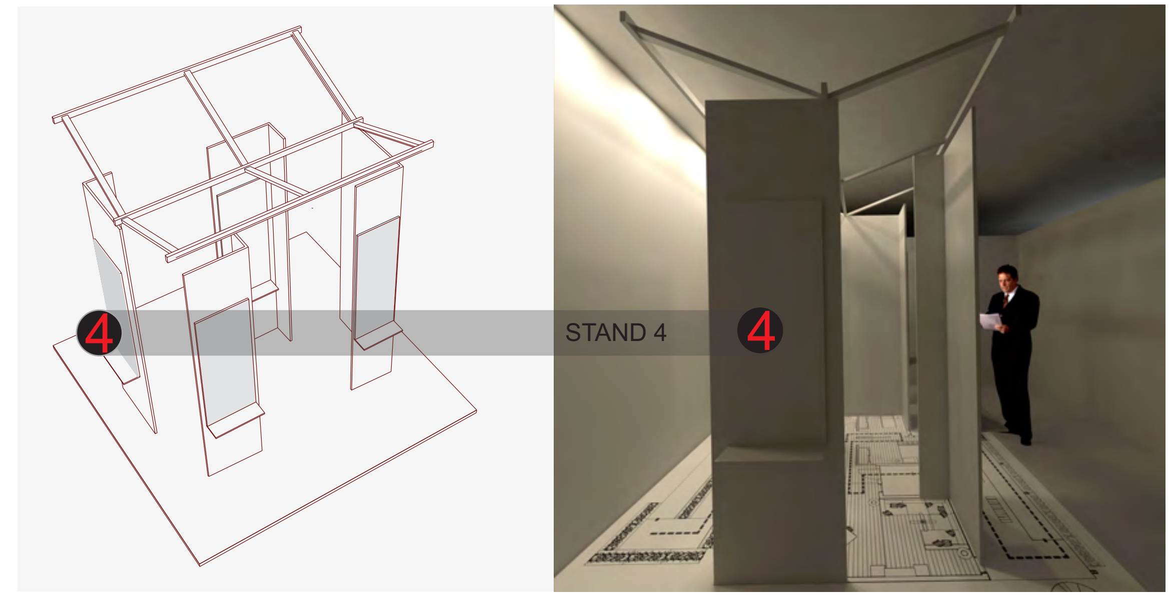
Figure19- Third section, offers more detailed information regarding radiant system during the night times.

This chilled water is then filtered and pumped through the radiant floor slab during the day to cool the house. Additionally, small quantities of the water can be heated to provide radiant heating in cooler months or nights, sustaining a consistent temperature in the home throughout all hours or seasons. The home uses a specialized heat exchanger to extract energy from domestic grey water to preheat potable water for the domestic supply, recycling the latent energy effectively and quickly. Recovering heat in this manner reduces the primary energy need for hot water in the home, making the process cheaper and more energy efficient.

Station 4

This station is designed to be the grand finale, i.e., the most important use of AR in order to excite and draw in audiences to the potentiality of this technology in architectural exhibition. There are two elevations of the Aggie Solar House printed on poster board. These two dimensional trackers will activate the AR tablet and bring to life in 3D form the entire details of the interior and exterior of the house, room by room, and wall by wall respectively.Method Using AR

In this last station, the audience will see some graphs and diagrams on the poster, and in order to make a memorable conclusion, they can experience an interactive walk through using AR as well. By holding the tablet toward the assigned tracker on the poster, viewers will observe the augmented 3D version of the solar decathlon house with elaborate details on the screen of their tablet. In addition she would be able to take a picture with the model using the “take a Picture” function, and send the picture to her email account.(see figures18-19)



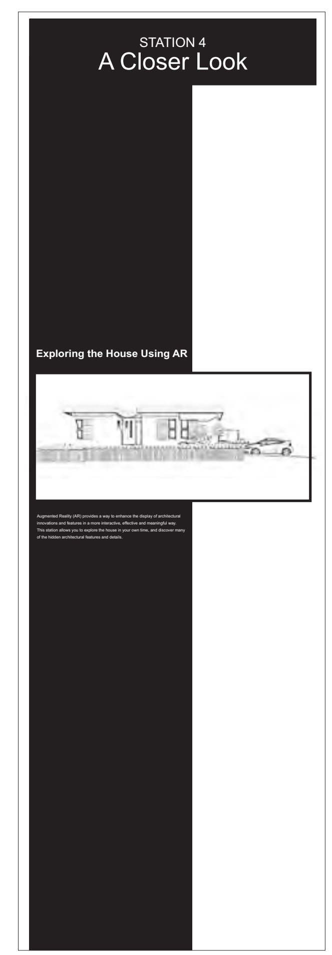


Figure18- Fourth section, closer look to the Aggie Sol house

Figure19- Second section, offers more detailed information regarding In-Line Framing

Universalization of AR in all aspects of architectural exhibition from idea to market

Unlike passive experiences of architectural presentation, what is different about augmented reality aided presentations is that it takes place in the physical environment as an extra layer of information with an active experience for the audience. In other words, audiences can actively participate in the creative aspects of the design. Unlike more traditional forms of animation, AR helps you to see the physical and virtual environments at the same time. You can even overlay information in any location in the world by adding GPS technology to AR. By using virtual components to stand in for physical objects, AR can save on the fabrication and material costs of real-world prototypes. AR platforms can also isolate individual elements within a spatial scheme for presentation at full scale. By using virtual components to stand in for physical objects, AR can save on the fabrication and material costs of real-world prototypes. Such applications are useful in clash detection to visually detect overlaps between proposed virtual content and real world elements. Today's commercial applications in this area are limited to mass-manufactured objects, whose modular nature provides a compelling business case for AR platforms that communicate scale.

AR platforms can also augment physical models and drawings with unlimited virtual content. The most common augmentation of presentation media today is when a paper drawing, such as a 2D plan, becomes the marker for a 3D model overlay. But the value-add of AR is in communicating information that other media cannot, such as 4D content (information with a time component). Overlays need not be limited to visual applications either, as AR can draw on other senses to communicate elements of a scheme, such as the acoustics within a space.

In conclusion, I look to various artists and architects who have demonstrated that through the use of technology and augmented reality, architectural exhibitions will continue to evolve and change, as we know it. It is architects like Pernilla Ohrstedt, who stated that in the future we will be able to travel to faraway places virtually because the scans of places will be so precise. She envisions allowing architects, urban planners, artists, curators and designers to try out ideas in the virtual world before moving on to creating them in the real world. Taking the reins from Ohrstedt, I will be developing the AR application for the 2015 US Solar Decathlon competition where the UC Davis solar house is going to be presented. My goal is to integrate the physical environment with the informative virtual layer to enhance the experience of the visitors who will be visiting our house in Irvine California. In addition, I believe the AR technology will help me as an exhibition designer and constructor to promote my design narrative for my future clients not only in exhibition centers such as the Solar Decathlon, but in the architectural marketplace worldwide.

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