Expanding Scenarios for Responsive Architecture: Applications to the Marginalized Space of Seniors

Responsive architecture has been represented many times in movies and television series such as Iron Man and Star Trek in various futuristic forms but current research has been attempting to make the future current: architecture schools and upcoming practices are applying the technology to facades, responsive installations, and biodynamic structures. This paper seeks to expand on applications for responsive architecture, speculating on areas with which we would not normally associate the digital. As well, this paper seeks to expand the discussion on where the concept of design with a capital D intersects with the digital.

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THE FUTURE IS NOW

We are fully capable of manifesting metamorphoses of our built environment: using control systems allows multiple sensors and actuators customized to specific conditions to respond very specifically to many criteria. This technology is not new and is quite accessible to students familiar with digital tools. Mainstream journals such as Wired have headlined articles on playing with this technology, and engineers use the technology with fluency. What is newer is the application to architecture, and this potential application provides architects with a Pandora's box of possible applications, the beginning of which we are only starting to imagine. This paper begins to expand the realm of possibility—applying responsive architecture to the space of seniors. Senior and extended care is an area often overlooked—viewed as marginalized spaces of little interest and even less funding, the extended care health facility is a potentially huge application of responsive technology, not only to physically assist occupants who cannot easily complete simple tasks themselves but also to augment the environment to simulate situations that are no longer accessible to the occupants. Those with dementia or limited mobility cannot access outdoors or connect easily with their loved ones—this interaction can be technologically simulated and mediated, increasing quality of life and expanding territories for applications of responsive environments.

New technologies and materials have almost always been responsible for large changes in architecture: for example the introduction of steel and glass and the introduction of digital modeling. All these jumps in technology are brought to architecture, experimented with, and then have significant impacts. The use of the technology's application cannot be foreseen but must be experimented with to determine what potential application will be the ones with the long-term impact. There are many potential applications for a new technology or material, and many of these applications are experimented with and then left to the side. The long-lasting impact in architecture must be discovered. Working with responsive environments in architecture is a huge new field, and the realm of what can be done is hard to imagine from where we now stand. It is only through experimentation that we can find the most beneficial uses of this powerful technology. From the perspective of architectural research in the field, the first step toward trying to understand the potential is to try a multiplicity of things with the new technology. To date the authors have investigated the use of responsive architecture in building envelopes, urban infrastructure applications, and, in this case, seniors facilities.

ALGORITHM EQUALS SPACE

Design decisions in responsive architecture include those that must be made with contemporary architecture but also decisions on what should be sensed and actuated, and what combinations of inputs or feedback will cause what kind of actions. Design in this sense is the programming itself: a different algorithm changes the design expression, configuration, and behavior. Different programming then results in different spatial conditions. As such, the programming becomes a powerful spatial design parameter. This direct translation of the algorithm into space is what causes this technology to be so powerful to architects. And yet it is also illusive to define the result: the spatial intent can change by the second: space is always in flux. The complication of the discussion and the multiplicity of different cases of spatial configurations and overlaps of conditions in the programming cause spatial readings that differ input by input and minute by minute. A different programmer (architect) could have a completely different spatial behavior by the result only of their programming decisions. In more complex programming, spaces may learn and program themselves, providing an adaptive environment which itself 'learns,' adding further complexity to this discussion.

The environment that senses can no longer be defined as only physical and only digital and the more sophisticated and proliferate its sensing and processing, the more 'alive' it becomes. The extreme of this is the environment as a prosthetic limb—completing that which cannot be done by the occupant. As such, the choice of an extended care facility plays literally into the discussion. In this role, the environment becomes an extension of the 'brain' collapsing physical and digital but also coming closer to collapsing the body/environment divide. While the discussion precedes the technology and applications by a significant amount, we can see where we might move to and the blurring boundaries the architect might need to negotiate.

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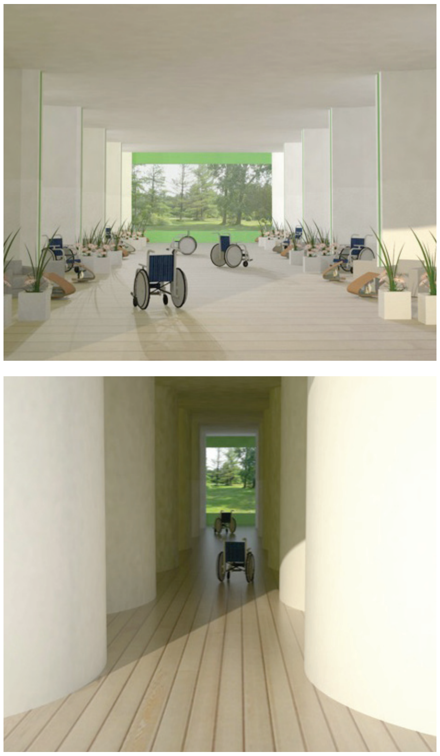

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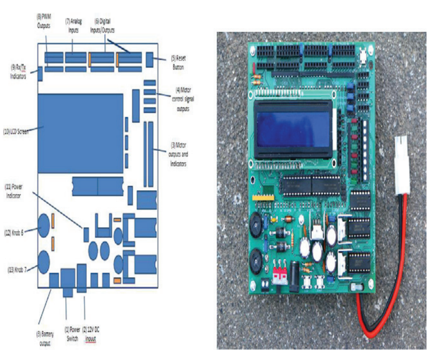

Figure 1: Responsive corridor, Configurations: all open/all closed.

Figure 2: TINAH Boards

THE TECHNOLOGY OF RESPONSIVENESS

The field of engineering that encompasses the technology required for responsive architecture is mechatronics. Its relationship to architecture is similar to the relationship of other engineering fields to architecture—fields such as structural, mechanical, or electrical engineering for buildings. As always, the architect must understand enough about the technology to use it as a media in her work. Just as with other engineering media that the architect designs with, the media has a distinct set of skills associated with designing with it. In this case the media to be understood includes the vocabulary of sensors, actuators, and control systems. The sensors sense input from the environment: light levels, locations of people, movement, temperature, changes in relative distance, and so on. The actuators cause action: a wall to move, a rotation of an element, a change in location of an element, a change in light level or color and so on. The control system is the 'brain' that determines what action to take given what input: the input can be an input from an initial reading or a feedback loop that is tracking something such as the wall's location in space. The control system can have complex programming that responds to multiple sensors in different ways and that can even 'learn' patterns of occupation over time.

The control system used in the examples shown in this paper is a TINAH board. This is a microcontroller-based control board with some embedded programming to facilitate the conventional input and actuation expected in a simple robotic device. These boards are based on the HandyBoard, a Motorola 68hc11=based controller system designed by Fred Martin at MIT in the mid-1990s. While this system is customized to make the life of the programmer easier, there are other more widespread control boards such as the Arduino (also referred to in the Wired article of April 2011) which has very good Web support and is well known among engineers and hobbyists. It allows small boards and interaction with the Rhino plugin Grasshopper through Firefly. All the designs proposed in the research are easily buildable today with current technology and hardware available online. Demonstration models, as with other architectural models, took an element of the design and scaled it down in order to demonstrate its feasibility.

In building a responsive model of a responsive architectural concept, the actuators must also be scaled down and likely modified from the full-scale actuators. The sensors in many cases can be the same sensors as proposed for the architecture. The control systems have simplified programming due to the lack of many inputs for sensing and the lesser number of things that must be actuated in the model as compared to the full-scale architecture.

TOPICS FOR RESPONSIVENESS

Responsive architecture has an allure: the motion and continually changing space provides an environment more in tune with our current gaming and digital environments. While it is strange to us, it is simultaneously familiar in its technological similarity to our ubiquitous gadgetry. The judgment required in architecture in general is equally or more important in the decision about what should be actuated and why.

This body of research looks at the marginalized space of the extended-care health facility. As the population in many countries ages, dealing with seniors and the spaces they require becomes more critical. As well, seniors are often a marginalized population: as they become older and weaker they have a smaller voice in society. They are similarly economically disadvantaged, which also exacerbates the position.

Extended care facilities have many potentially extremely valuable applications for responsive environments on multiple scales for many reasons: the fact that the residents in many cases have difficulties in completing tasks themselves is one reason, another is that the mundanity of the environment and the limitation on the experience outside of the walls of the facility. Many seniors cannot leave their facilities because of the inability of the staff to monitor their whereabouts and health. The adjustment of the space can provide benefits both because the occupants can be empowered with a feeling of autonomy and because the caretakers can be relieved of some of the mundane and potentially strenuous but necessary tasks in the day. As well, over time, the occupants of the extended-care health facility become continuously weaker and less able to complete simple tasks themselves: a deterioration that is frustrating and disempowering to the individual. The environment itself can respond to this: modifications can be made through programming to customize the settings of the environment to the capability of the individuals. For example, in one project working with responsive wall conditions, if the occupant had a problem identifying where their room was (a problem common for patients with Alzheimer's, for example), the wall could illuminate to identify to the patient which room was theirs. If the occupant has no problem with this, the wall does not have to identify to the occupant where to go. Over time, adjustments can be made in the responses, depending on the needs of the occupants or the health care providers.

Further, different patients have different needs and different conditions: patients with Alzheimer's have different requirements than patients with dementia who have different requirements than those who have only mechanical difficulties because of age or a stroke injury. A customizable responsive system allows flexibility for individual requirements and also for individual preferences. While this at some point may have seemed an expensive and unattainable technological hurdle, for today's sophisticated interactions (on an iPhone for example), the programming and control system technology is relatively simple and inexpensive.

SPECULATIVE PROPOSALS

Speculative projects in this realm were completed by teams of architecture and engineering students. Projects are proposed not for current seniors but for the students as seniors: where seniors today might be unused to an environment that responds to their movement or to environmental change, those who are engaged in our culture today will likely be fully comfortable with interacting with their environment and having the space change.

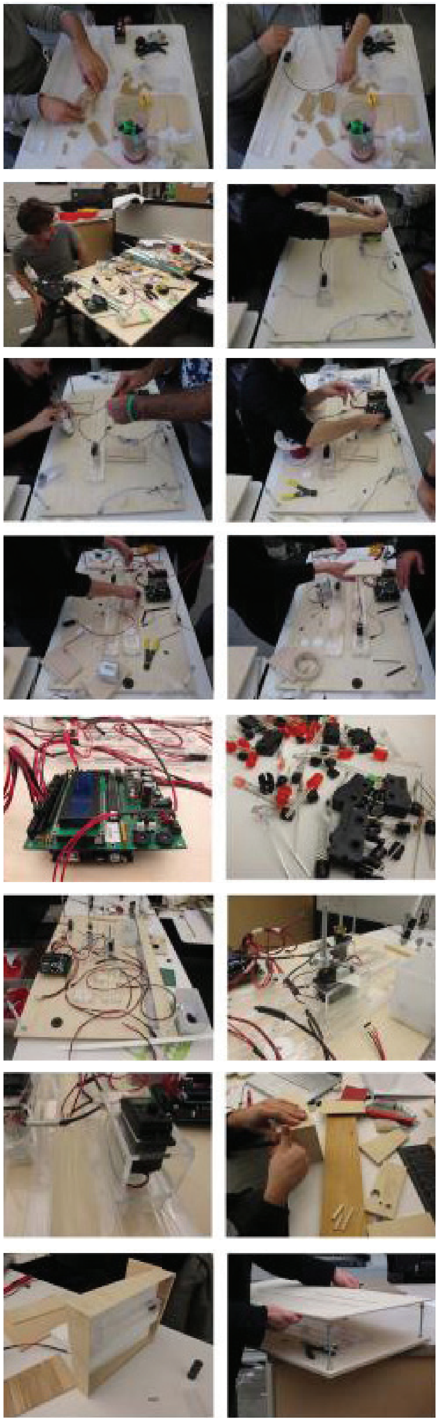

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Figure 3: Process of making

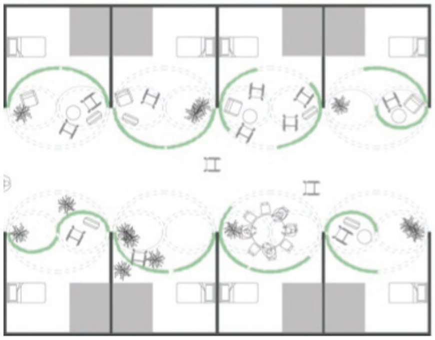
04 

Figure 4: Different possible wall configurations along the corridor

PROJECT: CORRIDOR

Changes in space can put space where it's needed. In many facilities, space is at a premium but when the space is not needed, it need not exist. Recognizing the undervalued space of the corridor in an extended-care health facility, one project put forward a proposal to allow the corridor to have 'porche.'. These porches are responsive mediating spaces produced by flexible mobile walls (Molo walls) between the room and the hallway. The concept is that when the room is occupied, the room expands into the corridor, but when it is unoccupied, the corridor extends into the room. The space moves to where it is needed. As well, by creating an innovative, dynamic buffer between the private and public spaces, it decreases the sense of institutionalization and provides variety and empowerment for the residents.

Control of the system is proposed in more than one way:

Direct user control: where the walls are controlled by a remote, allowing users to arrange their walls to suit the use they desire at that moment.

Radio Frequency Identification: allows identification of individual users of the space in order to tailor responses to their activities. The users will wear a small transmitter that will both identify them individually and locate them to allow the system to respond to different people and their movements.

Programmed timed actuator: to control the walls to respond to the different temporal patterns.

Touch sensor: activated when physically contacted.

The behavior of the system will respond to a number of different functions and activities directly related to the users of the space.

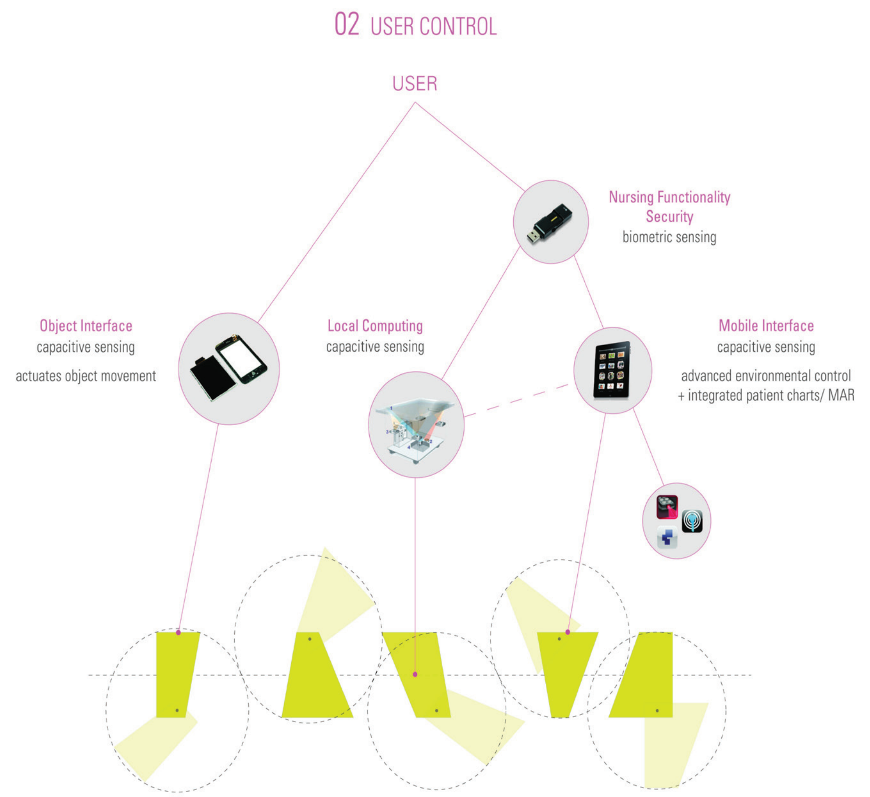
Direct Control: The primary concern of this system is to provide the occupant with empowerment to change and control their space in the confined settings of a care facility. To achieve this, a remote control will be used, perhaps something similar to an iPhone application, to allow people to manipulate their space.

The touch sensors will be used to control movement of wall to create opening in the wall system for users to enter the space.

Space Occupation: The goal is to maximize the use of space so that semi-private spaces when not occupied are made public. To accomplish this, the radio frequency is used, as it is able to identify when the resident leaves their personal space.

Wayfinding: The goal is to subtly aid residents in locating their room. *Radio frequency* senses when they enter the corridor, which will activate an individually colored lighting system within their wall.

Monitoring: The purpose is to provide an unobtrusive system to aid nurses in locating and monitoring patients. The radio frequency identification will sense when a resident is in their room. During the day a low level of colored lighting will indicate occupancy, whereas at night time a low level of "tested sleep-friendly" white light will be emitted.



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Temporal activities: At night walls will maximize the corridor space to allow for cleaning, maintenance and maximum circulation for the staff.

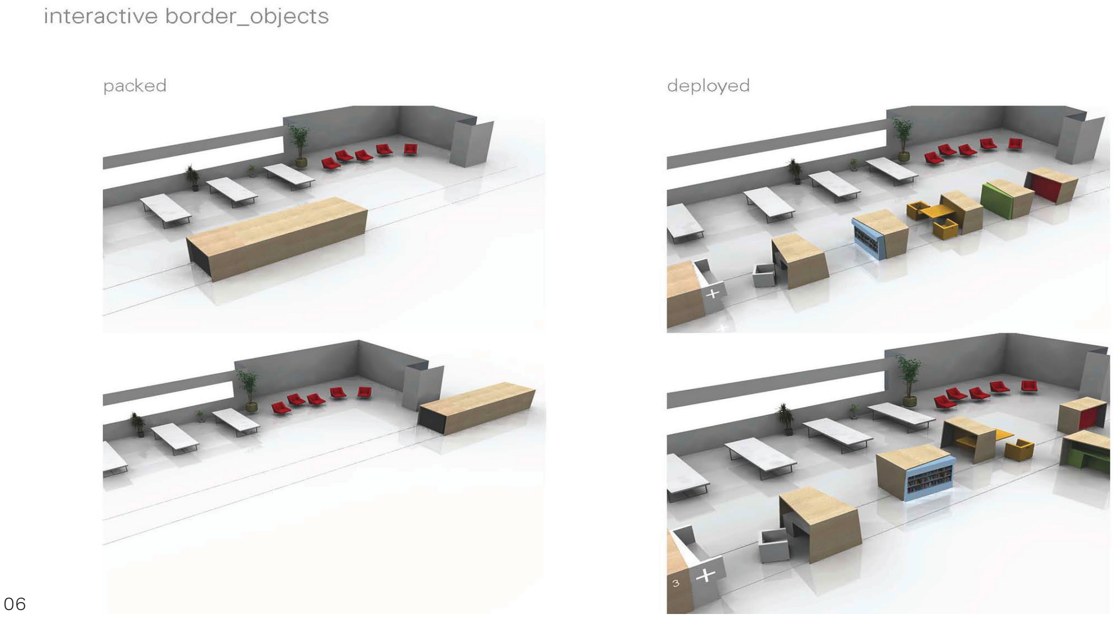
Safety: Touch sensors at the edges of the curtains will sense obstacles and prevent the system from colliding with objects and people.

The porches are semi-private but allow the space to be given over to the hallway, when the room is not occupied as well as transforming the hallway into a social and valued space rather than a neglected space of 'transportation' only.

PROJECT: BORDER

Another project looked at nursing stations: a necessity for those working in an extended-care health environment but a spatially intrusive and institutional element that reminds those living in the space that they are in a care facility. Mediating between "living" and "working" environments presents a unique challenge, taking on this delineation, or "border," between living and working through examining the relationship between the nurses' station and the residents' gathering spaces. In doing so, this project re-imagines this border as a mobile and permeable work space that also incorporates empowering functions for the residents. This space is one that can emerge when required, change and respond on commands or on recognition of those who work there, allow clinical work to take place as well as medication to be stored and dispensed.

Figure 5: Configurations of Project Border



Biometric sensing in the form of fingerprint recognition was the technology proposed for activating the more secure functions of the station. Nurses could activate the station on touching the sensor with their finger. Other non-identified patients would not activate the medical portion. Object interface in the form of an iPhone or other interface-type object could remotely activate the station on demand. Capacitive sensing with local computing would operate the individual units. Advanced environmental control and integrated patient charts would further enhance the function of the station.

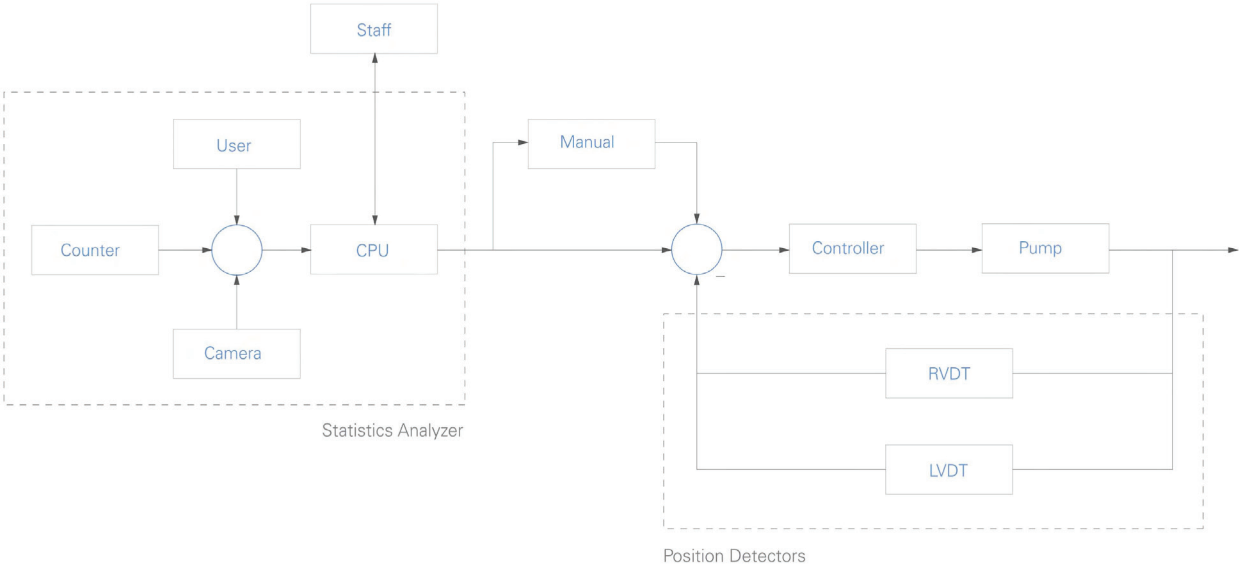
Station elements slide along a track in the floor and then have the capability of rotating and then deploying. Through the combination of these degrees of freedom in the movement, the station can appear to have much more spatial variation.

PROJECT: AQUABOT

Exercise facilities are particularly labor intensive for those who work in extended care facilities but highly beneficial to those limited to the facilities. An aquatic center that has a pool composed of a re-configurable surface, which transforms to accommodate diverse, beneficial aquatic activities, such as hydrotherapy and free swim was conceived to address this issue. This unpredictable, changing topography introduces the critical elements of “play” and “fun,” while offsetting stigmas and stereotypes often associated with extended-care facilities. The facility also encourages interaction of the residents with the community and other members of the community.

The topography of the pool was not intended to be waterproof but instead was designed as a permeable surface that worked on the principle of a large tank but whose supporting surface moved up and down to accommodate

Figure 6: Control system for Project Border



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the elevation desired for the occupants of the pool or the program desired at that particular time. The actuators for the pool are hydraulic and adjust the pool's geometry at key points, thus not requiring activation on all components. The triangular geometry evolved from an investigation of how to obtain maximum geometric flexibility from a surface. Sensors for the pool include cameras and counters with feedback to determine geometric location. Input for configuring the pool is proposed to come from a control system operated by facility staff.

PROJECT: ROOM

A stimulating or natural environment is also sadly missing in current facilities for the elderly, and mechatronics combined with advanced interaction with thin screen technology provides potentials for 3-dimensionalizing a space and providing simulations of natural or simulated conditions. The ability to sense and actuate based on exterior climatic conditions as well as individual preferences and occupation allow a fully responsive imitation of the natural environment.

For those bedridden, a lack of stimulation is a serious problem and can deteriorate quality of life significantly. The ceiling being the most viewed part of a room for bedridden patients, it is a key area for investigation of combining of screen technologies and mechatronic possibilities. In the case of the project ROOM, the surface of the ceiling becomes a screen but with capabilities of configuring its depth, adding to its life-like characteristics. Input is intended to be customized to the occupant and their wishes. The roof can represent exterior conditions from a camera mounted outside the facility and focused on the sky or on natural elements. At other times, the

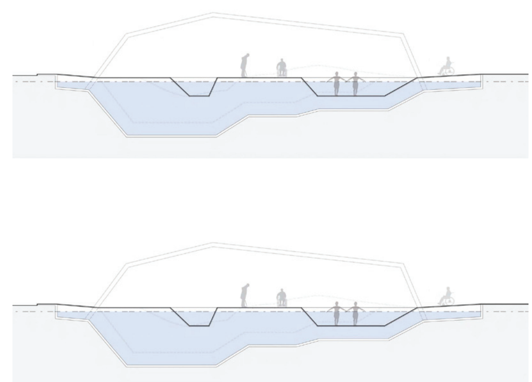
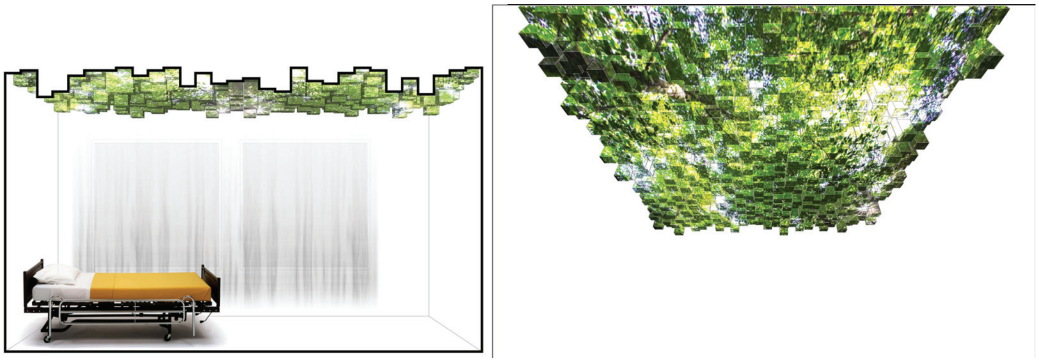


Figure 7: Diagram of potential movements for Aquabot



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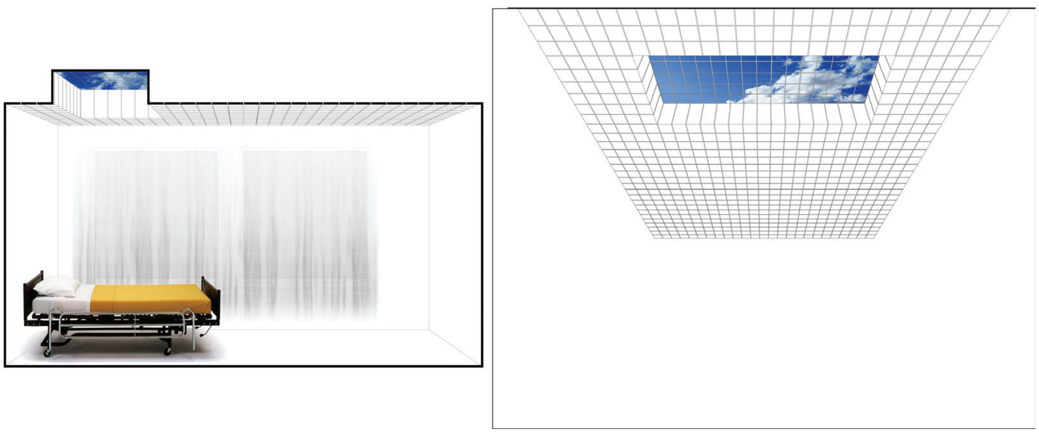

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Figure 8: Project ROOM configuration and perspective from bed

Figure 9: Project Room skylight simulation

ENDNOTES

1. See work of Nancy Cheng at eCAADe 2012 as well as work of Philip Beasley at University of Waterloo and work at CCA by Jason Kelly Johnson and Vera Parlac at University of Calgary
2. Chris Anderson, "How to Make Stuff," *Wired Magazine*, April 19, 2011, 90.
3. *Mechatronics* is the combination of mechanical engineering, electronic engineering, computer engineering, control engineering, and system design engineering in order to design and manufacture useful products. http://en.wikipedia.org/wiki/Mechatronics accessed Feb 27, 2011) Mechatronics is similar to robotics and cybernetics but involves moving elements rather than imitating human activity (robotics) or thinking (cybernetics).
4. Chris Anderson, "How to Make Stuff," *Wired Magazine*, April 19, 2011, 90.
5. Jason Johnson and Andy Payne. 'Firefly for Grasshopper.' http://www.grasshopper3d.com/profile/firefly, accessed April 10, 2011.

screen can present a video call from family members or a television show or movie selected by the occupant. Interaction with the screen can be preprogrammed or on a basic control only requiring waving in front of a set of options on the wall. Motion or light sensors indicating options can easily change the settings to another predefined option. Voice commands can also be configured, for those patients who have difficulty waving their hands in prescribed areas.

Other projects examined to date related to vertically relocating rooms, railings that activated upon someone coming near them, and responsive community spaces.

CONCLUSION

Each of the projects presented is significantly different from the next yet all are looking at the same technology. The breadth of the investigation into the use of the technology belies the breadth of the field waiting to be investigated. The use of architectronics moves toward a fully responsive environment whose interaction with the occupant is intelligent and seamless. We in architecture are still at the experimentation phase, nevertheless it is an exciting potential expansion for architecture and brings up critical discussion into what architecture is and where it is going as well as questions of what is physical and digital and where intelligence lies in such an interaction. ◆