Dance with Shadows

Capturing tacit knowledge with smart device augmented reality (SDAR)

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Tacit knowledge has been notified with its involvement in the creative and innovative process of design. However, it has been an elusive subject due to its difficulty to be articulated, recorded, and communicated. Augmented Reality (AR) is introduced as an affordable, accessible, and collaborative way to revisit tacit knowledge in the design process. In this paper, a computational design approach with Smart Device Augmented Reality (SDAR) is proposed for a real-time fenestration design in a targeted room. In comparison to standard methods of showcasing daylighting metrics, the use of Smart Device Augmented Reality (SDAR) is an alternative method as it delivers a dynamic experience by combining both the real and digital environments, enabling the visualization of the design in its intended site context with real-time feedback. The implementation of the proposed approach is explained and the design process with SDAR is also demonstrated in this paper.

Keywords: *tacit knowledge, augmented reality, simulation, real-time feedback*

INTRODUCTION

Tacit knowledge is personal, practical, and context-specific to the extent that even the knowledge-holder may not be aware of its existence. Terms like “intuition”, “know-how”, “procedural knowledge”, “implicit knowledge”, “unarticulated knowledge”, and “practical or experiential knowledge” have been used to describe tacit knowledge (Ambrosini and Bowmand, 2001; Polanyi 1962;1966). Because of its importance in combination with explicit knowledge (Nonaka and Takeuchi, 1995), various ways of applying and transferring tacit knowledge have been made. However, due to the difficulty of capturing or representing tacit knowledge in explicit form, communication with tacit knowledge still remains problematic (Dampney et al, 2002). Especially in architecture, its design communication comprises unique dispositions, possessing specialist knowledge, skills, and education. They are socially acquired through experience and practice, and continually reproduced over generations (Sandstrom and Park, 2019; Stevens, 1998; Bourdieu, 1977). In addition to natural language descriptions, drawings, physical & digital models, and various simulations have been the primary media of architectural design communication. In order to address the difficulties of design articulation within the role of conventional design communication media, Augmented Reality (AR) has been introduced to architecture.

Coined by Caudell and Mizell who worked for Boeing Company in 1990, the term Augmented Reality (AR) serves to create a reality that is supplemental to the physical environment (Caudell and Mizell, 1992). By adding an enhanced layer of computer-generated information to the real-world environment, AR allows a user to deal with 1) real-time feedback, 2) context-specific experience, and 3) full-scale immersion of its simulated reality. They become the instrumental features of the embodiment of tacit knowledge (Figure 1): 1) real-time feedback: users, clients, and professionals alike are encouraged to engage in interpersonal communication to enhance the quality of design decision making, 2) context-specific experience: users are able to experience design in the proper context of existing site conditions, 3) full-scale immersion: users are able to experience the design's proper scale allowing interaction with a given design space prior to project implementation (Sherman et al, 2019; Carmigniani and Furht, 2011; Yang, 2011).

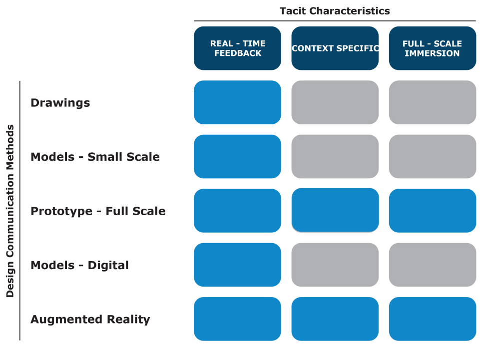

Figure 1
Instrumental features of the embodiment of tacit knowledge

With the advantages, AR has been employed in the design process for 1) developing a comparative analysis between physical and augmented modeling interactions (Webster et al, 2000), 2) providing a real-time interactive instruction for the assembly of a modular system (Kontovourkis et al, 2019; Kim et al, 2013), 3) assisting architectural design and communication with a user's immersive experience (Hsu, 2015; Danker and Jones; 2014). Compared to other media including drawings, physical & digital models, and Virtual Reality, AR provides better interpersonal experiences (Lawrence,1993).

AR systems have been developed with two different types of displaying devices: Head Mounted Displays (HMDs) and Smart Device Augmented Reality (SDAR). Through an optical see-through and gesture-controlled headset such as the Meta 2 display, DAQRI's Smart Helmet, and Microsoft's Hololens, HMDs provides the direct view of the real world in order to avoid distorting or reducing the user's view of the real environment. The enhanced information projected into the user's eyes is interactive to the user's head and body movements (Kontovourkis et al, 2019; Azuma, 1997). SDAR is achieved through the use of various devices including smart phones and tablet PCs so that the viewer of SDAR holds a device where the screen is in conscious awareness of the viewer. Also, the versatility of the smart device allows a user to explore outdoor environment and lighten up the learning curve of finger gestures to perform a given augmented reality. Furthermore, the collaboration of multiple users within SDAR provide bilateral design experience using built-in functions of the smart devices (Azuma, 2014; Hsu et al, 2013).

In this paper, Smart Device Augmented Reality (SDAR) is employed for investigating an alternative design method for implementing real-time feedback, context-specific experience, and full-scale immersion that embodies the essence of tacit knowledge into a design process. The proposed smart device augmented reality (SDAR) application consists of Rhinoceros 3D, Grasshopper3D and Fologram. It is applied for a fenestration design with daylighting metrics. The application allows a user to articulate the design's proposal not only by visualizing in a real-time environment but at the same time engaging themselves in the decision-making process. Through this iterative design communication within the proposed SDAR, the tacit knowledge involved in the fenestration design is shared among the stakeholders of the design. This investigation, however, does not intend to replace conventional design communication

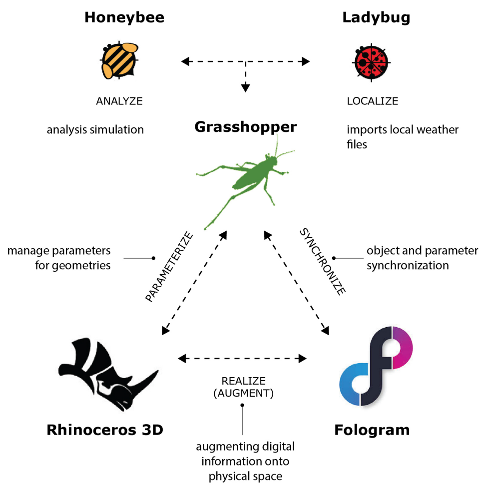

Figure 2
Framework

media, but instead to introduce the SDAR application as an additional layer where deemed appropriate.

SDAR: A FENESTRATION DESIGN WITH DAYLIGHTING METRICS

Framework

This SDAR application is developed for achieving 1) a real time feedback from the analysis with the visualization of daylighting metrics for a specified room, and its synthesis accordingly, 2) a context specific experience with the mobility of a smart device and its convenient usage, 3) a full-scale immersion with the interactive control of the application. Rhinoceros 3D and visual programming language Grasshopper 3D are supported by plug in applications: 1) Ladybug, 2) Honeybee and 3) Fologram (Figure 2). As a smart device, iPhone 8 with 2GB ram and 12MB pixel camera is employed.

This proposed application consists of 1) initiation of SDAR, 2) analysis of daylighting metrics, 3) synthesis of the fenestration, and 4) simulation of the synthesis outcomes. SDAR is initiated Fologram within Rhinoceros 3D. Its location is adjusted with a marker.

A classroom in Honolulu, Hawaii, was built in the digital model for the project and its coordinates were used for gathering the annual data set of the daylighting metrics on the site. Its section view was shown in Figure 3.

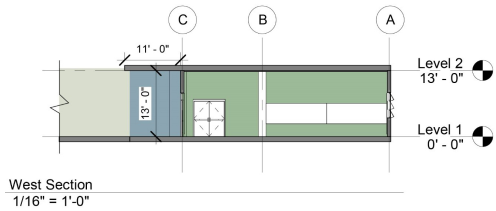

Figure 3
Section view

Initiation of SDAR

Fologram, a mixed reality application, was chosen because of its stable synchronized live stream with Rhinoceros3D and Grasshopper3D. Also, it works across multiple platforms - Hololens, iOS, and Android (Figure 4). The live connection of the device is established by scanning the QR code. A special marker is used for finding the correct location of the given geometry from Rhinoceros 3D as shown in Figure 5.

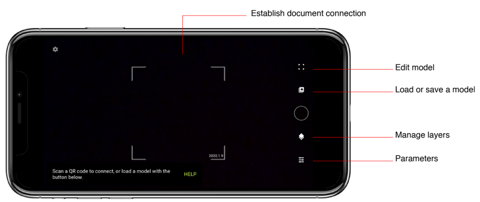

Figure 4
Fologram Interface
of a Smart Device

Analysis: Daylighting Metrics

This application allows a user to perform the analysis of daylighting metrics including 1) illumination (Figure 6), 2) radiance, 3) solar exposure (Figure 7). Honeybee and Ladybug, Grasshopper plug-ins, are integrated into this process where Ladybug allows us to utilize local weather data and Honeybee uses that weather data to run an analysis simulation of the desired space. Coupled with Fologram, the combination of these plug-ins allows the user to achieve visualization of daylighting metrics layered to a real environment (Figure 8). The user is put into the full-scale real room environment where the user can conduct a full interior walkthrough within the augmented space. By setting up the date and time of the analysis according to the targeted time period, the user also achieves the context-specific experience.

In addition, daylighting metrics, the user is able to analyze radiation maps in full context. This could inform the design of the fenestration so that radiation accumulation would not impact important areas within the room as it is being absorbed.

Similarly, with sun exposure, the user can visualize the amount of sunlight hours that falls directly on a surface in full context. This information may be looked at in parallel to radiation. With the daylighting metrics analysis, the user is be able to see where in particular that generates illumination, radiation, and sun exposure. The analysis of the daylighting metrics becomes a valuable source for the design of the fenestration.

On the layers tab of Fologram's user interface, the synchronized objects are displayed. The user may toggle on and off to control the visibility of the synchronized object. Sliders, Buttons, and Value lists are the current three parameters that can be synchronized to Fologram's interface. The user drops down the menu initiating one of the daylighting metrics in the fenestration's original state.

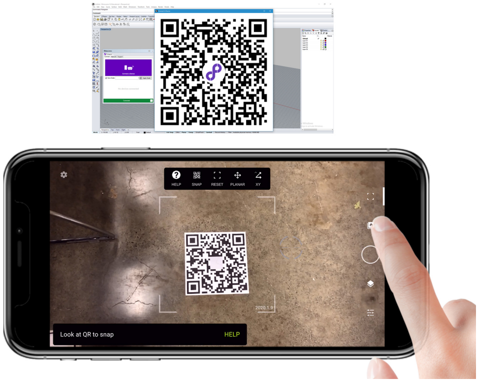

Figure 5
SDAR initiation a) QR code b) Marker

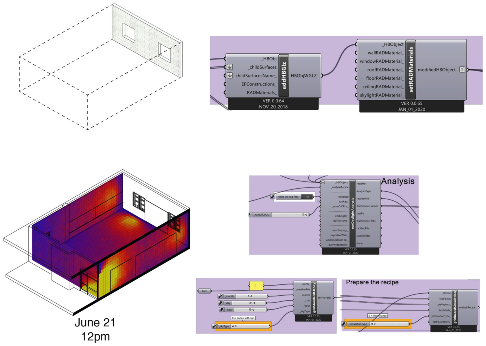

Figure 6
Daylighting: Illumination

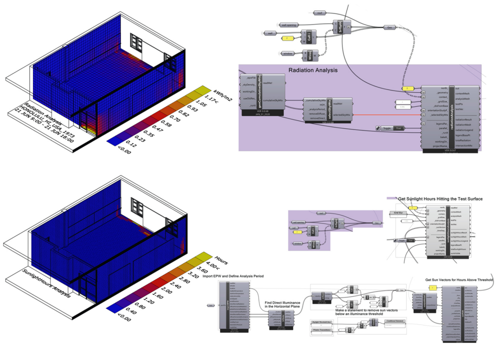

Figure 7
Daylighting: a) Radiation b) Solar Exposure

Figure 8
Analysis: a) Interface b) Illumination outcome

Synthesis

The analysis outcomes of the daylighting metrics become the resources for real-time feedback in order to perform the synthesis of the fenestration design. The user is in full control of the actions taken while they are being overseen by the mentor. This is achieved by allowing the user with professional guidance to (1) the addition and deletion of the openings, (2) the translation of their location, and (3) the modification of their sizes. After the synthesis, the user re-initiates the simulation to see how their new opening configuration would affect the daylighting analysis results in conjunction with the current real-time environment.

Each window opening is color-coded for the ease of object-parameter correlation (Figure 9). When viewing the opening the user may toggle on and off a specified color according to the location of the opening in the layers tab.

On the smart device, adding or subtracting windows is done through holding and dragging on the touchscreen canvas. The color-coded window indicators located above a target wall are used to add additional openings to the wall. Similarly, for the deletion, the user may simply swipe and place it anywhere off the target wall. In parallel, the translation of the window is the same by holding and dragging to any designated area of the target wall (Figure 10).

When the user is satisfied with the general window location, the user can then modify the size of the openings (Figure 11). These changes are made through parametric sliders in Grasshopper 3D as shown below. Each color-coded window opening is paired with a set of parameters that can control the width and height of the opening. The parametric sliders become the part of the user-interface on a smart device.

The synthesis process on the user-interface of the smart device consists of 1) selection, 2) addition & deletion, 3) translation, 4) modification as shown in Figure 12.

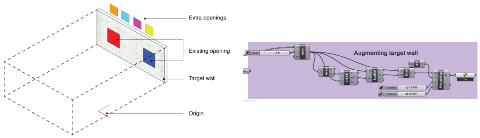

Figure 9
Synthesis: Initial Setup

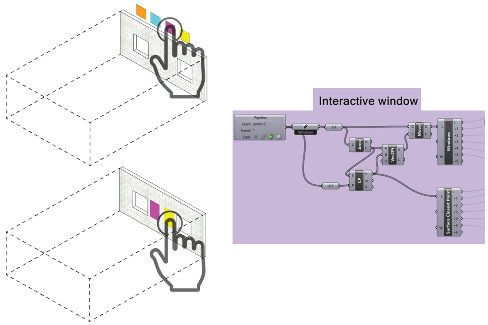

Figure 10
Synthesis: Addition, Deletion, and Translation

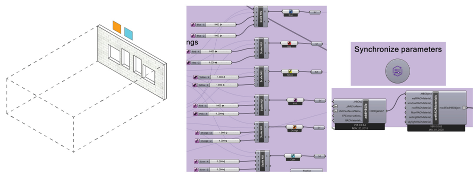

Figure 11
Synthesis: Changing the width and height of the opening

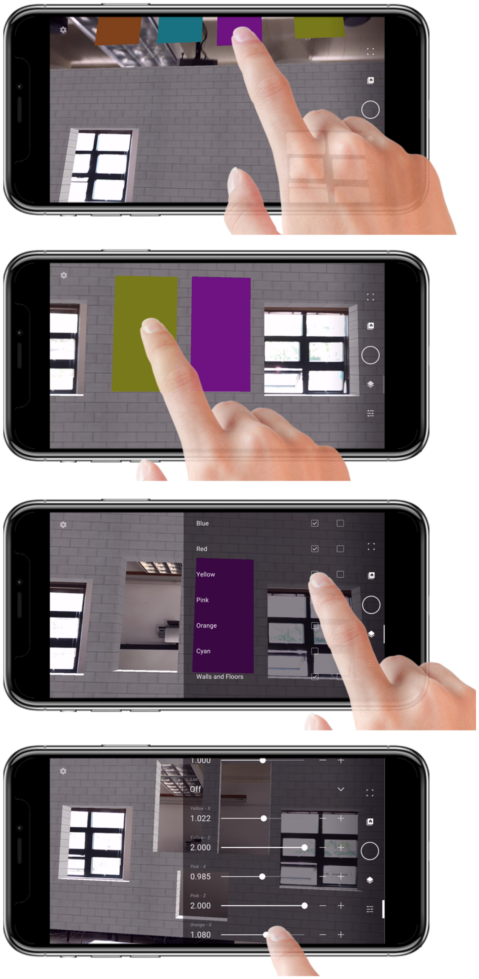

Figure 12
Synthesis: Process

Simulation
After confirming the new composition of the window openings, the user may then re-initiate the analysis. The results are reflected by the user's changes. The floor directly below the newly created openings show greater illumination results. With these new results the user can visualize and conduct a walk through in full context of the augmented environment (Figure 13).

The iterative cycle of the user engagement procedures including initialization of SDAR, analysis, synthesis, and simulation creates a dynamic interaction between designer and the user. By going through this cycle, the user articulates the design through visualizing in a full-scale context with learning valuable knowledge as they learn through their own actions with guidance from the designer.

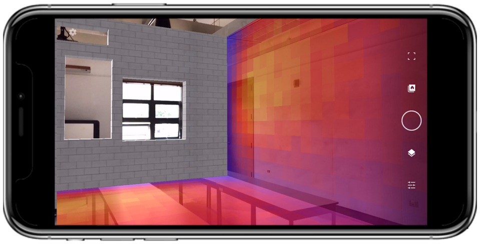

Figure 13
Simulation:
Outcomes

DISCUSSION
In this paper, Smart Device Augmented Reality (SDAR) was employed for investigating an alternative design method for implementing real-time feedback, context-specific experience, and full-scale immersion that embodies the essence of tacit knowledge into the design process. Real-time feedback was witnessed as users were directly engaged in the modifications of the openings, while being mentored by the designer, initiating constant communication after each decision made as they reflect on the analysis results. Users modified designs in the physical context of the room, looking at how their changes affect the interior daylighting on surfaces (floor, walls, desks, etc.). To provide full-scale immersion, the user was able to reference other existing elements within the room when size and location height considerations were being made while designing. Within the given SDAR, the user was directly engaged with the design, while being mentored by the designer. Design engagement procedures include 1) adding and subtracting windows, 2) translating the windows,

and 3) modifying the sizes of the openings via parameters. Toggling through the layers tab to show the opening in the wall, the user was able to initiate the simulation for conducting a full interior walk-through. This walk-through provided the user with a better understanding of future design iterations as they compare the analysis metrics against reality.

Since SDAR technology itself is in the early stage, there are shortcomings to be improved. First is a clipping plane issue. Within the proposed SDAR project, the augmented objects always appeared in front of everything physical even though they are behind the physical, hindering a user's full-scale immersion. Second is an unstable marker placement. It requires constantly scanning the marker in order to anchor the augmented object to an intended location in a given context. Third is a heavy processing load for performing the daylighting analysis within a smart device, and the last is a crowded user-interface due to the limited screen size of a smart device (Figure 14).

Figure 14
A crowded user-interface

Currently, two further directions are being pursued. One is a different type of AR system. In parallel with a smart device, the usage of Head Mounted Displays (HMDs) is developed for enhanced full-scale immersion. The other is to expand the application of the proposed SDAR to various performance-oriented designs not limited to daylighting metrics.

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