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Displaying a University's Frank Lloyd Wright Artifact Reproductions: Physical and Virtual Environments

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Abstract

Frank. Frank Lloyd Wright (FLW), an important 20th Century American architect, also designed furnishings such as table lamps, stained glass, and statues. A University's collection of museum reproductions of Wright's furnishings were displayed in built-in, glass front cases in a small, in-house museum. This physical collection of artifacts did not rotate often; presented artifacts only in frontal views; and offered only limited viewing times. Researchers suspected the museum cases' illumination was inadequate. In Part I, researchers performed an in situ study of the existing physical museum utilizing a spectrometer. This case study revealed existing, unshielded, lighting fixtures and display case light levels that did not comply with industry recommendations. Researchers made new recommendations for a retrofit featuring shielded, Light Emitting Diode (LED) strips. In Part II, researchers 3D scanned the furnishings reproductions using either a). Hand-held mobile scanner, b). Photogrammetry, or c). Desktop 3D scanner. Artifact complexity influenced the researchers' selection of appropriate scanning method. In Part III, researchers created two versions of a virtual museum environment, based on an existing FLW house. Version 1 used Unity 3D gaming engine supporting a user's interaction with museum artifacts. Version 2 used SketchUp and Enscape Virtual Reality (VR) tools. In Part IV, Researchers modified incomplete scans and installed scans in their new virtual museum. The virtual museum has been activated for online browsing. However, no retrofits of the physical museum's display case lighting have yet been made. The creation of the new virtual museum supplemented the existing physical museum experience. The virtual museum is anticipated to increase user exposure to the artifacts and increase the (virtual) accessibility of the artifacts without damage. The virtual museum also allows for searchable electronic records.

Keywords: 3D scanning, Virtual Reality, Virtual Museum, Museum Lighting

1. Introduction

Lloyd Wright (FLW), an important 20th Century American architect, designed complete environments that included table lamps, stained glass, and statues as well as other furniture and furnishings [1]. Some famous examples include the Sumac Vase, Robie Side Chair, Midway Garden Sprites, etc.

1.1 Existing Conditions

At a large, rural Midwestern University, a design program had long recognized the importance of allowing their users to study artifacts. Program donors had financially supported the purchase of several museum reproductions of Frank Lloyd Wright artifacts for faculty and student use in their facility. The University design program had thus amassed a small collection.

However, the researchers in the design program had noticed that the users' access to the physical artifact collection was somewhat limited. The facility offered only limited viewing times for the displayed artifacts corresponding to the building's open access hours. Due to the facility's exhibit space and security constraints the physical collection of Wright reproductions could not be exhibited in its entirety at one time. Most of the artifacts were fragile and some had already experienced damage through handling. The artifacts that were on display rotate infrequently due to a shortage of curatorial personnel. The displayed artifacts were observable from mostly frontal view only due to the configuration of the existing casework displays.

Further, the researchers anticipated that the artifacts' display case illumination was likely out-of-compliance with current industry-recommended quantity and quality. The Illuminating Engineering Society of North America (IES) is the acknowledged industry authority on lighting design recommendations for various applications including exhibits [2]. The IES recommends light level ranges based on complexity of tasks, anticipated "visual age" of viewers and light sensitivity of displayed artifacts. IES states that older people's eyes need more light to see at the same visual acuity as younger people's eyes [2]. Therefore, the researchers empirically measured and documented the existing conditions and compared the lighting to IES recommendations.

1.2 Virtual Museum Proposal

The researchers wanted to investigate if the existing Wright reproduction artifacts could be successfully 3D scanned in order to create a virtual collection to supplement the existing physical collection. To do so, the researchers experimented with three different light sources o explore with different attributes to explore compatibility with artifacts and with the scanners. Further, the researchers proposed to host this new virtual collection in a Virtual Museum, that would be accessible online and capable of being "toured", via VR with the aid of immersive VR Head

Mounted Displays (HMD), as well as through a non-immersive computer-based simulation. This Virtual Museum could provide accessibility to the artifacts without any physical restrictions.

Providing artifacts in a digital, three-dimensional format could also allow for detailed observations through Virtual Museum “tours”. With 3D scanned artifacts, users could rotate, zoom-in, view and compare various artifacts within the collection.

1.3 Virtual Museums

Most museums traditionally exhibit only a fraction of their entire collection of artifacts [3]. Furthermore, many artifacts are often fragile and delicate, precluding availability for public interactions [3]. VR technology allows users to interact with virtual museums’ artifacts in a variety of ways without risk to artifacts and potentially adding layers of information and interactivity.

With the advancement of technology, museums have begun extending their services through online media allowing them to reach out to broader audiences and mitigating issues of accessibility. According to Schewibenz [4] there are four types of Online Museums: Brochure Museums, Content Museums, Learning Museums and Virtual Museums. Virtual Museums are used in different domains, such as online platforms to host 3D artifacts. Different terminology such as on-line museums, electronic museums, hypermuseums, digital museums, cyber museums or web museums have been used to define these platforms [4]. Despite having no generally accepted definition, Virtual Museums are described as a *“logically related collection of digital objects composed in a variety of media which, through its connectivity and its multi-accessible nature, lends itself to transcending traditional methods of communicating and interacting with visitors.; it has no real place or space; its objects and the related information can be disseminated all over the world”* ([4], p. 146). The term, Virtual Museum, is used extensively even though some of its applications do not utilize 3D content nor virtual tours. In the current study, the term, “Virtual Museum”, describes an immersive 3D environment with 3D content. There were three key challenges in developing a Virtual Museum. The first challenge was understanding the requirements and the technological capabilities of the end-users. The second challenge was developing an architectural design to host the 3D artifacts. The third challenge was adopting technology to develop the virtual environment and 3D content.

Virtual visualization techniques and VR tools have advanced considerably since Morton Heilig’s Sensorama in the 1950s, to the first Head-Mounted Displays (HMD) in the 1960s, and eventually to the modern-day HMDs such as Oculus Rift [5]. In recent years, VR tools have become popular for testing the visual perception of space. The advantages of the Virtual Visualization techniques include higher ecological validity in comparison to the traditional tools, as well the higher level of control over visual elements, such as illumination and location of artifacts in space [6].

2. Research Methodology

2.1 Part I: In-situ Lighting Documentation

Researchers measured existing lighting conditions using an Asensetek Lighting Passport Smartphone Spectrometer, model number ALP-01 in the University collections' display cases that housed the physical Frank Lloyd Wright reproduction artifacts. Spot measurements at heights of 0'-0", 2'-6" (.76 meters) and 4'-0" (1.22 meters) above the finished floor, were taken at different locations within one typical display case following industry recommended measurement procedures. In addition to illuminance readings, attributes of light color and composition were also measured with the spectrometer. The researchers documented existing lighting fixtures' and lamps' specifications photographically and in field notes. Refer to Figure 1 for an example of the existing display case lighting. The existing exhibit cases were physically measured and then documented via Spectrum Genius Advanced software. The software provides data for the correlated color temperature (CCT), color rendering index (CRI), color quality scale Q1-Q15, dominate wavelength, purity, photosynthetic photon flux density (PPFD), and scotopic and photopic vision ratios.

Figure 1: Existing Bare Fluorescent Lamp Mounted in Top of Display Cases

2.2 Part II: 3D Scanning of artifacts

The researchers experimented with different 3D scanning methods to obtain optimal resolution for the scanned artifacts. They also experimented with different lighting conditions, as some scanners required certain lighting levels to function efficiently. The raw, 3D scanned artifacts were then rectified and cleaned using appropriate software.

The 3D scanning of artifacts was conducted using three instruments 1). A hand-held mobile scanner, 2). Photogrammetry, and 3). A desktop 3D scanner. Refer to Figures 2-a, b and c for images of the instruments. The instrument and method chosen for each artifact depended on the artifacts' visual complexity.

(a) (b) (c)

Figure 2: (a) Hand-held mobile scanner, (b) Photogrammetry, (c) Desktop 3D scanner

Members of the research team scanned Frank Lloyd Wright reproduction artifacts against a monochromatic background, using three different lighting conditions: Light emitting diodes (LED) (450 Lumens), LED Bright Stick (490 Lumens), Compact Fluorescent (760 Lumens).

The hand-held mobile scanner consisted of an Occipital Structure Sensor attached to an iPad Air tablet. This method of scanning allowed the researchers to scan larger artifacts such as chairs. Refer to Figure 3 for images of scanning in process.

Figure 3: Scanning using the Occipital Structure Sensor

Photogrammetry is the science of obtaining reliable information about the properties of surfaces and artifacts without physical contact with the artifacts, and of measuring and interpreting this information [7]. Photographs taken from multiple angles and stitched together can reproduce 3D artifacts through photogrammetry [7]. Several mobile applications allow the use of mobile devices such as smartphones and tablets for photogrammetry. In this project a Structure from Motion (SfM) 3D reconstruction software. Autodesk ReCap, was utilized.

The photogrammetry software required the use of a turn-table which could rotate the artifacts so that a continuous stream of photographs could be captured. The research team used a plastic, household, cake turn-table for this purpose. Refer to Figure 4 for an image of the turn-table.

Figure 4: Cake Turn-Table

Due to longer required scan times of approximately five hours for each artifact, a Matter and Form 3D Desktop Scanner was used for smaller Virtual Museum artifacts. The desktop scanner was light sensitive. The researchers experimented with different lighting conditions (LED and compact fluorescent) resulting in artifacts scanned with various resolutions. Refer to Figure 5 for scans created under different lighting conditions.

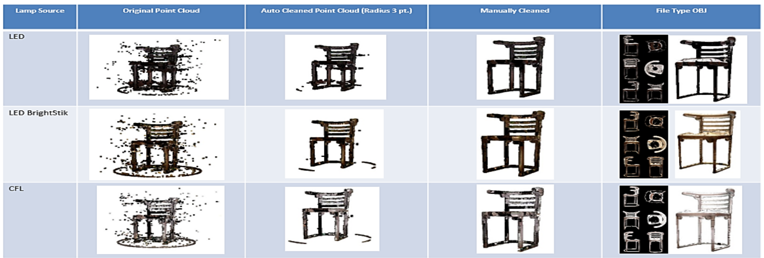

Figure 5: Scanner Test Data- Lighting Conditions

All of the preliminary desktop 3D scans which were created for this project were visually assessed by the researchers and appeared to them to be incomplete. They determined the scans required an additional cleaning step to remove extraneous 3D data. The device's proprietary software application was utilized for this purpose.

2.3 Part III: The Virtual Environment

The development of the virtual aspects of this project's Part III can be described in two phases.

Phase 1: Developing the Virtual Environment and

Phase 2: 3D Scanning and developing the virtual artifacts

<u>Developing the Virtual Environment</u>

The primary intended users of the planned virtual museum were students. Therefore, researchers decided that students should be able to utilize the virtual museum using their personal computers. Researchers designed a virtual environment, the 3D environment that housed the virtual artifacts, which was viewable with or without a VR HMD. The research team developed a 3D virtual model of the Gordon House which was originally designed by Frank Lloyd Wright in

1957 for Evelyn and Conrad Gordon. The physical house still exists; is located in Silverton, Oregon; and serves as a historic house museum [8].

The Virtual Environment was developed in two versions for this project. Version 1 used the Unity 3D gaming engine where viewers could interact with the museum reproduction artifacts (Figure 6). Version 2 used SketchUp and Enscape VR tools. In Version 1, Unity 3D allowed for enhanced user interaction with the environment which the combination of software's of Sketchup and Enscape in Version 2 did not allow. The researchers further developed Version 2 as the final version gave consideration to the rendering quality and the ability to recreate the necessary lighting conditions for the virtual museum artifacts.

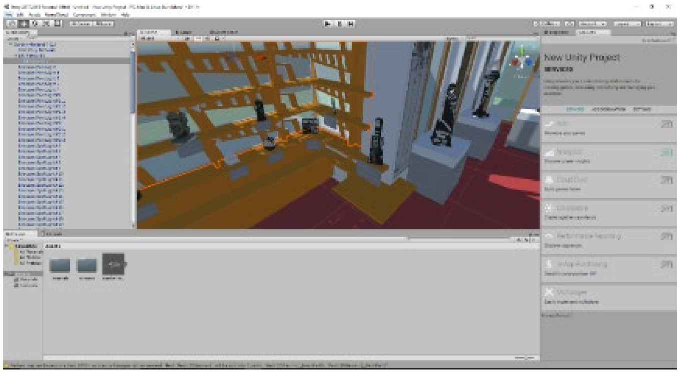

Figure 6: Testing different iterations of the Virtual Environment Using Unity 3D

The final version of the virtual environment that was developed was compatible with the two main types of VR HMDs on the market, HTC Vive and Oculus Rift (CV1) HMD. Refer to Figure 7 for images of users testing the Virtual Environment.

Figure 7: Users interacting in the environment using the HTC Vive HMD

3. Research Results

Research Results tell the clear result of the study. The detail of this part can be included chart, figure, table, etc. 3.1 In-situ Lighting Documentation of Existing Display Cases

The existing lighting of the physical Wright artifact collection was visually observed to be bare lamp (unshielded) fluorescent tubes which were measured to have a Correlated Color Temperature (CCT) of 3440 Kelvin. The Color Rendering Index (CRI) was measured to be 84. Refer to Figure 8 for a plan view of a typical existing University display case with corresponding light level measurement locations. Refer to Figure 9 for an elevation view of a typical existing University display case. Fifteen illumination readings were taken in foot-candles and converted to lux using an online converter. Results ranged from 31.03 foot-candles (334 lux) to 118.08 foot-candles (1271 lux). Using the IES Lighting Handbook, the Frank Lloyd Wright reproduction artifacts were classified by the researchers as low sensitivity to light (some textiles, some plastics and some woods) or no sensitivity to light (ceramics, glass, metal and some woods). Light level measurements were compared with recommendations for visual ages (for younger adults, adult and older adults) and for artifact sensitivity to light. Refer to Table 1 for samples of light level measurements and recommendations. Of the 48 possible combinations (N=48) of visual age and light sensitivity considered, there were only seven incidents of compliance (n=7, 7.77%). About one half of the light levels measured were over ± 10% of the recommended maintained illuminance targets (n=47, 52.22%). Over one third (n=36, 40%) of the light level measurements were under ± 10% of the recommended maintained illuminance targets.

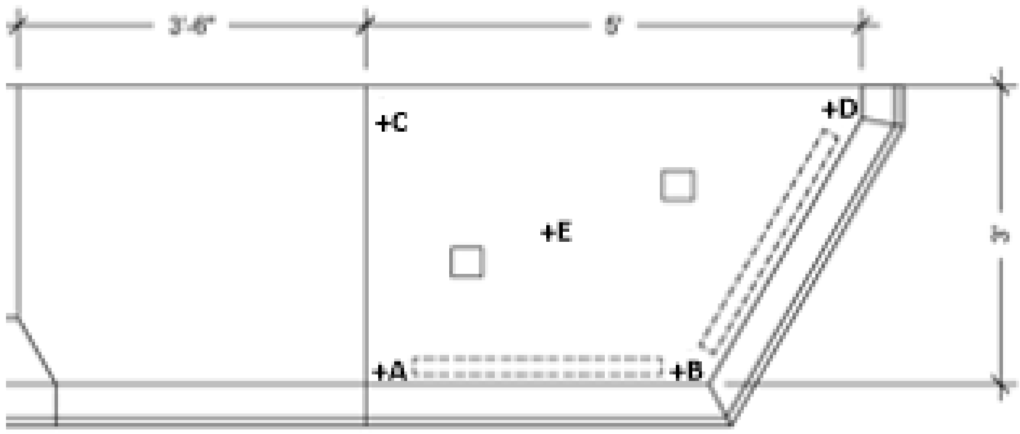

Figure 8. Plan view of existing physical museum display cases with table of light level measurement locations.

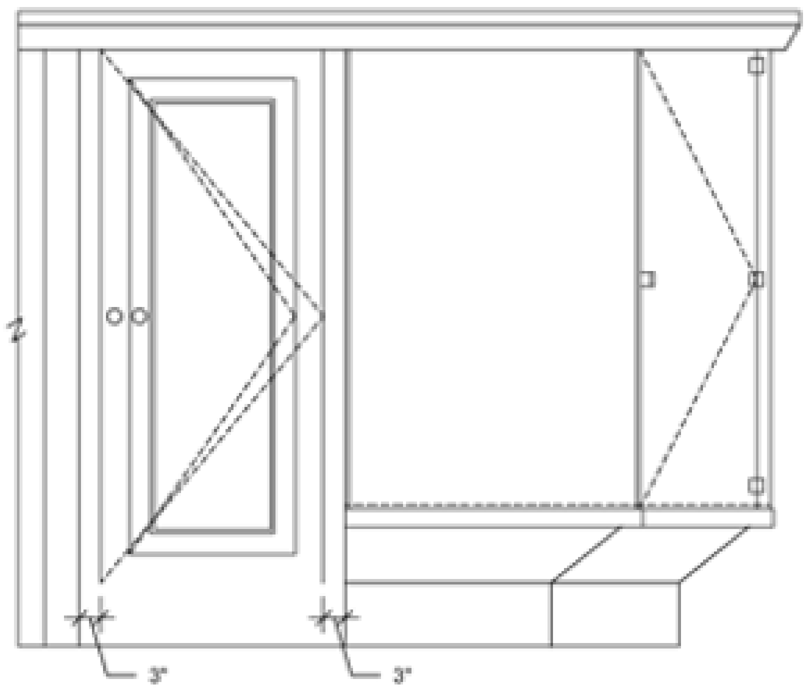

Figure 9. Elevation view museum display cases of existing physical

Table 1. Light level measurements and recommendations

Sample of Target Maintained Illumination Recommendations for Low sensitivity to light						Sample of Light level measurements							
Younger Adults <25		Adults, 25-65		Older Adults>65		Height Measured	Units		Compliance			Position in Case	
Lux	Foot candles	Lux	Foot candles	Lux	Foot candles	Above Floor of Case	Lux	Foot candles	Younger	Adults	Older		
100	9.29	200	18.6	400	37	0'-0"	334	31.03	>	>	<	A	Front Left
							416	38.65	>	>	**x**	B	Front Right
							334	31.03	>	>	<	C	Back Left
							401	37.25	>	>	**x**	D	Back Right
							400	37.16	>	>	**x**	E	Center
						2'-6"	526	48.87	>	>	>	A	Front Left
							763	70.89	>	>	>	B	Front Right
							496	46.08	>	>	>	C	Back Left
							595	55.28	>	>	>	D	Back Right
							788	73.21	>	>	>	E	Center
						4'-0"	1060	98.48	>	>	>	A	Front Left
							518	48.12	>	>	>	B	Front Right
							770	71.54	>	>	>	C	Back Left
							1271	118.1	>	>	>	D	Back Right
							788	73.21	>	>	>	E	Center

X Indicates compliance with recommended level

> Indicates measured light level was less than recommended level

< Indicates measured light level was more than recommended level

3.2 Virtual Environment

3.2.1 Developing the Virtual Environment (the 3D environment that houses the virtual artifacts)

A 3D Virtual Museum environment was developed by the researchers to host the reproduction museum artifacts. Refer to Figure 10 for a screenshot of the Virtual Museum. The Virtual Museum was intended to be accessible as an immersive, VR HMD-based experience as well as through a non-immersive experience via a web browser. The Virtual Museum was configured so that it could be downloaded through a dedicated website for the users. The downloadable file required no additional set-up.

Figure 10. Immersive Virtual Museum Screenshot

The website that was developed to host the 3D scanned artifacts included metadata tags, which was intended to allow users to search through the collection. The website was kept simple so that the users were able to interact with it easily. Refer to Figure 10 for a website interface screenshot.

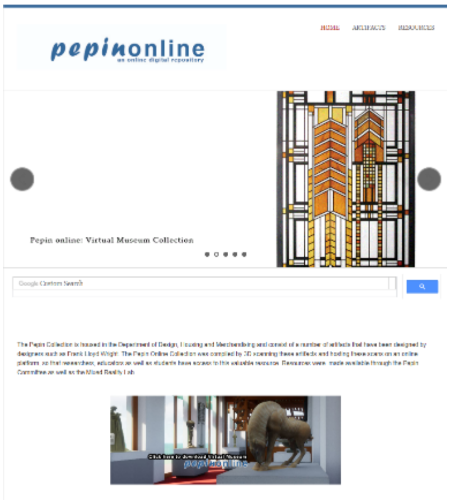

Figure 11. Website interface screenshot

3.2.2 3D Scanning and developing the virtual artifacts

For the initial phase of the project, thirty-two artifacts were 3D scanned using hand-held 3D scanners, Photogrammetry and Desktop 3D scanning. The 3D scans were refined and hosted on a 3D model sharing platform called Sketchfab. The use of Sketchfab allowed the artifacts to be embedded on a dedicated website for the artifact collection. Refer to Figure 12 for a screenshot of the website interface with information and embedded Sketchfab element.

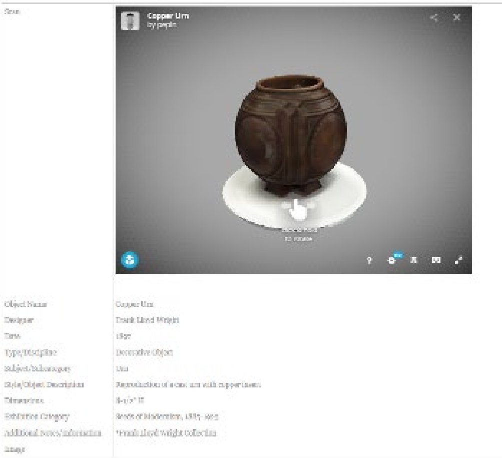

Figure 12. Website interface with information and embedded Sketchfab element

The Sketchfab platform allowed additional enhancements to be made to the artifacts, including enhancing lighting conditions and added VR support for the artifacts. Refer to Figure 13. For a screenshot of the scanned artifacts with enhancement.

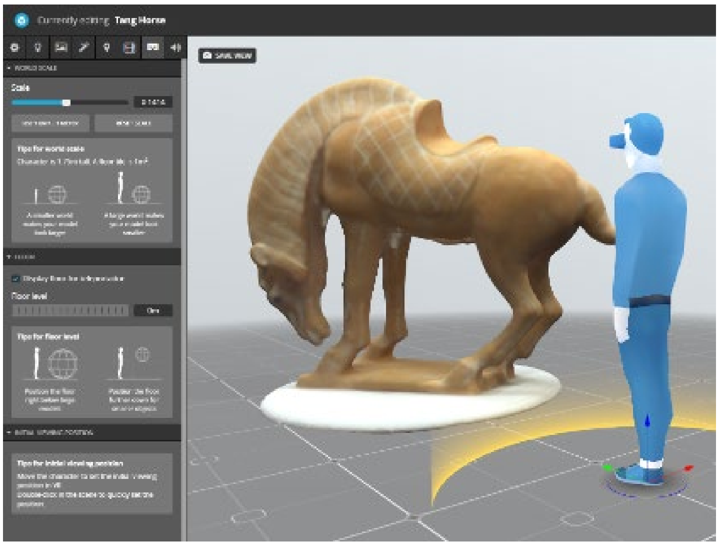

Figure 13. Sketchfab Interface for enhancing scanned artifacts

4. DISCUSSION AND CONCLUSIONS

4.1 Existing Display Cases

The IES makes recommendations for light level ranges for younger and older "visual ages". The primary age of display case viewers were expected to be younger (i.e. traditional undergraduate students). However, older viewers including non-traditional students, graduate students, University faculty members, staff and community members were also anticipated to visit the display cases and their needs should also be considered. The existing display case lighting system was controlled by one switch, permitting "on" or "off" only of one light level which was below recommendations for older eyes and higher than recommended for younger eyes. Further the existing lighting system was not flexible and could not react to variances in artifact composition in display cases. Further, older adults typically have more visual challenges with glare and unshielded light sources can be a source of glare.

4.2 Virtual Museum

With new developments in technology, 3D scanning of museums artifacts has been increasing [9]. The techniques employed in digitizing museum collections have been found to be time consuming as well as costly [10]. In the current project, the researchers focused on relatively simple methods that could be used to digitize an artifact collection. However, the methods employed in this project required a few improvisations. The researchers experimented with different types of lighting and lighting levels. The researchers found the desktop scanning method to be time consuming and decided to scan only small artifacts with fine details using that method. The researchers also utilized low-tech strategies in their methodology, such as the use of a rotating cake plate which had been originally intended for home bakers' use in frosting cakes.

3D scanning required the researchers to work with different technologies so that the most suitable method could be selected for the different objects in the collection. The collection of objects included small, medium and large objects. Different lighting conditions were used in the scanning of the objects using the hand-held scanner, and it was found that the LED illuminated scan had the most comprehensive results in terms of points in the 3D point cloud of the scan. The LED difference: LED BrightStik provided better results since it took less time to complete the scan as well as having lower amount of noise in the resulting scan. Furthermore, among the different techniques used, it was evident that high-resolution images supporting the 3D model in ReCap, allowed for visualization of finer details than those captured using a hand-held 3D scanner. Therefore, items that had finer details were scanned using the ReCap

Photogrammetry software. Refer Figure 14 for a comparison of scans taken with the hand-held scanner and utilizing Photogrammetry.

(a)

(b)

Figure 14. (a) Foo Lion, Hand-held scanner (b) Foo Lion, ReCap Autodesk Photogrammetry Scan

For smaller object scanning, a desktop 3D scanner was used even though the process took significantly more time. The achieved level of artifact detail was superior to those scanned through the previously mentioned methods.

5. Conclusions and Recommendations

5.1 Existing Display Case

While the challenges of accessibility will still exist, the researchers see merit in continuing to exhibit the physical FLW artifacts in the existing University display cases. The existing lighting systems were aging, unshielded, and did not utilize the latest technology. However, CRI and CCT were determined adequate. The researchers recommend lighting retrofits to improve view-ability and sustainability of artifacts that met lighting industry standards for light quantity, lighting system control flexibility and response to artifacts' light sensitivity. The researchers recommended a new, shielded, LED system controlled by occupancy sensors for the basic lower light level of display case illumination which would be adequate for younger adults and also meet recommendations for the most light-sensitive artifacts. Additionally recommended retrofits included a timer-controlled, on-demand, supplementary lighting system providing a higher light level for older adults. This proposed solution would support artifacts with low or no light sensitivity. LEDs are inherently energy-efficient and long-lived and these attributes will contribute to sustainability. LEDs are available in various Color Rendering Indices (CRI) and Correlated Color Temperature (CCT). For enhancement of artifacts and display case ambience, the researchers recommend that the LED retrofit utilize high CRI and Warm CCT products.

5.2 Virtual Museum

The researchers recommend conducting a usability study for the virtual environments on both the online platform as well as the virtual museum. It is recommended that the interaction factors, i.e., Navigation, Manipulation, and System Control as well as usability factors, i.e., Ease of Use, Efficiency and Satisfaction be evaluated.

6. Acknowledgement

The authors wish to thank Mackenzie Erdley, Oklahoma State University Freshman Research Scholar, for lighting data collection. The authors also thank Yang Pei, undergraduate student for her contributions to data collection and testing portions of this research project. Additional student workers acknowledged for this research include Kylee McKnabb Savanah Bush and Rachel Sample for contributions towards data collection and equipment testing. The authors acknowledge the Pepin Committee for funding the virtual aspects of this project.

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