Digital Geometry for Virtual Museum Based on Field Studies

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Abstract. The virtual museum is one direction of museum development. This digital museum allows freedom of access, number of accesses health-safety for the visitor, and security of collections. The design of the virtual museum space was developed simultaneously, to assist the presence of intellectual and emotional experiences, approaching the capabilities of conventional physical museums. Efforts to digitally reconstruct for museum space are strived continuously, by multiplying the room design variants and sharpening the attribute database. The attributes referred to here, are the geometry of the showroom platform, in the form of volume, percentage of pavilion cover, circulation, and arrangement of collections. More number of collections on digital space geometry designs and their attributes will enrich and sharpen the immersive performance of the virtual museum design in the future. This geometry data is also useful for further refining research, such as acoustic analysis and lighting design. The research method started with observation in 16 museums and exhibition galleries in East Java. The results of the observations were continued by collecting 24 variants of the general geometry design of the pavilion configuration space. The second stage is done with selection and tabulation based on similarities, to minimized repetition. At this stage, the analysis which is recorded from field observations regarding visibility, circulation comfort, and noise, was applied, so that the seven core geometric designs were obtained. Within the third stage, digital geometric drawing was created using Trimble SketchUp. Validation was done by testing the results, in the sound propagation ray-tracing software. The results of the study were seven digital geometries of the pavilion design variant. These geometries are capable of using as the basis, for developing more digital gallery or museum space design, with good quality space-visitor interaction.

Keywords: virtual museum, digital geometry, design variant, immersive

1. Introduction

East Java is one of the provinces with several tourist areas that are busy with tourists. One type of tourism object that attracts the public's interest is educational tourism through museums and science galleries. According to data obtained from JatimTimes.com (accessed September 29, 2020), it is known that the statistical value of the number of tourist visits has increased every year [1]. Apart from Surabaya, as an illustration, Batu City is another city in East Java that has many educational tourism projects. In this city, several objects have the concept of education and tourism in their development. Some of them
are Jatim Park 1, which has a Human Anatomy Museum, Jatim Park 2 and Fauna Museum, Batu Night Spectacular, Eco Green Park, Museum of Transport, and Predator Fun Park. In 2017, the total number of tourists with the above objects reached 2.5 million people. While in 2018, it is estimated that there will be an increase of approximately 500 thousand people. [2]. It can be concluded that the public interest in visiting this type of facility is relatively high.

Museums are closely related to history and science. The museum also functions as a documentary track record of the nation's civilization. These facilities generally store, record, and retell achievements in civilization, for the next generation to study. With the existence of a museum, the public can learn a variety of important information, as well as doing leisure tourism. This is in line with the museum's mission for conservation/preservation, education, and recreation. Some of the museum buildings are cultural heritage buildings, the rest are new buildings [3]. A building with this function, in an architectural typology, can be categorized as a showroom type building.

The architectural and interior design of showrooms-museums today facilitates the dynamic interaction of visitors with the content displayed. Not only observing, but visitors can also listen, operate, retrieve data, play, and be involved in the historical story that is displayed. In 1998, Thomas and Mintz surveyed the use of multimedia technology in various types of museums. They examined the potential for productive interactions between virtual representations and actual physical artefacts [4]. Mase et al. (1996) proposed the use of techniques associated with multimedia agents and virtual reality to augment the representation of artefacts [5]. Furthermore, in 1999 Cheverst et al., explained the use of handheld computers and wireless technology to support tourist visitors. This effectively expands the idea and provides potential connections between different museums. A virtual exhibition can be seen as a collection of digital objects, organized systematically through multimedia. Virtual exhibits offer flexibility to visitors, to communicate and interact with the exhibited objects, according to their needs and interests. (Alawad et al, 2015) [6].

According to Giangreco (2019), with the increasing availability of digital museum artefacts, in recent years there have been many questions about how to make exhibit collections that can be accessed and explored as widely as possible with impressions that are closer to the real condition [7].

This study aims to identify and contribute to the geometric database of the virtual digital museum through showroom design modes. The results of this study can be used for design or further research in similar fields.

2. Literature Review

The interior design responds to a shift in the way of presenting in a showroom-type building, by paying more attention to the visitor activity that develops in it. In the exhibition-museum type building in the classical sense, visitors see more, read, and move slowly between collections, becoming visitors who do more various activities, such as reading, listening, playing interactive multimedia, downloading content, and playing. Likewise, the visitor circulation pattern tends to be faster. The more diverse activities produce unique acoustic conditions.

2.1. A subsection Theory and Literature

2.1.1. Museum Interior Design.

This kind of exhibition facility will continue to grow. A typical exhibition hall-museum building is not only for an exhibition room but also as a space that has an interactive function between the exhibit and its visitors. "The museum as a dynamic space that is made meaningful through the interactions of space, objects, sociality, and the very meanings that flow from that interaction is a compelling one" (Paul Jones, Suzanne MacLeod, 2016) [8]. Advances in ventilation, lighting, and sound technology are supported by the increasing advancement of computer technology. Information technology has made breakthroughs in terms of storage, processing, and presentation. However, audio content is predicted to develop more if the problems mentioned in the previous paragraph can be overcome by technological developments. (Smith and Tinio, 2008) [9]. The material can be presented more diversely and interestingly. Collection
displays and information delivery can be designed and presented in more variety. The basic architectural
typology has also been modified because today's exhibition facilities can be more flexible in previously
unthinkable places. "Viewing the physical museum as an 'assemblage' of people, material, and practices
in a dynamic state of making means that researchers need to move beyond notions of architecture as the
static output of an architect." (Jones, MacLeod, 2016) [8]. As the technology of audio and radio
progressed, showrooms added sound to support the exhibition. Apart from being the main content, the
sound can also be found as a background. Since 1931 radio-guided tour is the precursor of the audio role
as the primary content carrier. After being hampered by World War 2, the use of audio in personal
museum guides has been widely used since 1957 in Europe and America. Visitors accept audio content
because it is considered more practical than reading written content. Currently, personal audio guides
with personal hearing instruments have not undergone any further development due to the high cost of
the device, practicality, social interaction, safety, and hygiene. (Tallon, 2008) [10].

2.1.2. Exhibit Layout and Visitor Circulation.
Several literature studies describe the development of exhibition concepts, changes in circulation, visitor
activity, display dimensions, and noise. (Falk, 2016) [11], (Mc Lean, 1993) [12]. The circulation patterns
in the interior of the museum exhibitions determine the flow of visitor movements or journeys within
the interior. The circulation in the showroom is shaped by interior elements.

Ching in Architecture, Form, Space, and Order, describes the building blocks of architectural space.
The primary elements are point, line, plane, and volume. Primary elements are significant elements that
always exist in architectural space before a designer/planner incorporates other elements. The next
elements discussed are form, organization, circulation, proportion, and many other elements. (Ching,
2007) [13]. Furthermore, schematically, Ching classified the elements that form a point without
dimensions, 1-dimensional lines, 2-dimensional planes, and 3-dimensional space. The configuration of
the elements that make up the 3-dimensional space (volume) seems more complex; length, width, depth,
form, space, surface, orientation, position. It can be concluded that (exhibition) space is a complex
configuration formed from interrelated elements and cannot stand alone. At the same time the circulation
patterns in the interior of the museum exhibitions determine the flow of visitors' movements or journeys
within the interior. According to McLean, 1993, there are at least three suggested patterns, namely a
direct circulation pattern (direct plan), an open circulation pattern (open plan), a radial circulation pattern
(radial plan), and a random circulation pattern (random plan). Each of them has advantages and
disadvantages in its application [12].

In design, a configuration is the result of a combination of several elements. While elements in the
design, in general, are physical components that are interrelated, these elements consist of lines, shapes,
textures, spaces, sizes, and colours. These elements cannot stand alone to form the configuration of
interior space. (F. D.K. Ching., 2018) [14], and review of other sources. Whereas in the context of
architecture, and space that has a function, the essential elements have been combined into more 3-
dimensional elements. The basic interior design is the floor, wall, and ceiling elements. These three
elements carry the furniture and utility components. These three elements and two components contain
various aspects: ergonomics, ventilation, lighting, aesthetics, materials, and acoustics. (F. D.K. Ching.,
2018) [14]. The interior configuration is created from the configuration of the elements above. This
configuration will physically affect the performance of space attributes such as lighting, spatial
impression, and acoustics. The configuration of the space-forming elements also affects the user's human
perception of the space attributes above. According to Mallapragada et al (2016), spatial planning has a
significant influence on visitor behaviour in both traditional and online environments. [15]. In a virtual
world, an art gallery layout aims to create an environment that can make visitors interested and spend
their time appreciating a work of art. Besides, it is hoped that spatial planning will facilitate a
comfortable and pleasant feeling. Several previous researchers have produced several findings regarding
the influence of spatial planning on the art gallery. The results of this study explain that the importance
of art gallery layout has in common with the arrangement of a virtual retail store [16].
Krasinikola-kis et al (2018) investigated the effect of retail store atmosphere on consumer behaviour in a 3D virtual shopping environment and found that the layout is an important determinant for visitors to construct cognitive maps [17]. Therefore, in an art gallery, the spatial arrangement will affect the display style. The flow of the placement of the exhibiting objects should be natural and mildly direct the visitor to each section to enjoy the visit with an excellent visual angle and distance [18]. According to Huang and Wu (1992), in physical exhibitions, the layout can generally be divided into several types, as shown below:

![Figure 1. Layout type on Physical Museum: (1) Grid, (2) Centralization, (3) Radial (4) Garis, (5) Cluster. Source: Huang and Wu, 1992](image)

2.1.3. Patterns of Human Behaviour in Exhibition.
Summarized by Veitch & Arkkelin (1995) [19], humans are always in touch with the environment as a source of stimuli. There is almost always a "bargaining" position between individuals and their environment. Humans have a unique psychological response to their environment, along with the various types, conditions and intensities of the environment as stimuli that are captured by the senses, processed and perceived in the brain and implemented in the form of actions or behaviour. The environment referred to here is the built environment in the form of architectural designs. In the context of designing, human psychological response patterns to their environment can be used as a guide for designing, to obtain a specific behavioural response from human users.

Lifestyle is one of the factors that influence human interaction with the environment. According to Putri et al (2015), lifestyle is behaviour that is produced by individuals through activities, interests, and opinions [20]. From this research, it can be understood that a lifestyle is a practice that others want to observe. In fact, many societies define urban society incorrectly. Urban society is a city community that can take care of itself, based on rationality, so that the interactions that arise in society are based on interests and not because of subjective reasons.

2.1.4. Geometric Illustration Using SketchUp Software.
SketchUp is a frequently used modelling software by designers in the design process at the modelling stage. Google Sketch Up is a graphics program that produces three-dimensional graphic images. According to Darmawan (2009) [21], Sketch-Up can be used as a medium to express ideas in modelling houses, buildings, maps, and so on. The features and interfaces of this software are more uncomplicated so that they are easy to use as a learning medium.

According to Melnyk & Kernyskyy (2018) [22], several previous studies have conducted many tests to find out which modelling software can be converted to environmental simulation software, for example, acoustic simulation and lighting simulation. The research resulted in the finding that Sketch-Up was a modelling software that was considered adequate. This conclusion is in line with Chopra's (2012) finding, which explains that the Sketch-Up software was chosen as a simple and easy to operate the software with a user-friendly interface [23]. The accuracy of geometric characteristics and material properties can be validated, with the addition of several software plug-ins according to drawing requirements. Chopra (2015) also explains that Sketch-Up has been assessed as software that can reconstruct a physical environment into a virtual environment with a good appearance [24].
This software coding environment also enables us to be used as material for acoustic and lighting environment software simulations, such as CATT and EVERTims and Blender. Accurate digital geometry depiction is a vital asset to build an entirely virtual museum [28], [30]. The most logical starting point in building a virtual museum is from reconstructing the real museum environment. Constructing real space and environment in digital form, logically, is the most accessible approach to reconstruct human experiences, impressions, and perceptions of the museum's physical environment. After the psychic (immersive) involvement has been developed, the level of emotional involvement through the more fantastic virtual space can be continued. Thus, digital imaging with good geometric accuracy is required.

Digital reconstruction can come from an observation-based mode study of the physical environment. Physical observation looks at the geometric layout aspects that most often arise from the various available layout and geometry models. The tabulated results are in the form of layout mode and showroom geometry and are referred to as the proposed model.

2.1.5. Previous Research About Virtual Museum.
A virtual exhibition can be seen as a collection of digital objects, organized systematically through multimedia. Virtual exhibits offer flexibility to visitors, to communicate and interact with the exhibited objects, according to their needs and interests. (Alawad et al, 2015) [6]. Museums around the world offer visitors to enjoy art, sculptures, and other exhibitions. According to Bowen (2004), this can overwhelm visitors and make most of the exhibition materials seem unattractive. This phenomenon can cause a decrease in the intensity of visitor interest in the art exhibition on display [24]. To overcome this problem, several researchers provide solutions by presenting works of art, artefacts, and exhibitions through virtual environments. Also, several previous researchers have an interest in introducing cultural heritage to the younger generation in a more effective way according to technological developments [6].

According to Tredinnick (2018), there is currently an increasing interest in virtual reality opportunities to improve the user experience [25]. Virtual Reality technology is often used to improve visitor experience [26]. Some researchers have found that a presence is generally considered a vital component of virtual environments because users must experience and interact with virtual environments in real-time (Silva et al. 2016) [27]. Sylaiou et al (2019) conducted a study aimed at observing the effect of material delivery through the use of the avatars for curators, carers, and visitors and observing the types of emotions arising from respondents. The results of the study explain the detailed geometric design of the avatar with high quality that can represent humans to convey exhibition information [28]. Another exciting thing is the fact that based on the data obtained, the respondents' emotions become more complicated when the respondent interacts with the museum visitor's avatar. The type of emotion the respondent responds to the curator avatar (or a specialist) is more towards a sense of admiration. When the narrator is someone who has almost the same status as the respondent, the types of emotions produced are empathy and personal emotion [28].

Later in the same year, Morales et al explored the comparison of presence between physical museums and virtual museums. In this study, Morales et al said that environmental simulation depends on the simulation's ability to replicate the response to the environment. One of the methods used is by observing the difference in visiting time between the two museums [29]. According to Dieck et al (2019), the use of virtual reality in historical museums provides an effect on the duration of the visit that is more effective, especially for middle-aged visitors [30]. This research examines the effect of the application of virtual reality in a museum space that has limited access for middle-aged visitors. The results of this study indicate that middle-aged tourists appreciate the use of virtual reality very well. They considered the use of virtual reality to be very helpful in terms of duration of visits and physical abilities. Through virtual reality, tourists can estimate visit times more flexibly and estimate their physical ability to explore various spaces. In addition, tourists can have experiences of unknown destinations and improve the quality of visiting experiences [30].
2.2 Methods.
This research began with field survey to eighteen museums in East Java. It conducted in early to mid-2019. The choice of the intended museum is based on a large number of tourist visits to the museum. It was carried out on different days and times at each museum. The documentation focused on collecting geometrical and spatial information. It includes hall size and category, the number of pavilions in the hall, dividing methods of the pavilions, pavilions volume, the visual distance of object and observer.

3. Field Study
The 16 museums include; Museum 10 Nopember, Museum Kedokteran UNAIR, Museum Ethnografi UNAIR, House Of Sampoerna, Museum Pendidikan, Museum De Jasasce Bank, Museum Kereta Api Bondowoso, Rumah Air Surabaya, Museum Mpu Tantular, Museum Ubaya Penanggungan Center, Museum Musik Dunia, Museum Satwa Batu, Museum Sumenep, Fun Tech Plaza, Museum Angkut, and Dinopark. The results of the survey documentation can be seen in Figure 2;

![Figure 2. Documentation of survey results from 16 museums in East Java. Source: 2019 personal documentation](image-url)
Observations are made by observing several aspects related to the interior layout. These parameters include; size category of the hall, the number of pavilions in 1 architectural space, dividing partitions between themes/pavilions, the volume of each platform, the massive levels of the barrier between platforms, the distance between collections and visitors, and how visitors absorb information data. Field observations found that several design patterns can be grouped into several design modes.

Based on the principles of interior design, building function influences interior configuration. We can find similarities of circulation pattern, the volume of the pavilion, as well as the partition types. By grouping the similarities, seven types of pavilion/showroom/platform were proposed. Furthermore, seven digital geometry modelling was carried out. The digital geometry of this proposed model can be used in digital simulation tests on aspects of acoustics, lighting, and visual ergonomics.

4. Finding
There are several similarities in the layout of the showrooms of the museums. In practice, designers produce a variety of interior element configuration designs for displays in a showroom. With so many showrooms, display models vary widely. However, from the initial observation of the 16 exhibition rooms (museums, galleries, visitor centers, etc.) in East Java, one can find many similarities or patterns of design trends. This pattern can be sorted and grouped into several types, which have the potential to be proposed as a typical variant of a permanent display system. These types can be used as a model for the configuration analysis of the elements forming the interior space in this study. The layout results that were found the most can be formulated into seven models.

![Figure 3](image_url)

**Figure 3.** (a) Typical Semi-Open Space with artefacts stuck to the walls; (b) Typical Open Space with artefacts attached to the walls; (c) Typical Enclosed Space with artefacts attached to the walls; (d) Typical Semi-Open Space with artefacts on the walls and the floor with discontinuous boundaries; (e) Typical Enclosed Space with artefacts in space resembling a diorama; (f) Typical Semi-Open Space with artefacts on walls and floors; (g) Typical open spaces with artefacts on walls and floors.

Modelling sketches are made based on the similarity analysis of the layouts of the museums and showrooms that have been observed. Regarding interior elements, Gibbs explained that an inner space has a configuration of elements called physical entities (shape, volume, colour, texture, etc.) which are influenced by environmental factors (light, sound, humidity, etc.) (Gibs J, 2005) [31]. The seven models of design configuration modes are obtained through an analysis process by considering the large category of the hall, the number of platforms in one architectural space, the dividing partitions between
themes/platforms (pavilion room coverage percentage), the volume of each platform, the massive level of dividing between the platforms, and the distance between the collection and visitors. The seven types of platforms have different geometric configurations (volume, shape, closure) with similar material types. There is an impression of simplification because the research does not look specifically at the ornamentation and decoration of space. So that if a room is decorated like a cave or an underwater aquarium, we still observe the basic geometry of the non-decorated indoor space.

5. Discussion
The difference in hall size (architecture) has a significant effect on the layout of the showroom. Typical showrooms with large halls can be illustrated by geometric depictions such as Figure D (such as the layout Museum Dino Park, Rumah Air Surabaya, Museum Angkut, and Fun tech plaza). Large halls allow for large amounts of content and more complex layouts. Artefacts can be arranged on the interior elements of walls and floors. Whereas in rooms with medium and small halls, the artefact presentation tends to be designed by optimizing the land. There are three types of design modes for artefacts with 3-dimensional shapes, as shown in Figure E (Typical Enclosed Space with artefacts in space resembling a diorama), Figure F (Typical Semi-Open Space with artefacts on the walls and floor), and Figure G (Typical open space with artefacts on walls and floors). Such as Museum 10 Nopember, Museum Ethnografi, House of Sampoerna, Museum Pendidikan, De Javasce Bank, Museum Mpu Tantular, Museum Musik Dunia, Museum Sumenep). In museums with sufficient space, the arrangement of artefacts could be arranged, which represented continuity flows. Such arrangement needs partitions/divider between platforms. The following museum belongs to the latest category.

Whereas for museums with 2-dimensional artefacts, three types of design modes such as in picture A (Typical Semi-Open Space with artefacts attached to the wall), image B (Typical Open Space with artefacts attached to the wall), and image C (Typical Space Covered with artefacts stuck to the wall). They have to utilize the area of the wall in an optimum way with 2-dimensional artefacts are more likely to have a layout by optimizing the use of walls as a medium. This is related to visual comfort, which has to be fulfilled by sufficient distance of the artefact to human, become a primer consideration, which in turn result in a space in the platform/showroom. In addition, the use of walls as a medium for presenting artefacts can also make it easier for visitors to access the distance between visitors, artefacts, and other visitors.

6. Conclusion
The typical physical model of the display system/bridge contributes to the atmosphere-forming of a specific space. Different configuration of the interior elements in the showroom display system will result in a different atmosphere.

1. Developing a physical museum or showroom to become a virtual one, requires continuous efforts to reconstruct the spatial model with accurate spatial geometric attribute accuracy.
2. Accurate digital depiction of the showroom's geometry allows it to become a foundation for environmental simulation research such as acoustic propagation, using acoustic testing software.
3. The accuracy of the geometrical depiction is possible to near-original spatial conditions if the data validation for the material properties can be fulfilled.

The results of this study would be used as a foundation in the development of designers and researcher's point of view in designing and analysing future showrooms.

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