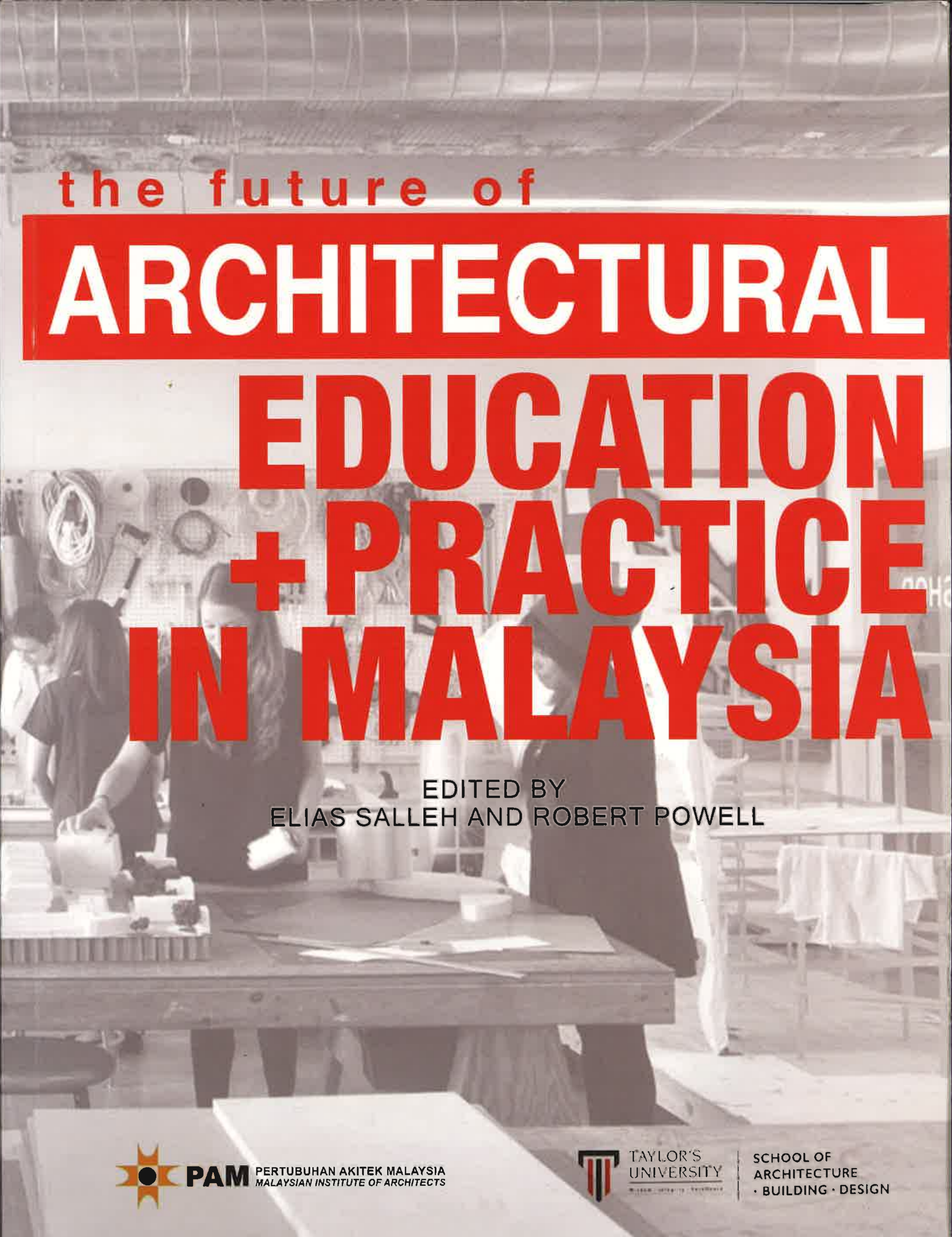
the future of ARCHITECTURAL EDUCATION + PRACTICE IN MALAYSIA



EDITED BY
ELIAS SALLEH AND ROBERT POWELL

PAM PERTUBUHAN AKITEK MALAYSIA
MALAYSIAN INSTITUTE OF ARCHITECTS

TAYLOR'S UNIVERSITY
SCHOOL OF ARCHITECTURE · BUILDING · DESIGN

The Future of Architectural Education + Practice In Malaysia

edited by

Elias Salleh and Robert Powell

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9 Taxonomizing architectural detail components for urban scale 3D models in virtual reality

Atta Idrawani Zaini and Raja Nur Syaheeza Raja Mohd Yazit

Introduction

The status quo of professional disciplines such as architecture may potentially be disrupted by the advent of the so-called '4th industrial revolution' tools, so much that it may influence the design thinking itself. This seemingly presumptuous notion may have some truth to it. Digital tools such as CAAD has not just changed the way architects produce designs in the last decades, but also the design process itself (Botchway, Abanyie, & Afram, 2015). But the more pertinent concern for any adaptation of technology is ought to be discussed from the practicality dimension, in preparing a discipline for any kind of disruptions that are rapidly evolving and challenging the status quo.

In a recent development, the renewed interest in making VR to be available and affordable to the masses has paved the way to the so-called 'second wave' of VR revolution (Stein, 2015). VR systems today are more capable that it could deliver a more responsive and immersive experience as compared to its 1990's predecessors, as the current VR hardware is easier to be manufactured with rapid improvements on its software capabilities (Halley-Prinable, 2013). The content, however, is mostly regarded to its entertainment values rather than its practicality for performing real operations. Being a discipline that is highly adaptive to changes, new tools and technology are therefore ought to be researched from architectural perspectives.

Architectural practice traditionally is depending on representations to communicate design ideas to the stakeholders to deliver information that is not yet materialized. VR has been used as a form of representational tool for urban planning and construction activities, including in urban development and site selection (Diao, Xu, Jia, & Liu, 2017). The key benefits of this include assessment in 3D space, effective communication, time-saving and encourage participatory planning (Jamei, Mortimer, Seyedmahmoudian, Horan, & Stojcevski, 2017). The key challenge, however, is the access has always been limited to organizations with high-end workstations. To increase non-specialists' interest in VR, the current pipeline of model acquisitions in architectural practice must be taken into consideration, as their method of modelling is usually done via user input rather than a procedural one. The notion of sufficiency in terms of details for this process is somewhat vague, therefore this paper is attempting to contribute a proper taxonomy. With this, the notion of scale and architectural characteristics are therefore regarded as the theme of discussion, as these notions are attached to the taxonomy.

Representations and Scale

For ages, architects have used scale models to aid the design process (Stavrić, 2013). Using scale models allows architects to manage the risks of possible errors and discrepancies in the final product. However, the operational use of these models may vary depending on the scale and the level of details (LOD) (Stavrić, 2013). The selection of scale typically depends on the actual size of objects, the size of the workspace and the project stage that is to be illustrated. Another critical consideration for scale models is deciding the LOD. Reducing the scale of models will typically increase the LOD and vice versa, as illustrated in Table 1. The concern of deciding the LOD in representations is mainly controlled by the scale, other than the notion of production capability, time and cost (Hudson-Smith, 2007; Kobayashi, 2006).

Table 1 *Common types of scale models (Stavrić, 2013)*

Type of scale model	*Common scale*
Detail model	2:1 or 1:1
Interior/ furniture model	1:25
Conceptual/ development model	1:50, 1:100, 1:200 *or with no specific scale*
Exhibition model, model of constructed objects	1:100, 1:200
Site model	1:250 or 1:500
City/ landscape model	
• Small environment	1:250 or 1:500
• Large environment	1:1000 or 1:2500

In the case of common 3D models, the saliency of details is not just becoming laborious to be preserved but also the notion of scale is quite ambiguous, thus there are no rules on dictating how salient a 3D building in a VE should be built. In the case of a full-scale VR 3D models, the issue is somewhat similar but with the concern of scale absent in the equation, the notion of details becomes more apparent. For architectural operations, it could as well be more logical for higher LOD to be preserved. But with the factor of time, cost and labor, the luxury of having high LOD are counterproductive to the process while it is also vital to preserve the truthful architectural characteristics. Thus, to recognize VR as a valid practical tool for architectural operations, it is relevant to use architectural forms and characteristics to become a basis for a taxonomy for constructing urban scale 3D models for VR. Therefore, the objectives of this paper are summed up into:

1. To study the current taxonomies of urban scale 3D models;
2. To define parameters for defining the taxonomy involving urban scale VR 3D models;
3. To propose a taxonomy of building forms and characteristics for urban scale VR 3D models.

Methods

This paper was accomplished mainly using 3 methods. The first is the setting up of the discourse framework through literature reviews. The second method warranted is quantitative with a total of N=96 respondents participated in a survey, in which they were asked to rank the architectural characteristic items which they perceived as critical to be preserved in an urban scale VR 3D model. The items contributing to building forms and characteristics were derived from the literature review. The items were measured at ordinal scale (Likert-type scale), ranging from the score of 1 (highly unimportant) to 5 (highly important). The items were then factorized through a PCA to reduce a larger set of variables into a smaller set of constructs. These architectural details were categorized into the already established principal components after all assumption tests for conducting the PCA (KMO measure of sampling adequacy, Bartlett's test of sphericity & correlation matrix) were passed. The data analysis was conducted using SPSS software. The factorized components were then triangulated with the framework established through the literature review to propose the taxonomy, which is the third method.

LOD in 3D Models

In practice, architects have always keen on pushing realistic representations in propagating designs as a way to mobilize the production of buildings (Altürk, 2008). These representations would typically have a very close resemblance to the actual entities, which prompts the notion of whether it is necessary to be having such realistic representations, especially in the design process. As discussed by Reinhardt (2008), the persuasive forms of representation have resulted to unusual perspectives thus unresolved result might be displayed too convincingly, which ironically makes them unreliable. But the ultimate goal of a VR system is to give the observers an experience of being immersed, thus to achieve this is through developing a highly realistic VE (Diao, Xu, Jia, & Liu, 2017).

The creation of realistic 3D VE is driven by the increasing computing and memory capacity, which is supported by the advancing software sophistication. The use of 3D graphics in various domains is therefore increased simply because it can be achieved now (Çöltekin, Lokka, & Zahner, 2016). As most discourses are geared towards the interest of non-architect specialists, the interest of achieving a pragmatic VE has long been ignored. This paper argues that architects may only need necessary visual information in their 3D models, thus it is always favorable to have the models schematized to a certain LOD, leaving only the necessary characteristics. Realism in this sense is secondary, as what is more important is the content of the VE rather than the quality of experience.

Schematization of LOD

The concept of LOD is very much related to the taxonomy, as it is used to suggest how thoroughly the 3D objects have been modelled (Biljecki, Ledoux, Stoter, & Zhao, 2014). LOD is a discipline within the interactive computer graphics bridging the complexity of 3D models and its performance by regulating several details used, as objects with less amount of details are technically faster to render than more complex objects (Luebke, Watson, Cohen, Reddy, & Varshney, 2002). The less detailed objects are usually small, distant or unimportant elements in a scene, which require less emphasis. The LOD often is reduced to reach the best and acceptable level of visual quality depending on the computing power.

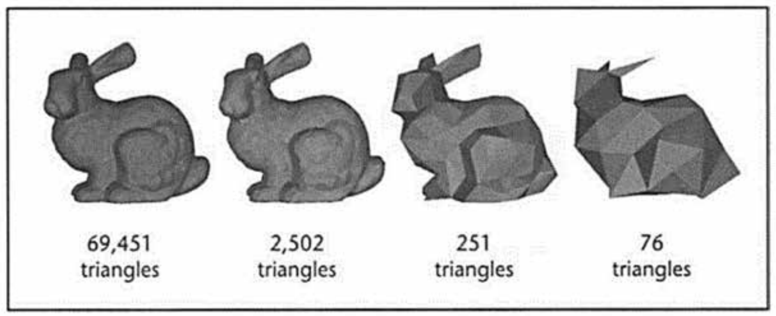

Fig. 1 *Different complexity in the level of details (Luebke et al., 2002)*

Ideally, reducing the LOD in the sampling of the 3D objects will eventually reduce the rendering computation, thus improving the frame rate, system latency and the system responsiveness (Luebke et al., 2002). This reduction therefore often comes at the expense of the visual detail. LOD defines the 3D buildings' semantics and would also be useful for leveraging the amount of data, the richness of detail and visual properties. But this term has been borrowed from computer graphics discipline and used without much discussions on architectural meaning, often taken from the considerations of performance and aesthetics rather than architectural characteristics. Therefore, this paper examines previous researchers' works on the taxonomies for urban scale 3D models that align with the interest of LOD schematization for architectural operations as a framework of the discourse.

Established Taxonomies of Urban Scale 3D Models

This section examines the established taxonomies of urban scale 3D models. The Shiode (2001) model proposes a simple continuum consists of LOD taxonomies arranged from low to high geometric content. The complexity of the model corresponds to each stratum is increasing, from 2D maps orthography being the primitive mode to a full volumetric CAD modelling being the most complete LOD, as illustrated in Fig. 2.

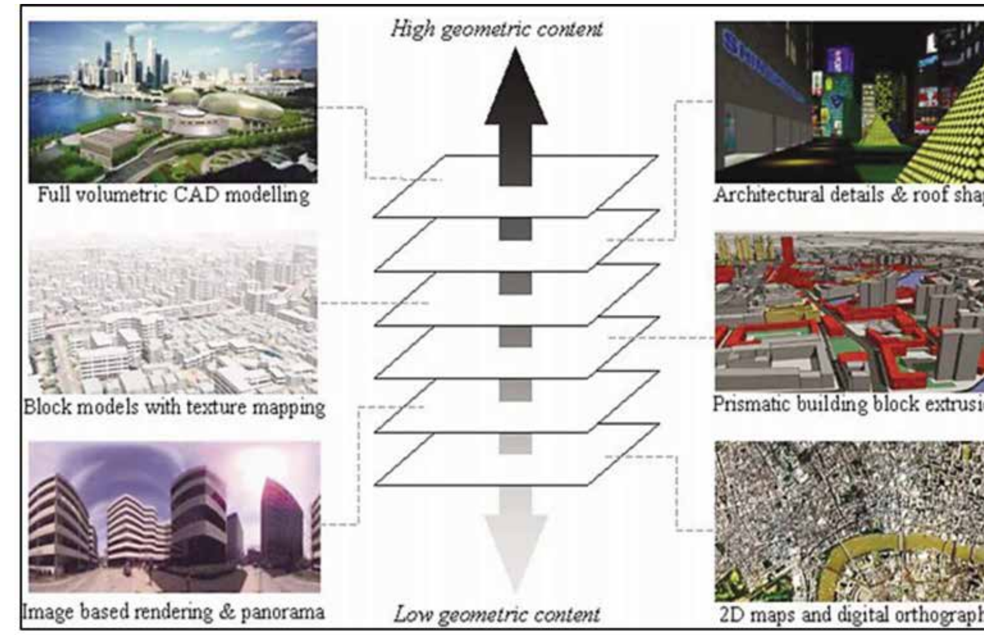

Fig. 2 *A taxonomy of urban scale 3D models by Shiode (2001).*

In another taxonomy as suggested by Horne et al. (2013), urban scale 3D models essentially can be divided into 'low level' (for presentation and evaluation) and 'advanced' model (for realtime editing and analysis). Kobayashi (2006) has also categorized the quality classes as 'online quality', 'PC quality' (rendered for simulations) and 'movie quality' (static and non-interactive). He added these models can be subdivided into 'street', 'block' and 'city' level, as summarized in Table 2.

Table 2 *Taxonomies of urban scale 3D models by Horne et al. (2013) and Kobayashi (2006)*

Approach	*LOD in VEs*	*Authors*
Operational	• Low level (evaluation) • Advance level (real-time editing)	(Horne et al., 2013)
Visual quality & level of viewing the model	• Online quality • PC quality • Movie quality Sub categories: • City level • Block level • Street level	(Kobayashi, 2006)

Another taxonomy is derived from the Open Geospatial Consortium (2012), which has been focusing on buildings as illustrated in Fig. 3. These 5 LODs have been accepted as a standard for CityGML 2.0 which describes the instances increase in geometric and semantic complexity through LOD 0 (footprints and optional roof edge polygons), LOD 1 (prismatic model through extrusion), LOD 2 (a simplified roof shape and other semantic components such as walls), LOD 3 (architecturally detailed model) and LOD 4 (complete model with indoor features). This taxonomy has been widely adopted by stakeholders in different industries in designing urban scale 3D models (Biljecki, Ledoux, & Stoter, 2016).

Fig. 3 *A taxonomy of urban scale 3D models by Open Geospatial Consortium (2012) (Biljecki, Ledoux, & Stoter, 2016).*

Çöltekin, Lokka, & Zahner (2016) have outlined a rough taxonomy of 3D visualizations based on visual realism and immersiveness. Though is not specific to urban scale 3D VE, this rough taxonomy highlights immersiveness being one important parameter that is in an almost direct correlation with the degree of realism, as illustrated in Fig. 4. They consider visual realism is an important part of the discourse on 3D, despite not all realistic visualizations are necessarily 3D and not all 3D models are realistic. Immersiveness in this sense serves as an objective for a VR content, thus it is argued that immersiveness can be achieved through realistic models, that can be achieved through high LOD.

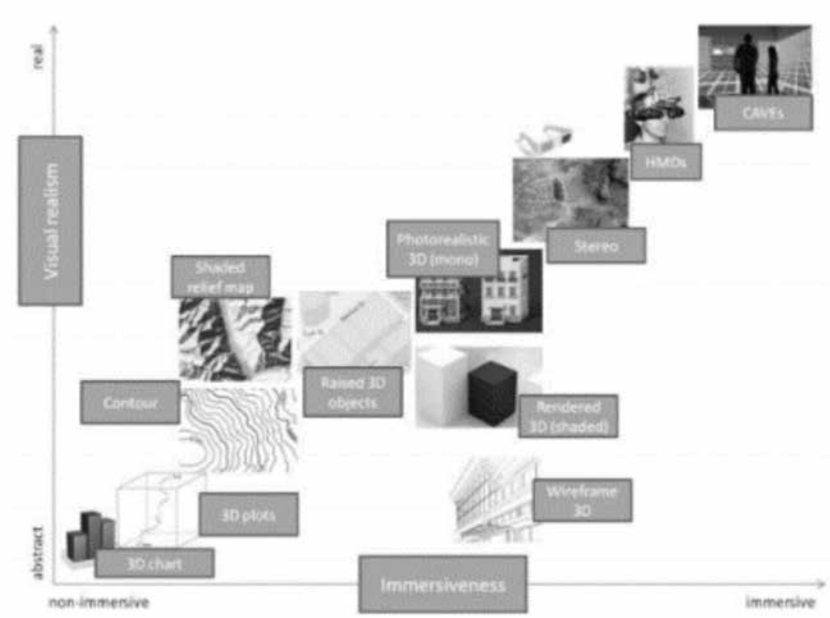

Fig. 4 *Taxonomy based on visual realism and immersiveness (Çöltekin, Lokka, & Zahner, 2016).*

Although Shiode's (2001) taxonomy may be applicable to 3D models in general, in the case of a full-scale 3D model (such as for VR), it is somewhat incomplete. There is no emphasis on full-scale immersion and the level of viewing. The taxonomy proposed by Kobayashi (2006) has included both visual quality and level of viewing, with the street level being a practical way of viewing an urban scale VE in VR. But this taxonomy alongside with Horne et al. (2013) model are too universal to be regarded as useful for a specific domain such as architecture. The concerns on the operational type and the level of viewing, however, are relevant to be applied in this study.

The Open Geospatial Consortium (2012) taxonomy, though is hierarchical and clearly differentiate both geometry and semantics of buildings, is progressively linear. It does not tell what can be considered as sufficient, or 'how detail is detail' for an architectural operation in VR. Thus, we propose that a taxonomy should allow more flexibility or 'fluid' for acclimatizing architects' pipeline of 3D modelling. It is, however, worth to note that the building form and characteristics in this taxonomy are legitimate items that may align with the interest of our study – which is to be based on architectural components rather than geometric polygons. As from the work of Çöltekin, Lokka, & Zahner (2016), the immersiveness is achieved directly through the level of realism, in which full-scale VE viewed in a VR system (HMD or CAVE system) are regarded as the highest form of 3D representation but is not necessarily having high LOD.

We, therefore, attempt to introduce a new model of taxonomy by incorporating the relevant inputs from these literature. The taxonomy is modelled for an urban scale VR 3D model that is regarded as 'low level' with 'PC visual quality' and to be viewed from the' street level', as these are the attributes commonly associated with VR simulation. 3D models with 'architectural details and roof shape' and with 'prismatic building block extrusions' are considered as the extreme ends of the continuum as they belong to the intermediate strata in the established taxonomies. Additionally, the dichotomous qualities of these two levels are more apparent and therefore would be more explicitly demonstrated. The predefined taxonomy for urban scale 3D models is therefore established as illustrated in Fig. 5.

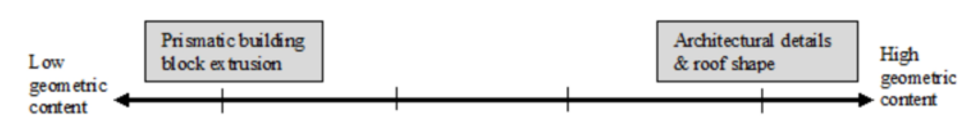

Fig. 5 *The predefined taxonomy for urban scale 3D models for this study.*

Building Form and Characteristics

People use buildings' characteristics as cues to remember in an urban environment (Zadeh & Sulaiman, 2010), therefore it is vital not to disregard building characteristics in generating urban scale 3D models. Buildings physical characteristics are particularly associated with culture, as represented in buildings' form, style, façade, ornamentation and roof form (Zadeh & Sulaiman, 2010). Building characteristics as according to (Appleyard, 1969; Gary W. Evans, Catherine Smith, & Kathy Pezdek, 1982) are also organized along three dimensions, which are building form, building visibility and building symbolic significance. Appleyard (1969) particularly defines building form by the movements around buildings, clarity of contour, size, shape complexity, surface color and texture, maintenance quality, and signage (Gary W. Evans et al., 1982), while building visibility and symbolic significance are the semantics related to human interactions with the buildings and therefore are not physically attainable in 3D models. This paper therefore only focuses on the building form and characteristics. Table 3 summarizes the building form components that are possible to be generated in 3D models.

Table 3 *Building form components as described by Appleyard (1969).*

Building form component	*Description*
Clarity of contour	The boundary sharpness that makes a building stand out from its ground.
Size	The height and bulk of a building as perceived from its approach view
Shape complexity	Simple shape allows faster perception while complexity attracts attention.
Surface colour and texture	A salient characteristic of a building can be of the brightness, coarseness and complexity of surface.
Signage	Verbal signs to attract attention.

From this, the form and characteristics components are then derived into items for the questionnaire. This is to rank architectural form and characteristic components of a 3D building that the respondents find as important to be preserved in urban scale VR 3D models. Some related components are incorporated into a single item based on a certain degree of logical judgment. The items, in no particular order, are presented as such:

Table 4 *Building form components as questionnaire items derived from the literature review.*

Architectural Detail Components	*Source description*
Color/ texture	Derived from building form components by Appleyard (1969)
Shape/ form	
Text/ signage/ symbol	
Size/ volume	
Orientation	
Height	
Roof profile	Derived from the Open Geospatial Consortium (2012) taxonomy (Biljecki, Ledoux, & Stoter, 2016).
Façade component	
Facade details	

The first 5 out of 9 items listed are a direct derivation from Appleyard's (1969) idea of building form components. His case study was done in a real-world setting, thus may have taken a more conservative method of merging the last 3 items. These 3 items have been consistently used as parameters in the established 3D model taxonomies, thus we separated them into additional items instead. The 9 items are then established as such, with the objective of getting the respondents to rank them based on their importance.

Data Analysis

In total, 96 random respondents (N=96) have participated in a survey with the ratio between male (53.1%) and female (46.9%) were almost equal. The ages of the respondents varied from 18 to 44 years old. This study used an approach of passing over individual differences, as to extend the public perception that is more universal. Thus, the sole criteria for selection of respondents was they must be above adolescent. For the reason of homogeneity, this study was inclined towards maximizing the number of respondents that fall under a certain age group, which is from 20 – 29 years old.

From the research design point of view, the respondents that have their background associated with the domain of architecture, urban planning and landscape architecture preferably are to be excluded as respondents. However, it was also reasonable to not withdrawing the inputs from the group as this study is highlighting VEs as architectural representations, thus diversifying the input including from these 'specialists' are much also needed. Additionally, due to the multidisciplinary nature of this study, it is impractical to be too selective. As this study was also explorative in studying recent technology, its liberal approach may be beneficial for allowing potential studies to be executed in future.

Results

A PCA was run in SPSS using the data from the nine items in the questionnaire. From the result, a scree plot (Fig. 6) describes the total variance explained by each component or its eigenvalue against its respective component is generated. The inflexion point of the scree plot indicates the components suitable to be retained. From the visual inspection of the scree plot, it has led to the retention of only 2 components.

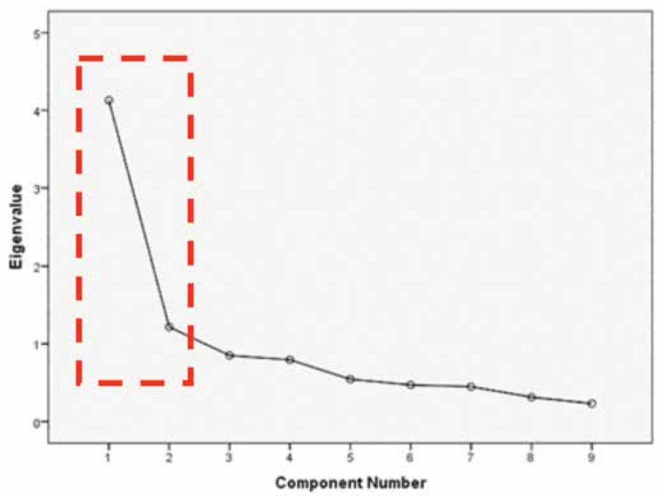

Fig. 6 *A scree plot for the PCA.*

The pattern matrix shown in Table 5 was generated and the number of components to influence the interpretability of the final solution was inspected. It is shown that the architectural detailing components of 'façade detail', 'size', 'height', 'façade component' and 'roof' belong to Component 1, while 'color', 'text', 'shape' and 'orientation' are in Component 2.

Table 5 *Pattern matrix.*

	Components	
	1	*2*
Colour	0.854	
Shape	0.812	
Roof	0.746	
Text	0.733	
Size	0.629	
Orientation		0.858
Height		0.759
Façade component		0.642
Façade detail		0.533

The two components then were justified to be the main components to explain the variances. The interpretation of the data is consistent with the architectural details which the questionnaire was designed to measure, with strong loadings of '**geometric extrusion**' items on Component 1 and '**distinction**' items on Component 2. The component loadings of the rotated solution are presented in Table 6.

Table 6 *The initial components and their component loadings.*

Initial components	*Proposed component loadings*
Façade detailing Façade component Size/ volume Height Roof profile	Geometric extrusion
Color/ texture Text/ signage/ symbol Shape/ form Orientation	Distinction

The subjective decision is proposing that the building forms and characteristics that fall under 'geometric extrusion' are regarded to be components affected by volumetric suppression and extrusion, including active modifications on its surfaces which define a building's form and characteristic. The items fall under 'distinction' are regarded as the components contributing to the enrichment of the forms and characteristics itself, a quality that may be used to distinguish the buildings' semantics even further. These two components are therefore the main units to define the parameter for the taxonomy.

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The factorized components are used as units to define the parameters, as summarized in Table 7. In the table, the units of 'geometric extrusion' and 'distinction' are given dichotomous levels (high and low), as per the intention of this paper to establish a more 'fluid' taxonomy rather than a linear one.

Table 7 *The Parameters of Taxonomy*

Items	*Factorized components*	*Parameters description*
Façade detailing Façade component Size/ volume Height Roof profile	Geometric extrusion	• Low geometric extrusion ○ Low geometric content ○ Prismatic block extrusion. • High geometric extrusion ○ High geometric content ○ Details with profiles
Color/ texture Text/ signage/ symbol Shape/ form Orientation	Distinction	• Low distinction ○ Monochrome ○ Rough information • High distinction ○ Color and texture ○ Granular information

To extend the definition of the predefined taxonomy established earlier, this paper then proposes the parameters to be the strata separator, as illustrated in Fig. 7. The parameters do naturally agree with the extreme ends in the predefined taxonomy. Therefore, to further illustrate this concept can be useful to the real-world application, Fig. 8 illustrates a model of how the parameters overlap.

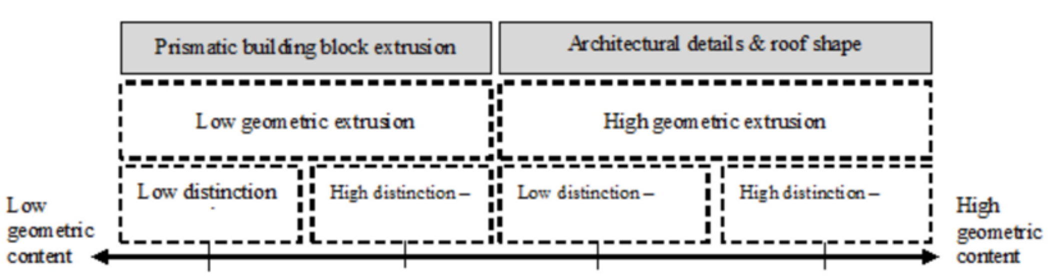


Fig. 7 *The proposed taxonomy for urban scale 3D models in VR.*

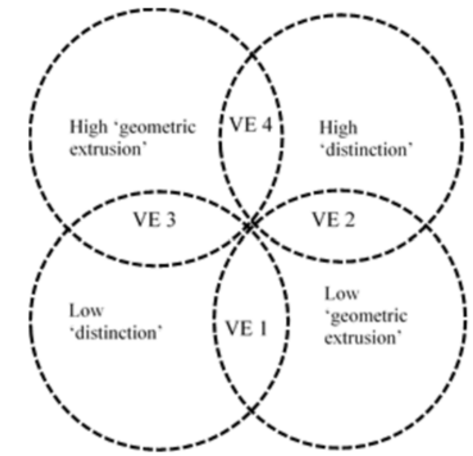
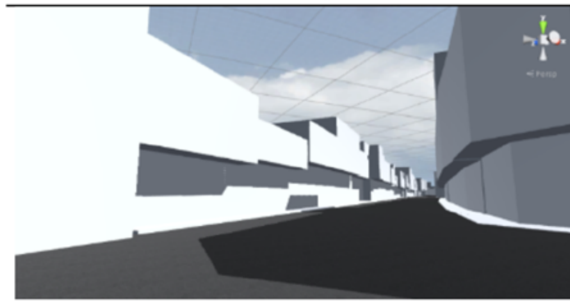
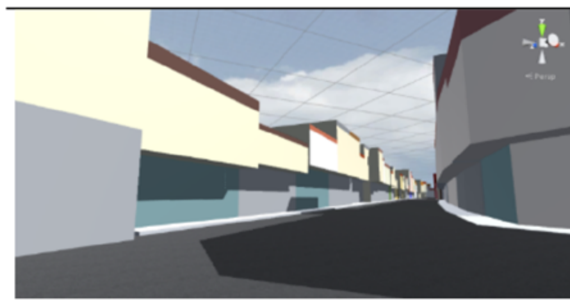


Fig. 8 *VEs prescribed to the components' attributes.*

The model in Fig. 8 illustrates the overlapping of the parameters (low and high) ascribed to the 'geometric extrusion' and 'distinction' components. The dichotomous levels of 2 different components naturally contribute to the birth of 4 different VEs with different LODs due to the overlapping. As 3D modelling pipelines among architects are often performed through user input, there should be no dictating rules in the procedure, instead, the unique way this taxonomy could work is due to its flexibility. An architect may find a specific operational dimension of a VE, which corresponds with the best parameters. VE 1, for instance, may be used for rudimentary assessment of an urban environment. Thus, the architect may produce an urban scale VE with low 'geometric extrusion' and 'low distinction'. The concern of how salient the models should be is still very much depending on the demands of the project, within the already established boundary. This is a flexible yet intuitive approach in conscious and heuristic 3D modelling, rather than blindly producing models with specific LODs simply because it can be achieved. With this, this paper then proposes the taxonomy of building forms and characteristics for urban scale VR 3D models through illustrations in Table 8 exemplifying how the VEs can be built based on the proposed taxonomy.

Table 8 *Examples of VEs that may be derived from the taxonomy.*

Illustration	*Description*
	VE 1 • Low distinction • Low geometric extrusion ○ Low geometry/ polygon. ○ Prismatic block extrusion. ○ Monochrome.
	VE 2 • High distinction • Low geometric extrusion ○ Low geometry/ polygon. ○ Prismatic block extrusion. ○ Colour & textures
	VE 3 • Low distinction • High geometric extrusion ○ High geometry/ polygon. ○ Details with roof shape. ○ Monochrome
	VE 4 • High distinction • High geometric extrusion ○ High geometry/ polygon. ○ Details with roof shape. ○ Colour & textures

Conclusion

Despite there are 4 main VEs that can be regarded as direct derivations from the taxonomy, they are not necessarily confined within the suggested parameters, as compared to in other established taxonomies. In this case, our proposed taxonomy acts more as a basis rather than a rule, which open-endedness would accommodate architects' 3D modelling pipelines. The building forms and characteristics are saturated into the components of 'geometric extrusion' and 'distinction', therefore the taxonomy is more simplified and less restrictive to be used as a basic guide for architects to build 3D models for VR, that is already restricted by the factors of cost, labor and time. Urban scale 3D models should not be pressured to fulfil the capability of new technology and should acknowledge a certain degree of reliance on human judgments. Therefore, our taxonomy would allow architects to be more involved in the modelling process, a gesture of respecting the tradition within the architectural domain that gave birth to the profession itself, which is the art of 'making' of the representations. This would prepare the discipline with unforeseen disruptions that are aggressively challenging the status quo of the profession, especially with the advent of the '4th industrial revolution'.

REFERENCES

Altürk, E. (2008). Architectural representation as a medium of critical agencies. *The Journal of Architecture, 13*(2), 133–152.

Appleyard, D. (1969). Why Buildings are Known: A Predictive Tool for Architects and Planners.

Atkinson, R., & Willis, P. (2009). Transparent cities: Re-shaping the urban experience through interactive video game simulation, (July 2015).

Biljecki, F., Ledoux, H., Stoter, J., & Zhao, J. (2014). Formalisation of the Level of Detail in 3D City Modelling. *Computers, Environment and Urban Systems, 48*, 1–15.

Biljecki, F., Ledoux, F., & Stoter, J. (2016). An Improved LOD Specification for 3D Building Models. Computers, Environment and Urban Systems, 25-37.

Botchway, E., Abanyie, S., & Afram, S. (2015). The Impact of Computer Aided Architectural Design Tools on Architectural Design Education. The Case of KNUST. Journal of Architectural Engineering Technology, 4(2).

Chang, R., Butkiewicz, T., Ziemkiewicz, C., & Wartell, Z. (2008). Legible Simplification of Textured Urban Models. *IEEE Computer Graphics and Applications, 27*–36.

Çöltekin, A., Lokka, I., & Zahner, M. (2016). On the Usibility and Usefulness of 3D (Geo)Visualizations - A Focus on Virtual Reality Environments. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 387-392.

Diao, J., Xu, C., Jia, A., & Liu, Y. (2017). Virtual Reality and Simulation Technology Application in 3D Urban Landscape Environment Design. Boletín Técnico, 72-79.

Gary W. Evans, Catherine Smith, & Kathy Pezdek. (1982). Cognitive Maps and Urban Form. *Journal of American Planning Association, 48*(2), 232–244.

Halley-Prinable, A. (2013). *The Oculus Rift and Immersion through Fear*. Bournemouth University.

Horne, M., Podevyn, M., & Thompson, E. M. (2013). An Overview of Virtual City Modelling: Emerging Organisational Issues. *Journal of Chemical Information and Modeling, 53*(9), 1689–1699.

Hudson-Smith, a. (2007). Digital Urban - The Visual City. *Casa*, (124), 0–14. Retrieved from http://discovery.ucl.ac.uk/15177/

Jamei, E., Mortimer, M., Seyedmahmoudian, M., Horan, B., & Stojcevski, A. (2017). Invesigating the Role of Virtual Reality in Planning for Sustainable Smart Cities. Sustainability, 9.

Kobayashi, Y. (2006). Photogrammetry and 3D City Modeling. *Digital Architecture and Construction, 90*, 209-218.

Leavitt, N. (1999). Online 3D: Still waiting after all these years. *Computer, 21*(7), 4–7. Retrieved from http://search.proquest.com/docview/197397429?accountid=15533

Losciale, L. V., Lombardo, J., & De Luca, L. (2012). New semantic media and 3D architectural models representation. *Proceedings of the 2012 18th International Conference on Virtual Systems and Multimedia, VSMM 2012: Virtual Systems in the Information Society*, 533–536.

Luebke, D., Watson, B., Cohen, J. D., Reddy, M., & Varshney, A. (2002). *Level of Details for 3D Graphics* (1st Editio). New York: Elsevier Science Inc.

Reinhardt, D. (2008). Representation as research: Design Model and Media Rotation. *The Journal of Architecture, 13*(2), 185–201.

Shiode, N. (2001). 3D Urban Models: Recent Developments in the Digital Modeling of Urban Environments in Three-Dimensions. *GeoJournal, 52*(3), 263–269.

Stavrić, M. (2013). The Use of Scale Models in Architecture. In *Architectural Scale Models in the Digital Age* (pp. 41–83). Springer-Verlag/Wien.

Stein, J. (2015, August 6). Inside the Box: The Surprising Joy of Virtual Reality. Time Magazine (pp. 30-39). New York: Time Inc.

Zadeh, F. A., & Sulaiman, a. B. (2010). Dynamic street environment. *Local Environment, 15*(5), 433–452.