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Developing a website for rendering based on renderers' experience

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Abstract
This study aims to formulate a concept for an online rendering website based on renderers' experience on using rendering software (V-Ray, Enscape and Lumion). Rendering software is essential to professionals (architects and 3D visualisers) and students alike. We conduct a survey of students, architects, and 3D visualisers regarding their rendering experience. There are various complaints about rendering: lengthy, costly hardware parts, and hardware incompatibility. We see a solution in providing an online-based rendering service on a website by implementing cloud computing technology. Accordingly, further research needs to uncover other possible solutions to provide the ultimate rendering experience.

Keywords
Rendering software; online rendering; designer

Desarrollar un sitio web de renderizado basado en la experiencia de los renderizadores

Resumen
El objetivo del estudio es formular un concepto para un sitio web renderizado, basado en la experiencia de renderizadores que han usado software como V-Ray, Enscape y lumion. El software es esencial para arquitectos, visualizadores de 3D y estudiantes. Les distribuimos una encuesta sobre sus experiencias, y recibimos quejas sobre lo caro y complejo que resultaban las piezas de los equipos, y también sus incompatibilidades. La solución sería proporcionar un servicio online en un sitio web con la tecnologia de computacion en la nube, pero es necesario investigar más para descubrir soluciones que mejoren la experiencia.

Palabras clave
Software de renderizado; renderizado en línea; diseñador

Introduction

Over the years, various modelling software has emerged to aid both architects and architecture students alike. The software helps users to produce digital working drawings and three-dimensional modelling. 3ds Max, Rhino, Revit, and Sketchup are among the most used 3D architectural modelling software (Pickavance & Turner, 2021)**.** It becomes mandatory for people in the architecture field to use modelling software because of its effectiveness in visually representing their projects (Arisman, 2018). Moreover, visualisations aid clients to understand designers' concepts (Petrasova et al., 2018). It has become a standard of the architecture industry.

Each modelling software provides rendering software. For instance, SketchUp allows V-Ray as a rendering plugin (Skidmore, 2019). Rendering software visualises design results in two-dimensional and three-dimensional images. Working drawings are in two-dimensional pictures—floor plans, views, sections, plans and details. Meanwhile, three-dimensional imagery visualises projects as a whole in perspective images. Three-dimensional rendering is a two-dimensional representation of modelling that implements various textures, colours, and materials to achieve realistic images (Umar et al., 2020). It allows photo-realistic visualisations in imagining both interiors and exteriors (Ratcliffe & Simons, 2017).Visual simulations can induce emotional reactions and influence perceived ambience (Kim et al., 2019). Various industry such as architecture and automotive relies on it (Křivánek et al., 2018). Thus, it is valuable in the industry as a whole.

With technological developments, rendering software has also improved visually and technically since its industry existence in the mid-1980s (Peddie, 2019). Rendering results depend both on modelling and settings of material and lighting to cultivate lifelike pictures. Visually, each rendering software has a different display quality. There is rendering software that displays real-time rendering and non-real-time rendering. Rendering software technically demands compatible computer hardware components such as CPU (Central Processing Unit), VGA (Video Graphic Adapter), and RAM (Random Access Memory) that support the rendering process (Maulana & Kurniawan, 2019). Therefore, users need high-performing hardware specifications to get maximum rendering results in a relatively short time. However, hardware with high specifications requires a high cost to procure.

Meanwhile, users often complain about the lengthy rendering process because their computer hardware does not support it. Rendering requires plenty of computational power (Figure 1), so users with average computer specifications can only do limited tasks while rendering. The process is usually long. Moreover, the software often forcedly shuts itself because it is not responding during the rendering process. In the end, rendering software users do not get the maximum visualised image results. These things are a small part of the complaints rendering users made other than the hardware cost.

A comparison was made with other studies to show this study's validity. Some studies have discussed rendering software in terms of its various elements—rendering speed, scene modelling, hardware requirements, and online rendering development. One research shows that rendering speed depends on the computer hardware specifications (Wood et al., 1996). Meanwhile, another study found that upgrading GPU can optimize rendering results (Xing et al., 2016). Furthermore, dividing the view into several scenes can increase the speed of rendering processes (Tobler, 2011). On the other hand, a study shows the possibility of WebGL usage for the rendering process (Taivalsaari et al., 2017).

This study aims to create an alternative concept for an online rendering website based on the designers' experience, which may help web-based software developer. Utilising a website for rendering does not require high-end hardware specifications. By applying cloud technology to rendering, users will not need to add high-end hardware specifications at relatively high prices to achieve maximum rendering results. Cloud services can operate data-intensive computing (Varghese & Buyya, 2018). Moreover, cloud computing employs internet cloud storage for computing (Santiko et al., 2017). Therefore, designers can facilely utilise the online rendering website and present their architectural tasks.

Existing solutions are available, other than upgrading hardware specifications. A render farm is a service to have professionals render one's projects. Render farms and cloud rendering are not interchangeable. The former has professionals who render the projects (for instance, RenderNow), while the latter has the users themselves who render the project as if they are using a computer program. Chaos Group, the company behind V-Ray, has started offering Chaos Cloud (cloud rendering) as an option. Fox Renderfarm and TurboRender also offer cloud rendering on their websites. Thus, a solution based on cloud computing is possible.

Cloud computing has progressed drastically. We see this feature can solve the problem of rendering

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Name	Status	22% CPU	59% Memory	2% Disk	0% Network	97% GPU	GPU engine	Power usage	Power usage tr...
Apps (2)									
Lumion.exe		20,5%	2.138,7 MB	0 MB/s	0 Mbps	97,1%	GPU 1 - 3D	Very high	Moderate
Task Manager		0,8%	29,4 MB	0 MB/s	0 Mbps	0%		Very low	Very low

Figure 1. Computer status while rendering.

difficulties users usually have. With cloud computing, the rendering process is done online and does not need hardware with high specifications. This alternative allows users to reduce the cost of buying hardware. High hardware specification is not required for the users, as the process depends on the service quality of the website—depending on the server machine that the website uses. The website needs two server machines: receiving commands and facilitating rendering processes. It needs high-performing processing units (CPU and GPU) and large memory (storage and RAM). One needs to have a stable Internet connection because it affects the response time. It may be an issue in places with a slow and unstable Internet connection. However, Internet connection improves as technology evolves. Cloud rendering can be an option for users with moderate computer hardware specifications.

Figure 2. A hand-drawn sketch (Source: Pangarso, 2013).

Study object

Architectural visualisation or presentation has undergone many developments—starting with hand drawings (Figure 2) (Pangarso, 2013) to computer image visualisation (Figure 3, Figure 4, and Figure 5). On the one hand, designers use sketches to construct ideas, and they are implemented in various industry (Bao et al., 2018; Bressa et al., 2019; Mao et al., 2020; Shih et al., 2017). Designers also sketch to emulate broad concepts about their projects (Jiang & Zhang, 2019). Detailed hand drawings done in detail—the industry standard—are usually time-consuming. In contrast, computer visualisations are time-efficient, and they also simplify architectural presentations and visualisation efforts (Ramadhanty & Handayani, 2020). There are various sectors that utilise 3D modelling programs: automotive (Popovski et al., 2020), city planning (Buyuksalih et al., 2017), and healthcare (Birbara et al., 2019). The programs can also model natural objects (Monna et al., 2018) such as rocks (Agrafiotis et al., 2017) and trees (Lau et al., 2018). Thus, 3D modelling software is versatile.

On the other hand, the results of computer visualisation are getting closer to the original design object (Syafril et al., 2020). Thus, an easy rendering application is needed to create and modify models to get the results of architectural visualisation (Aliaga et al., 2007). In architecture design, the term 'rendering' is used to describe the development of drawing quality visually, which make it easier more communicative in presenting the design such as explaining the depth, showing 2D drawing realistically, presenting the quality of material shapes, etc (Mitton, 2004). Rendering is the process of converting 3D models into 2D images (Popovski et al., 2020). Thus, it is widely serviceable to visualise designs as if they are real-life photographs.

Background

Visualisation in architecture

There are many ways to generate digital visualisations. One of them is by using rendering software. Blender, Autodesk Revit, Lumion 3D, V-Ray, and Corona are the most popular ones in the architectural world (ArchitectureLab, 2018). They have distinct advantages, and each software operates in different manners. The difficulty level of each software also varies, and it depends on users' capabilities

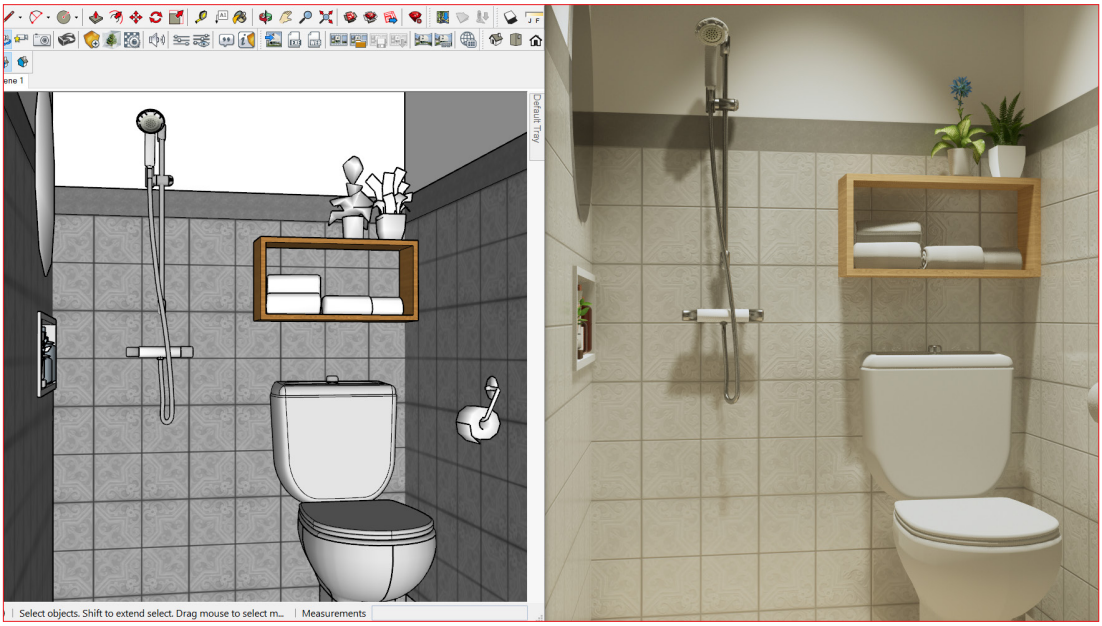

Figure 3. Digital visualisation with Enscape

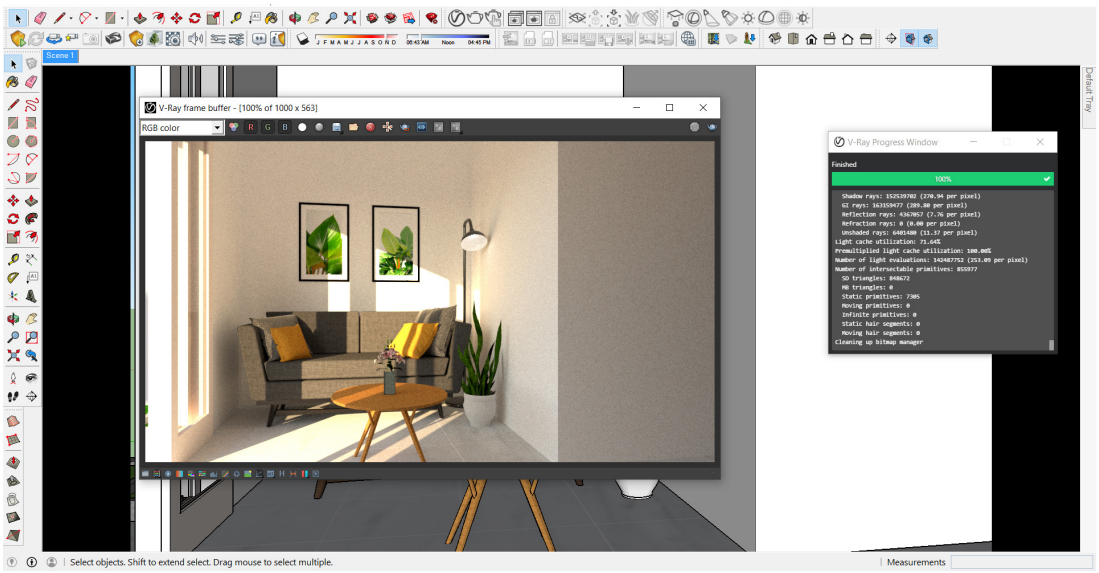

Figure 4. Digital visualisation with V-Ray

and the results required. This research studies how users operate the most frequently used rendering software: Enscape, V-Ray, and Lumion. From investigating difficulties people have, we can generate a solution by identifying patterns in those problems.

Figure 3 exhibits the rendering process using Enscape from modelling in Sketchup. Working as a plugin, Enscape allows users to see the visualisation process in real-time. In effect, users can see the comparison and contrast differences side-by-side.

Figure 4 displays the rendering process in V-Ray of a scene previously made in Sketchup. Like Enscape, V-Ray is also a plugin for various 3D modelling programs. While Enscape uses a real-time rendering system, V-Ray uses a progress window that displays the rendering process. With the feature, users can see the progress in detail.

Figure 5 shows the rendering process in Lumion. As a standalone program, users have to import their modelling to the program. Lumion is powerful

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Figure 5. Digital visualisation with Lumion

for making architectural animation videos. Similar to Enscape and V-Ray, it also displays the rendering process in real-time.

Moreover, there are many ways to visualise a building or area in architecture, either manually or digitally. Visualisations will be beneficial for describing in detail the building or area to be built. So, a designer needs to consider the tools he uses to visualise his design.

Methodology

The research uses mixed-method to explain discussion points. It discusses the specifications of the rendering hardware and software requirements according to the literature review. This research studies the usage of V-Ray, Enscape, and Lumion. They are the most frequently used rendering software in the architecture field. We ask architecture/design students, professional architects, and 3D visualisers for the study to analyse their rendering experience. We hypothesise there may be some difficulties relating to the rendering process and hardware. The analysis results are formulated in provisional findings and ended with a temporary concept formulation as the basis for making website rendering.

Development

We gather 60 respondents from architecture/design students, professional architects, and 3D vis-

Users	Hardware	CPU	GPU	RAM
Architecture or design students	PC	Intel Core i7 7700k	NVIDIA GTX 1060	16 GB
	Laptop	Intel Core i7 8750h	NVIDIA GTX 1050 Ti	16 GB
		Intel Core i5 8250 Li	NVIDIA Geforce 930MX	8 GB
Professional architects	PC	Intel Core i7	NVIDIA GTX 1060	16 GB
	Laptop	Intel Core i7 6th gen	NVIDIA Geforce GTX 860M	8 GB
		Intel Core i3	NVIDIA	4 GB
3D Visualisers	PC	Intel Xeon	NVIDIA RTX 2080 Ti	128 GB
		Intel Xeon	NVIDIA RTX 2080 Ti	64 GB
		Intel Core i7 9700F	NVIDIA Geforce RTX 2060	32 GB

Figure 6. Respondents' specification of hardware

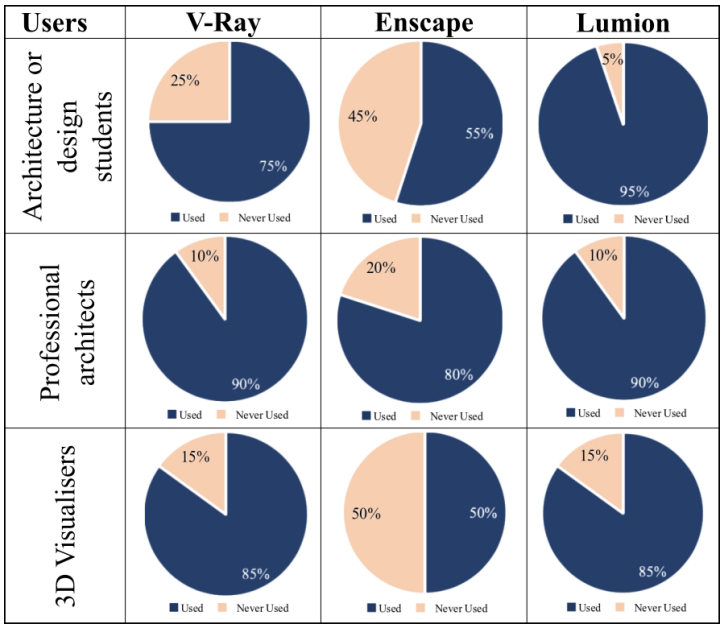

Figure 7. Respondents' software usage

ualisers to answer questions about various topics: rendering software usage levels, experiences in rendering, computer specifications, and final rendering results. We also ask detailed questions to three architecture/design students, three professional architects, and three 3D visualisers regarding their rendering outputs, hardware specifications, and what they expect from rendering software. We then analyse the data from 60 respondents and detailed answers from each chosen respondent. The analysis results are formulated in provisional findings and ended with a temporary concept formulation as the basis for making website rendering.

Results

Hardware usage

Computer hardware is one of the supporting tools for visualizing architectural drawings, including the rendering process. Therefore, its specifications affect the quality of rendering results. Central Processing Unit (CPU), Graphics Processing Unit (GPU), and random-access memory (RAM) are the primary hardware that supports the image and video rendering process. The higher the hardware specification, the better the rendering quality and the faster the rendering process.

The questionnaire results show that students, professional architects, and 3D visualisers use different hardware specifications **(Figure 6).** Architecture/design students and professional architects are more likely to use laptops when they work. Students mostly used laptops (16 respondents), while only four used PCs. They prioritized flexibility in their working space—finishing their projects on their laptops anywhere. Presenting their design to clients is vital for architects, while students for their lecturers. Professional architects used both laptops and PCs (ten respondents each). It depends on their companies because some can work from home with their preferred devices (PCs or laptops). Moreover, consultations with clients are more versatile with laptops (for professional architects), as they can be done outside the architecture firm. In contrast, Personal Computer (PC) is widely used more by 3D visualisers. 3D Visualizers mostly used PCs (12 respondents), while only eight used laptops. They need powerful and high-specification computer hardware to render their projects, whereas professional architects might not critically need to render their projects. Their occupation does not require them to meet clients, and PC offers a flexible option to build customised hardware according to users' needs.

Meanwhile, almost all respondents use Intel Core for their CPU. Although not as fast as Intel Xeon, they are still capable of facilitating the rendering process. CPU is for rendering computations. The number of cores indicates the difference between the product series. For example, the 11th generation Intel Core i3 has up to four cores, i5 up to six cores, and i7 up to eight cores. Intel Xeon has up to 28 cores. Many cores for CPU mean higher clock speed. It guarantees a faster rendering process because it is done simultaneously in different CPU cores. New Intel Core generations allow more power efficiency and higher dynamic power range than their predecessors (Doweck et al., 2017). While students and architects do not require exceptional visualisations, 3D visualisers require to render in detail. Thus, they need a CPU with high specifications. Meanwhile, outstanding performance, not heating up quickly, and the branding of Intel products seems to be a consideration for respondents in choosing these products.

Respondents use various GPU model depending on their background. Rendering with GPU depends on the rendering software requirements. Some software may only use between only CPU or GPU, and some use both. Like CPU, GPU also determines rendering speed by its cores. NVIDIA CUDA® cores are distinct in each product: GTX 1060 has 1280, NVIDIA GTX 1050 Ti has 768, NVIDIA RTX 2080 Ti has 4352, and NVIDIA RTX 2060 has 1920. CUDA® is a platform developed by NVIDIA to facilitate computational graphic processes. The number of cores in GPU also affects

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rendering speed because it can run the process in parallel with each GPU core. 3D visualisers use GPU with high specifications because of the necessity to render in detail.

Meanwhile, RAM size affects the result's quality of the render process done in a stop. RAM saves data from scenes in a complete render process done in a phase: textures, mesh, volume, and other computational data. Consequently, a low RAM specification can barely achieve high-detailed results in a stop, hence the need to render in tandem. From the questionnaire, there are different RAM specifications according to respondents' background. Students use 8–16 GB, while professional architects and 3D visualisers utilise 4–16 GB and 32–128 GB consequently. Different from students and architects, 3D visualisers need RAM high specifications to render in detail.

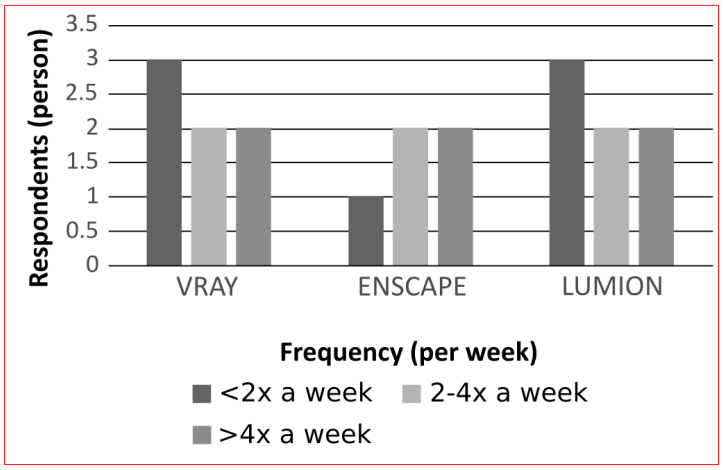

Figure 8. Frequency of using rendering software

The use of 3D rendering software (V-Ray, Enscape, and Lumion)

Based on Figure 7, most respondents have used each rendering software. It seems that professional architects are familiar with using the 3D rendering software: V-Ray, Enscape, and Lumion. V-Ray is the least expensive, starting from USD 59 per month and USD 699 per year. The pricing for Enscape starts from USD 69.90 per month and USD 479 per year. Meanwhile, the perpetual license of Lumion starts from USD 1,581. Enscape is the less popular rendering software for design/architecture students and 3D visualisers, as about 50% of users have never used the software. In contrast, all three groups widely use V-Ray. V-Ray early initial release in 1997—compared to Enscape in 2015—might be one reason for its popularity. Meanwhile, all groups are familiar with Lumion. It is a versatile program to render both animations and images (Hadiyatna & Harapan, 2020), hence the popularity.

The results in Figure 7 may infer users' experience level to software usage. Each group has the highest experience levels according to their use in different software: Lumion and Enscape for students, V-Ray and Enscape for professional architects, and V-Ray and Lumion for 3D visualisers. Ninety-five percent (19 out of 20 respondents) of architecture or design students had used Lumion. Seventy-five percent (15 out of 20) of students had used V-Ray, and fifty-five percent (11 out of 20) had used Enscape. Meanwhile, ninety percent (18 out of 20) had used V-Ray and Lumion. Eighty percent (16 out of 20) of them had used Enscape. Meanwhile, eighty-five percent (17 out of 20) of 3D visualisers had used V-Ray and Lumion. Only fifty percent (10 out of 20) of them had used Enscape. Other reasons such as usage frequency may also affect experience levels.

Figure 8 shows the frequency of using rendering software. The questionnaire answers show a pattern concerning the most used software for each group. While 3D visualisers and architects utilise V-Ray more often, students and architects favour Enscape more frequently. Visualisers and students use Lumion more often. Meanwhile, the intensity of using the software affect the mastery level. According to Dreyfus, there is a five-stage model of adult skill acquisition, i.e. novice, competent, proficient, expert, and master (Dreyfus, 2004). We ask three respondents from each group regarding their rendering software usage frequency and mastery levels. Students' mastery level of using V-Ray and Lumion may fall into novice to the proficient range, but for Enscape may range from beginner to experts as they use the latter more often. Professional architects' proficiency range of utilising V-Ray, Enscape, and Lumion may fall from novice to expert. In contrast, 3D visualisers are the most skilled in using V-Ray, and their mastery level ranges from competent to master. Thus, each group has its strength in implementing various rendering software.

Architectural presentation support

Rendering software supports architectural presentations by visualising models made using 3D modelling software such as Sketchup, 3ds Max, Blender, and many others. The modelled objects may consist of interiors, exteriors, furniture, and landscapes or urban area. Respondents' modelling file size ranges from less than 100 MB to more than 500 MB—depending on how much detail put into the models. Laptops produce 3D models with

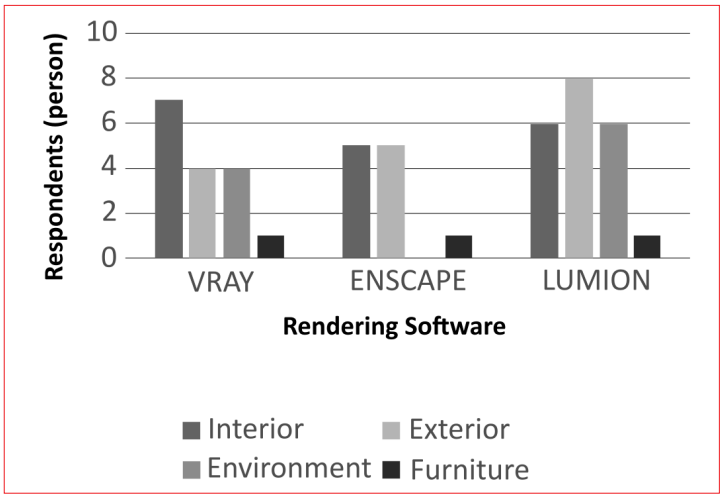

Figure 9. Types of modelling

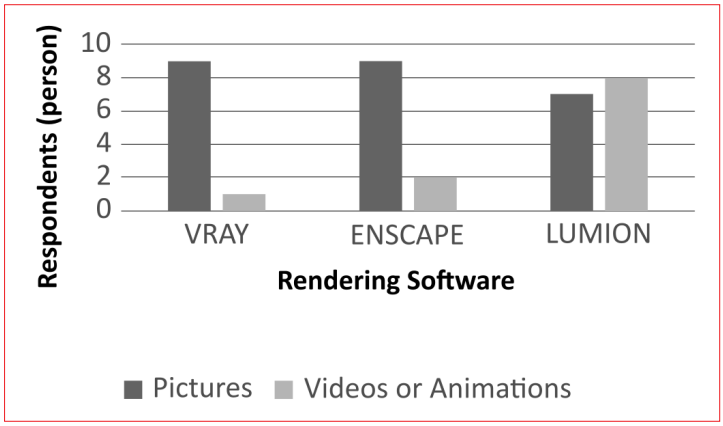

Figure 10. Rendering outputs

Figure 11. Lumion interface

the size up to 500 MB, while models in PC can reach more than 500 MB. Then, users can start the visualisations with rendering software after they finish the 3D modelling.

Based on the survey (Figure 9), respondents use V-Ray most often to visualise interiors. V-Ray provides an extensive rendering configuration—a much-needed feature in rendering interiors where users need a careful approach in designing lighting and scenes as a whole. Meanwhile, respondents utilise Enscape for both interiors and exteriors. As a real-time rendering plugin (Lorenzo & Lorenzo, 2019), Enscape offers a compact feature to generate appropriate visualisations, hence the usage for both interiors and exteriors. Meanwhile, users implement Lumion more for exterior scenes. Able to produce appropriate architectural animations and images (Xiuhong & Yongli, 2019), Lumion is powerful for rendering exteriors because of its extensive library for landscaping. Thus, each software has specific and preferred abilities.

The results of the visualisation can be in the form of images/photos or videos/animations. Users can render image and videos in all the rendering software: V-Ray, Enscape, and Lumion. Meanwhile, respondents have preferred software for rendering outcomes (Figure 10). They mostly use V-Ray and Enscape for images or photos, while Lumion for videos or animations. Thus, the usage is in line with the software's intended use.

Meanwhile, the level of detail of the rendering results depends on the users' need. Generally, students need illustrations and realistic rendering, while architects and 3D visualisers need more realistic rendering. While students only need to showcase their design to lecturers, architects and 3D visualisers need to convince clients by using more realistic visualisations. Therefore, the need for realistic rendering is vital to architects and 3D visualisers.

Online rendering model plan

After gathering results about rendering software usage, we ask respondents about their wishes in an online rendering website. They majorly complain about how arduous the rendering process and the software often needs to be forcedly shut. Rendering results usually do not meet users' satisfaction because their computer hardware does not support the rendering process. The high system requirement for rendering software is an obstacle because it drains the hardware capacity. As a result, users require high-performing and expensive hardware specifications to use rendering software with maximum capability. The survey results also show that the required hardware specifications for rendering software are considerably high. Thus, there are plenty of complaints regarding rendering software usage.

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Figure 12. V-Ray interface

Figure 13. Enscape interface

Based on the survey, here are the features that respondents expect from a website for rendering:

- A friendly appearance: the user interface (UI) is simple (uncomplicated), and the user experience (UX) is easy to understand
- Relatively fast rendering time: it does not take too long to generate images or videos
- Light-weight process (LWP): it does not take up CPU or GPU usage, so users can still multitask while rendering
- Having a large selection of materials and assets: users can access texture images and 3D libraries to support project visualisation
- Access to virtual reality: users can link visualisation results to virtual reality (VR)
- Can match offline results: The results from online rendering are not much different than from existing software
- Real-time rendering: users can see the rendering process directly and quickly

The ease of use and support in architectural presentations are the main concerns of rendering software users. Respondents mention many points regarding an online rendering website—fast rendering speed, light-weight web experience, user-friendly display (UI and UX), real-time monitoring, and diverse collections of materials or assets. UX and UI are especially vital in the creative platform (Kadir et al., 2020). Excellent UI and UX can lead users to prefer the rendering website (Kristiadi et al., 2017). Thus, it is vital to design the website display accordingly.

Lumion is easily recognisable with icons (Figure 11). There are various universal icons associated with music, configurations, editing, and deleting. Each icon only has two colours contrasting each other. Therefore, users do not face much difficulty while using the program.

V-Ray works as a plugin to 3D modelling programs. Figure 12 displays the interface on Sketchup. Like Lumion, V-Ray uses icons with two colours so users can understand the software layout quickly.

Enscape is also a plugin for 3D modelling programs. Figure 13 exhibits the interface on Sketchup. It also has simple symbols like the other two software. From analysing all three rendering programs, we conclude that the rendering website needs easily recognised icons.

Another aspect to consider is a material library. Each rendering program has an industry-specific library (Peddie, 2019). The rendering website also needs the same feature as the existing software, hence the need to have a material or asset library. With an asset library, users can choose materials for achieving satisfying results (Li & Bai, 2020). Lumion has various materials to render indoor and outdoor scenes (Figure 14). Natural materials such as vegetations are also included.

Unlike Lumion, materials in V-Ray are from the models (Figure 15). However, users can edit materials in V-Ray by changing textures or adding reflectance to the materials. Thus, users can control the output quality.

On the other hand, Enscape has an extensive material library (Figure 16). Users can choose furniture from the library. From studying the rendering programs, we conclude the website's asset library needs to be extensive or furnishing indoor and outdoor scenes appropriately.

Other than that, respondents want a feature for virtual reality (VR). With VR, users and clients can feel the design directly as in real life. Rendering software can now visualise 360-degree imagery (Hui et al., 2020); thus, it is beneficial for VR. It is vital to put current technological advancements for the website to compete with existing rendering software.

We asked the respondents regarding the advantages of cloud rendering by giving several options to choose. Figure 17 shows a concept flow chart that combines online rendering objectives based on respondents' answers—fast rendering speed, light-weight rendering experience, excellent user interface (UI) and user experience (UX), real-time monitoring, and diverse collections of materials or assets.

Furthermore, the objectives must be parallel to which users can visually see the rendering progress in real-time (Figure 18). The website needs to have a compelling and practical design, so users can effortlessly operate it. Moreover, an attractive design can attract more users. On the other hand, the website needs cloud storage to

Figure 14. Lumion material library

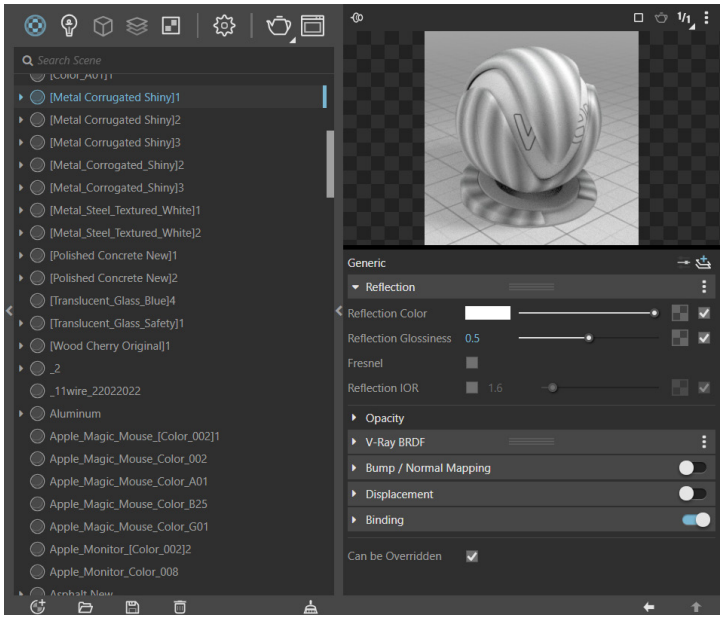

Figure 15. V-Ray material library

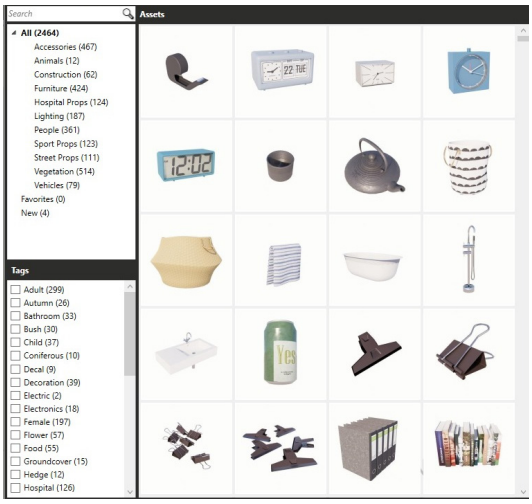

Figure 16. Enscape material library

save and load components quickly, so it lifts the workload of computer hardware to process the rendering. Therefore, the website needs to satisfy users' needs while bringing the best experience by implementing up-to-date technology.

We design the website according to the questionnaire's results (Figure 19). The layout consists of a menu bar, a toolbar, modelling window, modelling submenu, user account menu, rendering window, and rendering submenu.

There are three sections in the menu bar: file, edit, and help. Each part has a drop-down menu. Users can utilise the file menu to create, open, save, and export files. In the edit menu, users can do various editing: undo, redo, cut, copy, paste, delete, select, make group, hide or unhide, and lock or unlock elements in the modelling. The help menu is for viewing tutorials.

The toolbar contains navigation buttons for editing: select, eraser, rotate, move, tape measure tool, text, pan, zoom, asset editor, render, and lighting (sphere, spot, line, rectangular, and IES light). In the user info, users can edit their account in the account settings or sign out. Meanwhile, the modelling window allows users to create, import, edit, and display 3D models before rendering.

The modelling submenu stores a wide variety of textures (2D materials), lighting (sphere, spot, line, rectangular, and IES light), and 3D assets (vegetation, vehicles, people, accessories, etc.).

The rendering window displays the rendering process and results in real-time. The open/close window allows users to open and close the modelling or rendering window.

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The rendering submenu contains helpful tools for adjusting images before rendering. It consists of four sections:

- Rendering: styles and camera settings
- Image: contrast, saturation, colour temperature, and effects
- Atmosphere: illumination, horizons, and clouds
- Capture: output resolution and format

Moreover, users can directly drag and drop 3D models to be rendered. They can also choose files by using the import menu on the drop-down menu. There are various file extensions supported by the website: 3D Studio Mesh (.3ds), Autodesk Collada (.dae), Autodesk (.fbx), Wavefront 3D Object File (.obj), SketchUp (.skp), and AutoCAD (.dxf).

Conclusion

Rendering offers indirect values to graphic design. Finished rendering outputs (pictures and videos) can be material for graphic designers to communicate messages that they want to convey. In summary, the answers from the respondents—architecture/design students, professional architects, and 3D visualisers—concludes the main qualities of reliable rendering software: (1) a user-friendly appearance, (2) relatively fast in the rendering process, (3) light-weight processing or does not drain computer hardware usage, (4) has a large selection of material and assets, and (5) real-time rendering capabilities. Therefore, an online rendering website can be a solution to provide a fast and light rendering experience. It does not require high-end hardware specifications. From the survey, respondents want a rendering website that is easy to operate and supports sophisticated architectural presentations. According to respondents, there are central objectives of an excellent online rendering website: fast rendering speed, light rendering experience, excellent user interface (UI) and user experience (UX), real-time monitoring, and diverse collections of materials or assets. Besides, the objectives must be parallel in which users can visually observe the rendering progress while it occurs. Therefore, the parallel concept—simultaneously shows rendering results in modelling while in progress and provides a quick and light experience through excellent UI/UX—is a suggestion to consider in designing an online rendering website.

Accordingly, further research needs to uncover other possible solutions to provide the ultimate rendering experience. There are various sectors that relies heavily on providing realistic visualisations, and innovations in rendering will accelerate their growth.

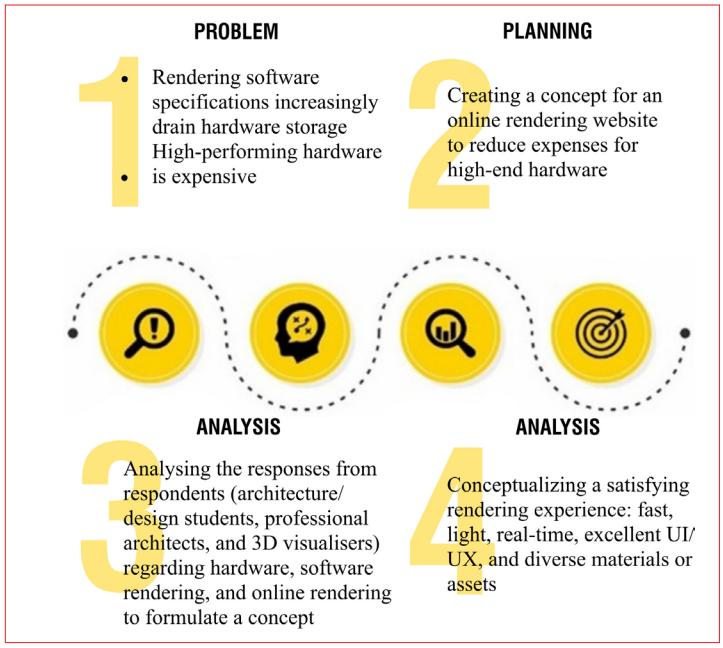

Figure 17. The concept for an online rendering website

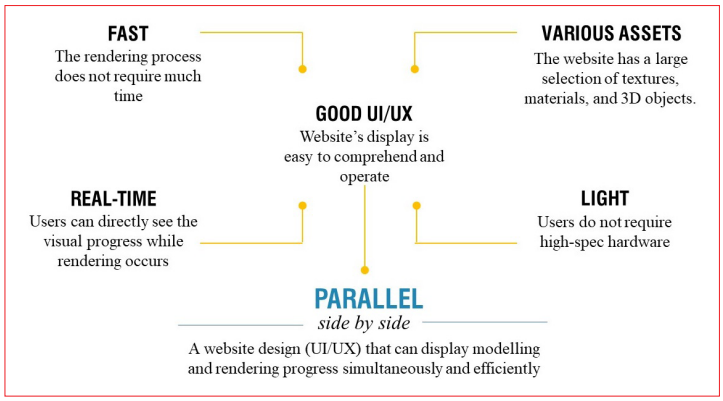

Figure 18. Goals for an online rendering website

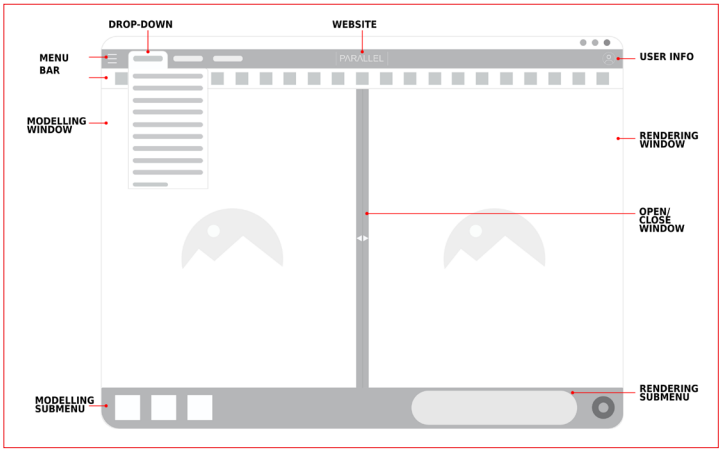

Figure 19. The website layout

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