

CMGT Graduation Report



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Abstract

This research investigates the possibilities available to improve the efficiency of 3D architectural animation created by The Virtual Dutch Men for websites and social media. The primary focus is on reducing current rendering times, as clients frequently request minor iterations.

An interview was conducted with the Lead Designer and 3D Animator, and desk research was performed to explore industry standard and innovative renderers. Among the eight different renderers considered, Chaos Vantage, D5 Render, and Unreal Engine 5 are being studied in greater depth.

Render tests revealed that Unreal Engine 5 is the fastest renderer in terms of rendering speed. However, further investigation through desk research highlighted that Unreal Engine 5 is not particularly user-friendly due to its diverse range of purposes and functionalities.

On the other hand, D5 Render performs well in terms of render times, comparable to those of Unreal Engine 5. However, it does not fully support Xref and Forest, which are integral components of The Virtual Dutch Men's workflow.

Although Chaos Vantage is not the fastest renderer among the three options, it still outperforms V-Ray, which is currently used. Moreover, Chaos Vantage demonstrates compatibility with Xref, Forest, Railclone, and Pulze. Taking into account the data obtained from render tests and the insights gained from desk research, it can be concluded that Chaos Vantage will be the most favorable solution overall, particularly once compatibility with Anima 5 is established.

Keywords: Chaos Vantage, D5 Render, Unreal Engine, render engines, Anima 5

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Introduction

The Company

The Virtual Dutch Men is a 3D architectural visualization company that was established in 1995 under the name Archivision. The company is located in Almelo and employs 18 individuals with varying specialties, including 3D designers, interior designers, traffic managers, and project leaders. The primary focus of the company is creating artist impressions of architectural projects, products, 3D animations, and 360-degree virtual reality (VR) tours.

Problem Definition

In addition to artist impressions, The Virtual Dutch Men also specializes in creating architectural 3D animation for clients to use on their websites and social media platforms for promotional purposes. However, the process of creating and adjusting these animations can be time-consuming because, clients often request small changes to the animation. Therefore, The Virtual Dutch Men is seeking a technical solution to more time efficiently create and implement changes to their architectural 3D animations.

End User

In this research, employees of The Virtual Dutch Men will be considered the end users.

Indicators of success

Technical solutions that reduce the time required to create and adjust a 3D animation without compromising creative freedom are being sought. Any additional technical or non-technical solutions will also be considered as indicators of success.

Research Goals

The main focus of this research will be searching for a technical solution to reduce the rendering time within 3DSMax for the purpose of 3D architectural animation content for social media and websites. The second goal is to make the process of creating animated people and crowd simulations more time efficient.

1. Understanding and working out the difference between the three best renderer options.
2. Research the minimum and maximum required video quality and formats for social media.
3. Identify other possibilities to effectively reduce the time needed to create architectural 3D animation.

Research Question

Main Question

How can the production speed of architectural 3D animations be increased by implementing technical solutions and techniques that are compatible with The Virtual Dutch Men's current pipeline, resulting in a more time-efficient process and cost reduction?

Sub Questions

1. What is the current production process of The Virtual Dutch Men to create architectural 3D animations?
2. What cause the long production time required to create architectural 3D animations and how can this process be more time efficient?
3. What software is currently widely used within the architectural visualization industry and can be used to streamline the architectural 3D animation process?

Methodology

Sub Question 1: *What is the current production process of The Virtual Dutch Men to create architectural 3D animations?*

To gain a comprehensive understanding of The Virtual Dutch Men's animation workflow and pipeline, the first step is to learn the basics of their software. This will involve talking with employees to get an understanding of their current activities.

Secondly, starting with practice assignments in AutoCAD and 3DSMax. These assignments include text and video tutorials created by employees of The Virtual Dutch Men. The terraced house assignment will cover every aspect of their workflow.

Qualitative data will be collected through working with the software, asking questions to employees, and conducting desk research on the internet.

Sub Question 2: *What are the causes of the long production time required to create architectural 3D animations?*

To gather the necessary information to answer this research question, an interview will be conducted with the studio director/lead designer/3D animator, because he is the only employee on location creating 3D animations. Prior to the interview, a list of specific questions about the 3D animation production process was created. The answers to these questions about the current animation workflow will provide the required qualitative data to analyze and understand the problem (see Appendix A).

Sub Question 3: *What software is currently widely used within the architectural visualization industry and what new software can be a potential solution to streamline the architectural 3D animation process?*

To gather data on the currently widely used architectural visualization software, desk research will be conducted. Qualitative data will be obtained from forums, community pages, and articles on the internet, and quantitative data from online research articles and surveys. Those data will provide a proper indication of the software commonly used in the architectural visualization industry.

Render Test Plan of Approach

Chaos Vantage, D5 Render, and Unreal Engine 5 are GPU-based renderers, while V-Ray is a render engine that utilizes both CPU and GPU. To ensure accurate data, each render test will use the same render settings (*Table 1: Basic Render Settings Used*). Render tests will be performed on a single workstation (*Table 2: Specifications of Render Workstation*). Three different scenarios will be tested: still images, a 10-second camera animation, and a 10-second camera animation featuring animated human characters.

Regarding image quality, a resolution of 4K has been selected because it is the minimum quality at which TVDM currently renders. The video quality was set to 1920x1080 at 30fps, which is the maximum resolution and fps available on social media platforms.

These three scenarios will be tested in a 3DSMax scene created using the TVDM workflow. Data from the test scene will be extrapolated to a larger-scale scene.

Table 1: Basic render settings used

Image Output	.PNG
Quality	4K (3840 x 2160)
Video Output	.PNG Sequence
Quality	Full HD (1920x1080)
Frame Rate	30 FPS
Video Duration	10 seconds (300 frames)

Table 2: Specifications of the used workstation

Graphics Processing Unit	NVIDIA GeForce RTX 3060
Central Processing Unit	Intel® Core™ i7-8700K CPU @ 3.70GHz
RAM	4x 8GB 3200MHz
Motherboard	Gigabyte Z370M D3H-CF
Operating System	Microsoft Windows 10 Pro

The gathered data will be presented in bar charts. The V-Ray data represent the current render times on a single workstation with the render settings used by The Virtual Dutch Men. These data will be included in the chart to facilitate a comparison between the current single workstation situation and potential new renderers.

Scope

Deliverables

This research project will present a report that highlights the positive and negative differences between the currently used V-Ray renderer and multiple other 3DSMax compatible render engines. In addition, data obtained from multiple render tests conducted using different renderers will be presented in the graphical format to determine the best solution. Finally, a conclusion and recommendation for the best render engine solution specifically for The Virtual Dutch Men will be provided.

Inclusions/Exclusions

The scope of this research project includes an investigation of real-time render engines compatible with 3DSMax. Based on desk research, three render engines with the highest potential will be selected for more detailed analysis, specifically in the context of their application to architectural 3D animation within The Virtual Dutch Men's workflow.

Excluded from the test results are animations including Anima 5 within Chaos Vantage, as these two companies are currently working on a collaboration, but their compatibility is not yet established.

Assumptions

It is assumed that one of the render engines listed under "Technological Advancements and Innovation" will be the most efficient alternative in terms of time. In addition to being new render engines, they offer features that enhance the 3D animation process. Another assumption is that the identified solution will not only be used for rendering architectural 3D animations for websites and social media but also become the default render engine for the company.

Constraints

The project may be constrained by a limited budget available to invest in a render engine, as most render engines are based on monthly or annual subscriptions. Furthermore, it is essential that the selected render engine is compatible with 3DSMax.

Resource Allocation

Access to the software used in The Virtual Dutch Men's current pipeline is required for research and analysis purposes. Personnel allocation may be necessary to obtain additional information about their workflow. Finally, access to the render engines that require analysis and testing is essential to draw a proper conclusion.

Preliminary Investigation

Before embarking on research for solutions, it is crucial to analyze and comprehend the current workflow and pipeline involved in the production of an architectural 3D animation project. This will facilitate the identification of existing flaws that can be improved upon and research for specific solutions.

Summarization interview with the studio director

An interview has been conducted with the studio director and lead designer. The goal of this conversation was to gather information about the current approach in creating architectural 3D animations, the software being used, their clients, and to understand the issues they are facing (see Appendix A).

If the client does not provide a 3D model that can be directly used in 3DSMax, The Virtual Dutch Men will use the *HuizenGUI to recreate the desired building based on the drawings from the architect. The situation is the environment around the building, such as streets, sidewalks, grass, flowers, 3D people, cars, and so on. Once the client is completely satisfied with the result, The Virtual Dutch Men begin creating the architectural 3D animation by animating camera movements in 3DSMax to create different shots. Anima 5 is a software package that is used often by TVDM employees to quickly animate groups of people or individuals and import them back into 3DSMax. Chaos V-Ray is the render engine used for 3DSMax rendering.

Based on this conversation, rendering is the most time-consuming factor while creating 3D animation. Since clients often require several iterations, everything must be rendered multiple times, particularly when they request 4K quality. Therefore, the primary focus of this research will be to explore multiple technical solutions for reducing the render time.

Client Meeting

The employees of The Virtual Dutch Men who are involved in the project have a meeting with the client to discuss the desired product and the process to achieve it.

****In the official report the workflow of The Virtual Dutch Men is explained.
However, they prefer to not publish it online****

Researching Phase

During the research phase, multiple rendering engines will be explored, initially in a preliminary manner. With the fundamental information gathered, three of the most innovative renderers with the highest potential will be further investigated in detail.

The focus will be on examining the user interfaces of these renderers. Considering the time constraints often faced by companies, it is crucial that the user interface is not overly complex. Additionally, this analysis will reveal any useful features or missing elements that may be beneficial in the workflow.

Industry used, 3DSMax compatible, render engines

At The Virtual Dutch Men, 3DSMax is the 3D software used to create architectural artistic impressions and 3D animation. Therefore, the following render engine research will be specifically focused on the 3DSMax ecosystem.

According to the results of an architectural visualization rendering engine survey conducted by *CGarchitect, Chaos Group's V-Ray and Corona Renderer are the most commonly used render engines in architectural visualization. The data was collected from 2500 responses between August 14th and December 16th, 2021 from CGarchitect users and Facebook groups associated with real-time render engines and architectural visualization (*New CGarchitect Rendering Survey Shows Trends in Arch Viz | CG Channel, 2022*). While these results are from 2021 and may be slightly outdated, they still provide a good indication.

Table 3 : CGArchitect Rendering Survey in Architectural Visualization results

	2021	2020	2019	2018
V-Ray	60.6% (-4.3%)	64.9% (+6.0%)	58.9% (-4.5%)	63.4% (+1.0%)
Corona Renderer	37.2% (+2.2%)	35.0% (+3.7%)	31.3% (+0.9%)	30.4% (+11.3%)
Lumion	24.9% (-0.2%)	25.1% (-3.7%)	28.8% (+15.1%)	13.7% (+4.8%)
Unreal Engine	22.5% (+2.9%)	19.6% (+3.2%)	16.4% (-4.5%)	20.9% (+10.4%)
Twinmotion	19.2% (+5.1%)	14.1% (+9.9%)	4.2% (+0.9%)	3.3% (+1.5%)
Enscape	12.4% (+2.2%)	10.2% (+5.3%)	4.9% (+1.3%)	3.6% (+2.8%)
3ds Max Interactive	7.4% (-1.0%)	8.4% (-2.9%)	11.3% (+2.6%)	8.7% (+8.0%)
Cycles	6.9% (+1.0%)	5.9% (+2.0%)	3.9% (-0.2%)	4.1% (+0.6%)
D5 Render	5.0% (+3.5%)	1.5% (+1.5%)	0.0% (+0.0%)	0.0% (+0.0%)
Eevee	4.9% (+0.4%)	4.5% (+4.5%)	0.0% (+0.0%)	0.0% (+0.0%)
<i>Results in red show a fall in usage</i>		<i>Results in green show a rise in usage</i>		

The results indicate that despite a decrease of -4.3%, Chaos V-Ray remains the most widely used render engine in architectural visualization, followed by Corona Renderer at 37.2%. Additionally, the survey reveals that Unreal Engine 5 has reached a new peak since 2018 with a 22.5% market share.

While industry stalwart Cinema 4D and the new real-time renderer Chaos Vantage are not among the top ten render engines in the survey, they still hold 4% of the total market share, with Chaos Vantage climbing ten places (CGArchitect Digital Media Corporation, 2022).

V-Ray



Currently, The Virtual Dutch Men use V-Ray to render their final images. The Chaos Group developed this render engine in 1997. One advantage of V-Ray is the possibility to render using both GPU and CPU, resulting in faster rendering times. Post-processing effects are also available to make renders look more like real-world photographs.

Corona Renderer



Corona Renderer is developed by the same company as V-Ray and is designed to be easier to use than both V-Ray and Arnold. It is also less expensive than many of its competitors, making it a popular choice for architectural visualization. However, there are some disadvantages to use this renderer. While its simplicity can be an advantage, it may not be suitable for those who already use more advanced render engines. Additionally, Corona has a lack of flexibility due to a limited set of features. Another limitation is that it only supports CPU rendering (*Denham, 2019*).

Lumion



Lumion is software specifically developed for architectural visualization, designed to render images, videos, and 360° panoramas. It is compatible with almost every 3D and CAD program, and the LiveSync plugin provides a real-time rendering feature. A subscription includes access to Lumion's content and material library (*Lumion, n. d.*).

Twinmotion



Twinmotion is a renderer developed by Epic Games. By exporting your 3DSMax scenes as Datasmith files, one can import them into Twinmotion. According to the Twinmotion website, this renderer is only the beginning. Using Epic Games' Unreal Engine 5 would be an advanced option. Nevertheless, Twinmotion offers real-time environments, high-quality assets, and helpful sharing tools (*An Overview of Twinmotion Features and Capabilities, n. d.*).

Enscape



Enscape provides high-quality batch exports in 360° panorama, video, exe-file, or web-standalone formats. Users can change the scenery inside Enscape using the environment settings and Enscape library. The client chat feature allows clients to provide feedback (*Discover All Enscape Features Online | Enscape Netherlands, n. d.*).

Technological advancements and innovation

Chaos Vantage



At the end of 2020, Chaos Group released Chaos Vantage, a real-time engine that requires minimal effort to set up. Existing V-Ray users can simply drag and drop their scenes into Vantage. The ray-tracing technology uses the materials and lights you set up in your scene in real time.

However, not everyone will be able to use Vantage immediately because, it requires an Nvidia RTX graphics card. Since this is not a plugin but rather a separate software, it offers additional features besides rendering. Quickly animating camera movements can come in handy when creating iterations or pre-visualizations (*REVIEW: Chaos Vantage, n. d.*).

D5 Render



As with Vantage, D5 Render is also a real-time ray-tracing renderer designed specifically for architecture, interior design, landscaping, and CGI. This GPU render engine is based on Unreal Engine 5 and Nvidia RTX technologies. Subscribing to D5 Render also provides access to a regularly updated asset library.

Unreal Engine 5



Like Twinmotion, Unreal Engine 5 is also developed by Epic Games. Initially developed as a game engine in 1996, it is now widely used in the film and gaming industries. Although not as widely adopted within the architectural industry, it does provide the necessary functionalities.

Most used render engines conclusion

Chaos V-Ray remains the most widely used rendering engine in the architectural visualization industry, followed by Corona Renderer and Lumion, according to CGarchitect's survey. Vantage and D5 Render were released in 2020 and 2021, respectively, and thus represent newer entries in the market. While they have not yet gained as much traction, they offer advanced and innovative features.

This study will shift its focus to Chaos Vantage, D5 Render, and Unreal Engine 5 to provide a more detailed analysis of their capabilities and potential solutions.

Chaos Vantage

Live link

The live link feature in Chaos Vantage provides users with a real-time ray tracer view of their scene, allowing any changes made in 3DSMax to be instantly reflected in Chaos Vantage.

Upon installation of Chaos Vantage, the live link toolbar will automatically appear in the 3DSMax user interface (see Figure 13: Chaos Vantage toolbar in 3DSMax).



Figure 13: Chaos Vantage toolbar in 3DSMax



Start a live link between 3DSMax and Chaos Vantage



Send the current 3DSMax scene as a static .vrscene to Chaos Vantage



Import changes from Chaos Vantage to 3DSMax



Render animation with Chaos Vantage

Live Link requires V-Ray GPU 5 or newer as the current rendering engine before starting linking. In a matter of seconds, a 3DSMax scene of 12 million poly's is imported to Chaos Vantage.

User Interface

The UI exists of a toolbar at the top of the screen. Furthermore, six tabs with different options.

Camera

In this tab, users can adjust the speed and height of the camera while navigating through the scene. Additionally, they can modify the resolution and field of view of the viewport.

Another feature is the ability to add depth of field, which allows blurring of objects in the foreground or background. The automatic vertical tilt correction ensures that vertical lines remain vertical.

Camera clipping is also available to restore visibility of objects that are either too far away or too close to the camera. Lastly, users have the option to add new cameras to create different shots (*Figure 14: Chaos Vantage camera tab*).

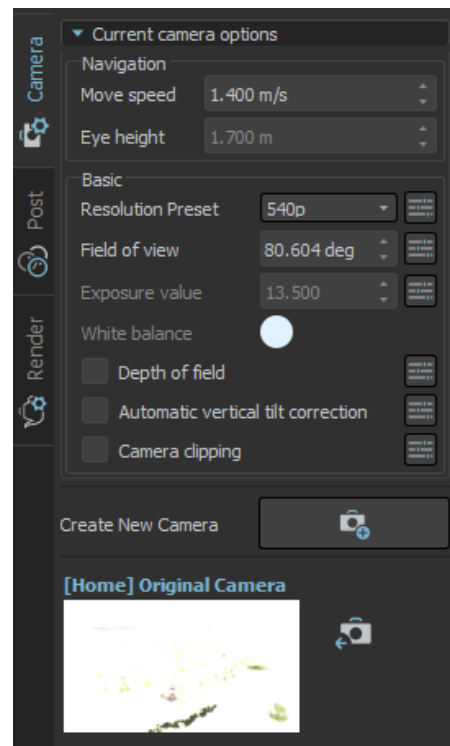


Figure 14: Chaos Vantage camera tab

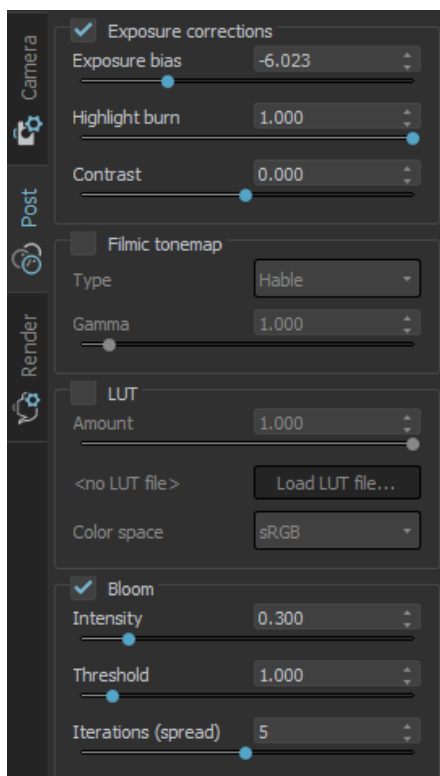


Figure 15: Chaos Vantage post tab

Post

The post tab is used to make adjustments to lighting and color correction. Exposure bias and highlight burn can be used to increase or decrease the light intensity in the scene. If the colors appear flat one can slightly increase the contrast.

A filmic tonemap provides more advanced options for fine-tuning the lighting in the scene. LUT (Lookup Table) is a color correction file that functions as a filter on top of the scene, allowing for adjustments to make it appear warmer or colder, for example.

Bloom is a glow effect that simulates light passing through windows or lamps (*Figure 15: Chaos Vantage post tab*).

Render

The render tab provides users with options to adjust the reflections within the scene. Global illumination, reflections, and refractions can be tweaked to control the overall reflection effects. The other sliders and checkboxes are used to enable or disable the rendering of specific texture maps.

The advanced tab offers users more specific settings that build upon the aforementioned settings (*Figure 16: Chaos Vantage render tab*).

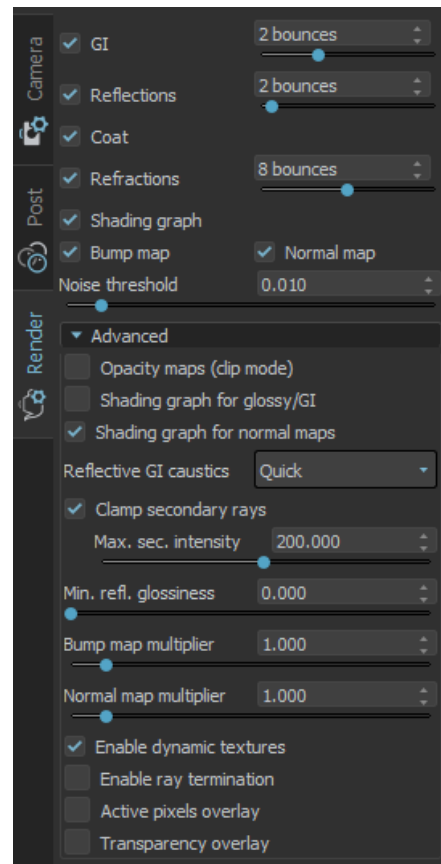


Figure 16: Chaos Vantage render tab

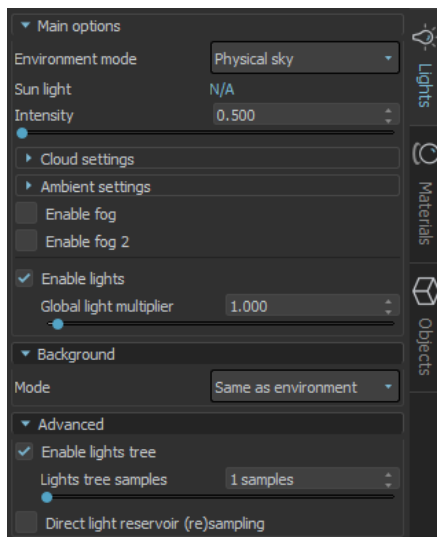


Figure 17: Chaos Vantage lights tab

Lights

The lights tab provides options for adjusting the lighting within the scene. The environment can be changed to a physical sky, clouds and their shadows can be added and adjusted.

Additionally, an image can be used as the background. Near and distance fog settings can also be added and tweaked to achieve the desired result (*Figure 17: Chaos Vantage lights tab*).

Chaos Cosmos Browser

The Cosmos Browser is an online asset library provided by Chaos. It includes a wide range of 3D models, such as furniture, accessories, lighting, vegetation, vehicles, and people.

Additionally, it offers 22 different material types that can be directly used in Vantage. The library also provides various day, evening, and studio HDRIs that can be added to the scene.

Moreover, themed asset collections are available, including festive season, Asian, and Scandinavian styles.

Lastly, the library includes assets from other 3D model companies. These features are inaccessible when using Live Link, and the 3DSMax scene needs to be exported to Chaos Vantage using the designated blue button mentioned in the Live Link section (*Figure 18: Chaos Cosmos Browser*).

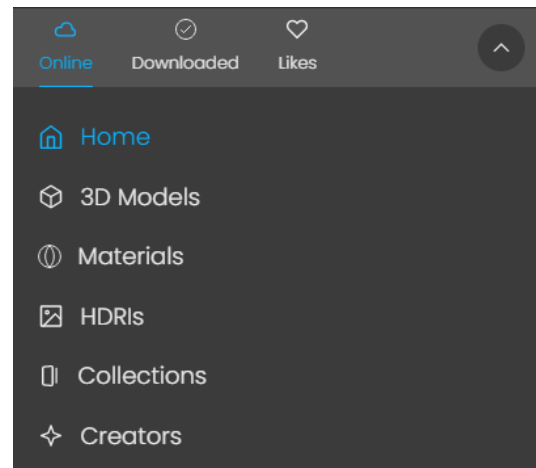


Figure 18: Chaos Cosmos Browser

From the Cosmos Browser, users can select 3D assets of people and drag them into the scene within Chaos Vantage. Once added to the scene, the 3D humanoid model can be rotated, scaled, and positioned as desired (*Figure 19: 3D humanoid model from the Chaos Cosmos Browser added in the scene*).



Figure 19: 3D humanoid from the Chaos Cosmos Browser added in the scene

Animating

Camera

Chaos has simplified the process of animating cameras in Chaos Vantage. Users can easily add two new cameras and position them at the start and end of the desired animation sequence. If necessary, additional cameras can be added in between to specify the movement of the shot (*Figure 20: Chaos Vantage with multiple cameras*).

In the timeline located at the bottom of the screen, users can drag and drop the cameras. Each camera in the timeline is indicated by an orange vertical line. When right-clicking on the timeline, users can adjust the duration of the animation and modify the transition settings, such as changing from a linear transition to ease in and/or out (*Figure 21: Chaos Vantage transition settings*).



Figure 20: Chaos Vantage multiple cameras

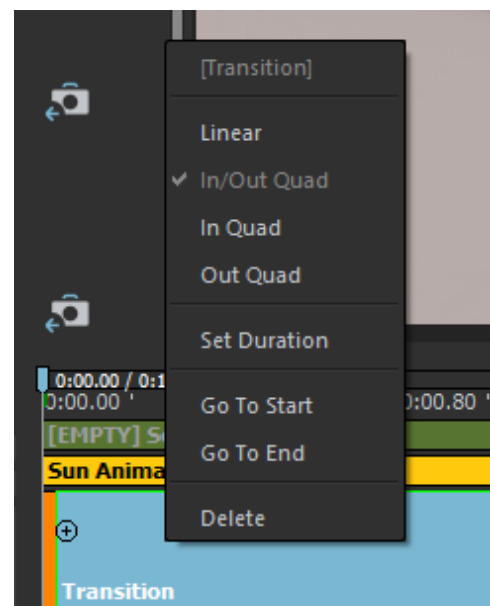


Figure 21: Chaos Vantage transition settings

Sun

To animate the sun in Chaos Vantage, the 3DSMax scene must be exported to the software. Similarly, when using the Chaos Cosmos Browser, this export is required. Once in Chaos Vantage, users can select the option 'Animated Geolocation', which allows them to specify a specific location on Earth as well as a specific time and date. It is essential to set this information for both the start and end keyframes to create a smooth transition of sunlight throughout the animation (*Figure 22: Chaos Vantage sun position mode*).

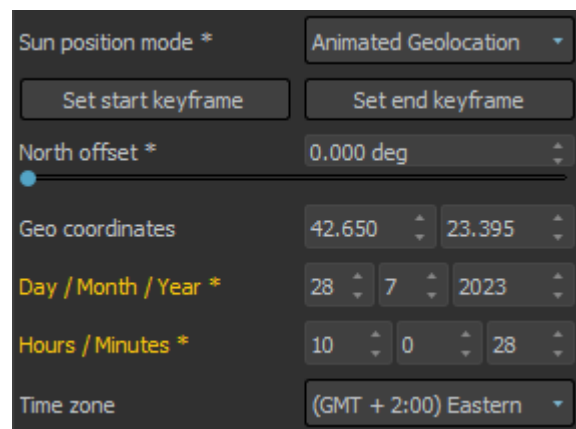


Figure 22: Chaos Vantage sun position mode

Chaos Vantage Conclusion

The Chaos Vantage Live Link feature is effective once the connection is established. The option to adjust the viewport quality allows viewing the render in 1440p for detailed analysis or smooth navigating in 540p. Consequently, the need for test renders is eliminated.

However, there were occasional issues when importing the test scene from 3DSMax to Chaos Vantage using a Live Link. In some instances, the roof of the building remained invisible (*Figure 23: Missing roof in Chaos Vantage*). Fortunately, disconnecting the Live Link and retrying the process resolved the problem.



Figure 23: Missing roof in Chaos Vantage

The *UI of Vantage offers various options, particularly in terms of lighting and post adjustments. This can save time in post-production work using software such as Photoshop.

The Cosmos library provides a diverse selection of assets that can be used to enhance the scene if anything was omitted during the previous stages of the process. However, it is worth noting that the loading and importing of assets in the Cosmos library can be slow.

Additionally, it is unfortunate that none of the assets in the library are animated. The Cosmos library is primarily designed for adding static 3D humans and cannot be used for creating animated characters. As of March 2023, animated models from Anima 5 cannot be used in Chaos Vantage.

However, Chaos is actively working with Anima 5 to address this issue and find a solution (Anima People - Chaos Forums, n. d.). Despite this limitation, Chaos Vantage shows great potential and can be a valuable tool in the future. The inability to use animated Anima 5 models in Vantage is a drawback that could have been mitigated if the Cosmos Library included animated models.

D5 Render

D5 Render can be installed for free. This free option has some limitations in terms of assets available from their library.

D5 Converter

The D5 Converter functions similar to Chaos Vantage Live Link.

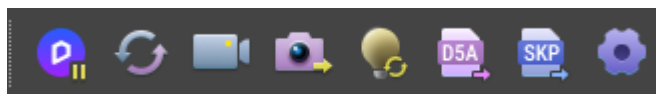










Figure 24: D5 Render toolbar in 3DSMax

However, to use the D5 Converter, additional software needs to be downloaded from their website. Once installed, an additional toolbar will appear in the 3DSMax user interface to facilitate the usage of the D5 Converter.

- | | |
|--|--|
|  Start a live connection between 3DSMax and D5 Render |  Send the lights from the 3DSMax scene to D5 Render |
|  Synchronize 3DSMax scene with D5 Render |  Export 3DSMax scene as .d5a file |
|  Switch view in D5 Render |  Export 3DSMax scene as .skp file |
|  Send a 3DSMax scene to D5 Render |  Opens the settings menu |

User Interface

Camera

New cameras can be added to the scene list in the top left corner by creating a new scene. These cameras can be controlled in either the orbit or fly mode. In orbit mode, the camera movement is controlled using combinations of ctrl, shift, alt, and mouse interactions. Fly mode, on the other hand, is controlled using keyboard inputs. To navigate 'W', 'A', 'S', and 'D' keys can be used for movement, while 'Q' and 'E' keys are used for vertical movement.

Additionally, D5 Render provides settings for the field of view, focal length, and clipping plane. The depth of field feature can be enabled, and the point of focus can be set using the set focus tool (Figure 25: D5 Render exposure settings). Furthermore, at the bottom of this menu, multiple default camera angles are available for selection.

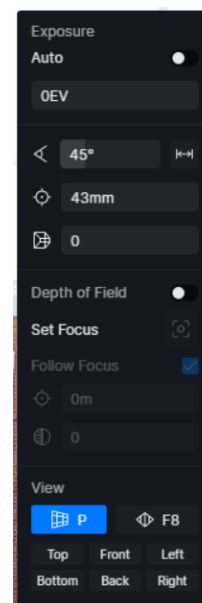
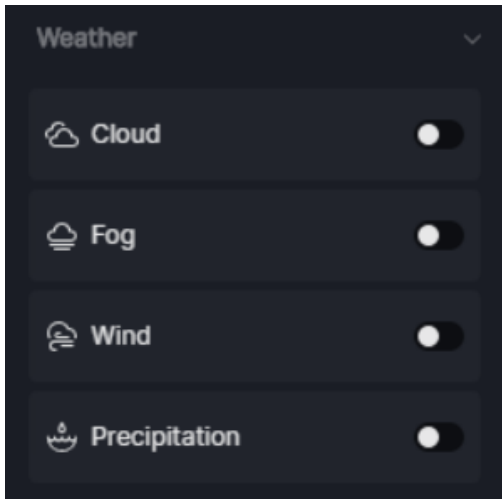


Figure 25: D5 Render exposure settings



Weather System

The weather in D5 Render can be customized to match specific requirements. Various parameters such as the number of clouds, their thickness, density, height, and movement speed offer control over creating different weather scenarios. Fog settings allow for adjustments in color, height, density and starting distance, enabling the creation of atmospheric effects.

Wind strength and direction can be modified to affect the movement of trees, bushes, and plants, adding realism to the scene. The precipitation settings enable the addition of rain or snow with adjustable strength.

Figure 26: D5 Render weather settings

Based on the set strength, D5 Render automatically generates falling raindrops or snowflakes, water puddles, and a layer of snow on surfaces (Figure 27: D5 Render snow and rain comparison).



Figure 27: D5 Render snow and rain comparison

Skylight

In the lighting tab of D5 Render, the skylight can be adjusted based on the time of day, geographical location, and sunlight intensity. This allows for realistic lighting conditions that align with specific settings. Additionally, users have the option to choose a default HDRI (High Dynamic Range Image) from D5 Render library and adjust its light intensity and rotation to suit their needs. Alternatively, they can use a local HDRI image for more customized lighting effects.

Post-processing

The effect tab includes default post-processing sliders, including exposure, contrast, highlight, shadow, slope, white balance, bloom and lens flare.

D5 Asset Library

The asset library from the D5 render can be divided into three parts.

- **Models**
With a collection of over 9,000 models, the D5 Render library provides users with a wide range of options including interior elements, exterior objects, characters, and animals. These models can be used to enhance and populate scenes in D5 Render.

It is worth noting that while there is a substantial selection of models available in the library, access to the full range of models requires the purchase of the pro version of D5 Render. This version unlocks the complete library, providing users with unrestricted access to all available models for their projects (Figure 28: D5 Render model library).

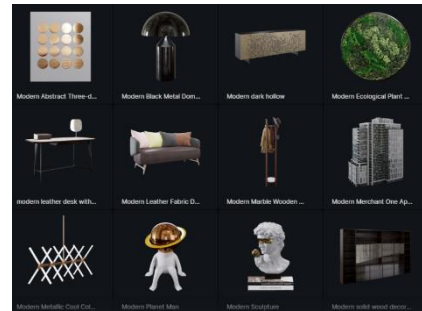


Figure 28: D5 Render model library

- **Materials**
When a material is selected, users have the option to use the eye dropper tool to quickly modify the material of a specific surface. D5 Render automatically attempts to adjust the texture size to fit the face. However, if necessary, users can manually alter the texture sizes to their desired specifications.



Figure 29: D5 Render material

- **Particles**
73 different particle effects can be added from the particle menu, ranging from water, fire, fluid, smoke, to falling leaves (Figure 30: D5 Render particle library).

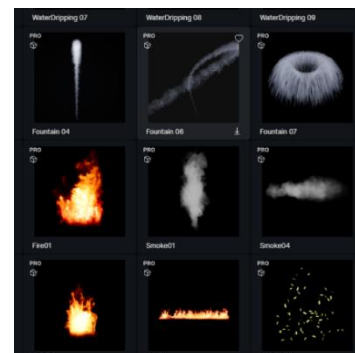


Figure 30: D5 Render particle library

Animating

Camera

By adding two new cameras to the scene, a basic camera animation can be created. The first camera will define the starting position of the animation, and the second camera will define the end position. Additional cameras can be added to specify the path that the camera should follow.

Clicking on the camera icon in the top right corner opens a new window. The cameras created in the scene list need to be added to the animation timeline. The duration of the entire animation can be set between the two cameras in the animation timeline. If desired, an ease-in and ease-out effect can be applied.

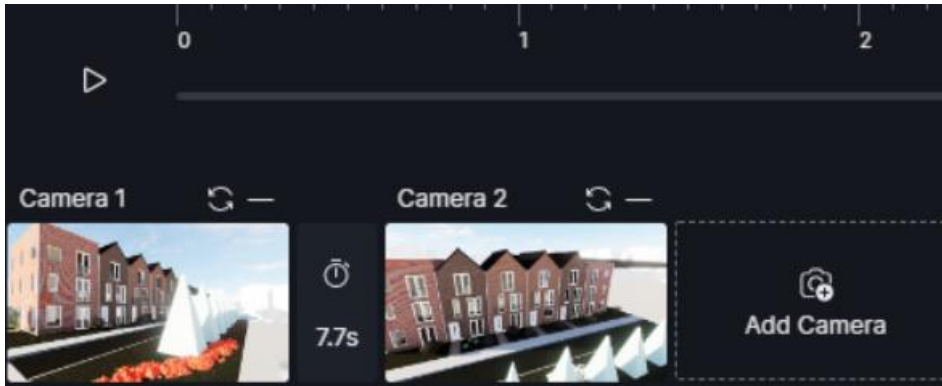


Figure 31: Camera usage in D5 Render

Objects

In the following example, a car model from D5 Render has been added to the scene. The wheels of the car automatically rotate based on the keyframe speed when dynamic and rate matching are turned on. The rate matching switch can be activated to synchronize the model's own movement rate, such as the character's step rate or wheel speed, with the keyframe movement rate.

When the car is selected in the animation window, keyframes can be added by clicking on the 'Add Keyframe' button located in the top right corner. A keyframe on the animation timeline is represented by a blue diamond shape.

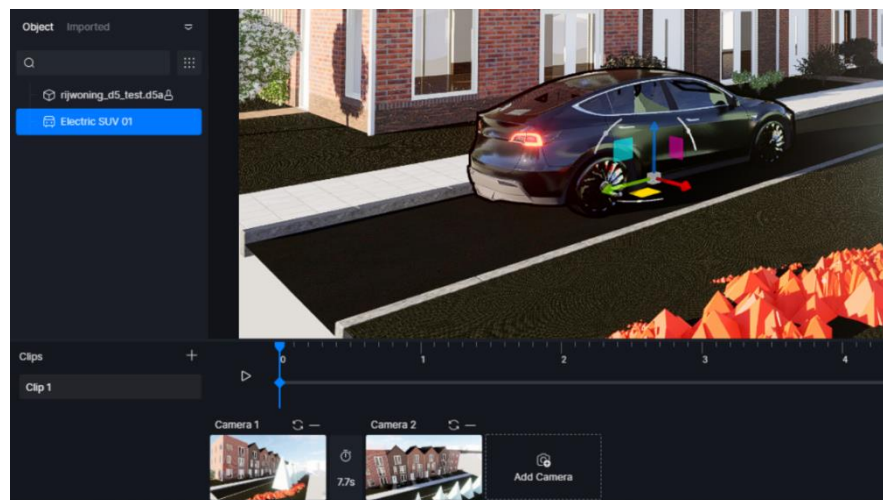


Figure 32: Animating object in D5 Render

Characters

D5 Render cooperates with Anima 5 by adding their characters to the D5 Render Assets. From the D5 Render Assets, characters can be dragged into the viewport. The icon in the top left indicates if the model is animated (*Figure 33: Dynamic Anima 5 model in D5 Render*).

One can choose from 1000 characters with different poses, ages, clothing styles, static, animated, and activity.

Selecting the model will enable extra settings to adjust the speed and rewind the animation.

Models concerning walking have on the spot movement. To make the model actually moving forward in the scene, it needs to be keyframed.

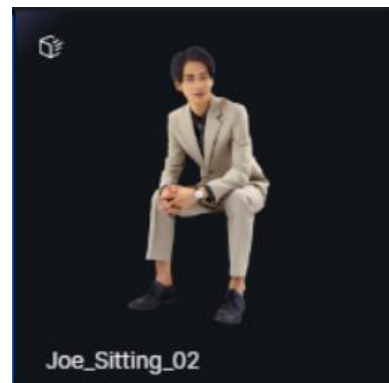


Figure 33: Dynamic Anima 5 model in D5 Render

D5 Render Conclusion

D5 Render offers users several useful tools and features that enhances and simplify the production process. The clear and modern interface makes it easy to learn and make efficient adjustments.

While many assets in the library are exclusively available to subscribers, there is still a vast selection to choose from. Adding models that were overlooked during the modeling phase or introducing liveliness to the scene can be quickly accomplished. Many models also come with specific options for customization, such as changing the car's color, toggling lights on or off, and selecting the driver's position on the right or left side.

However, despite these positive aspects, there is a drawback to use D5 Render. The software only supports the import of FBX models. As The Virtual Dutch Men utilize their own asset library, which employs proxy models in the viewport but actual meshes during rendering, these models remain as proxies in D5 Render (*Figure 35: Proxy objects in D5 Render*).

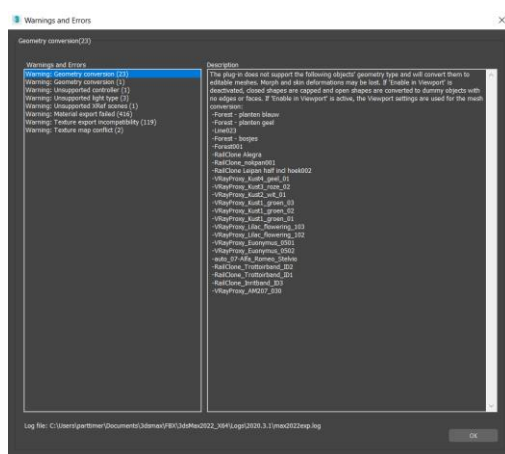


Figure 34: Proxy errors in the conversion process from 3DSMax to D5 Render



Figure 35: Proxy objects in D5 Render

Two workarounds are available for addressing this problem. The first option is to convert all the proxy objects to mesh objects within 3DSMax. However, this approach is not feasible due to the high polygon count of these proxy objects, which primarily consist of trees, flowers, and bushes. Converting them to meshes would significantly slow down the 3DSMax scene.

The second option is to use the models provided by D5 Render to incorporate trees, flowers, and bushes into the scene. However, it is worth noting that the D5 Render library may not have all the specific plants and trees that clients often request.

While D5 Render shows great potential in various use cases, it is currently unsuitable for The Virtual Dutch Men's rendering workflow due to the aforementioned limitations.

Unreal Engine 5

Since Unreal Engine 5 is a significantly larger software compared to Chaos Vantage and D5 Render and is used for various purposes beyond architectural visualization, the research on Unreal Engine 5 will be tailored specifically to the requirements of The Virtual Dutch Men. It will cover the same topics and headers as the research conducted for Chaos Vantage and D5 Render.

Direct Link

Before using the Direct Link feature, it is necessary to install the Datasmith exporter for 3DSMax on the workstation. The download for this exporter can be obtained from the Unreal Engine 5 website. Once installed, a new tab related to Datasmith will become available. In the plugin manager of Unreal Engine, the Datasmith importer must be selected. These settings will be automatically enabled if the architectural template is chosen within Unreal Engine 5.

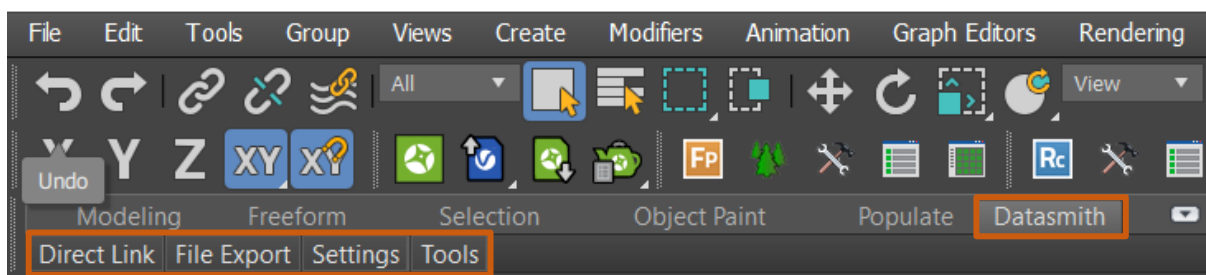


Figure 37: Installed Datasmith user interface in 3DSMax

In the Unreal Engine 5 toolbar, there is an option to establish a connection between Unreal Engine 5 and 3DSMax using Direct Link.

Upon selecting this option, a menu will appear, providing various choices to specify which elements should be synchronized to Unreal Engine. In 3DSMax, there is an option to enable automatic synchronization, which ensures that any changes made in the 3DSMax scene are automatically synchronized with Unreal Engine. Alternatively, synchronization can be manually initiated by clicking the synchronize button.

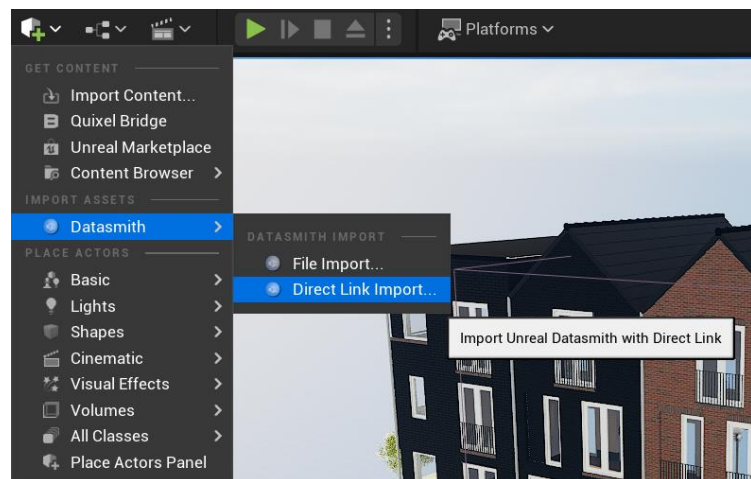


Figure 38: Import 3DSMax scene to Unreal Engine 5 through Direct Link

User Interface

Camera

Cameras that are created in 3DSMax can be imported into Unreal Engine. In the top left corner of the interface, there is an option to switch between different camera angles or select a different camera altogether.

By holding down the right mouse button and using the 'W', 'A', 'S', and 'D' keys, the user can freely navigate and explore the scene. Additionally, in the top right corner of the viewport, there is a control to adjust the camera speed if necessary.

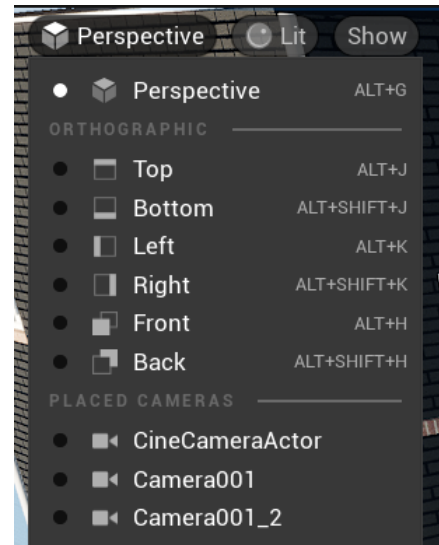


Figure 39: Available cameras in Unreal Engine 5

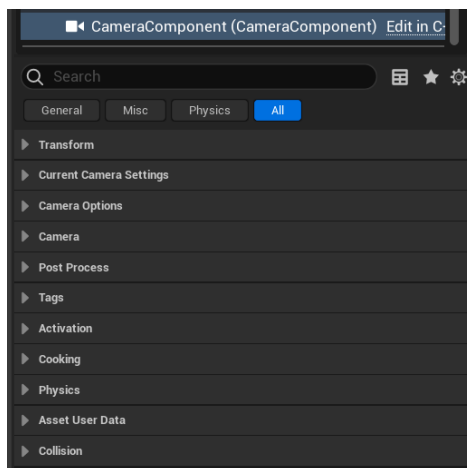


Figure 40: Unreal Engine 5 camera settings

Selecting a specific camera from the outliner provides access to a wide range of advanced options. These options allow the user to finely adjust the camera settings according to their preferences.

Lighting

From 3DSMax, SunSky is automatically imported into Unreal Engine. By selecting the SunSky from the outliner, various changes can be made. Adjusting the latitude and longitude alters the scene location. Based on the specified location, the SunSky adjusts its intensity, color, and position among other settings. If necessary, one can specify a date, time, and location to recreate a specific lighting scenario. All shadows automatically adapt to the corresponding lighting conditions.

Using the 'add' button from the toolbar, one can incorporate various types of lights. Directional, point, spot, rect, and sky lights are available for different lighting requirements.

Unreal Engine 5 Assets

Marketplace

This library caters to various industries and categories. In addition to architecture, it offers assets for automotive, fashion, film, live events, and training purposes. In the context of architectural visualization, the library provides assets related to architectural visualization, animation, characters, megascans, and textures. While megascans is exclusive to this library, the other categories are already covered in the research conducted on Chaos Vantage and D5 Render.

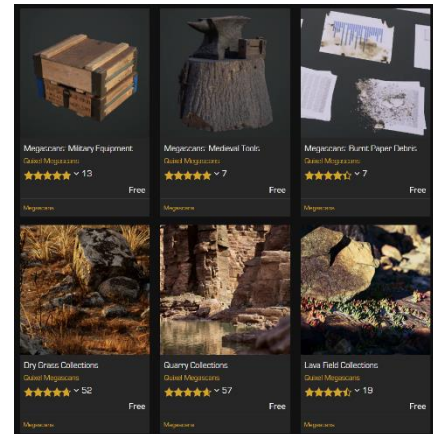


Figure 41: Unreal Engine 5 megascans

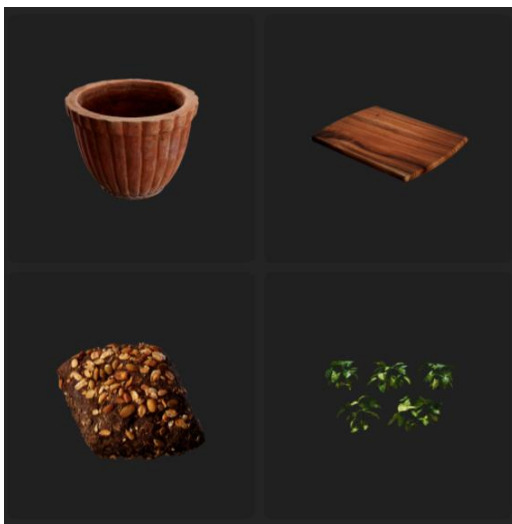


Figure 42: Models from Quixel Bridge

Quixel Bridge

Megascans are photorealistic 3D assets created by Quixel Bridge. This asset library can be accessed through the toolbar in Unreal Engine. Before adding a model to the scene, it needs to be downloaded.

Quixel offers both general-purpose models suitable for various scenarios and location-specific assets such as libraries or garden houses.

Animating

Camera

Before adding a camera to the scene, it is helpful to position the flying camera and then create a new camera based on the current position. To do this, click on the hamburger menu icon located in the top right of the viewport and select 'Create camera here'. Additionally, right-click in the 'Content Browser' and navigate to the 'Cinematics' tab to add a 'New Level Sequence'.

Once the desired camera is created, it can be dragged into the timeline to begin to work on the animation. Moving cinematic shots need to be animated using keyframes. Within the camera options in the timeline, the transform values can be keyframed to achieve the desired animation.

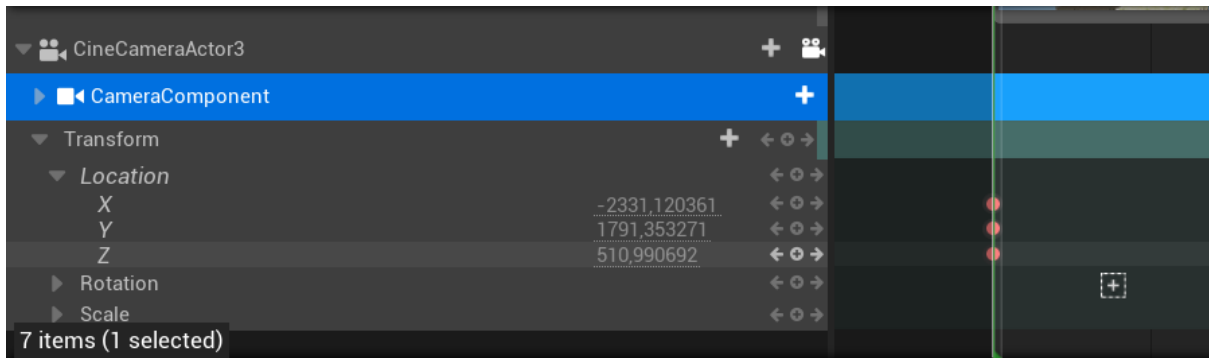


Figure 43: Animating a camera in Unreal Engine 5 using keyframes

The 'Sequence Curves' feature is a graph editor used to fine-tune the keyframed animation. It is primarily used to make quick adjustments to the animation speed and transition effects. By right-clicking on the keyframe dots, users have the option to modify the tangents. Another method is to manipulate the handles of the tangents to achieve the desired effect.

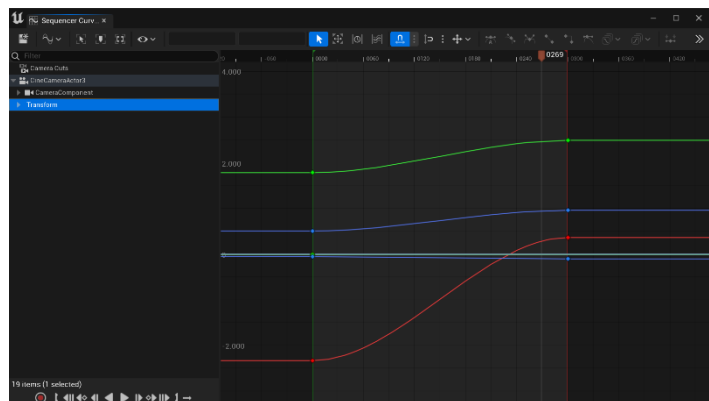


Figure 44: Unreal Engines Sequence Curves

Objects

Each object in the scene can be animated individually. The process of animating objects follows the same approach for cameras. However, it should be noted that neither the assets from the Quixel Bridge nor the Unreal Engine 5 Marketplace offer animated objects. Therefore, while it is possible to animate a car model from these libraries, the wheels will not be able to rotate automatically.

Characters

When installing Anima 5, users are provided with the option to install the Anima 5 plugin for Unreal Engine 5.0 as well. This step is essential for importing an Anima 5 scene into Unreal Engine. Once Anima 5 is installed, users can proceed to create their character animation within Anima 5. In Unreal Engine 5.0, there is a dedicated option to import an Anima 5 scene into the engine. This feature allows for the importation of the desired Anima 5 project into the currently active Unreal Engine 5 project.

Unreal Engine 5 Conclusion

Unreal Engine 5 is a highly popular software widely used by prominent companies and studios in the film and gaming industries. However, due to the complexity of Unreal Engine, it has a steep learning curve. For first-time users, the abundance of buttons, sliders, and values in the user interface can be overwhelming. Many features offered by Unreal Engine 5 are irrelevant when using it for architectural visualization.

The compatibility with XRef is advantageous, although when initially importing a 3DSMax scene into Unreal Engine, not all texture maps and lighting may appear the same and require adjustments. During testing, it was observed that the viewport in Unreal Engine 5 experienced frequent FPS drops to 10 FPS, negatively impacting the user experience. For reference, the workstation experiencing these FPS drops in Unreal Engine 5 is equipped with an Intel Core i7-8700K, NVIDIA GeForce RTX 3060 and 32GB RAM.

On the other hand, creating camera animation in Unreal Engine 5 is user-friendly. The ability to add a camera precisely at the viewport's current position allows for a quick approach in determining the start and end positions of the animation. The graph editor is a time-efficient tool for making changes to the animation.

Creating character animations, however, is a more challenging process. Anima 5 character animations are incompatible with Unreal Engine 5. Instead, Unreal Engine 5 offers high-quality metahumans, which are realistic human models. While these models can be utilized, they are overly advanced for architectural visualization purposes. Rigging and animating these models with a skeleton and applying textures require significant effort compared to use Anima, especially when multiple characters are needed.

Render Testing Results

Table 4: Terraced House Render Results

Render Engine	Still Image Render Time	Camera Animation Render Time	Camera + Human Animation Render Time
V-Ray	30 min, 21 sec	9h, 57min, 49 sec	34h, 44min, 31 sec
Chaos Vantage	20 sec	1h, 45min, 13 sec	-
D5 Render	2 min, 27 sec	5 min, 58 sec	7 min, 13 sec
Unreal Engine 5	4 min, 13 sec	2 min, 14 sec	3 min, 27 sec

Table 5: Terraced House Render Results

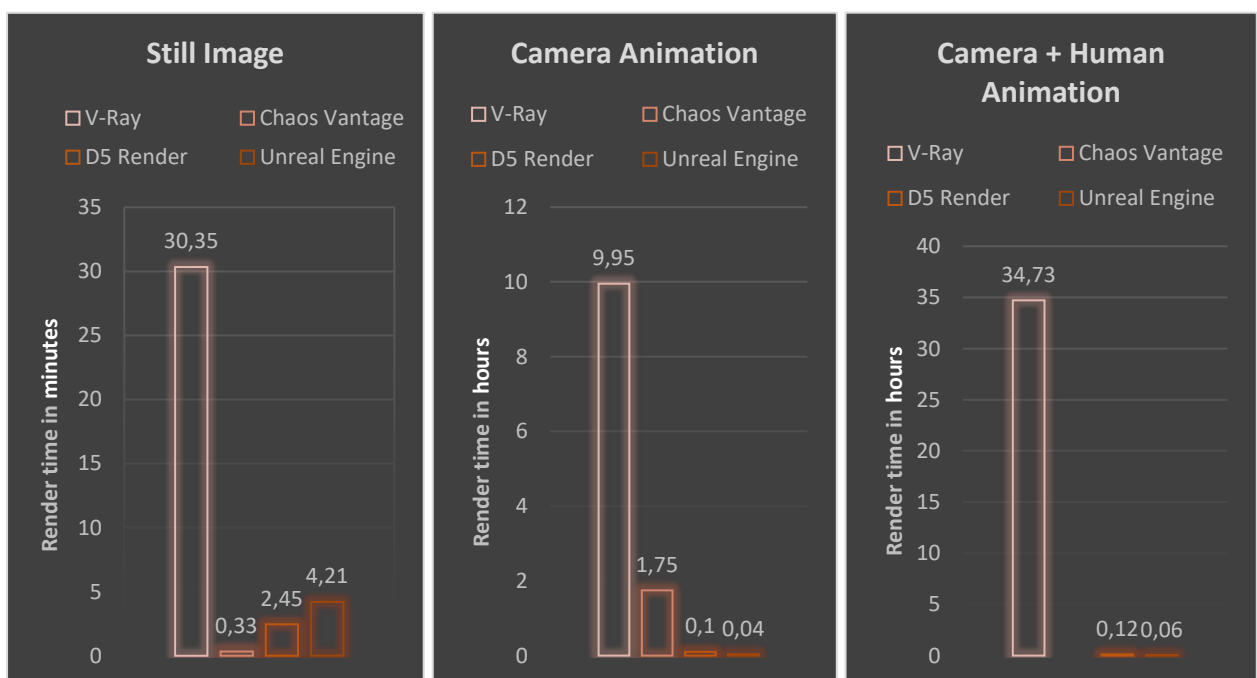


Figure 45: Rendered test project

Research Conclusions

Chaos Vantage, D5 Render, and Unreal Engine 5 offer live features that allow quick previewing of adjustments being made.

Among these options, the Chaos Vantage Live Link stands out as the most user-friendly and efficient choice. It is compatible with XRef, which is highly advantageous as it allows the file structure and workflow in 3DSMax to remain unchanged.

Setting up the live view with D5 Render and Unreal Engine 5 is also possible but requires more effort compared to Chaos Vantage. To render a 3DSMax scene in Unreal Engine 5 or D5 Render, the 3DSMax scene needs to be converted into either a .datasmith file for Unreal Engine 5 or a .D5a file for D5 Render. The conversion process can take a few minutes depending on the size of the project.

However, due to compatibility issues, it is likely that D5 Render and Unreal Engine 5 may not import all Forest assets used in 3DSMax correctly. In such cases, it is possible to replace those assets either within 3DSMax or by using the asset libraries provided by D5 Render and Unreal Engine. However, considering the time efficiency, replacing assets may not be beneficial.

In terms of usability, both Chaos Vantage and D5 Render are more user-friendly than Unreal Engine 5. Both offer basic functionalities for adjusting lighting, camera settings, animation, and asset libraries. On the other hand, using Unreal Engine 5 for the first time can be overwhelming due to its extensive array of features, values, sliders, and settings primarily used for game development and VFX creation.

Regarding Anima 5 character animations, there is no single perfect solution available. Importing an Anima 5 project into D5 Render is not possible, although D5 Render does offer Anima 5 characters in its library, allowing for the addition of characters within D5 Render. This eliminates the need to use Anima 5 as a separate software package. Adding a few characters from the D5 Render library to the scene can be done quickly. However, creating a crowd simulation one by one would be extremely time consuming.

Using Anima 5 in Chaos Vantage is currently unsupported. In a forum post by Chaos employee Alexander Atanasov in February 2023 ("Problem With Anima 4D People Material - Chaos Forums," n.d.-b), it was mentioned that Anima 5 and Chaos are working together to make Anima 5 compatible with Chaos Vantage. Although Atanasov stated that this issue is nearly resolved, no specific release date for this feature has been provided.

Regarding rendering performance, all three renderers outperform V-Ray in terms of render speed. The most noteworthy result observed is Chaos Vantage, which is approximately 21 times slower than D5 Render and Unreal Engine 5 when rendering a 10 seconds camera animation.

Based on the gathered render data, the results can be extrapolated to scenes of larger size. Client projects can be twice as big, which means that the render times will be doubled.

Based on the information and data gathered, it can be concluded that there is no perfect solution available for a more time-efficient creation of 3D architectural visualization animation.

Recommendation

All the positives and negatives have been taken into consideration, and it can be concluded that Chaos Vantage would be the best solution. TVDM is already using Chaos V-Ray, which means licenses have to be upgraded instead of buying new software, which is often more expensive.

The compatibility between Chaos Vantage and Forest and Railclone, which D5 Render and Unreal Engine 5 lack, holds significant importance for TVDM. Changing the entire workflow is not a realistic scenario, and therefore maintaining compatibility is crucial.

While rendering with Chaos Vantage is much faster than V-Ray on a single workstation, it may not be the fastest option among the three. However, considering the additional time required for setting up the scene in the renderers before rendering, Chaos Vantage proves to be the fastest and most user-friendly solution.

Besides the possibility to render animation on a single workstation, TVDM currently employs Pulze Render Manager to send render jobs to the render farm. Pulze has the capability to send Chaos Vantage projects to the render farm, resulting in even faster rendering.

Before Chaos Vantage can be used in production, TVDM will need to wait for compatibility with Anima 5 to be established.

Discussion

The research conducted aimed to explore ways to enhance the time efficiency of 3D architectural animations produced by The Virtual Dutch Men for websites and social media.

Through an interview with the Lead Designer and 3D Animator, and desk research on industry-standard and innovative renderers, valuable insights were gathered. Among the eight renderers considered, Chaos Vantage, D5 Render, and Unreal Engine 5 were selected for further investigation.

Render tests revealed that Unreal Engine 5 exhibited the fastest rendering times. However, additional research indicated that Unreal Engine 5's extensive functionalities and purposes might hinder its user-friendliness.

In contrast, D5 Render showcased rendering times comparable to Unreal Engine 5 without compromising performance. Nevertheless, D5 Render did not fully support crucial elements of The Virtual Dutch Men's workflow, such as Xref and Forest.

Although Chaos Vantage was not the fastest renderer among the three options, it still offered superior performance compared to V-Ray, the renderer currently in use. Moreover, Chaos Vantage demonstrated compatibility with essential components of the workflow, including Xref, Forest, Railclone, and Pulze.

Considering the render testing data and the findings from the desk research, it can be concluded that Chaos Vantage presents the most promising solution overall, particularly when its compatibility with Anima 5 is established. By adopting Chaos Vantage,

The Virtual Dutch Men can benefit from improved rendering speeds and enhanced compatibility with their existing workflow. This would allow for smoother production processes, reduced rendering times, and increased productivity.

Additionally, the potential integration with Anima 5 holds promise for further expanding the capabilities and efficiency of their 3D architectural animations.

Overall, this research provides valuable insights and recommendations for The Virtual Dutch Men, enabling them to make informed decisions regarding their rendering workflow and optimize their time efficiency in delivering high-quality architectural animations for websites and social media platforms.

Reflection

Process Reflection

Looking back at my research process, I am satisfied. I did not over enthusiastically start my research on the first day, but taking the time to learn the basics proved to be a good approach. This, combined with the interview, helped me understand the problem and search for a specific solution.

To prevent stress at the end of my internship, I was given the opportunity to dedicate two to three weeks to my research. This head start was very helpful in the long run. However, after those weeks, I was happy to be able to assist with client projects. In the future, I will strive for a more diversified approach..

By exploring multiple possible solutions, I gained insights into the differences among various renderers. I then converged on the three most innovative options. However, when encountering issues, it was sometimes challenging to find the necessary information to resolve them due to the relative novelty of the selected renderers. I extensively scoured forums, videos, communities, and review sites, gathering as much information as possible.

Considering the remaining time, I perhaps could have conducted more detailed research on an additional renderer. However, exploring new software is a time-consuming process, as I experienced with Unreal Engine 5.

Regarding the testing phase, I am satisfied with the various types of render tests performed, including still images, camera animations, and camera animation with character animation. By evaluating the render times of still images, I discovered that my solution could be beneficial for still image visualization as well. There was no need to conduct a render test for a 10-second shot because such durations are uncommon. Additionally, I encountered several failed tests due to issues like RAM overload. This could have been avoided with shorter animation.

Unfortunately, I was unable to test the rendering of a Chaos Vantage project through the Pulze render farm. This was due to a problem with the license server on the side of the Chaos Group, preventing the acquisition of a new license.

To a certain extent, I am convinced that my research can be of value to The Virtual Dutch Men. It depends on the compatibility between Chaos Vantage and Pulze. If they work smoothly together, I am convinced that The Virtual Dutch Men will transition to Chaos Vantage. Alternatively, Chaos Vantage can be used to quickly produce test renders, present real-time results to clients during meetings, or render short animation for social media.

Self-Reflection

Reflecting on myself as a young professional, I am proud of myself. From the very beginning, I felt very welcoming and at the correct place. This helped a lot in connecting with colleagues.

In instances where I found myself dissatisfied with certain outcomes or developments, I was not hesitant to engage in discussions with the company coach to address my concerns.

I showed genuine interest and a pro-active attitude every day. On the communication side, I tried to be as clear as possible toward colleagues. For example, when handing over a project to a colleague or report what changes have been made. I never received feedback from others for being unclear. I assume I did a good job on that aspect.

Furthermore, documenting specific actions, problems, or errors along with their corresponding solutions within the workflow ensured that I did not have to repeatedly ask the same questions. This was advised during my previous internship in the third year.

It happened to me sometimes I forgot to make changes in other project files while stated I was finished. In the future, I must triple check if I am actually finished before stating.

Appendix

A) Interview with the studio director regarding 3D animation workflow

In the official report the interview with the studio director is shown here. However, they prefer to not publish it online due to private information

Glossary

TVDM	The Virtual Dutch Men
CGarchitect	An open online community for architectural visualization
GPU	Graphics Processing Unit, a computer part designed to accelerate graphics rendering
CPU	Central Processing Unit, the most important processor in a given computer
UE	Abbreviation of Unreal Engine
AutoCAD	Commercial computer-aided design (CAD) and drafting software applications
HuizenGUI	In English HousesGUI, is a TVDM self-made tool to quickly add all the geometry needed to build the building based on the selected spline from the construction drawings from AutoCAD.
Connecter	A digital library with assets to create scenery in 3DSMax
UI	User interface
HDRI	High Dynamic Range Image are used to create a more natural looking image
FPS	Frames per second
VFX	Visual Effects created in games, movies and series

Reference List

- *New CGarchitect rendering survey shows trends in arch viz | CG Channel.* (2022, February 20). <https://www.cgchannel.com/2022/02/2021-cgarchitect-rendering-survey-shows-trends-in-arch-viz/>
- CGarchitect Digital Media Corporation. (2022, January 11). *2021 Architectural Visualization Rendering Engine Survey Results | Jeff Mottle.* CGarchitect.com. <https://www.cgarchitect.com/features/articles/712bd906-2021-architectural-visualization-rendering-engine-survey-results>
- *The best render engines for 3ds Max.* (n.d.). <https://garagefarm.net/blog/the-best-render-engines-for-3ds-max>
- Denham, T. (2019, December 31). *Arnold, Corona & V-Ray Render Engines: What Exactly Do They Do?* Concept Art Empire. <https://conceptartempire.com/arnold-corona-vray-render-engines/>
- *REVIEW: Chaos Vantage.* (n.d.). 3dtotal. <https://3dtotal.com/news/reviews/review-chaos-vantage#article-introduction>
- *D5 Render Reviews & Product Details.* (n.d.). G2.com. <https://www.g2.com/products/d5-render/reviews>
- *3D Rendering Software for Architects | Lumion.* (n.d.). Archdaily. <https://www.archdaily.com/catalog/us/products/11884/3d-rendering-software-lumion>
- *An Overview of Twinmotion Features and Capabilities.* (n.d.). Twinmotion. <https://www.twinmotion.com/features>
- *Ontdek alle Enscape-functies online | Enscape Nederland.* (n.d.). <https://www.enscape3d.nl/toepassingen>
- XYZ design S.R.L. (n.d.). *XYZ design 3d people models and character animation software - anima-ALL.* XYZ Design S.R.L. <https://secure.axyz-design.com/en/anima-all>
- Daniel Szalapski. (2022, June 24). *Beginner Introduction to Chaos Vantage in 3ds Max Using Vray GPU.Real-time Rendering.* [Video]. YouTube. <https://www.youtube.com/watch?v=v5z4swV10zg>
- Adam Z - Learn Archviz. (2022, June 10). *Chaos Vantage FULL Tutorial | Learn All Tools in 20 Min | You Need This in Your Archviz Workflow* [Video]. YouTube. <https://www.youtube.com/watch?v=u116PwxXFeM>
- *Render tab - Chaos Vantage - Chaos Help.* (n.d.). <https://docs.chaos.com/display/LAV/Render+tab>

- *Anima people - Chaos Forums.* (n.d.). Chaos Forums. <https://forums.chaos.com/forum/chaos-vantage/chaos-vantage-issues/1173374-anima-people>
- *Problem with Anima 4D People material – Chaos Forums.* (n.d.). Chaos Forums. <https://forums.chaos.com/forum/chaos-vantage/chaos-vantage-issues/1166363-problem-with-anima-4d-people-material>
- *Render.* (n.d.). D5 Render. <https://support.d5render.com/support/solutions/articles/72000544011-render>
- Unreal Engine. (2022, November 10). *Datasmith Direct Link Workflows in Editor | Unreal Fest 2022* [Video]. YouTube. <https://www.youtube.com/watch?v=53er5KOi3HQ>
- Unreal Engine. (2020, April 3). *Learn How to Use Quixel Megascans in Unreal Engine | Webinar* [Video]. YouTube. https://www.youtube.com/watch?v=KhTPayu_YUs
- Levine, G. (2022, April 12). *Anima 5 with Unreal Engine 5 Sneak Peek Released.* <https://80.lv/articles/anima-5-with-unreal-engine-5-sneak-peek-released/>