

**Honours Project - MHW225671**

**INTERIM REPORT**

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**Department of Computing**

**Submitted for the Degree of: Computer Games (Software Development)**

**BSc Computing**

**BSc ITMB**

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**Project Title: Voxels place within games.**

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**“Except where explicitly stated, all work in this report, is my own original work and has not been submitted elsewhere in fulfilment of the requirement of this or any other award”.**

**Signed by Student: Date:**

## Introduction

Polygons are accepted as the current standard geometric primitive for both the 3D Modelling and Video Games industries; they can be defined as any closed 2D shape made of entirely straight lines. Current GPU manufacturers and tech giants have heavily invested into polygons, originating back to the late 1990s when the term was popularized by the GeForce 256 GPU. (TheBat!, 2023) This can be ascribed to their simplicity and efficiency with the many rasterization techniques at that time. However, their most prominent drawback is within its ‘*imitation*’ of real-world objects, as many techniques are only aesthetically, and not physically simulating the mesh. This is more specifically seen in games within the 3D dissection of polygonal models at runtime, where the model holds no data for the new face required to be created.

A suggested alternative, Voxels; also known as volumetric pixels; are a geometric primitive holding data for the entire model, including what cannot be seen. This primitive is used to represent values in three-dimensional space on a grid. Voxels function similarly to physical particles, therefore creating a more sophisticated implementation used to imitate the real world. Often, Voxels are referred to as 3D pixels and have a wide use in Procedural Generation, Particle Simulation, and Destructible Physics. Voxels are uniquely stored within a grid, allowing efficient usage of Object-Oriented Programming (OOP) and the Entity Component System (ECS), allowing each voxel to hold a unique property. This is shown within the 3D voxel game ‘*MakeFarm*’ by David Szymon Grobert, as each block held a definition for if its object was breakable, and if so, what item should be dropped. (GROBERT, 2023)

Polygons have held their position as the standard geometric primitive in many of the 3D visualization industries for over 20 years. This has resulted in many of the competing primitives to fall behind, as new technologies advance polygons forward. Many rendering practices for these primitives require the conversion of their structures into polygons, a major of which being the Marching Cubes algorithm. (Lorenson & Cline, 1987) Most previous rendering techniques for mainstream geometric primitives are insufficient for modern day usage, as researchers are now aiming to create greater realism. Due to the observation that is Moore’s law, which dictates that the number of transistors within computer chips double every two years, graphics are no longer restricted by our hardware, but by our software approach. A common implementation includes Ray Tracing, a method of emulating the light reflections and refractions of the real world. Ray Tracing is entirely possible within Voxels, although a similar process named Ray Marching is generally used, however, both of which do not require the need to convert to a polygonal mesh. These techniques potentially creating a new use case for Voxels, with the possibility of gaining a wider acceptance as an alternative to polygons. The improved graphics that come with Ray techniques leads way into the necessity for Particle Simulation and Destructible Objects, creating a greater sense of realism, and both of which voxels are suited towards.

Atomontage, a leader in voxel development with a 13-year running micro-voxel engine, are consistently pushing the boundaries of voxel development forward. Atomontage are known for their usage of projection based voxelization, soft-body dynamics and their voxel editor’s recent open beta launch in 2021. (Atomontage, 2023) Daniel Tabar, and Branislav Siles, the founders of Atomontage, shared that the future of voxels lies within cloud services, as with their current implementation, the voxels are relatively inexpensive on both the view, and the server. The future of Atomontage aims to revolutionize both the cloud gaming industry, and the interactive sandbox games genre, and Daniel Tabar has stated that their engine could be compared to “*Roblox + Minecraft + a higher resolution*”. (JTVentures, 2023)

Atomontage is not only invested within the games industry, but also has ties to medicine from one of its most supportive angel investors, Tommy Palm (Siles, 2019). Voxel-based 3D visualization is an incredibly large sector within medicine, with competing software such as ‘*3D Slicer*’, ‘*Voxel-Man ENT*’ and ‘*SolidWorks 3D-Doctor*’. These provides a multitude of tools ranging from CT Lung Analysis to Virtual Training Simulators, all of which involve intensive usage of volumetric data. The usage of voxels within medicine comes from the necessity of creating not only a realistic model, but also for accurate mapping of different tissue types (Slicer Community, 2023) (Voxel-Man, 2023) (Dassault Systemes, 2023) As voxel techniques are researched, these software could potentially receive updates allowing more realistic, and accurate models for its users. A study within the effect of Field-Of-View and Visual Realism on virtual training tasks found that visual realism may impact the virtual training performance negatively, it impacts the real-life assessment positively. (Ragan, et al., 2015) This suggests that if voxels gain more realistic rendering techniques, that it could positively impact training procedures for users of Medical Simulations.

The games industry is at the forefront of voxel realism development, a recent voxel success story includes Tuxedo Labs ‘*Teardown*’. Featuring a fully destructible environment, particle simulations of fire and smoke, and an incredible in-house lighting system, it has garnered almost 76,000 positive reviews on steam, gaining the award for ‘*Excellence in Design*’ at the Independent Games Festival in 2021. (Tuxedo Labs, 2023) (Informa Tech, 2023) According to the Tuxedo Labs modding wiki, the artists used ‘*MagicaVoxel*’, a lightweight voxel art editor, to create all assets for the game. (Tuxedo Labs, 2023)

* Maybe a paragraph here about MagicaVoxel 3d modelling software.

These tools are incredibly powerful in creating 3D environments; however, they require hundreds of hours in development to take form. A more efficient method, used for both rapid prototyping and final model products is LiDAR (Light Detection and Ranging). LiDAR uses pulses of light to rapidly generate point clouds, which are simply a collection of points in three-dimensional space. As suggested by Xu Yusheng et al., point clouds can be efficiently converted into a voxel representation,

This paper would like to investigate the possible future of voxels as a possible replacement for polygons as the standard geometric primitive for 3D visualization. The intent is to highlight the current strengths and weaknesses of voxels, opening possible future research avenues.

## Contextual Review

Limitations of voxels as of current day.

John Carmack – Lack of GPU accelerated hardware.

Giga voxels paper.

Neural Sparse Voxel Fields.

Compression techniques used within Voxels which improve speed and performance.

Morton’s Code.

Current tools within games.

Aesthetical aspects of voxels and polygons.

Hardware accelerated.

Previous research on the comparison between voxels and polygons.

Hybrid engines using models of both voxels and polygons. Hybrid Rendering Techniques.

* Put relevant materials of this study into context.

## Methods & Design

* What are you going to do?
* How are you going to do it?
* How does it help *solve* the research question?
* Describe the methods including its design features.
* Can include references, sources and constraints.

## Project Plan

* What are the main tasks involved within this project?
* What are the intended deliverables at the end of this project?
* Create a work plan, e.g. Using a Gantt Chart

## Ethical Considerations

* What ethical issues should be noted?
* Evidence of approved application.

## 1. Introduction Notes (part of 60%)

* Opening statement should be clear, the issue I am looking to solve should be well argued and should naturally lead into the research question.

1. Introduce current ‘standard’ geometric primitive.
2. Give insight as to why polygons are the standard geometric primitive.
3. Introduce alterative of voxels and give definitions.
4. Give insight as to why voxels are not the current standard geometric primitive.
5. Suggest that voxels have been overlooked when looking at its specific use case/the future of voxels could have more voxels use cases.

## 2. Contextual Review Notes (part of 60%)

* Extensive use of literature from scholarly articles. Follows smoothly from statement to statement and shows critical engagement with literature.

## 3. Methods & Design Notes (20%)

* Clear description of design methods that are to be employed. Methods are well justified over any alternative methods, which is backed up by supporting materials. Description of procedures and tools is clear.

## 4. Project Plan (20%)

* High level of understanding of the tasks involved within the project objectives. Document is fully chaptered with sufficient detail. Work plan describing all considerations. Ethics is fully presented, approved, or not required based on evidence.

## Notes

### RSPI Project

Compare three separate models of varying complexity and compare file size of Voxels and Polygons. The voxel model is created by using the polygonal model and applying a voxelization method until all components are visible.

I found I had issues with this, specifically with, is this not inherently biased towards polygons as they are created using any technique they want, whereas voxels are limited to the voxelization algorithm.

Also, the method of ensuring models are relative in different format was to voxelize until all components are visible, which could incredibly vary depending on what the user assumes is a component. (In this case it was facial shape, arms, legs and muscle definitions)

### Topic

Reaffirm already existing research that Morton’s code/Z-Order curve can help Sparse Voxel Octree tree traversal.

Show the point of contention within voxels and showcase best use cases for each. Main point – Mention although Polygons may be better than voxels in terms of many rasterization techniques, however looking into the future of computer graphics, ray marching can hold its own against ray tracing.

## Questions

1. Is my introductions direction clear enough, and are any more in text references required?
2. Does specific referencing matter? Moore’s law was first stated in 1965, later changed in 1975, however, most references link to an article published in 1995.
3. Does the question need to be answered fully, or can the research push toward answering the question? (The question of are voxels better than polygons, showing voxels have lower file size could provide more information)

Key Papers

[Traversing Sparse Voxel Octrees](https://nccastaff.bournemouth.ac.uk/jmacey/MastersProject/MSc18/05/traversingsparsevoxeloctrees.pdf)

[UE5 Lumen](https://advances.realtimerendering.com/s2022/SIGGRAPH2022-Advances-Lumen-Wright%20et%20al.pdf)

It is fine to introduce a topic direction in the introduction, and pivot within the contextual review as long as it is relevant and makes sense. For instance, going towards see if voxels have a potential future, then changing to well this future will require an aesthetical component.

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## Voxels

Voxels take their name from Volumetric Pixels and represent a value in three-dimensional space on a grid. They are one of the many geometric primitives, and are mainly used within particle simulation, and subsequently dynamic creation and destruction. They are vastly different from the current dominant geometric primitive of polygons, as current GPU manufacturers mainly support the usage of polygons. They also lack research, as their support within the 3D computer graphics community puts them as an aesthetic, rather than a different method.

Voxels strengths lie within advanced rendering techniques much like raytracing, as with traditional rendering techniques, the conversion of the Voxel structure to polygons is required. This can be seen in the Marching Cubes Algorithm, Surface Nets, and Voxelization. Some techniques including Voxelization lose the benefits of voxel data manipulation at runtime and are mainly used for their aesthetic during.