

**Honours Project - MHW225671**

**INTERIM REPORT**

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**Department of Computing**

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**Signed by Student: Date:**

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 created.

On the other hand, Voxels; also known as volumetric pixels; hold data for the entire model, including what cannot be seen. Voxels are a geometric primitive used to represent values in three-dimensional space on a grid. Voxels function similarly to physical particles, therefore making them a more sophisticated implementation used to imitate the real world. Often times, 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 object should be dropped. (GROBERT, 2023)

Polygons have held their position as the standard geometric primitive for over 20 years, which has caused other datatypes to fall behind, as new technologies advance fitted towards polygons. The majority of rendering practices for these data types, revolve around converting these structures into their polygon equivalent, for instance the Marching Cubes algorithm. However, recently researchers have aimed to create greater realism within their projects, a common method being Ray-Tracing. The equivalent voxel technique (Ray-Marching), does not require the need to convert to a polygonal mesh, potentially creating a new use case, or alterative for polygons. The requirement for better graphics leads way into Particle Simulation, and Destructible Objects, both of which voxels are suited towards.

Despite the prevalence of polygons, Atomontage aims to push the boundaries of voxels. They are a leader in voxel development, with a 13-year running micro-voxel engine. (Atomontage, 2023) Recently they have showcased their Physically Based Rendering in browser showing control over the creation and destruction of voxels, the Level of Detail (LOD), and various lighting effects. Atomontage are mainly known for their usage of projection based voxelization, soft-body dynamics and their voxel editor’s recent open beta launch in 2021.

Voxel-based modelling has become a powerful tool as an alternative to traditional mesh-based modelling to both the medical and games industries with its advancements in speed and file size. The recent voxel success comes from Teardown, a game made by Tuxedo Labs which features a fully destructible environment, particle simulations of fire and smoke, and hundreds of interesting tools. It has garnered almost 61000 positive reviews. (Tuxedo Labs, 2023) According to the Tuxedo Labs modding wiki, the MagicaVoxel GPU-Based voxel art editor was used to create all 3D models in Teardown. (Tuxedo Labs, 2023)

These tools are incredibly powerful in creating 3D environments; however, they require hundreds of hours in development to take form. A more efficient way of generating 3D models involves Photogrammetry, or the 3D scanning of real-world assets. It has been a term first coined by Sir John Herschel in 1839 and has been said to describe more detail that could normally be done by hand. (Randles , et al., 2010) The most effective way to scan the real-world is the use of LiDAR to generate point clouds. These point clouds can be converted to other model types however are best converted to voxels.

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 voxel use cases.

## 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.

https://advances.realtimerendering.com/s2022/SIGGRAPH2022-Advances-Lumen-Wright%20et%20al.pdf

Key Papers

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

## 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