Digital Design Network+
Case Study 1 Individual Report Template

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Institution	University of Bristol
Team	3
Focus	Primary: Faster, Secondary: With Less
Design Process	Concept design phase
Tools Used	Unity, Meta Quest 3
Links	https://youtu.be/slqB1A0UocI https://youtu.be/_Ab6KiUbDD4 https://youtu.be/Avnvr6hxWAw Blog link TBD.

Executive Summary

This work has explored the use of Extended Reality (XR) to enable designers to rapidly create, iterate and evaluate designs in a 3D spatial environment. Using a voxel-based geometry creation system, with predefined component types that can be scaled and moved, complex designs can be created with ease. A built-in suite of high-level analysis tools enable designs to be evaluated and compared between instantly, enabling designers to design in an informed manner, and provide more robust comparisons between concepts.

Problem

This work package has focused on exploring the gap formed between sketching and initial concept generation and CAD (Pei et al., 2011; Ranscombe & Bissett-Johnson, 2017). The former is highly flexible and rapid, but limited to 2D without high skill levels and does not easily facilitate analysis, and the latter is able to represent 3D geometry and enables analysis, but is much slower and less flexible than sketching, and is still limited to a 2D interface (computer monitor) (Veisz et al., 2012).

Thus, a gap between the two stages of design exists in the lack of a tool for flexible and rapid 3D geometry creation that can be used to facilitate early, high-level analysis (Ibrahim & Pour Rahimian, 2010; Snider et al., 2025).

Digital Design Solution

The system used a Meta Quest 3 headset, with a virtual environment developed in Unity.

The voxel-based geometry creation and modification made use of an Octree data structure that enables it to expand as needed by the user, while maintaining sufficient efficiency to allow it to be modified and repeatedly regenerated at the "speed of thought". This structure can have material added through a scalable sphere or rectangular 3D "paintbrush" and material removed using similar tools (See Figure 1). This can be thought of as a similar system to using 3D printing pens, and sculptural carving, without any limitations on the size of the pen or carving tools, and without any constraints imposed by the physics of the real world (i.e. gravity, material strength, adhesion limits etc). Together, the voxel-based data structure and material addition/carving enables an intuitive method to create free-form 3D geometry, with similar freedom to sketching without the 2D constraints.

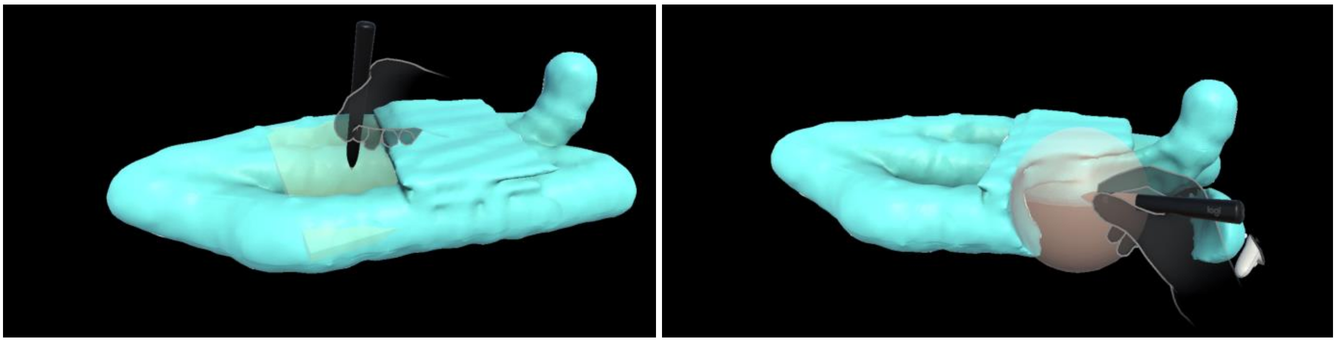

Figure 1. Examples of voxel addition and carving using different shaped tools

In addition to the voxel-based geometry, several predefined component types can be added into the scene, such as batteries, motors, propellors, control systems, payloads, etc. These component types have simplified relationships between size and performance (i.e. battery volume $\propto$ storage capacity), which enable the analysis discussed in the next paragraph. Additionally, tools such as the linked item duplicator, X-ray vision, and CAD importing further help designers explore, iterate and understand their designs as fast as possible (See Figures 2 & 3). The linked item duplicator enables components to be duplicated and twinned, so scaling one will control the size of all duplicates, which is essential for designs using several of the same component, e.g. propellors. The X-ray vision converts the voxel-based geometry to a transparent material, allowing designers to see and move/rescale encapsulated components. The CAD importing feature converts geometric representations in other formats (e.g. STEP, STL, OBJ, etc.) into the voxel format, enabling rapid design iteration and variation using the capability of the created design tool.

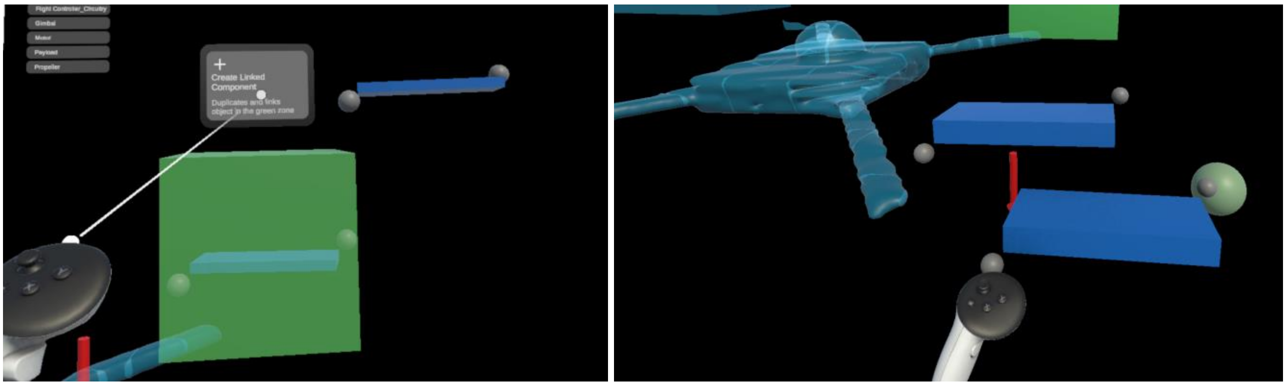

Figure 2. Item Duplication with linked component scaling

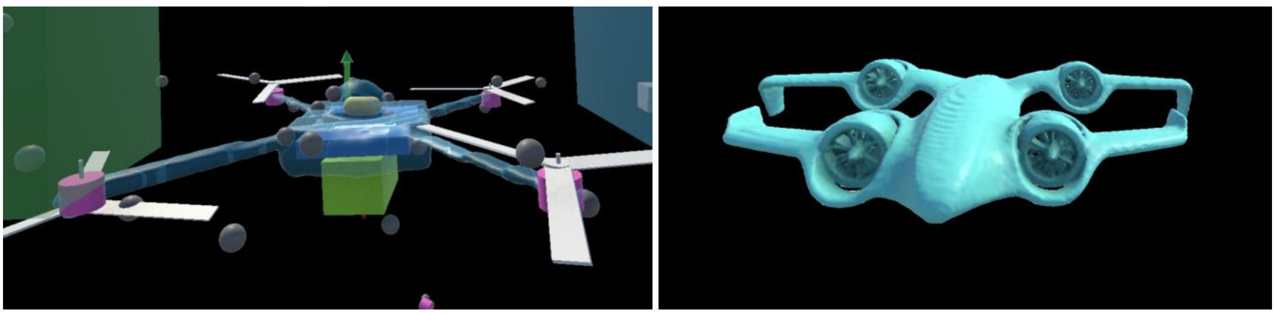

Figure 3. X-Ray vision (translucent voxel geometry) and CAD model importing

In addition to the geometry creation / iteration, and predefined component manipulation, the digital design tool includes several high-level analytical tools to inform designers about the rough performance capability of their designs (see Figure 4). This analysis includes information such as total mass, expected lift, Thrust to Weight Ratio (TWR), predicted flight time, and expected maximum payload capability. However, many other factors could be evaluated/predicted with relative ease if needed, depending on the requirements of the design, e.g. camera coverage, bluff body drag, thermal dissipation, etc.

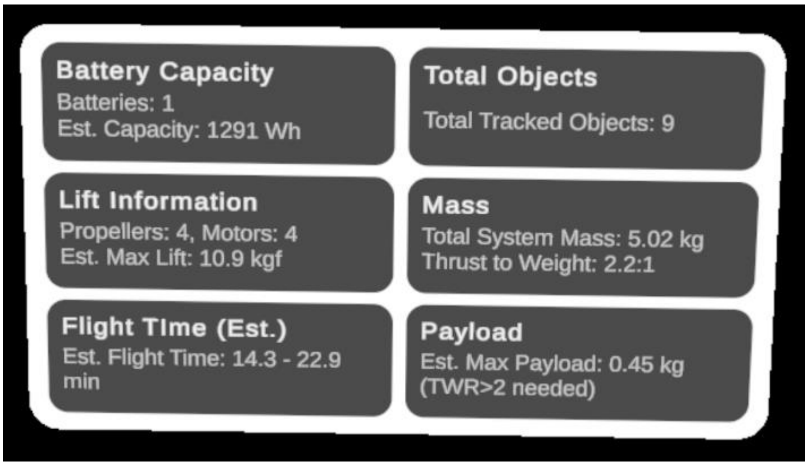

Figure 4. High level analysis dashboard, showing key estimates of design performance.

This analysis is largely based on simplifications and assumptions of component performance. For example, the total mass is based on assumed density values of each component and the voxel geometry, and scaling of each. Similarly, the predicted lift calculations rely on simple actuator disc theory, paired with estimations of power based on motor size. While these will not produce exact results, they are likely to be sufficient to inform the designer of whether their design is viable and compare it to other designs. This analysis essentially automates many of the "back of the envelope" calculations made by designers to evaluate and compare between initial concepts.

How it makes Digital Design Better, Faster and/or With Less

Faster:

This tool enables designers to rapidly explore and develop designs in a 3D environment, without being slowed down by the precision required of conventional CAD packages, or the difficulties of creating a 2D representation of a full 3D design through sketching. Additionally, the automated high-level analysis means that designers can be guided throughout the design process to create a quality design with fewer iterations, and far fewer manual calculations or comparisons between concepts are needed. These features mean that this tool could significantly improve the time taken to reach a suitable design for embodiment and detailed design.

With Less:

The 3D interaction of the design space of this tool enables designers to understand their design at scale and gain a physical perspective of its size, shape and layout. Typically, this would only be possible using physical prototyping, which is costly and can be resource intensive, especially if the design undergoes many iterations. However, the shift to digital prototyping in a 3D environment could help designers to identify and mitigate many issues that may only be detected through physical prototyping. This could result in fewer design iterations and physical prototypes required to reach a final design, thus reducing the cost and resources of the process.

Better:

While this tool does not offer increased design understanding over existing tools and methods, it enables deeper insight into a design earlier in the design process and uses less resources. This means designers can identify and design a high quality design faster, resulting in a similar quality of design in less time and with less cost. This could enable designers to spend further time refining their design, to reach a better final output, but improving design quality was not a key driver for this project.

Reflections

I think that the process has been very useful in solidifying my belief that the use of XR and spatial computing in design could be incredibly valuable for design. Key advantages will be in designing intuitively and rapidly, and marrying analysis and insight into the creative elements of the design process, rather than alternating between the two domains of analysis and creativity.

However, I think there are still several major barriers that will need to be overcome:

- **Data interoperability** – currently VR systems are largely incompatible with CAD systems, and these will need to be married together to maximise the benefit of both. This will not be trivial.
- **Positioning** – these systems will not and *should not* replace conventional CAD systems. 3D spatial designing is by its very nature a fuzzy and imprecise thing, and designs need to be more precise as they gain definition. However, XR offers a fantastic synergy with traditional CAD, with many of the two's weaknesses and strengths complementing each other.
- **Adoption and User Interfaces**. Other digital tools (e.g. CAD-CAM) have reached maturity, and significant investment has been made to optimise UI design. As such, designers expect similar levels of polish and intuitivity in new design tools. Designing an intuitive XR design tool is very difficult and I worry that this could be another major barrier to what could be a very valuable addition to the designer's toolbox.

References

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