Digital Design Network+
Case Study 1 Individual Report Template

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Institution	University of Bristol
Team	2
Focus	Better and Faster
Design Process	Flow Simulations and Design iterations
Tools Used	Unity, Meta SDK, OpenXR, Meta Quest 3
Links	Post | Feed | LinkedIn AmanKukreja/D2N: MR based Low-fi CFD Simulation

Executive Summary

This project explored how Mixed Reality (MR) can support faster, more interactive engineering design through a digital design workflow based on low-fidelity computational fluid dynamics (CFD)-style simulations. The work focused on developing and demonstrating an MR-based design environment that visualises airflow behaviour around a drone wing at real scale, while allowing the geometry to be modified and the simulation to update accordingly. The aim was to provide an early-stage design tool that supports rapid exploration, discussion, and iteration.

Problem

The current AMRC drone design digital thread has several visualisation endpoints, as shown in Fig. 1. These endpoints provide users with information about component relationships, allow parametric design modification, support kinematic simulation, enable design review, and also perform flow simulations. However, there is seemingly no/slow interaction between simulations and design changes, limiting users to purely geometry-based guesses of flow patterns and potentially preventing designers from exploring the full design space [1].

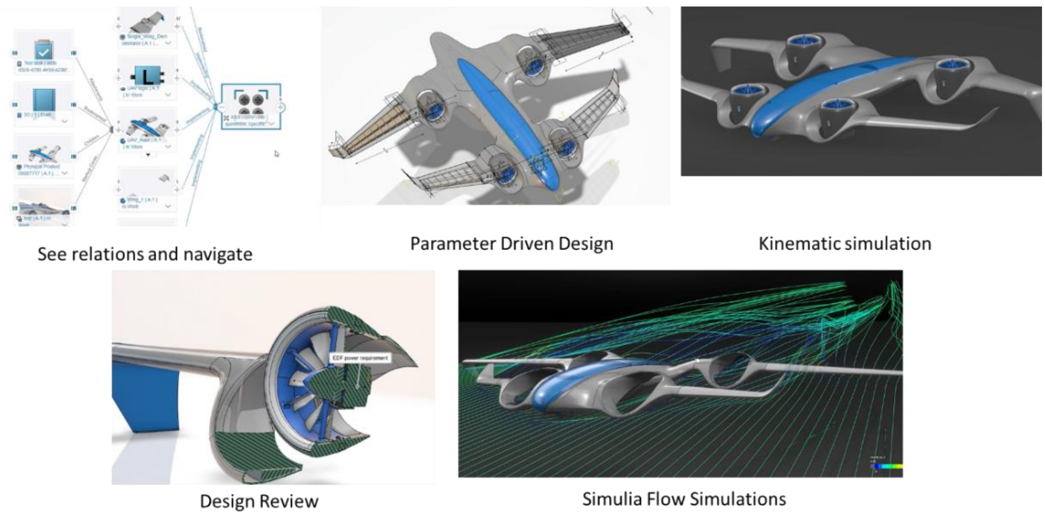

Figure 1: Current AMRC visualisation endpoints

In general, this lack of connectedness and the unavailability of digital design tools for faster in-situ simulations create a persistent challenge in engineering design, i.e. there is a gap between early-stage conceptual thinking and the time, cost, and effort required to evaluate design changes [2]. This is because conventional CFD tools are often slow, specialised, and workflow-intensive to support design iterations/changes [3]. Therefore, the current pipeline may prevent designers from exploring potentially useful design ideas. The problem addressed in this project was, therefore, how to create a digital design tool that enables more immediate, embodied, and accessible exploration of flow analysis-related design decisions in the context of drone design.

Digital Design Solution

The proposed solution is an MR-based low-fidelity CFD-style simulation platform for the design of drone wings. The system allows a user to visualise airflow behaviour around a wing in Mixed Reality at real scale, modify the freeform geometry of the wings, and observe updated simulation behaviour as the design changes, in real time. The whole system was designed in Unity 6 using the Meta SDK package and coded in C#. It was then built as an Android package and deployed to the Meta Quest 3 headset to run untethered, demonstrating the system's portability and low-cost access.

Fig. 2 shows the flow diagram of the developed system. The user in Mixed reality (MR) can interact with the scene in three ways: 1. Change geometry by grabbing and moving control points (Fig. 3 (a)), 2. Change the location of the plane of intersection (analysis plane, Fig. 3 (b)), and 3. Change the simulation mode (Fig. 3 (c)).

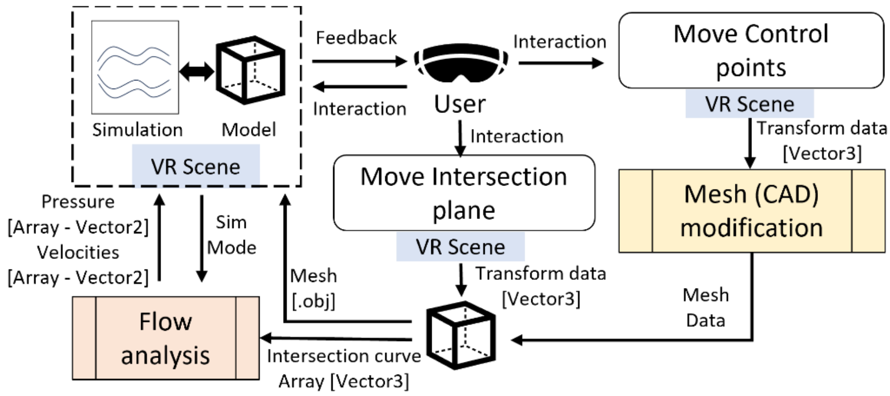

Figure 2: Flow diagram of the proposed digital design solution

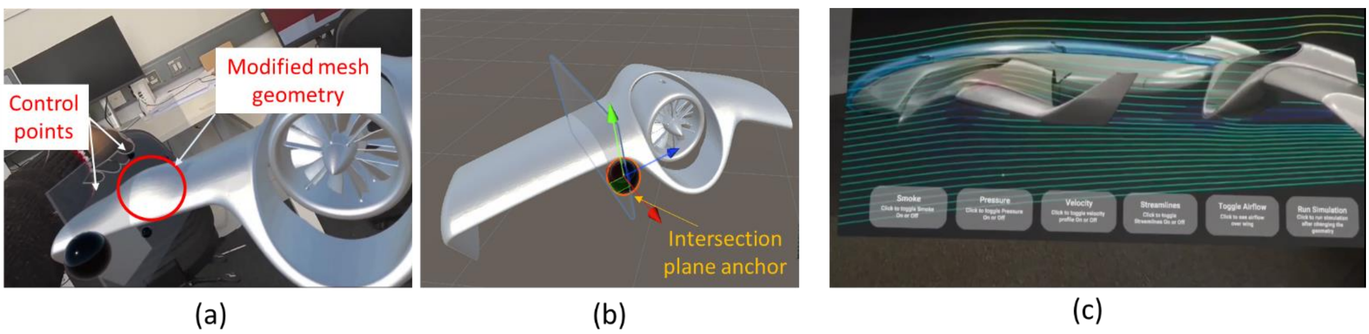

Figure 3: Controls: (a) Geometry Modification, (b) Modify Plane of Analysis, (c) Change Mode of Simulation

The system has two main processing modules that work in the back-end to enable user-interaction: 1. Mesh modification, and 2. Flow analysis. Consequently, the user can visualise the geometry changes and their impact on the air flow around the wing in real time. Mesh modification uses the movement of control points to displace mesh vertices within a specified radius of influence. The displacement is given distance-based weighting to ensure smooth, continuous deformations of the mesh rather than abrupt changes. The flow analysis was implemented using a grid-based fluid simulation method that iteratively updates velocities and pressure values by solving for incompressibility using a Gauss–

Seidel-based pressure correction. Flow behaviour is consequently propagated using semi-Lagrangian advection, where both velocity and smoke fields are transported across the grid over time.

The front end provides the visualisation of the flow patterns in five different modes:

1. Smoke Field (Fig. 4 (a)): Helps visualise flow direction around the wings and wake formation.
2. Pressure Field (Fig. 4 (b)): Shows stagnation points and separation regions.
3. Velocity Field (Fig. 4 (c)): Provide information about velocity distribution
4. Streamlines (Fig. 4 (d)): Shows streamline curvatures and vortex shedding
5. Full 3D Flow Simulation (Fig. 5): Gives a full 3D view of streamlines over an actual 3D model of the wing and how particles move around it.

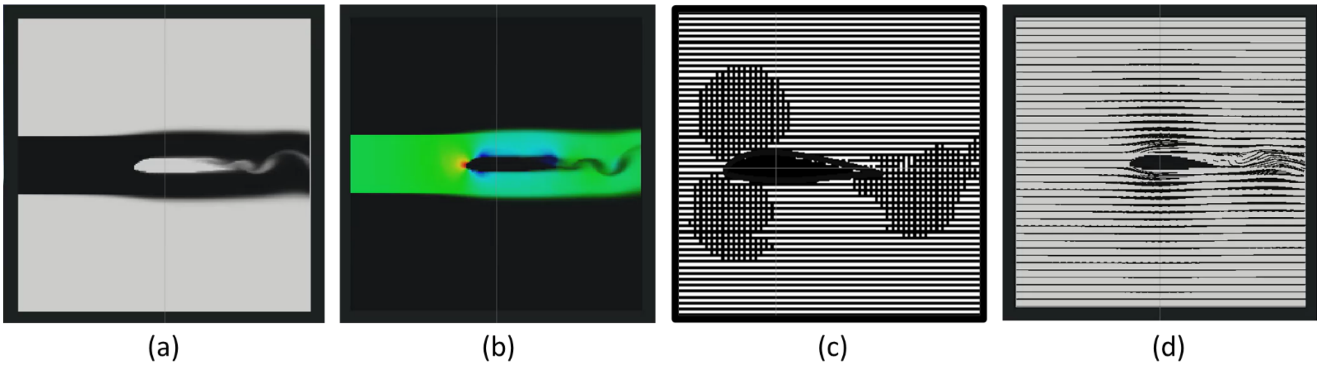

Figure 4: (a) Smoke Field, (b) Pressure Field, (c) Velocity Field, (d) Streamlines

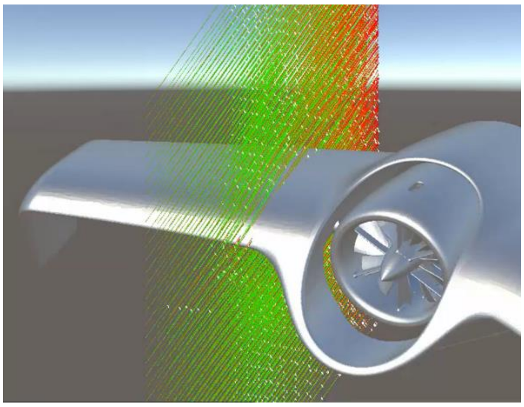

Figure 5: Full 3D air flow simulation

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

This solution improves digital design primarily by making early-stage design evaluation more interactive, more immediate, and less dependent on fragmented workflows.

Better: The platform improves design quality by allowing users to see and reason about flow behaviour directly in context and at real scale. This supports more informed discussion, earlier identification of issues, and a better understanding of performance implications during concept development. It may also help bridge communication between technical and non-technical stakeholders, since the behaviour of the design can be visualised rather than only described through drawings or static models.

Faster: The main speed benefit comes from shortening the iteration loop. Instead of modifying geometry in one tool, exporting to another simulation environment, waiting for results, and then making changes again, the MR platform allows direct interaction and immediate feedback. This accelerates concept testing and allows more options to be explored within the same time window.

Reflections

A key learning from this activity is that there is strong potential for MR to become more than a visualisation medium in engineering design. When combined with interactive simulation, MR can serve as a design-thinking environment where geometry, performance, and discussion can be brought together in one place. CFD simulations are a completely new paradigm for me personally, as my background is in manufacturing, and hence, it proved to be a great learning experience.

There are several key challenges in building tools, data interoperability, adoption of these tools and integrating them into current design workflows. From a development perspective, data flows remain a challenge due to the inherently different purposes of Game engines and engineering CAD kernels. Whereas, for adoption, successful uptake depends on usability, trust, training, and a clear value proposition in terms of time saved or decisions improved. There is also a hardware barrier to adoption, which is likely to be overcome by improved, lighter, and higher-performing VR/AR headsets/glasses in the future. Additionally, the user interface could be a very important factor for the adoption.

References

1. AMRC digital design thread
2. K.-H. Chang, *Product Manufacturing and Cost Estimating Using Cad/Cae*. Elsevier, 2013. doi: 10.1016/C2012-0-00833-2.
3. S. Solmaz and T. Van Gerven, “Interactive CFD simulations with virtual reality to support learning in mixing,” Comput. Chem. Eng., vol. 156, p. 107570, Jan. 2022, doi: 10.1016/j.compchemeng.2021.107570.

Appendix

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