Revolutionizing aerodynamic design with a VR-enabled workflow

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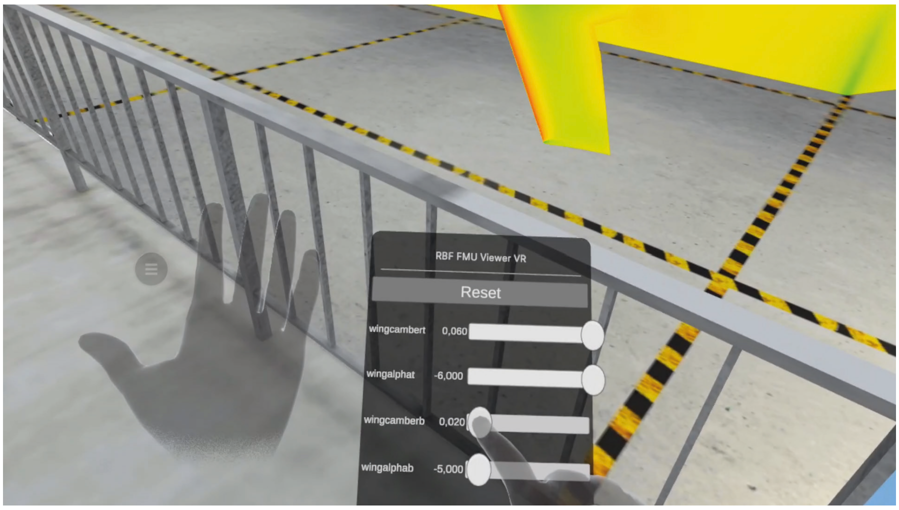
The aerospace industry is undergoing a rapid digital transformation, embracing innovative technologies to streamline design workflows, increase efficiency, and drive innovation like never before. One of the most exciting breakthroughs is the integration of virtual reality (VR) with reduced order models (ROMs), to enable real-time aerodynamic design exploration.

Traditionally, engineering workflows have been slow and resource-intensive, with design iterations relying on lengthy computational fluid dynamics (CFD) simulations. This article presents a game-changing approach – one that seamlessly links CAD modelling, CFD, and ROMs within an interactive VR dashboard. The result? A fast, immersive, and intuitive tool that allows engineers to explore designs in real-time, making the whole process more dynamic and efficient.

Bridging the gap: from CAD to VR

Aerodynamic performance optimization has traditionally been a highly iterative process. Engineers must analyse multiple design variants using high-fidelity CFD simulations, which are accurate but computationally expensive and time-consuming. Integrating VR and ROMs into the workflow helps overcome these challenges by providing a real-time design environment with interactive parameter exploration.

By incorporating CAD parameterization and mesh morphing, engineers can seamlessly



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adjust shapes without the need for repeated re-meshing. This not only streamlines the design process, but also reduces computational delays, allowing for faster and more efficient iterations. The idea is to create a direct link between CAD and the mesh, so that shape modifications are defined at the CAD level while the numerical analysis model is updated via mesh morphing. This ensures excellent shape control, with the mesh automatically updated and computational times significantly reduced.

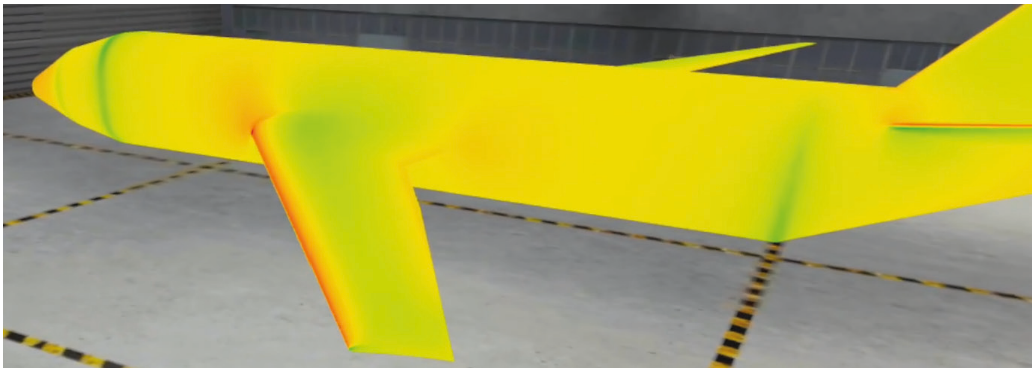
To enable this CAD-mesh link, we have created a tool (based on the OpenCASCADE engine) that generates two isotopological point clouds – one on the baseline and one on the modified variant. These point clouds are interpreted as an RBF field, which can then be used to transfer shape modification data from the CAD model to the mesh.

Another key benefit of using mesh morphing is that it ensures that each design point maintains an isotopological mesh, i.e. the same number of nodes and elements across all variations. This consistency is crucial for developing POD-based reduced order models (ROMs). ROMs provide compact yet highly accurate representations of high-fidelity CFD results, preserving predictive accuracy while drastically reducing simulation time.

Functional mock-up units (FMUs) enable standardized data exchange, ensuring compatibility between different simulation tools and digital twin environments. FMUs have been adopted as the standard for transferring information and integrating ROMs into the VR framework.

The virtual reality interface revolutionizes the way engineers interact with aerodynamic data, providing an immersive environment where they can visualize the impact of design changes and make informed decisions in real time.

By integrating these technologies, engineers can instantly adjust design variables and see the impact on aerodynamic performance in real time – all within an interactive 3D environment. This direct approach makes the design process more intuitive, efficient, and engaging.



Industrial applications and benefits

The effectiveness of this workflow was demonstrated using the open parametric aircraft model (OPAM), a simplified representation of a Boeing 787. This test case clearly demonstrated how the combination of ROMs and VR can revolutionize the aerodynamic design process. One of the most significant benefits is the dramatic reduction in the time required for design iterations, allowing engineers to explore more possibilities more quickly and easily. Traditional CFD-based workflows often take days or even weeks to generate results, whereas this approach allows for real-time modifications and evaluations, enabling much faster decision-making.

Another key benefit is the improved engineering insight. The immersive capabilities of VR provide an intuitive understanding of complex aerodynamic effects, allowing engineers to see firsthand how changes in shape affect airflow and performance characteristics. This, in turn, promotes more informed decision-making and greater confidence in the final design results.

The collaborative potential of this workflow is substantial. By enabling engineers, designers, and decision-makers to interact with the same 3D model in a shared virtual space, cross-discipline collaboration is enhanced, communication barriers are broken down and the development process is streamlined. Additionally, the use of FMUs ensures seamless integration with existing CAE (computer-aided engineering) and PLM (product lifecycle management) tools, making this approach easy to adopt within established workflows.

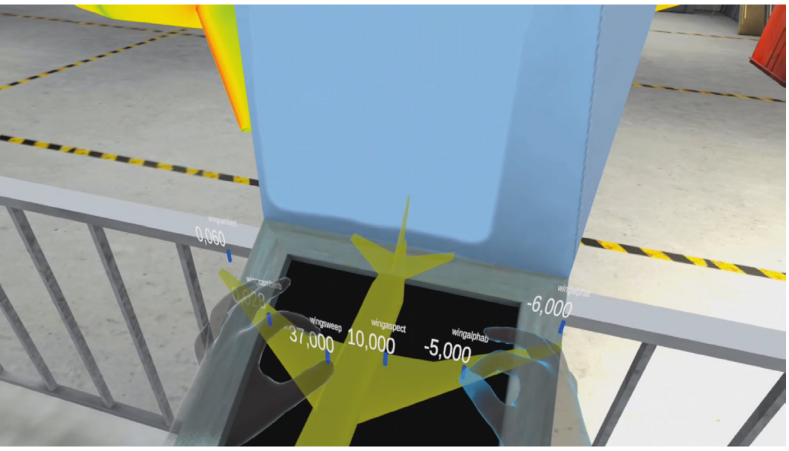
The VR-enabled dashboard

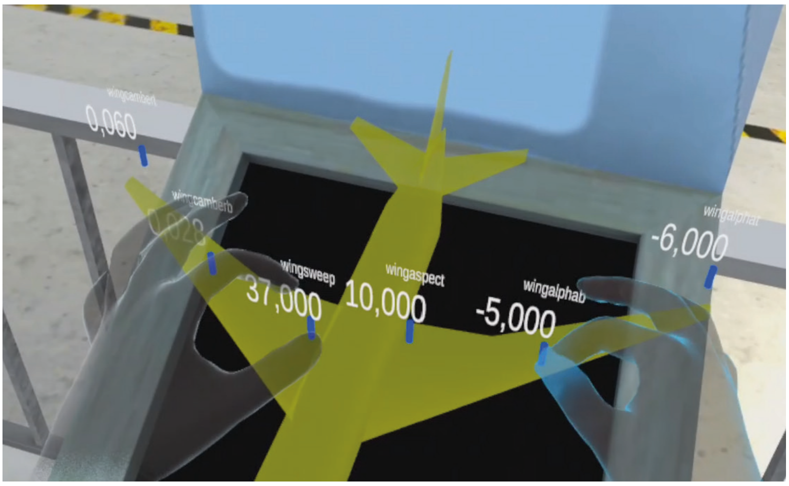
Developed in Unity, the VR-enabled dashboard introduces a powerful interface that allows engineers to manipulate aerodynamic parameters in real time and receive immediate feedback on performance. The Meta Quest 3 headset was chosen for its high-resolution display, intuitive interaction features, and, crucially, its ability to operate in a wireless configuration.

Unlike research VR applications that require a connection to a powerful workstation, our solution runs as an on-device application, providing greater flexibility and enabling collaborative experiences without the need for tethered setups.

We are also actively developing an app for Apple Vision Pro, bringing this innovative technology to an even more immersive platform. The expected release is imminent, promising an exciting leap forward in interactive aerodynamic design. This expansion will significantly broaden the accessibility of this innovative workflow, making it available across multiple innovative VR platforms.

The system provides a dynamic and responsive environment where users can control aerodynamic parameters through intuitive interfaces. Instead of relying on traditional numerical input methods, engineers can use sliders and handles to precisely adjust design variables and receive immediate feedback as changes take effect.
For those who prefer a more tactile approach, the system allows direct manipulation of 3D model control points, providing a more interactive way to modify aircraft geometry. Furthermore, real-time data overlays provide continuous insights into critical aerodynamic





metrics, including drag, lift, and pressure distribution, ensuring that design choices are always backed by data-driven analysis.

This reimagined design process represents a significant departure from traditional simulation-driven workflows, shifting towards a more intuitive and immediate method of performance evaluation.

Expanding the potential: future applications

Although originally designed for aerospace applications, this VR-integrated ROM workflow has the potential to revolutionize various other industries.

- In the medical field, this approach is being adapted to support surgical planning, allowing medical professionals to interact with the patient's anatomy in a virtual environment. By visualizing and optimizing procedures before they take place, surgeons can increase precision, reduce risks, and improve patient outcomes.
- In automotive design, similar approaches can be used to optimize vehicle aerodynamics, leading to improvements in fuel efficiency and overall performance.
- In marine engineering, streamlined hull designs can be tested to minimize hydrodynamic drag and improve overall vessel efficiency.
- In wind energy, turbine blade designs can be rapidly adjusted to maximize power generation while maintaining structural integrity.
- In industrial aerodynamics, applications range from optimizing HVAC (heating, ventilation, and air conditioning) systems to analysing urban wind flow dynamics and improving industrial cooling solutions.

The flexibility and scalability of this approach makes it incredibly adaptable to industries where real-time design evaluation and optimization are essential. By allowing engineers to interact with complex aerodynamic data in an immersive and intuitive way, this technology can revolutionize not just aerospace design, but a wide range of engineering disciplines.

Conclusion

This VR-enhanced aerodynamic design workflow represents a ground-breaking shift towards interactive, high-speed, and highly efficient engineering processes. The combination of ROMs, FMUs, and immersive VR is transforming the way engineers interact with simulation data, providing a level of insight and engagement that was previously unattainable.

As industries place greater emphasis on faster, more cost-effective, and data-driven design cycles, the role of real-time simulation and VR will become increasingly important. Future advancements will expand the dataset, integrate AI-driven optimization techniques, and explore even broader engineering applications. This will further refine and enhance the workflow, pushing the boundaries of what is possible and enabling engineers to solve complex problems with greater efficiency and precision.

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About RBF Morph

RBF Morph is a cutting-edge company specializing in advanced mesh morphing technology powered by Radial Basis Functions (RBF). Our flagship solution, seamlessly integrated with Ansys, enables fast, precise, and efficient shape modifications for CAE simulations—eliminating the need for remeshing. This breakthrough technology accelerates design optimization, parametric studies, and real-time shape adaptation, making it an essential tool for engineers and designers. Widely adopted across the aerospace, automotive, and biomedical industries, RBF Morph empowers companies to push the boundaries of innovation, enhancing performance, efficiency, and reliability in product development.