Practical Case Study: Shape optimization for fixed Wing UAV

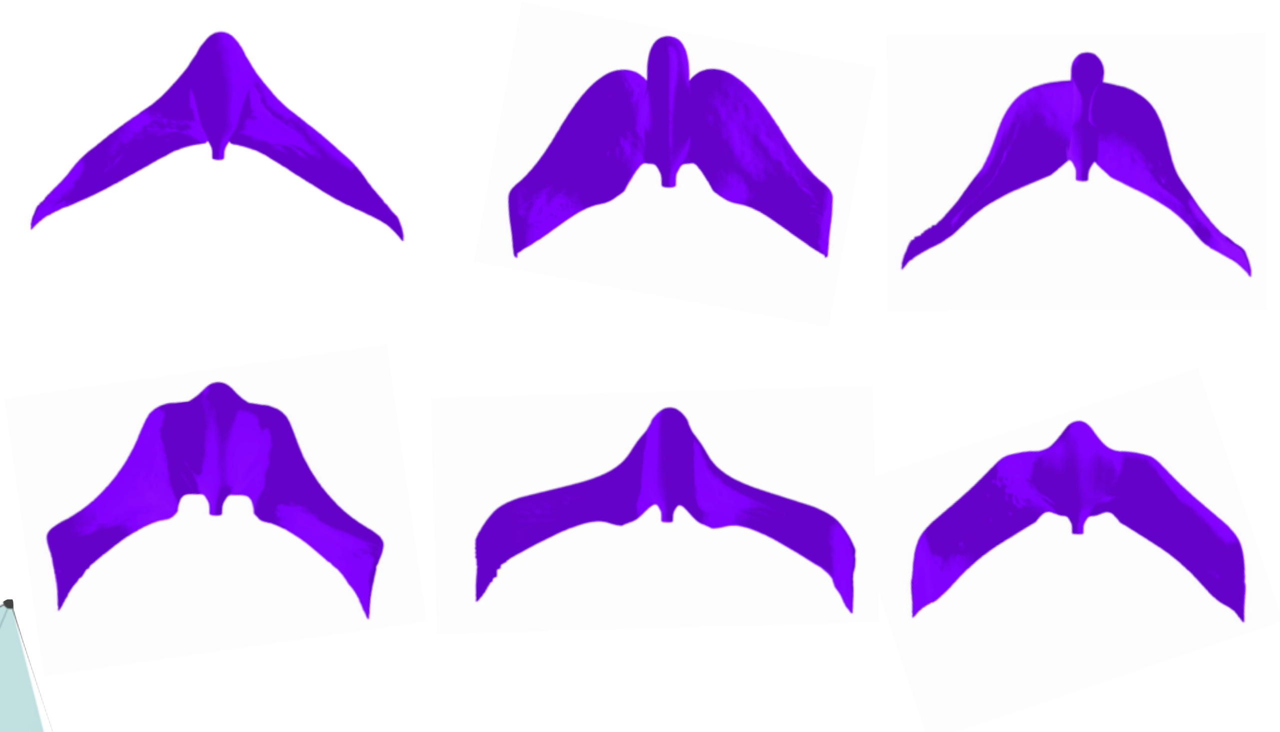
Goal

An engineer wants to improve the design of an existing fixed wing UAV by increasing lift by 1.5 times in order to let it carry heavier loads. He wants to leverage on drag measurements for 10 previous prototypes which were tested in a wind tunnel, on an historical simulation results database produced by is department over the years with 500 simulated shapes. He can also use new simulation, but each call to a simulation costs 100$ and takes one day on a cluster of machines.

Step 1 - Preliminary design

The engineer needs to show a prototype to its management team and quickly produce a good design which has exactly the right behaviour. He feeds its historical data into our Neural Network in the form of 3D surface meshes (standard ".stl" or ".obj" files) and lift values. Our network will be able to quickly create a approximate model for the lift of an arbitrary new design. This lets our neural network explore very quickly all possible designs and **provide a first drone shape which approximately meets the target criteria**.

Contrarily to existing "surrogate methods", which also create an approximate model based on ML to quickly estimate drag, our software can leverage historical data from many different sources, without them having an underlying shared parametrization. This is critical in the case of the company which has a large legacy of simulation results.



Step 2 - Manual search for a good design

The engineer now attempts to manually modify this initial design to improve it. The traditional option would be to iteratively try a few designs and test them in simulations. However, once again each of these iterations takes a full day of computation, **which**

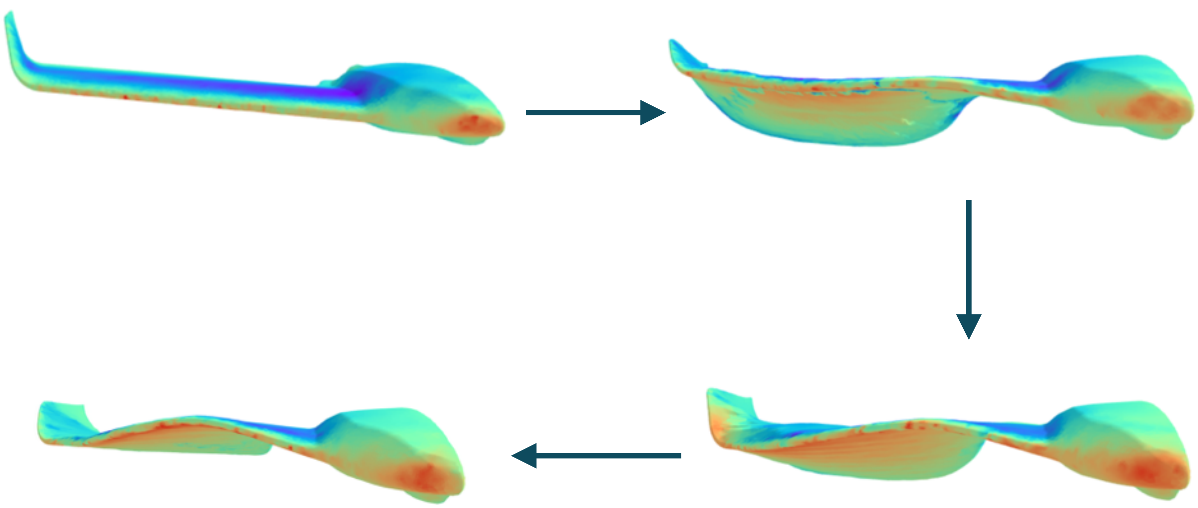
slows down work drastically. Thanks to our solution, he can get **an estimate of the lift of each new design, interactively on its CAD tool**. Since our algorithm also provides a confidence score on the lift prediction -- i.e. how close it is expected to be to what the simulator would give -- he is wisely advised to call back the simulator when necessary and this new data point will be used to refine the estimates.

> *Existing methods based on simplified flow equation, can also provide an approximate simulation relatively quickly. However, it necessitates to parametrize an approximate simulator, which will in most cases return results which are completely different, even for the know cases, and on average, from those of the actual simulator. On the opposite, our network will always provide results which are close to the one of the simulator.*
> *As opposed to parametric surrogate methods -- e.g. Kriging --, ou approach leaves the user completely free in the design. He can use his own CAD software, import designs from outside.*

Step 3 - Numerical shape optimization

The work that was done manually by the engineer in the case above, can be automatized and accelerated. Hence, in order to maximise the performance of its design, the engineer now uses our automatic shape optimization loop. As in step-1, the engineer provides a set of design goals. He chooses to interface our program to the simulation software he was using -- we are already compatible with several popular ones —, which will be called back only when it is necessary to improve the accuracy of the prediction. This leads to a design a human could not have thought of, briging performance gains and time savings.

> *Previous methods for shape optimization, based on response surfaces and implemented on commercial softwares, are limited by the fact that they need a low dimensional parametric representation of the shape. With our approach, the optimization algorithm can create arbitrarily complex shapes, and the user can easily manually interact with the optimisation algorithm. Therefore, numerical optimization becomes much more smoothly integrated in the whole engineering process.*



Numerical optimization process

Competitors working with “classical’ response surfaces:

- https://www.caeses.com/products/caeses/design-exploration-and-shape-optimization/
- https://www.ansys.com/products/platform/ansys-designxplorer/designxplorer-capabilities#cap2
- http://www.mscsoftware.com/application/design-optimization
- …

	Standard approaches	Neural Concept AutoSurro	Practical Gain
I want to interactively estimate the performance of a wing while designing in my CAD software.	• I have to go though a *painful and manual* Geometry processing and meshing process. • Good simulators are *slow* and fast simulators are *inaccurate.*	I get a *reliable prediction* for any new design, based on a *massive history of accurate simulation.*	*Geometry processing is the first pain point for CFD* engineers and the main factor slowing down the transfer *from Design to Engineering.*
I want to numerically optimize this design.	• Require to choose a restricted parametrization of the shape and stick with it forever. • Need to recompute data from scratch. Underwhelming in the age of data.	• I change my parametrization whenever I want. • More exhaustive search of the space. • I can flexibly use historical data from many sources.	• Makes it much more natural to use numerical optimization everyday. • Optimal decisions along the whole conception process.

Difference between our approach and competitors on practical tasks