Aerodynamic Innovation through Machine Optimisation

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1st Annual SU2 Conference
June 12th, 2020
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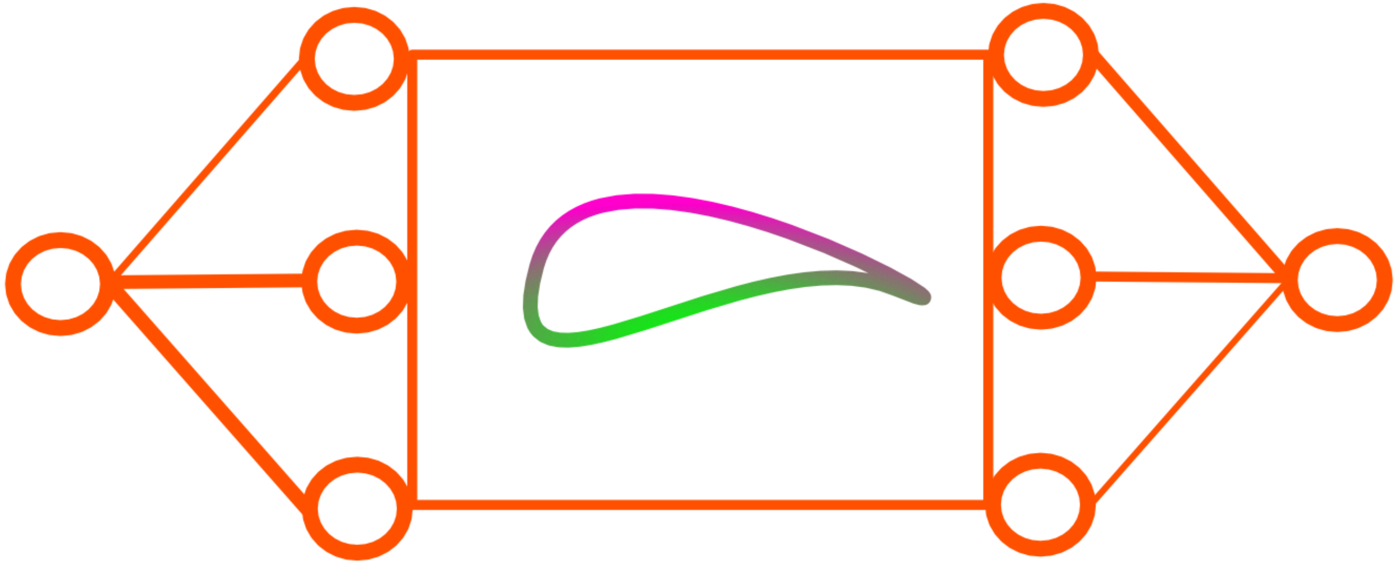
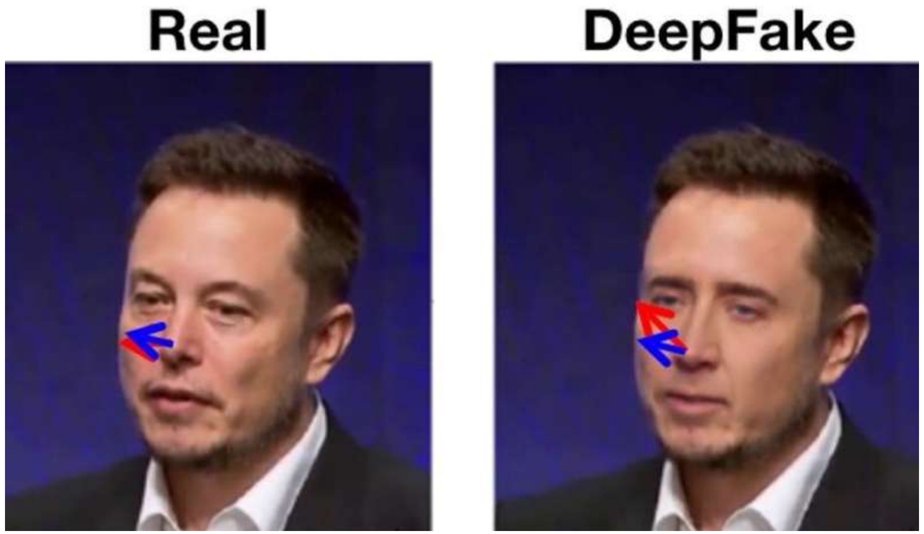
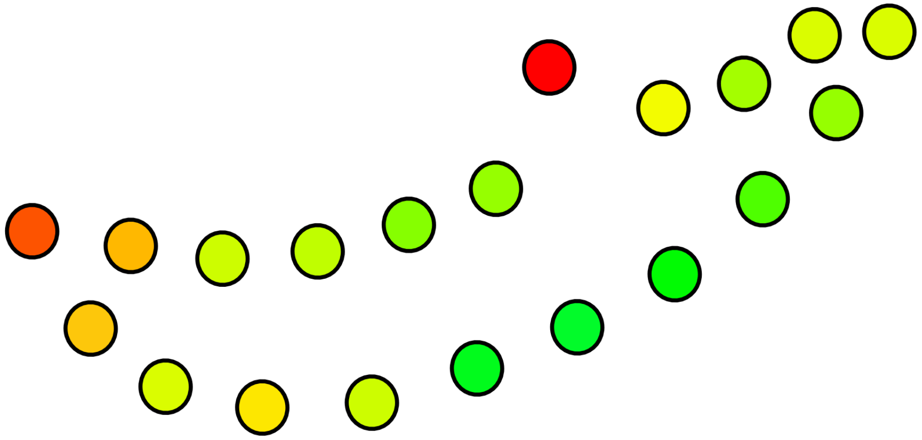


Machine Learning in CFD

As general ML moves from prediction to generation, CFD has opportunity to truly innovate.

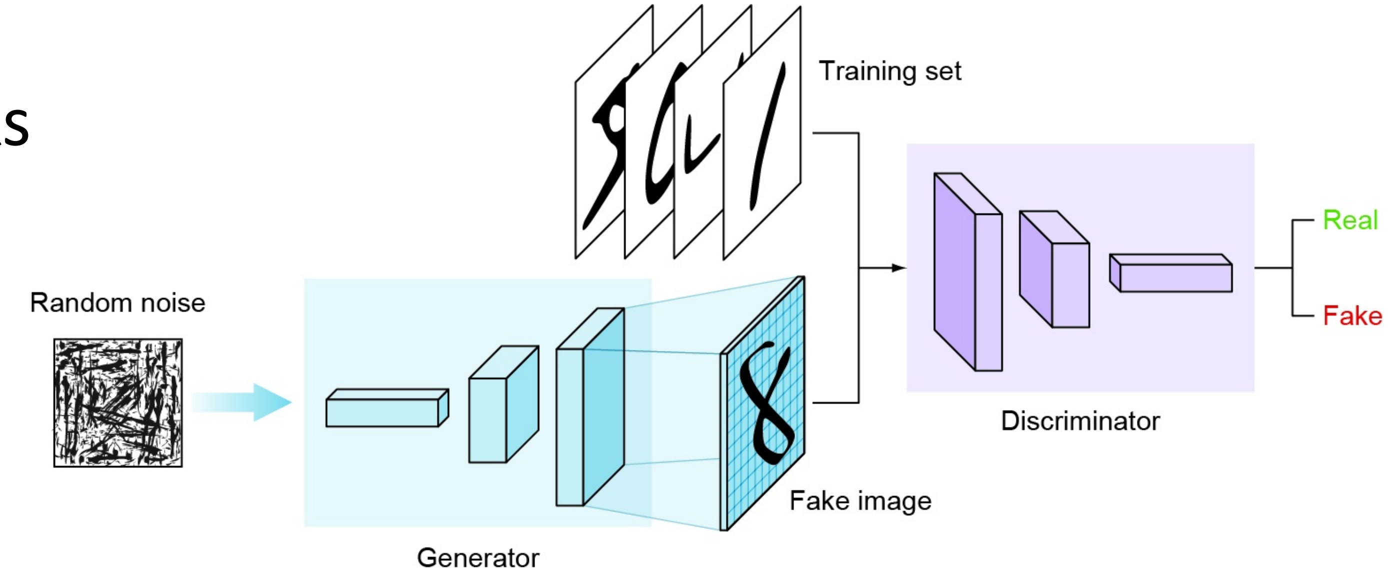


Frameworks now exist that can theoretically teach machines to design aerodynamic surfaces, if given a solid optimization function.



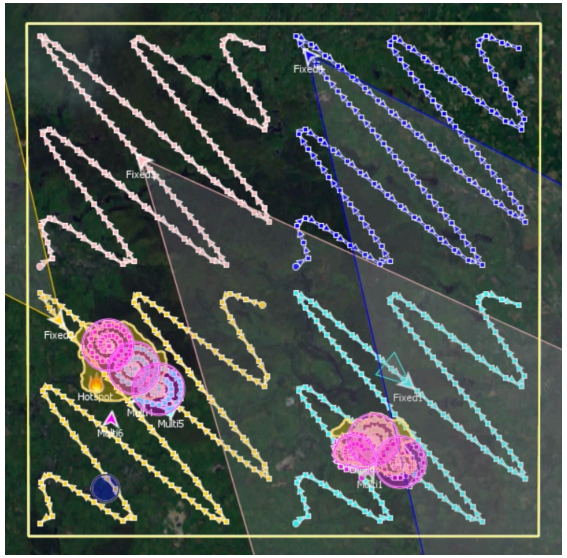
Foundational Work

Generative Adversarial Networks



Bézier Surfaces

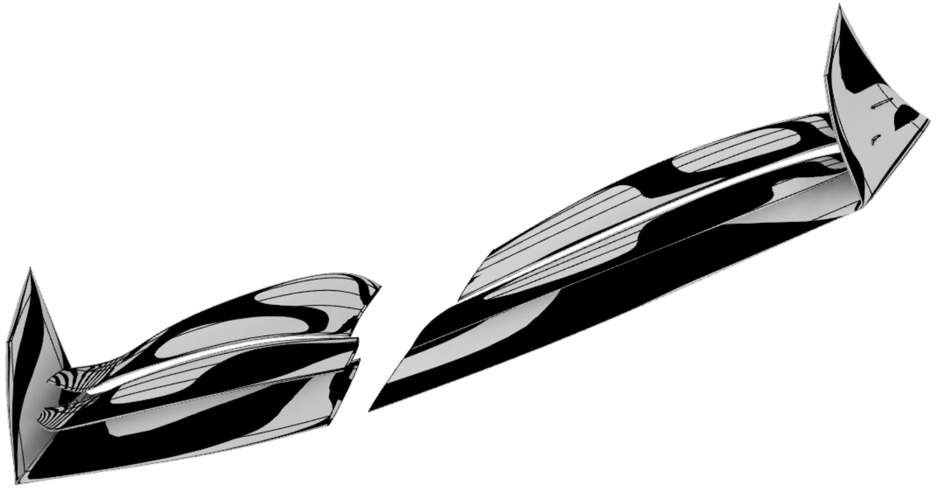
Swarm AI Management (novel to CFD)



Swarm AI in Aerofoil Management (EFA)

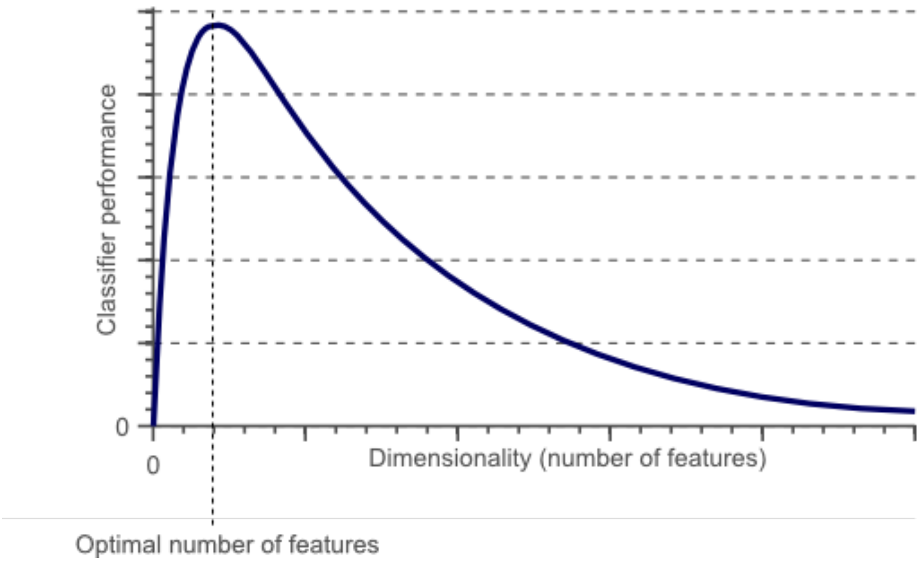
EFA allows a machine to decide when to add or remove surfaces.

EFA quickly and accurately identifies surfaces causing problems.

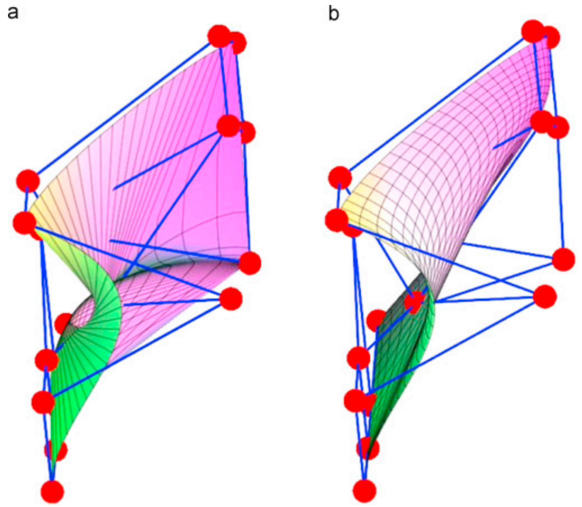


Bézier Surfaces and Dimensionality Reduction

Neural networks work best with fewer dimensions. Both computational cost and network accuracy improve with dimensionality reduction.

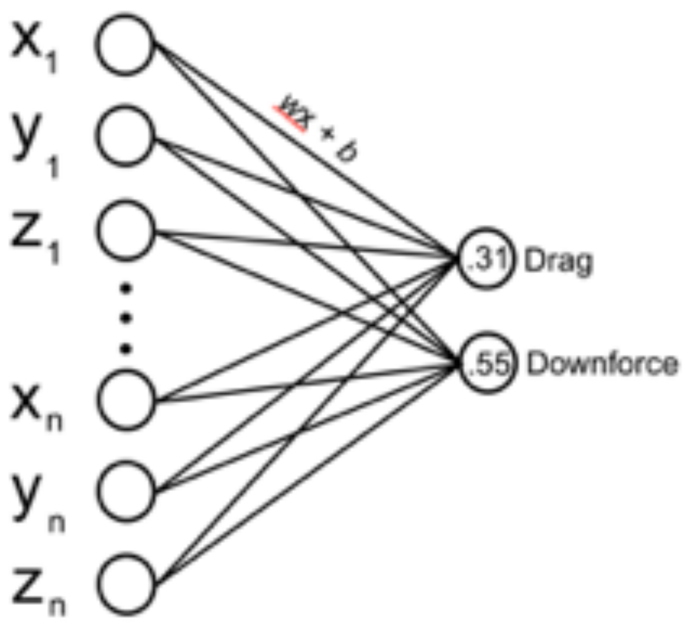


Bézier surfaces are controlled by a few points- controlled movement from a few points can create deeply complex patterns.

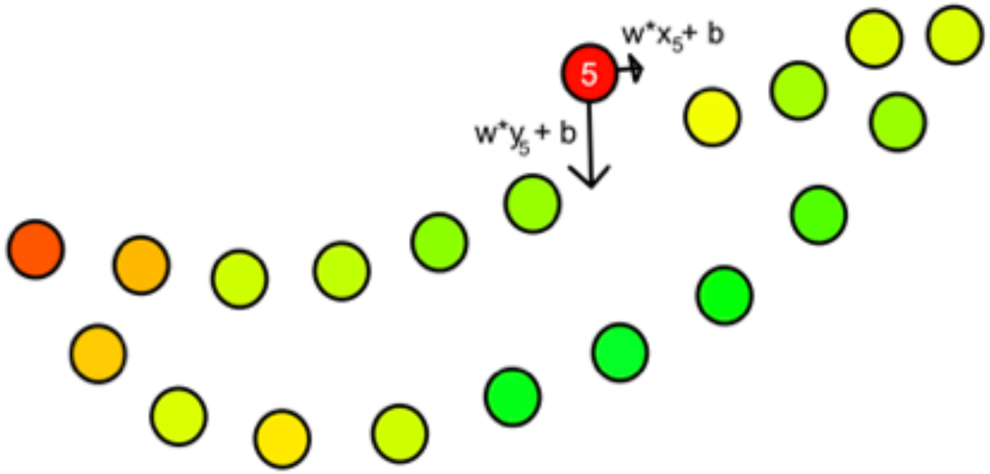


Aerofoil Optimisation through Backpropagation

Linear transformations applied in ML can be translated to point movements.

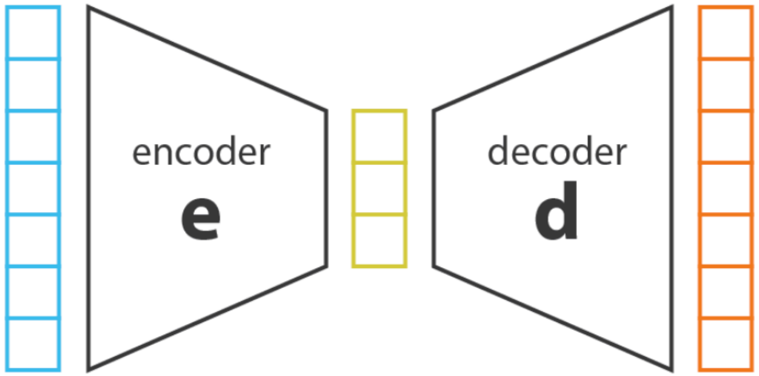


Backpropagation can optimise surfaces in a pointwise manner (including Bézier points).

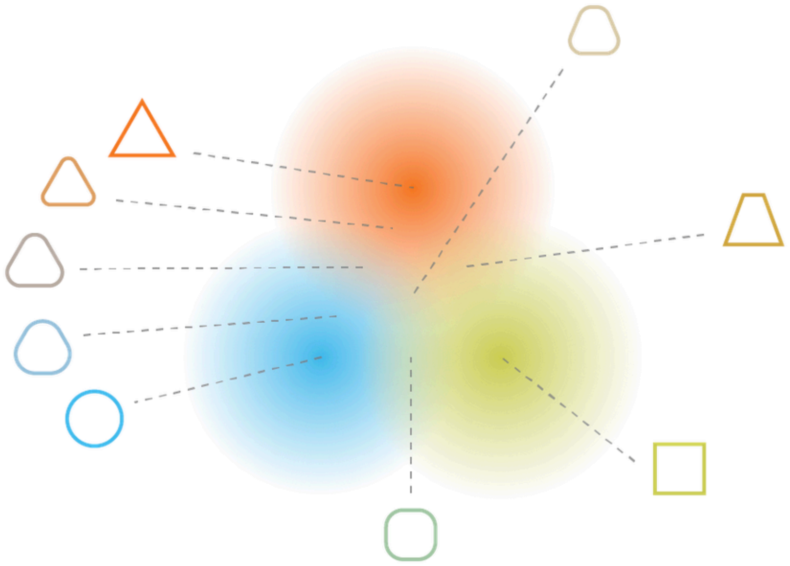


Autoencoded Latent Space

Autoencoders perform dimensionality reduction on input data and create a latent input space between the two.

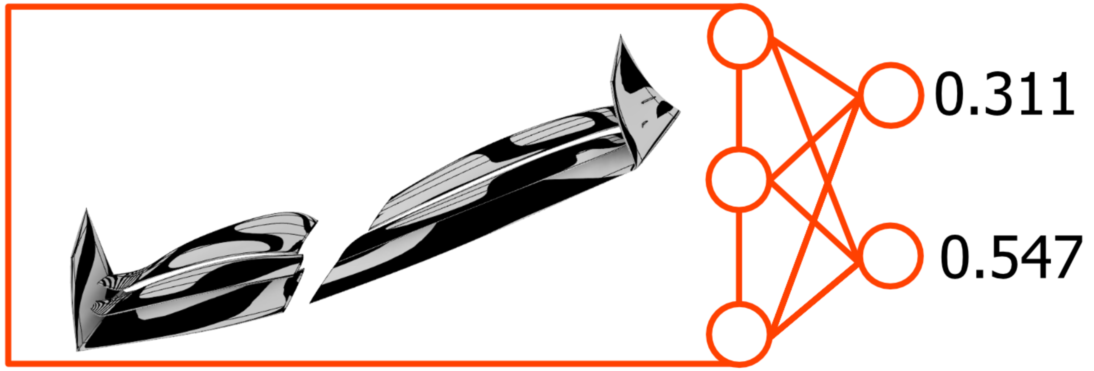


Sampling from this latent space allows machines to generate new data from inferred patterns.

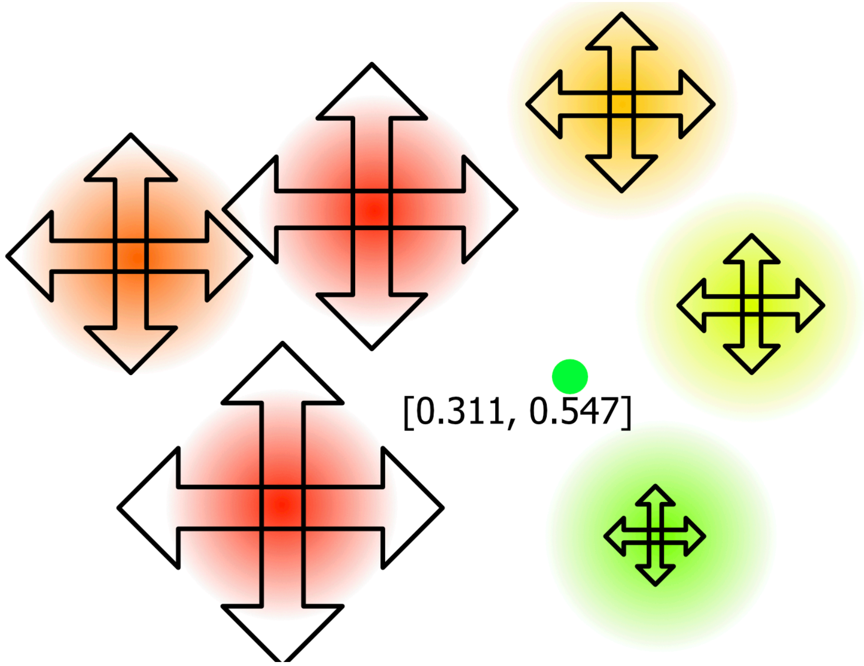


GAN Wing Generation

Autoencoders can learn to identify good and bad wing designs in latent space.



Using an error function of drag and downforce, good wings are distinguished from bad in latent space.



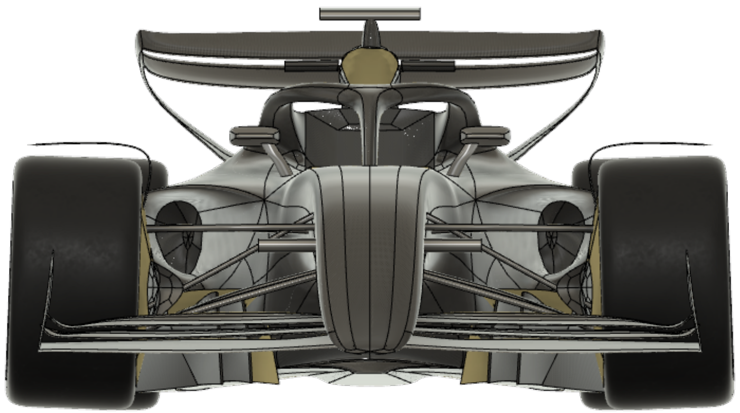
Technical Implementation

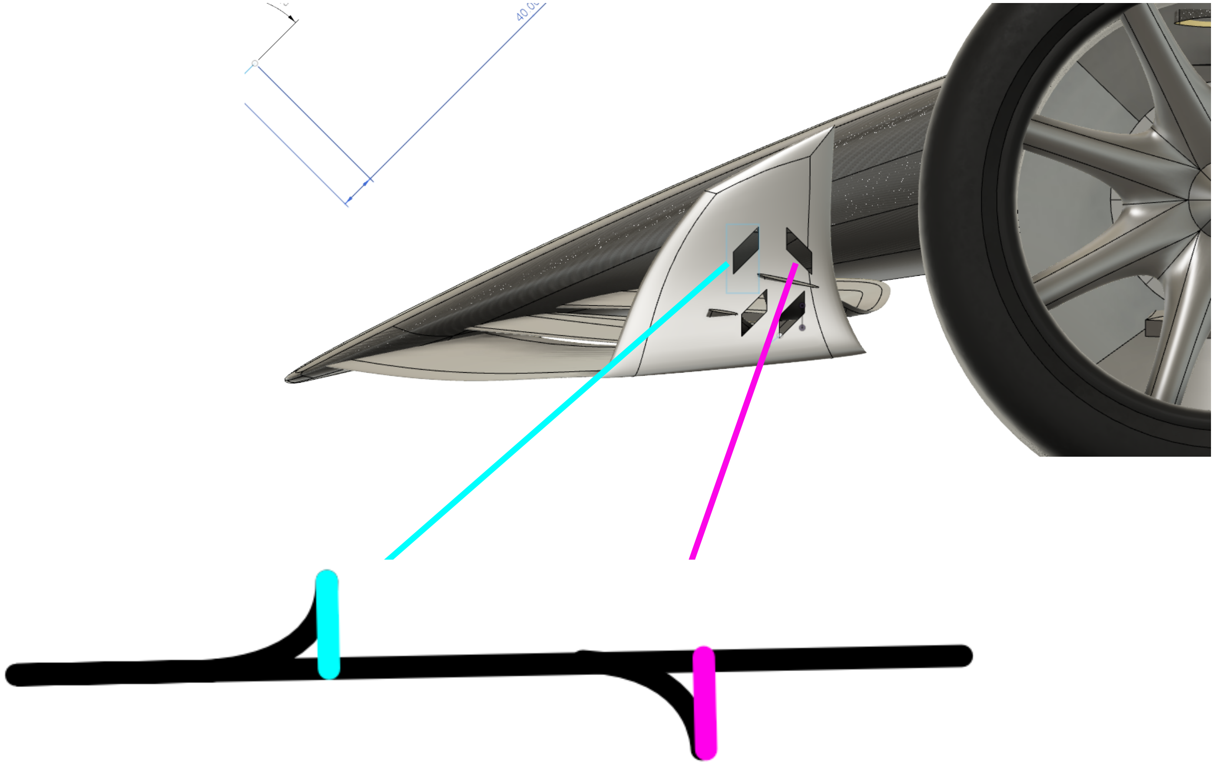
- Numba in Python (C-like runtime)
- Logistic regression and backpropagation appropriately transform Bézier coordinates
- EFA adds/removes surfaces where appropriate
- Mesh smoothing removes anomalous points
- SU2 computes overall drag and downforce coefficients through simulation
- Management functions upsample Bézier mesh to pointwise and track surface changes
- Running on Tesla K80, provided by Azure

$$C_{drag} = \frac{2F_{drag}}{\rho v^2 \bullet A}$$

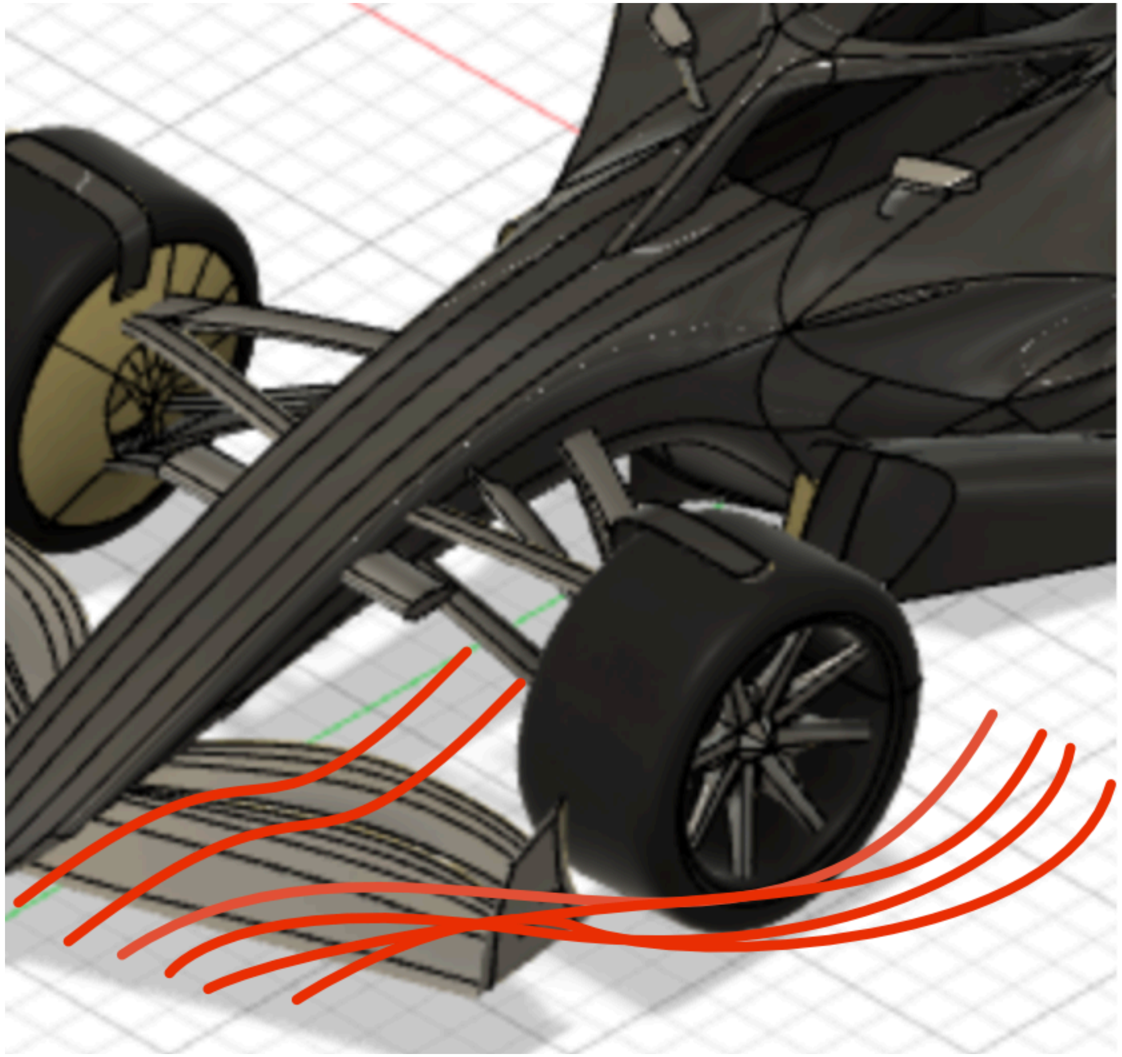
$$C_{downforce} = \frac{2 \bullet F_{downforce}}{\rho v^2 \bullet A}$$

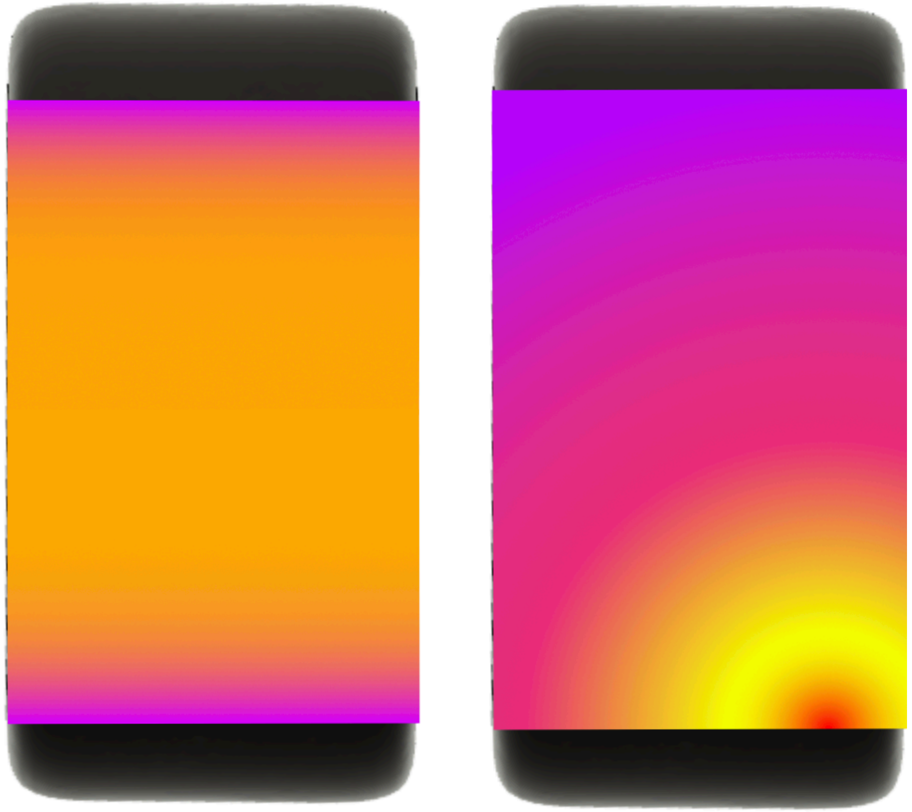
Formula One Front Wing Analysis (Part 1)





Formula One Front Wing Analysis (Part 2)





Why SU2 works for AI in CFD

- Multiphysics Simulation
- Open Source
- Accessible through fluent C++ API
- Excellent support from community and developers
- Aiming on an upwards trajectory and embracing innovation

Thanks for watching!

Questions?