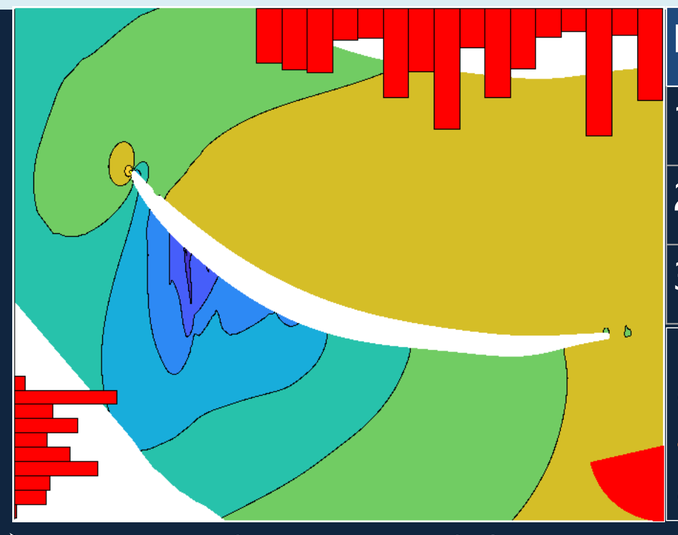
Airfoil Pressure Field Prediction using Machine Learning & Artificial Intelligence

Xu Zhang, Ivan Voutchkov, Andy Keane
UTC for Computational Engineering, Faculty of Engineering and Physical Sciences, University of Southampton
Fred Witham, Marco Nunez
Rolls-Royce plc.

Overview

This research tries to predict the pressure field contour map around the airfoil geometry using machine learning (ML) and artificial intelligence (AI) techniques including Artificial Neural Network (ANN), Convolutional Neural Network (CNN), and conditional Generative Adversarial Network (cGAN).

More than 341,000 airfoil pressure filed images have been collected using Hydra suite simulations. As shown in Figure 1, the ten design variables are embedded in the bottom-left corner vertically, while the 16 noises are embedded in the top-right corner horizontally and the target MO loss are encoded as a sector shape on the bottom-right corner. For classification problem, each image also has an assigned label according to its MO loss value, as shown in Table 1.



MO loss and Label	Records
1 – low (<3.0)	20,635
2 – mid (<3.5)	114,706
3 – high (<5.0)	206,258

Figure 1 (left): the exemplar pressure filed image with embedded design variables, noises, and MO loss value

Table 1 (above): the label criteria and record numbers of each category

- CNN and ANN models are trained offline using collected images as shown in Figure 2 (a) and (b). The training history is shown in Figure 3 (c) and (d).
- The cGAN's generator and discriminator were trained simultaneously as shown in Figure 2 (c) and (d).
- The trained models were saved and plugged into the workflow as the next step after cGAN, as shown in Figure 3 (a) and (b)
- The prediction accuracies were measured by comparing to real CFD simulation results, as shown in Figure 3 (e) and (f).

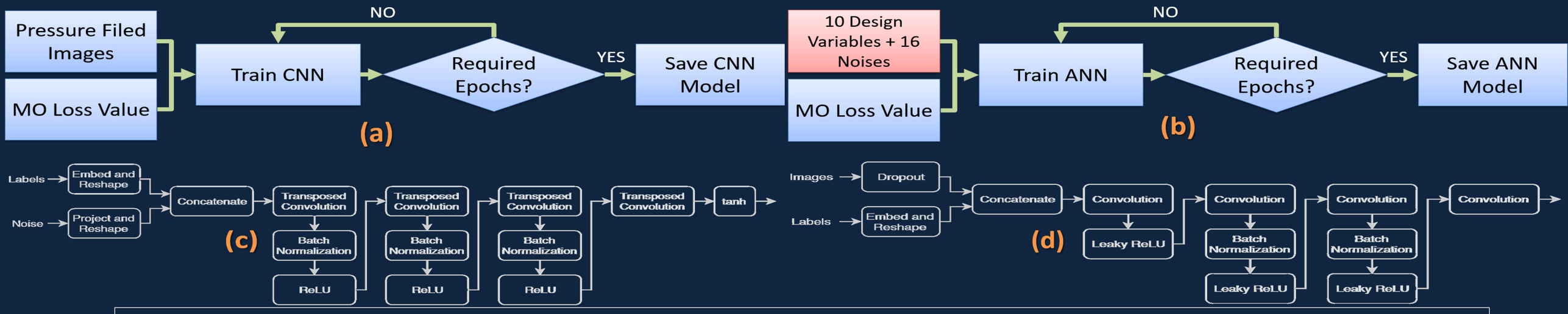
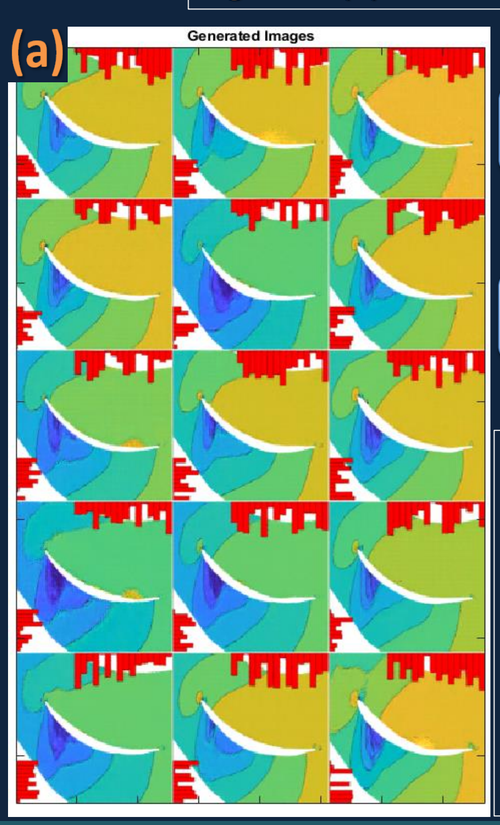
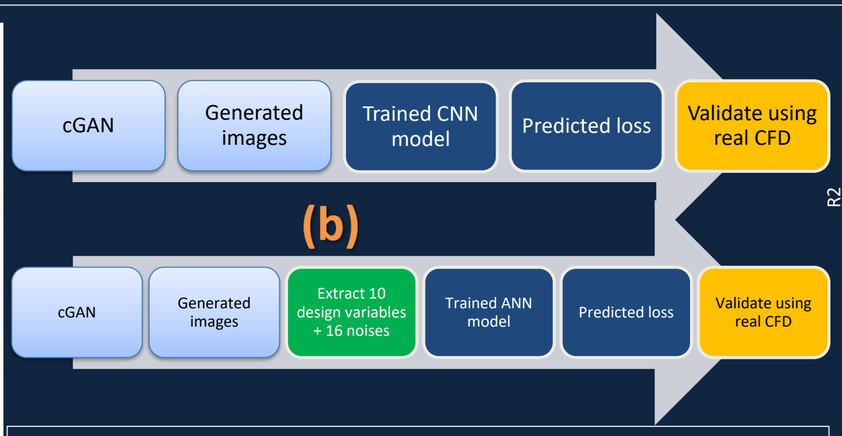
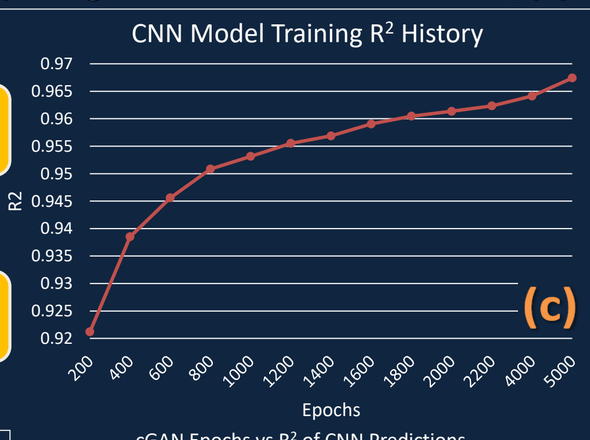


Figure 2: (a) The CNN training workflow; **(b)** The ANN training workflow; **(c)** The generator workflow of cGAN; **(d)** The discriminator workflow of cGAN







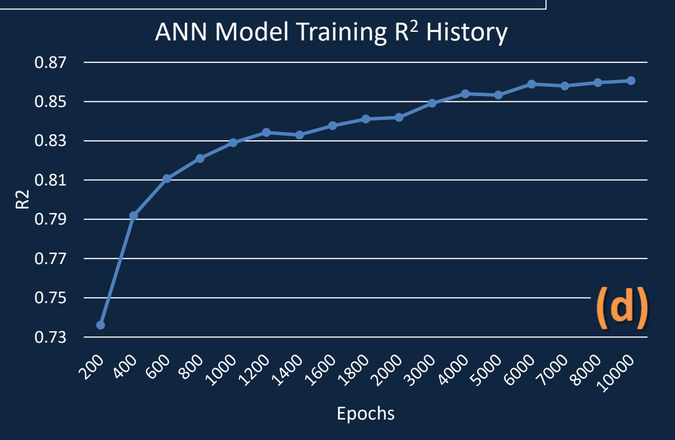
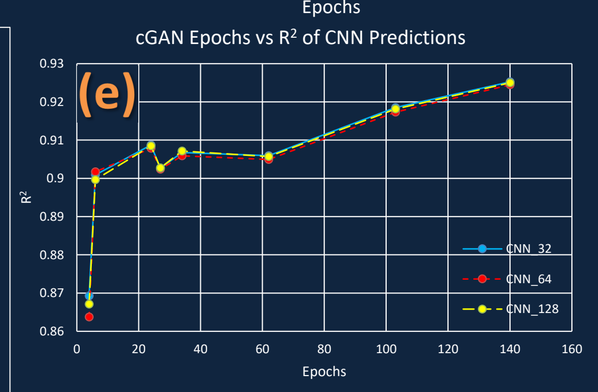
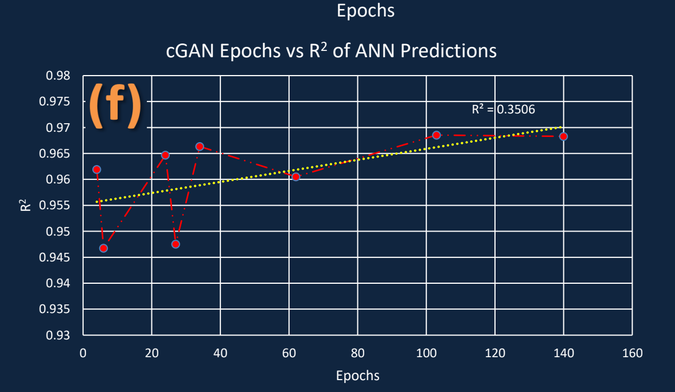


Figure 3: (a) cGAN generated pressure field images; **(b)** cGAN+CNN & cGAN+ANN workflows; **(c)** Training history of CNN model; **(d)** Training history of ANN model; **(e)** CNN prediction accuracy against cGAN epochs; **(f)** ANN prediction accuracy against cGAN epochs

Note: prediction accuracy was calculated using NN predictions against real CFD simulation results.





http://www.soton.ac.uk/engineering/research/groups/CED/posters.page | email: xu.zhang@soton.ac.uk
Computational Engineering & Design Group, B176, Boldrewood Campus,
University of Southampton, SO16 7QF, U.K.

This work is funded by the COLIBRI project