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## Airfoil Flow Optimized Control With an Upstream Cylinder

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# Airfoil Flow Optimized Control with an Upstream Cylinder

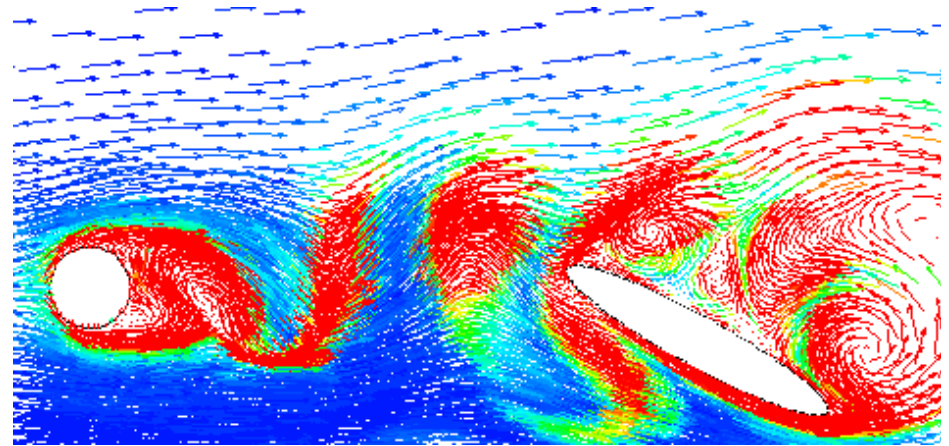
**Nicole Steiner, Meihua Zhang, Zhongquan Charlie Zheng**  
**Utah State University**

AIAA SciTech Forum, 3-7 January, 2022

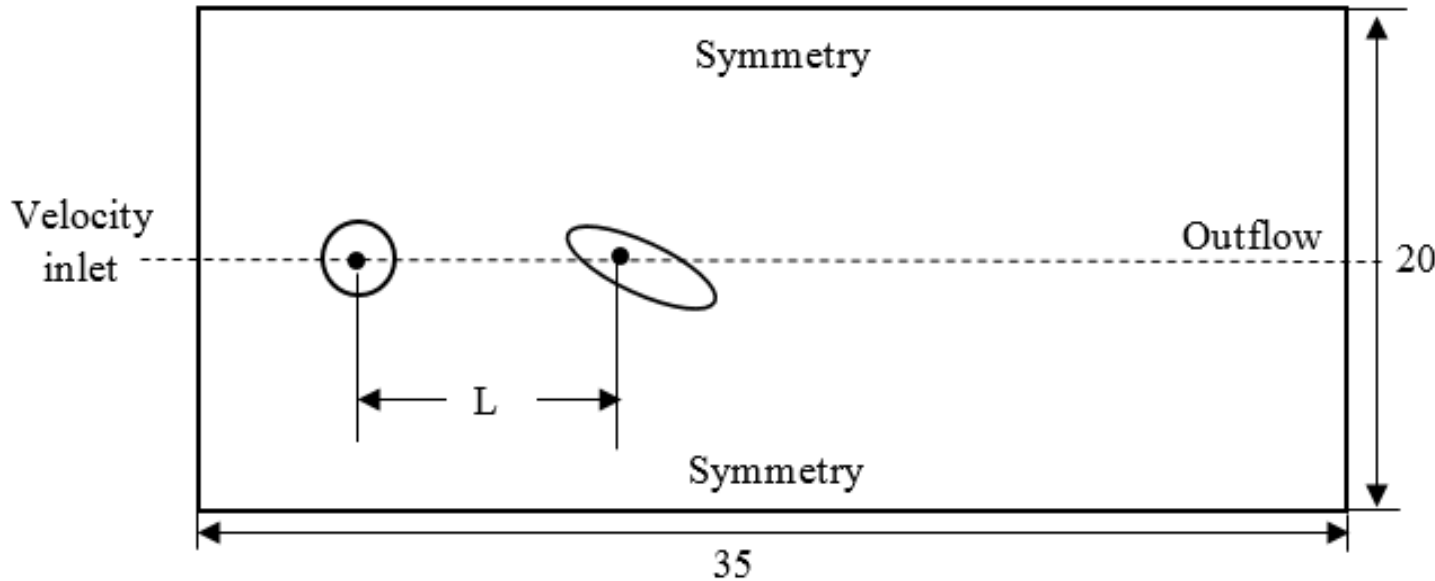
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# Airfoil Flow Optimized Control with an Upstream Cylinder

- An upstream object can affect the flow behavior of a downstream object
- Parameters are optimized to produce the greatest lift/drag ratio with a constrained lift coefficient
- The multi-variable optimization with constrained condition is achieved by neural network AI algorithms



# Airfoil Flow Optimized Control with an Upstream Cylinder



For the reference case, the configuration is the same dimensions and airfoil with no cylinder

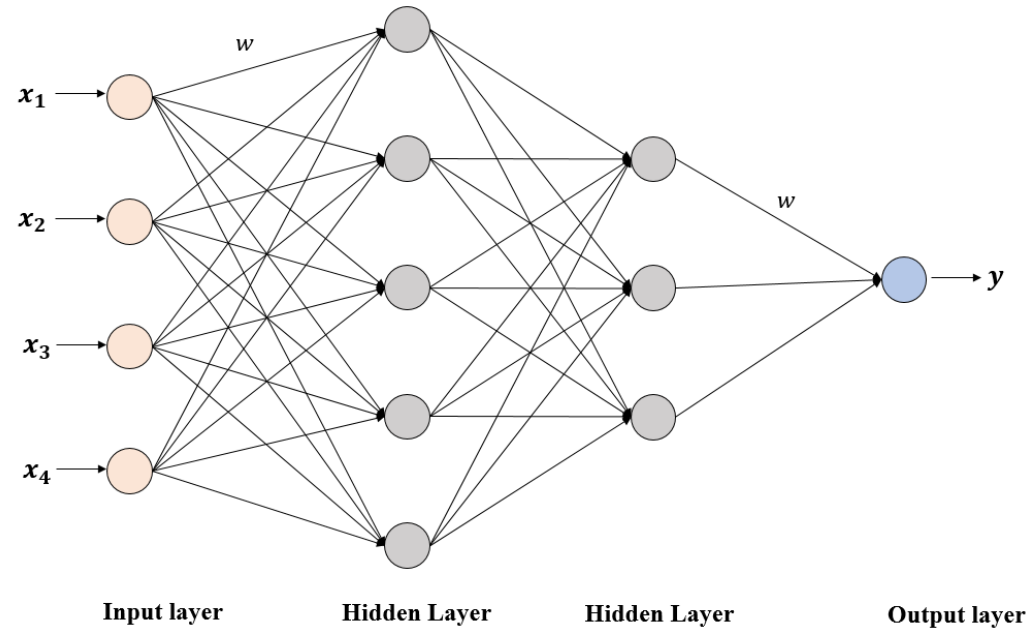
Motion of the cylinder is defined by:  $y(t) = A \sin(2\pi ft)$

# Airfoil Flow Optimized Control with an Upstream Cylinder

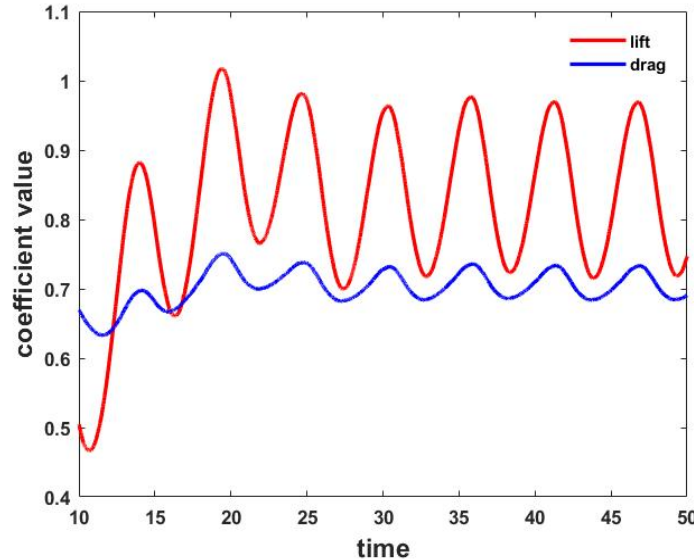
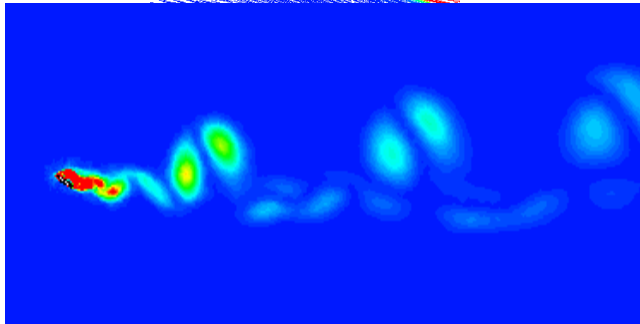
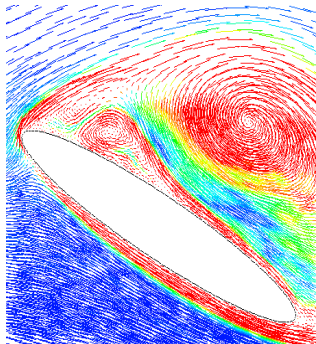
- 60 control cases were selected using the orthogonal test method
- Control parameters:
  - Oscillating frequency ( $f = 0.5, 1, 2, 4, 6$ )
  - Oscillating amplitude ( $A = 0.01, 0.02, 0.03, 0.05, 0.06$ )
  - Cylinder diameter ( $d = 0.1, 0.2, 0.3, 0.4, 0.5$ )
  - Distance between cylinder and airfoil ( $L = 1.25, 1.5, 2, 3, 4$ )
  - Reynolds Number ( $Re = 100, 500, 1000, 2000$ )

# Airfoil Flow Optimized Control with an Upstream Cylinder

- A BPNN was used in conjunction with a genetic algorithm to optimize parameters
- The GA optimized the lift/drag ratio with the condition  $C_L \geq 0.4$

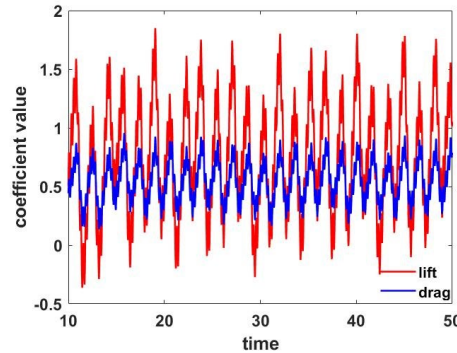
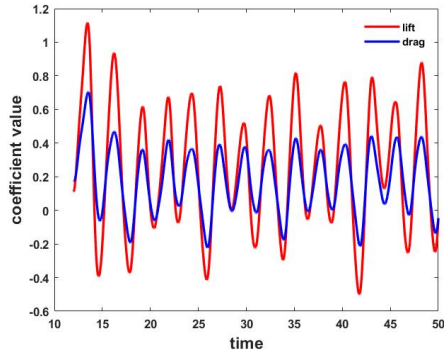


# Airfoil Flow Optimized Control with an Upstream Cylinder

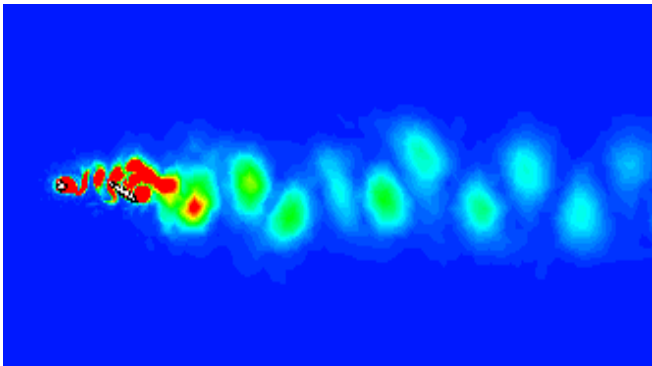


- $\frac{C_L}{C_d}$  for the reference case is 1.1779
- The average lift coefficient is 0.82969
- The average drag coefficient is 0.79436

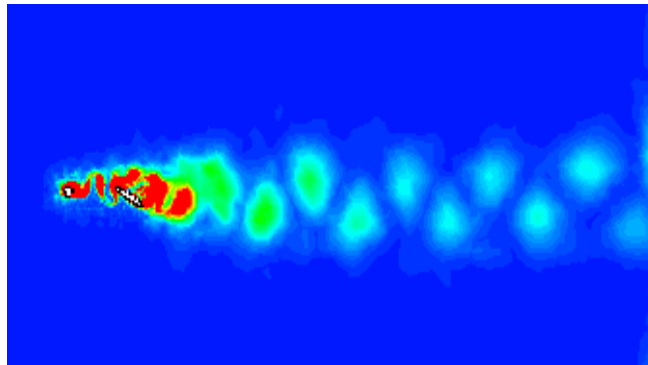
# Airfoil Flow Optimized Control with an Upstream Cylinder



- The lift/drag ratio and lift coefficient increased with higher frequency



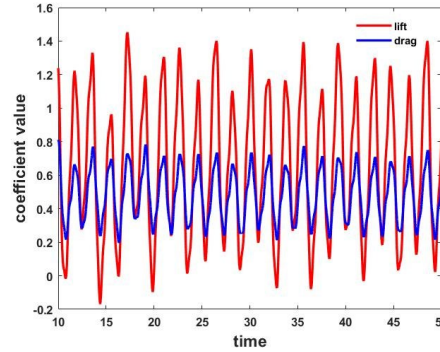
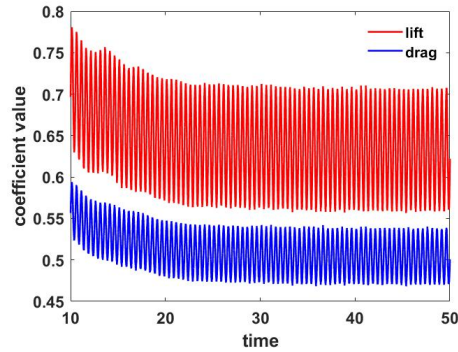
$f = 0.5$



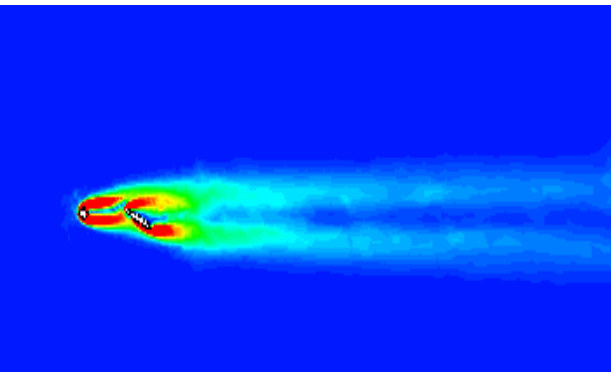
$f = 4$



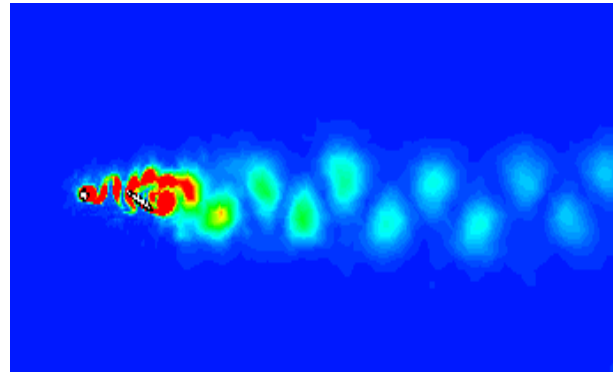
# Airfoil Flow Optimized Control with an Upstream Cylinder



- The lift/drag ratio and lift coefficient increased with higher Reynolds Number

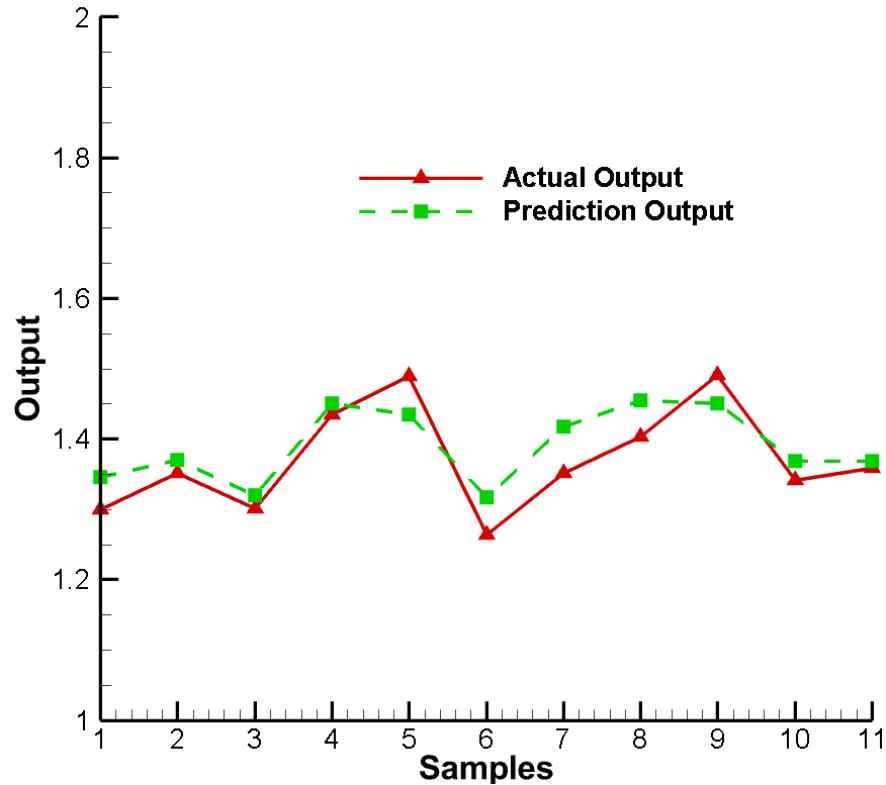


$Re = 100$



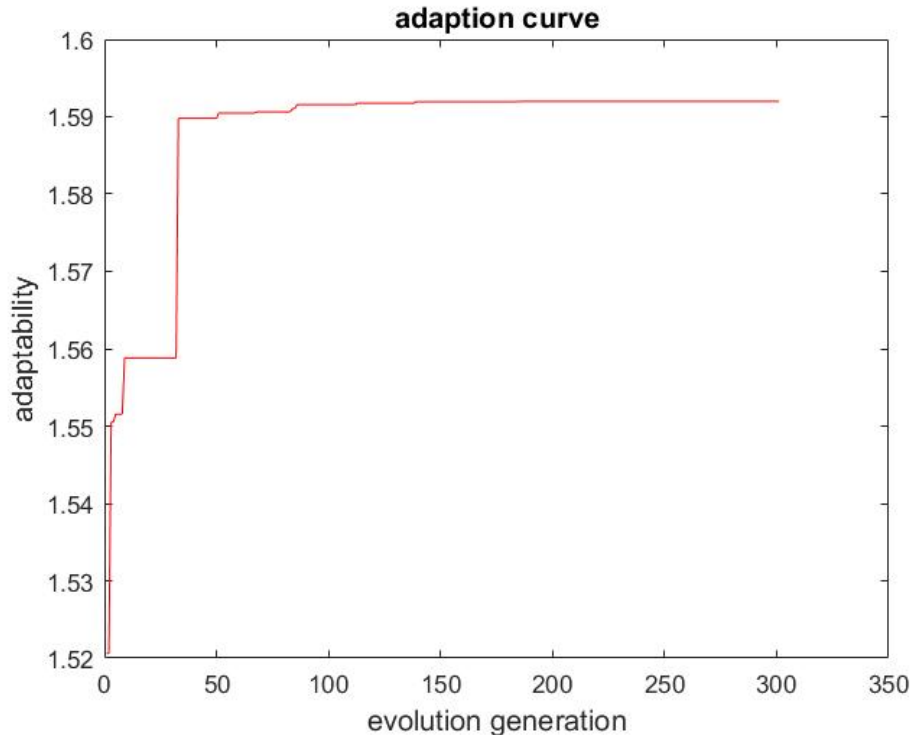
$Re = 1000$

# Airfoil Flow Optimized Control with an Upstream Cylinder



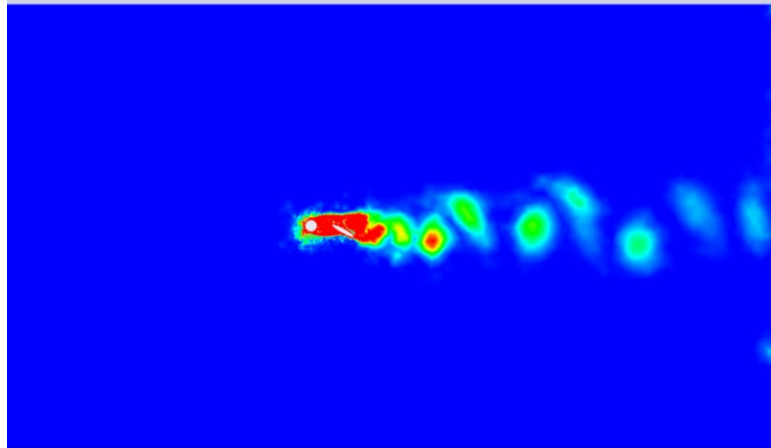
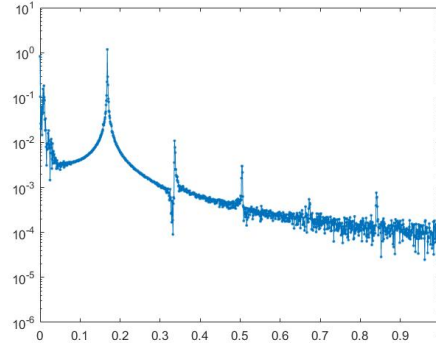
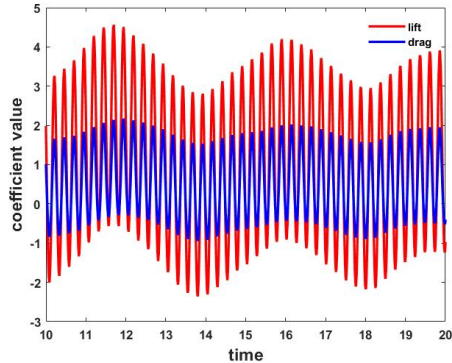
- The BPNN predicted lift/drag ratio values within 10% of the actual values

# Airfoil Flow Optimized Control with an Upstream Cylinder



- The GA predicted the optimal lift/drag ratio for  $C_L \geq 0.4$
- The optimal case had the following parameters and output:
  - $f = 4.0414$
  - $A = 0.0522$
  - $d = 0.5410$
  - $L = 1.20033$
  - $C_L = 0.5968$
  - $\frac{C_L}{C_d} = 1.5920$

# Airfoil Flow Optimized Control with an Upstream Cylinder



- The prediction case produced a lift/drag ratio of 1.7319 which was slightly greater than the GA prediction
- The actual lift/drag ratio of the prediction case is 50% greater than the reference case

# Conclusion

- The BPNN and genetic algorithm combination was effective in predicting the optimal case for the lift/drag ratio with a lift coefficient constraint
- Reynolds number has a positive correlation with lift/drag ratio
- Higher values for frequency would likely show an increase and then decrease in the lift/drag ratio, indicating an optimal value for the frequency
- The lift/drag ratio of the optimized case is 1.5 times the reference case, a significant improvement due to flow control by adding an oscillating cylinder upstream of the airfoil.



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