Flow behaviors of a downstream object can be affected significantly by an upstream object in close proximity. This concept is used for flow control in this study to maximize the lift/drag ratio on a NACA0012 airfoil. A cylinder with cross-flow translational motion is placed upstream of the airfoil, as shown in Fig.1(a). Numerical simulations are carried out with an improved immersed-boundary method to solve the incompressible, viscous flow at the Reynolds number of 2000. To achieve optimal condition for a maximum value of $c_l/c_d$, a combination of the back-propagation neural network (BPNN) algorithm and genetic algorithm (GA) is used. The way how they work together is shown in Fig.1(b).

For the reference case, flows over the stationary airfoil under angle of attack $\alpha = 15^\circ$ is calculated, and the value of $c_l/c_d$ is 2.495. In the control model, control parameters that influence the dynamics of flow around the airfoil are systematically investigated, including the oscillating frequency and amplitude of the upstream cylinder, the distances between the cylinder and the airfoil, and the diameter of the cylinder. The oscillating frequency of the upstream cylinder varies from 0.5 to 10, the distance between the cylinder and the airfoil from 1.5 to 5, the diameter of the cylinder from 0.1 to 0.4, and the oscillating amplitude from 0.02 to 0.1. Each control parameter gets five different values. The results show that when the oscillating frequency increases, the average lift and drag coefficients and $c_l/c_d$ increase until negative values occur. When the cylinder to airfoil distance increases, the average lift and drag coefficients increase first and then decrease, whereas $c_l/c_d$ decreases first and then increases. As the cylinder diameter increases, both of the average lift coefficient and the average drag coefficient decrease, whereas $c_l/c_d$ increases. As the oscillating amplitude increases, the average lift and drag coefficient and $c_l/c_d$ all decrease first and then increase.

Vortex structures behind the airfoil for the reference case belong to the regular pattern, as shown in Fig.1(c), whereas the structures of most of the controlled cases belong to the irregular pattern. In addition, most of the $c_l/c_d$ values in the control cases are larger than that of the reference case. Therefore, setting a small oscillating cylinder in front of the airfoil is an effective and simple way to improve the lift/drag ratio of the airfoil.

The calculated values of $c_l/c_d$ and the control parameters of the control cases are applied to train the network, which can predict the optimal value of the lift/drag ratio and the corresponding control parameters. The predicted case is simulated, and the error between the calculated and the predicted $c_l/c_d$ is less than 5%, which shows the prediction by combining the neural network algorithm and the genetic algorithm is working. The vortex structure of the predicted case belongs to the irregular pattern, as shown in Fig.1(d). Compared to the reference case, the value of $c_l/c_d$ of the predicted case is 6.93, which increases by 178%, shows a significant improvement due to flow control by placing an oscillating cylinder before the airfoil.

**FIGURE 1:** (a) Sketch (b) Neural network model (c) Vortex structures of reference case (d) Vortex structures of predicted case