## Calculation of Motion

YS Flight Simulator calculates four forces of flight, Lift, Drag, Thrust, and Gravity, and integrates the velocity and position using Euler’s method. Thrust is kept zero in this experiment, and the gravity is calculated as mass times the gravity constant.

Lift and drag forces are calculated as:

Where , , , , and are lift coefficient, drag coefficient, air density, velocity, and wing area respectively. is calculated from the standard-atmosphere table, velocity is a state variable of an aircraft, and is calculated from the geometry. Calculation of the lift and drag coefficients are explained in the next section.

## Approximation of and

Lift coefficient () of a typical wing almost linearly increases with angle-of-attack () until reaches the critical angle-of-attack at which the wing stalls. When increases beyond the critical angle-of-attack, the function of no longer behaves linearly to due to the turbulent flow over the wing. However, it is known that drops sharply with gets larger. In the simulator, is approximated by a piecewise-linear function of which increases linearly until reaches the critical angle-of-attack and linearly drops beyond that angle as shown in .

Figure Approximation of the lift coefficient with a piecewise-linear function

Drag coefficient () typically takes the minimum value near the angle-of-attack at which denoted as . The value of increases non-linearly for smaller and larger . The value of can be very well approximated as a quadratic function of that takes the minimum value at as shown in .

Figure Approximating the drag coefficient with a quadratic function

## Calculation of Pitch Rotation

YS Flight Simulator calculates the pitch rotation by second-order approximation. While computing the pitch rotational acceleration, the program assumes that the velocity is constant in the time step, and assumes a rotational spring and damper between the aircraft longitudinal axis and the velocity vector. Then the pitch acceleration () is calculated as:

where is the rotational damping coefficient, is the rate of change of angle-of-attack, is the rotational spring constant, is the elevator input by the user.

Pitch rotational velocity and pitch angle are integrated by Euler’s method as:

where and are the pitch rotational velocity and pitch angle of the next time step.

With this calculation, the airplane tends to rotate to bring closer to the elevator input . Larger value of makes the aircraft more maneuverable, and larger makes the aircraft more stable.

and both are a function of velocity. Both values are smaller for slower airspeed and larger for faster airspeed since the aircraft tends to be less maneuverable and less stable at slower speed. The functions of and are empirically set.