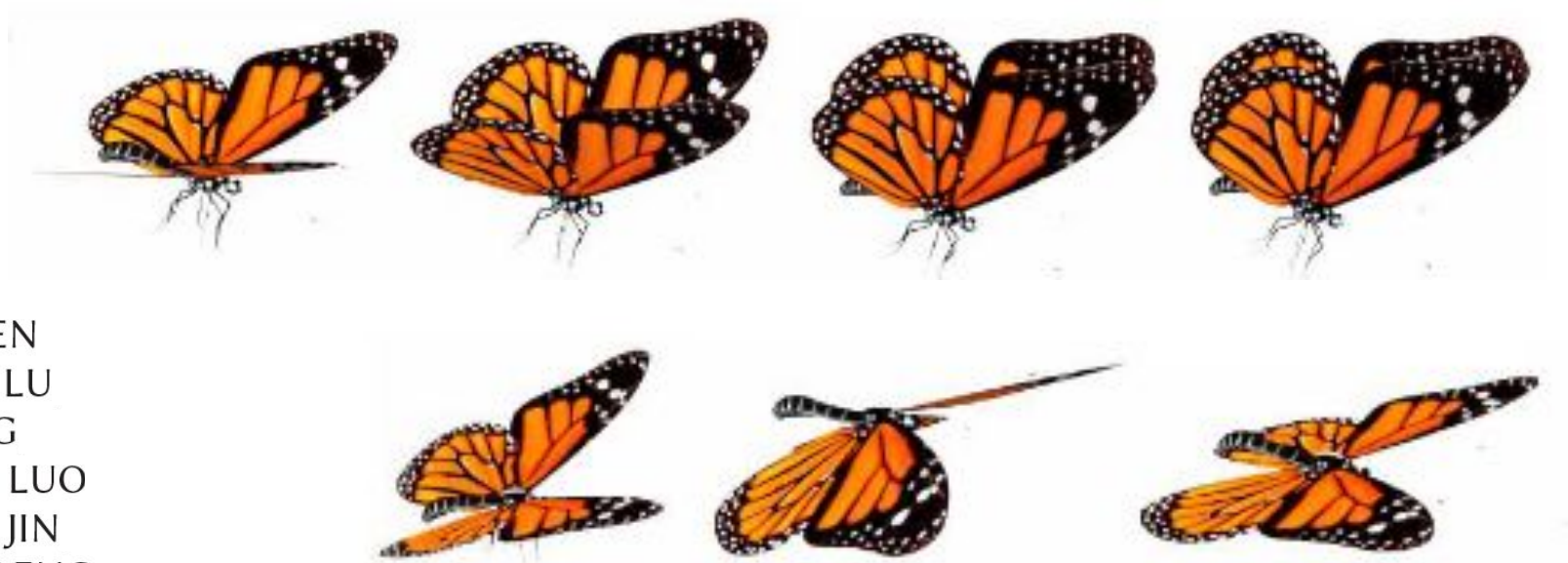


A Practical Model for Realistic Butterfly Flight Simulation



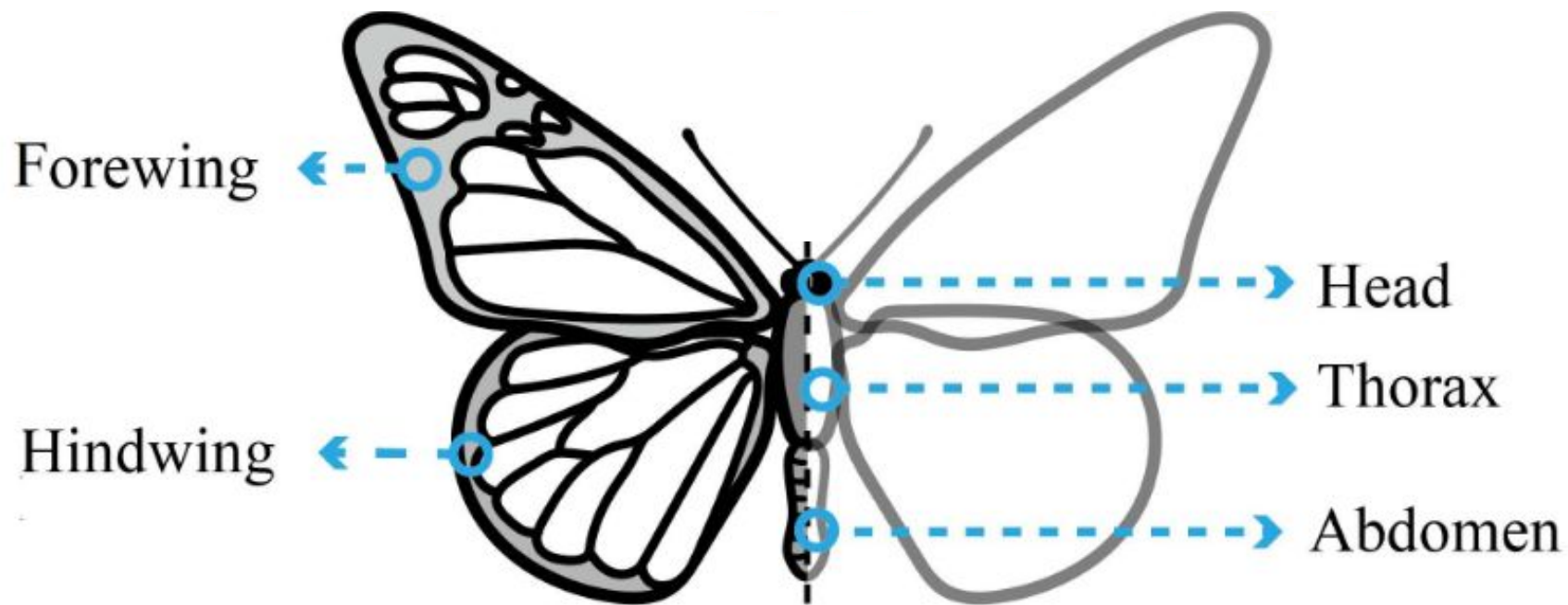
QIANG CHEN
TINGSONG LU
YANG TONG
GUOLIANG LUO
XIAOGANG JIN
ZHIGANG DENG

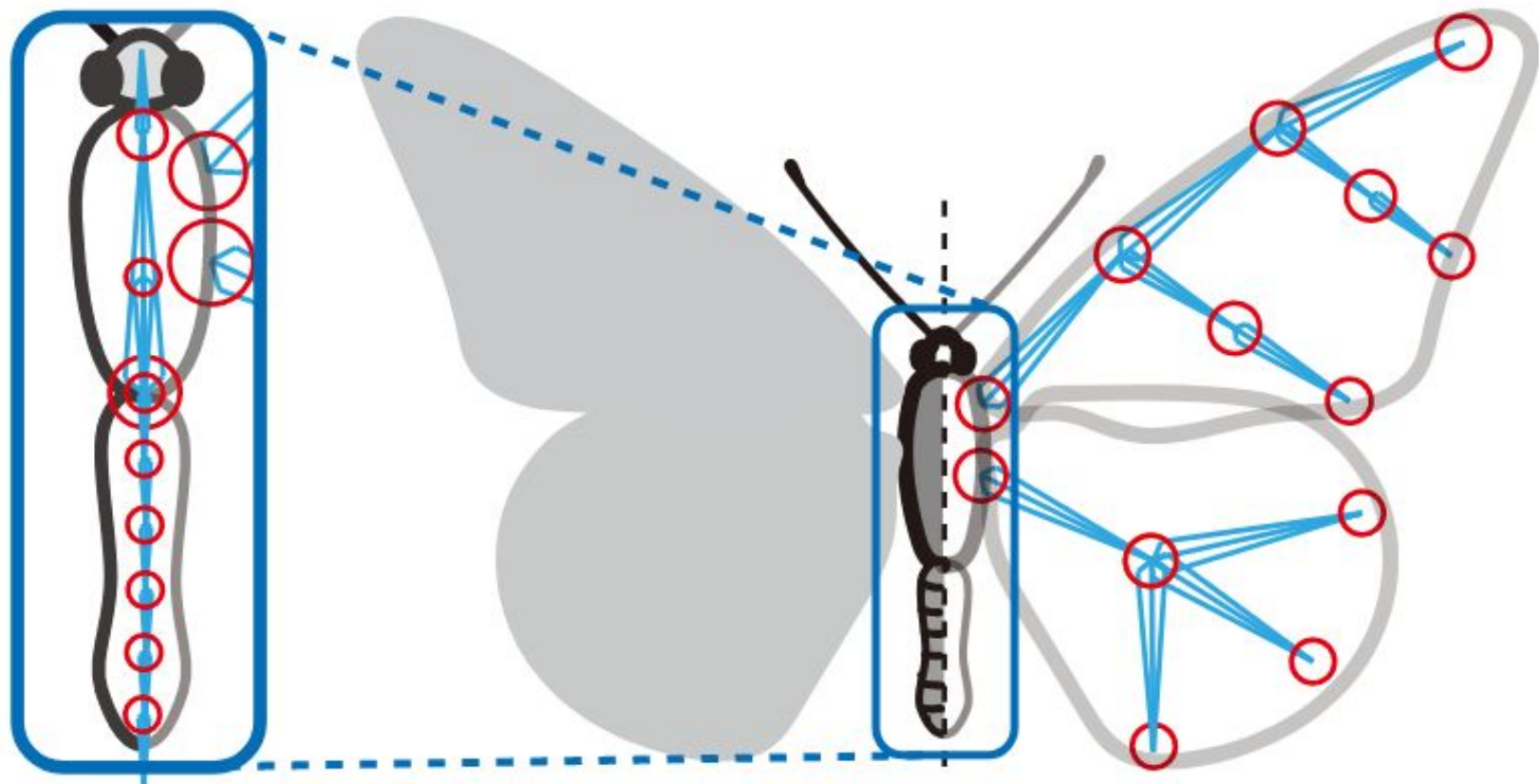


Monarch



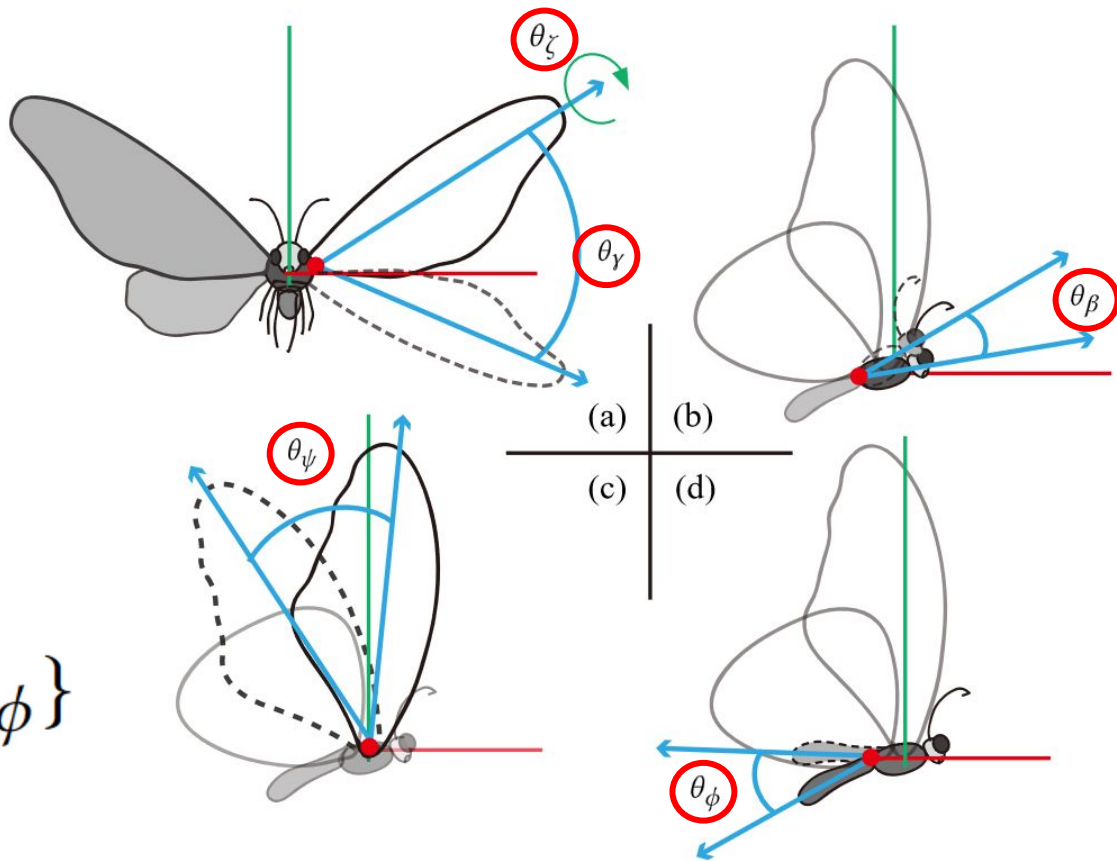
Swallowtail

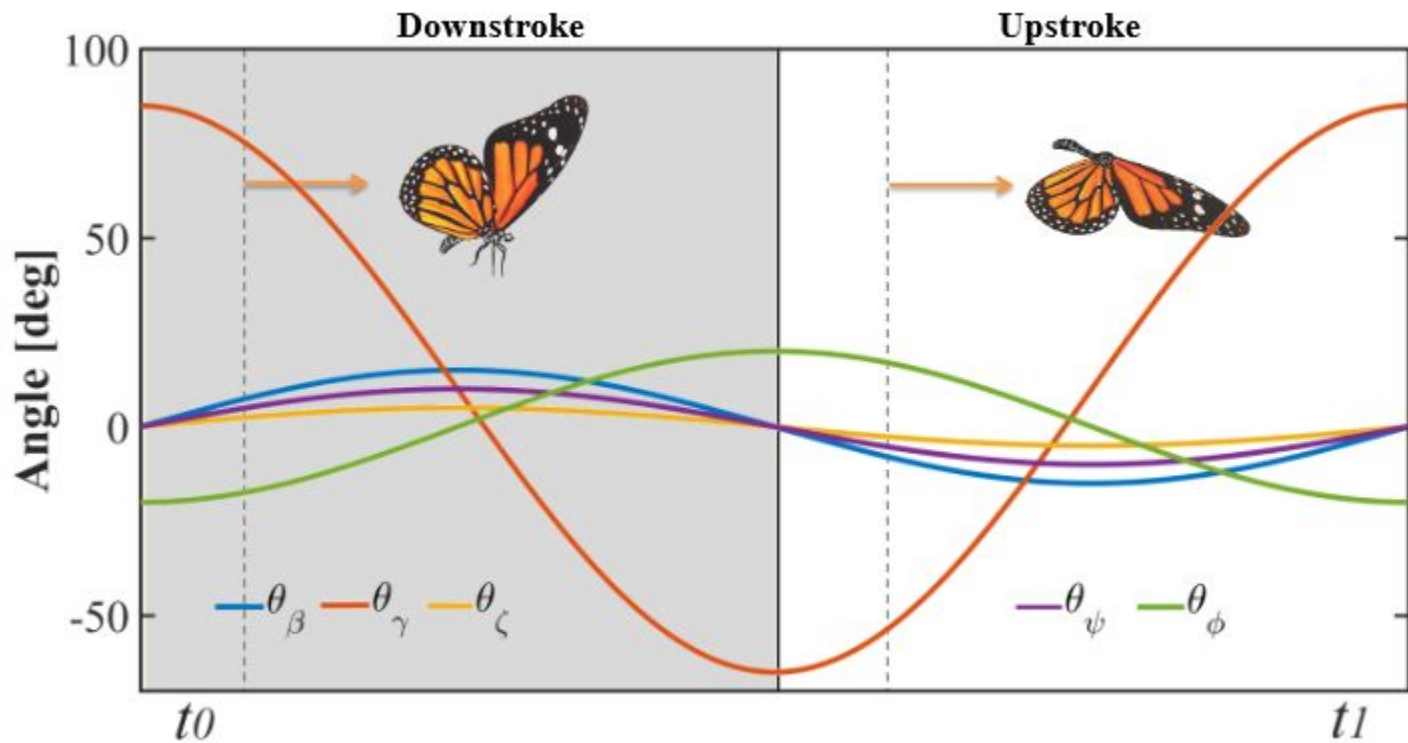




5 degrees of
freedom

$$\chi = \{\theta_\beta, \theta_\gamma, \theta_\zeta, \theta_\psi, \theta_\phi\}$$



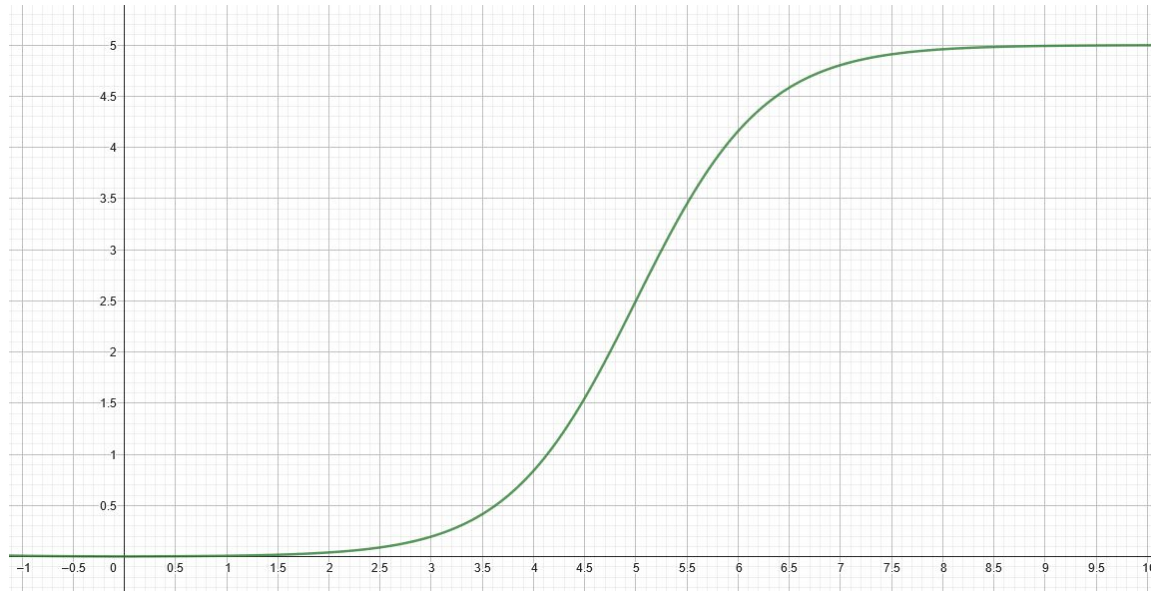


$$\theta_*(\varphi_a^*(\mathbf{u}), f^*(\mathbf{u}), \varphi_p^*, \varphi_m^*, t) = \varphi_a^*(\mathbf{u}) \cos \left(2\pi f^*(\mathbf{u})t + \varphi_p^* \right) + \varphi_m^*$$

where $*$ $\in \{\beta, \gamma, \zeta, \psi, \phi\}$

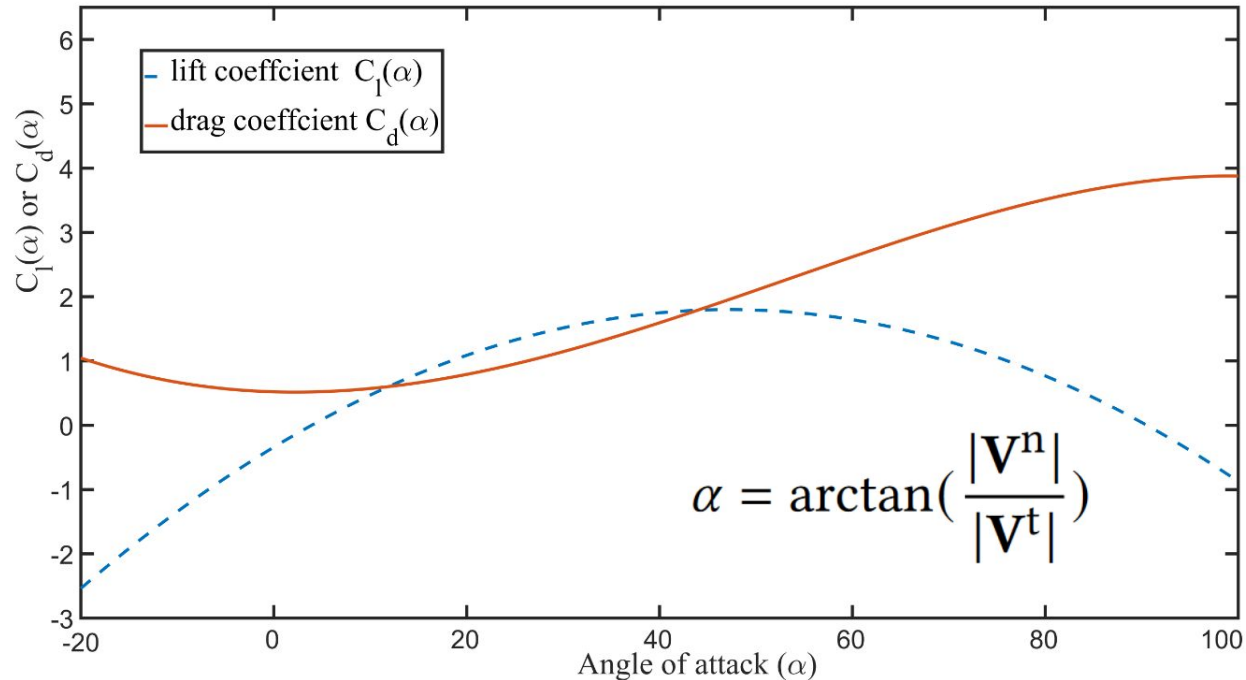
$$f^*(\mathbf{u}(t_0)) = R_f^* \frac{1}{(1 + e^{-16(|\mathbf{u}(t_0)|/|\mathbf{u}^{max}| - 0.5)})}, * \in \{\beta, \gamma, \zeta, \psi, \phi\}$$

$$\varphi_a^*(\mathbf{u}(t_0)) = R_{\theta_a}^* \frac{1}{(1 + e^{-16(|\mathbf{u}(t_0)|/|\mathbf{u}^{max}| - 0.5)})}, * \in \{\beta, \gamma, \zeta, \psi, \phi\}$$

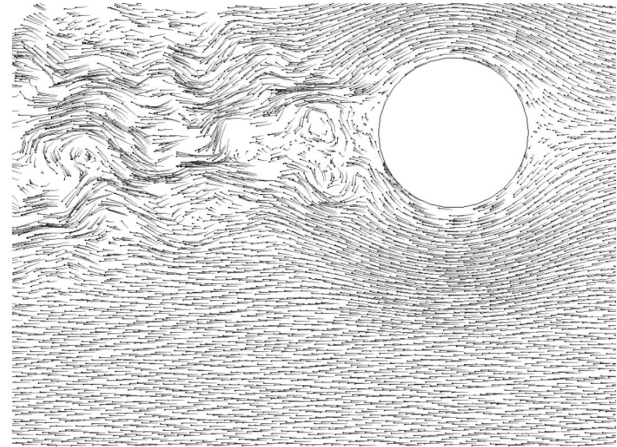
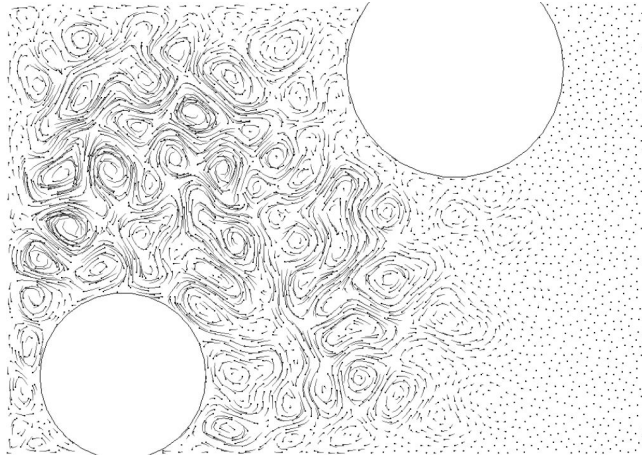
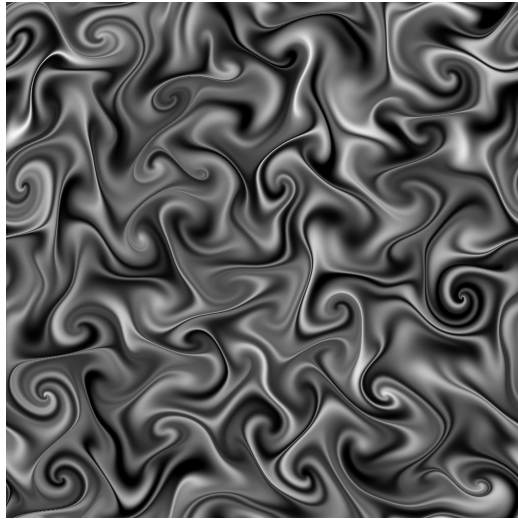


$$\mathbf{F}_{i,\text{lift}} = \frac{1}{2} \rho A_i |\mathbf{V}|^2 C_l(\alpha)$$

$$\mathbf{F}_{i,\text{drag}} = \frac{1}{2} \rho A_i |\mathbf{V}|^2 C_d(\alpha)$$



$$\mathbf{F}_{vor} = \nabla \times \left(\left(s_1 \left(\frac{\mathbf{p}}{gain_x} \right), s_2 \left(\frac{\mathbf{p}}{gain_y} \right), s_3 \left(\frac{\mathbf{p}}{gain_z} \right) \right) * \eta \right)$$



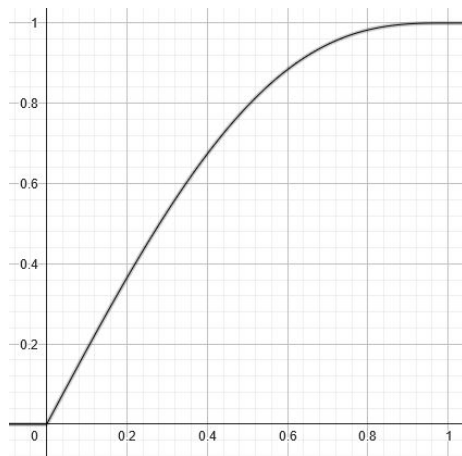
Curl-Noise for Procedural Fluid Flow [Bridson 2007]

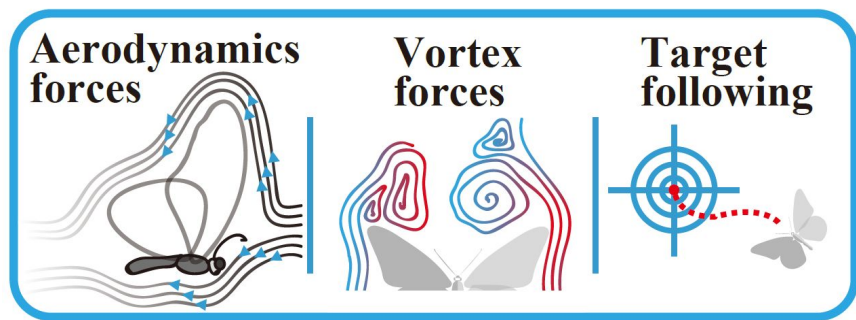
$$\mathbf{a}_{loc} = (\sum_{j=1}^4 \mathbf{F}_j + \mathbf{F}_{vor} + \mathbf{g})/m$$

$$\mathbf{a}_{pre} = R(d) \frac{1}{m} \frac{\mathbf{p} - \mathbf{q}_i}{|\mathbf{p} - \mathbf{q}_i|},$$

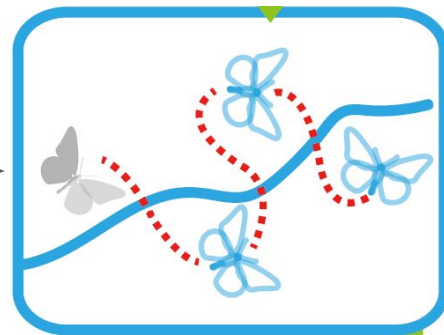
$$\min(1, |\mathbf{p} - \mathbf{q}_i|/L)$$

$$\mathbf{u}_t = \mathbf{u}_{t-1} + (\mathbf{a}_{loc} + \mathbf{a}_{pre})\Delta t$$

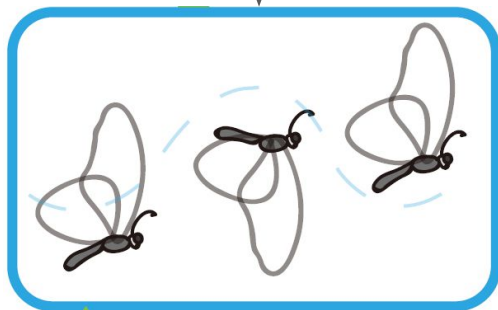




accélération



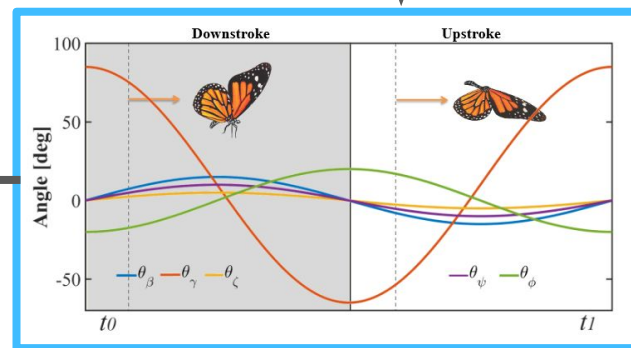
déformations



vitesse $\mathbf{u}$

$$f^*(\mathbf{u}(t_0))$$

$$\varphi_a^*(\mathbf{u}(t_0))$$



Our current approach can simulate the wing-abdomen interaction of the butterfly. However, it does not include the simulation of butterfly takeoff and landing motions, which may need certain coordination between legs and body. Specifically, based on our observations, insects may obtain momentum

are not able to obtain such data for our model calibration or training. Therefore, the simulated motion by our current approach may not be perfectly aligned with real butterflies in the natural world, although it is practical and efficient to generate visually compelling simulations.

The skeleton-driven body deformation in our current approach is insufficient to produce the subtle softness and weaving motion effects, often observed on the wings of a real butterfly. Advanced deformation and simulation algorithms (e.g., physically-accurate modeling algorithms) need to be designed

Pas de décollage /
atterrissage

Pas assez de données pour
reproduire les mouvements
d'un vrai papillon

Modèle trop simpliste pour
reproduire les déformations
des ailes

https://www.youtube.com/watch?v=_6cuoTipGAs

