

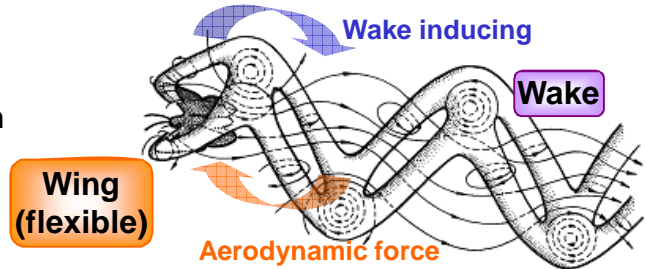
# Indirect Control Effects of Structural Flexibility of Wings in Flapping Flights of Butterfly

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## Summary

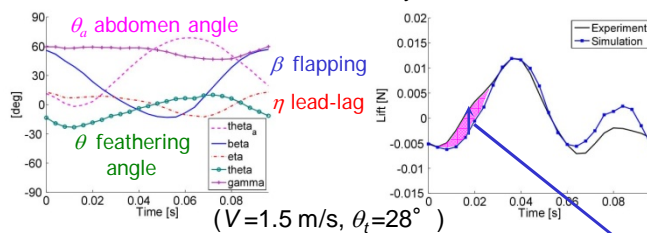
### Indirect control

- (1) free-vortices in wakes provide stabilization effect
- (2) structural flexibility of wings introduces stabilization effect

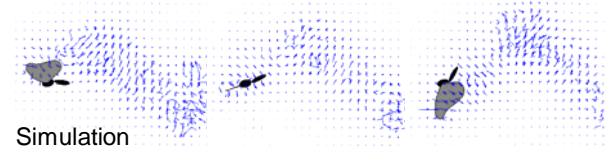
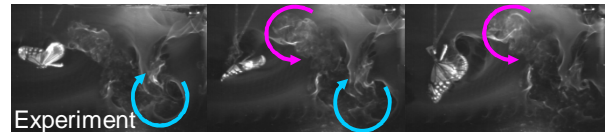


## Accuracy of model with rigid wing (panel method model vs experiment)

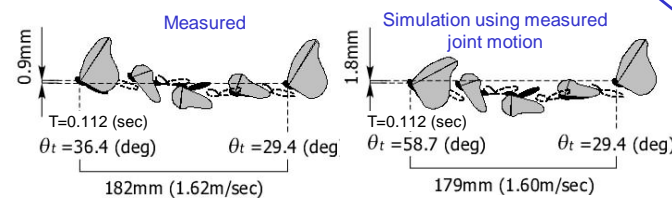
Numerical model is accurate in aerodynamic forces



Numerical model is accurate in flowfield



Numerical model almost duplicates measured free flight motion!

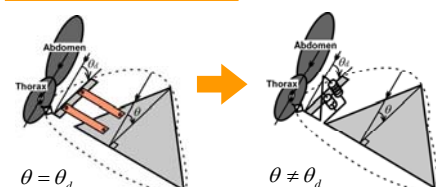


## Indirect control by wake-induced flow [Senda, et al. 2006, 2008]

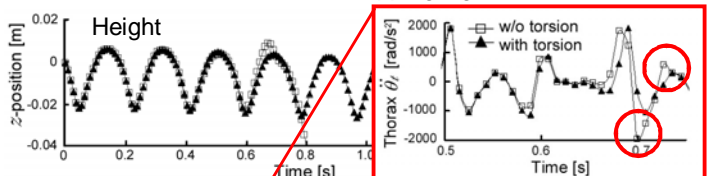
	flowfield	almost periodic flight	flight with initial perturbation	stability
(a) with wakes				 rather stable
(b) without wakes				 unstable

## Indirect control by wing structural flexibility

Deformation by aerodynamic forces



Thorax motion of two models in flapping flights



Oscillation in thorax angle

