

Abstract Submitted
for the DFD17 Meeting of
The American Physical Society

A role of abdomen in butterfly's flapping flight JEEVA JAYAKUMAR, KEI SENDA, NAOTO YOKOYAMA, Kyoto University — Butterfly's forward flight with periodic flapping motion is longitudinally unstable, and control of the thoracic pitching angle is essential to stabilize the flight. This study aims to comprehend roles which the abdominal motion play in the pitching stability of butterfly's flapping flight by using a two-dimensional model. The control of the thoracic pitching angle by the abdominal motion is an underactuated problem because of the limit on the abdominal angle. The control input of the thorax-abdomen joint torque is obtained by the hierarchical sliding mode control in this study. Numerical simulations reveal that the control by the abdominal motion provides short-term pitching stabilization in the butterfly's flight. Moreover, the control input due to a large thorax-abdomen joint torque can counteract a quite large perturbation, and can return the pitching attitude to the periodic trajectory with a short recovery time. These observations are consistent with biologists' view that living butterflies use their abdomens as rudders. On the other hand, the abdominal control mostly fails in long-term pitching stabilization, because it cannot directly alter the aerodynamic forces. The control for the long-term pitching stabilization will also be discussed.

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Date submitted: 31 Jul 2017

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