Mathematical butterflies provide insight into how insects fly

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Researchers have developed sophisticated numerical simulations of a butterfly's forward flight.

In Robert A. Heinlein's science-fiction novel, The Cat Who Walks Through Walls, one of the characters states that butterflies are just "…self-propelled flowers." While Heinlein's description of the insect's aerodynamic ability is quite poetic, it does little to scientifically explain it. Four Japanese researchers have done a bit better by developing sophisticated numerical simulations of a butterfly's forward flight. In a paper in the American Institute of Physics' journal *Physics of Fluids*, the researchers describe how they mathematically modeled a butterfly as a four-link rigid-body system consisting of a thorax (the segment of the insect to which the wings are attached), an abdomen, and the two wings.

Using data from observations of butterfly flight in wind tunnels, the researchers conducted three different types of simulations with their model that were defined by the position and attitude of the thorax: tethered (where the thorax is fixed), prescribed (where the thorax is programmed to move in an expected manner) and free-flight (where the thorax movement is unrestricted). They found that their mathematical butterfly did – as predicted – make use of the tiny, swirling vortices that form in the direction of travel during a downward flap, pushing air down and providing lift. However, they also observed that the flow around the butterfly is much more turbulent than expected. This turbulent flow triggers the complex trajectories characteristic to the flights of butterflies that may be one of the strategies by which the insects avoid

predators.

Finally, the researchers determined that the pitching angle of the thorax is the key to controlled periodic flight, noting that living butterflies likely can continually sense the attitude of their thorax and adjust their flapping motion accordingly to ensure stability. The researchers state that their future work will focus on identifying the mechanism by which this control is achieved.

More information: "Aerodynamic forces and vortical structures in flapping butterfly's forward flight," is published in *Physics of Fluids*. pof.aip.org/resource/1/phfle6/v25/i2/p021902_s1

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