Flight Control system of Flapping Winged Micro Air Vehicles

By Joel Hauerwas

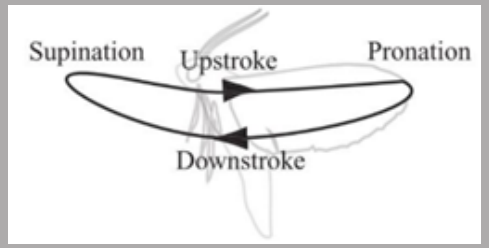
Background

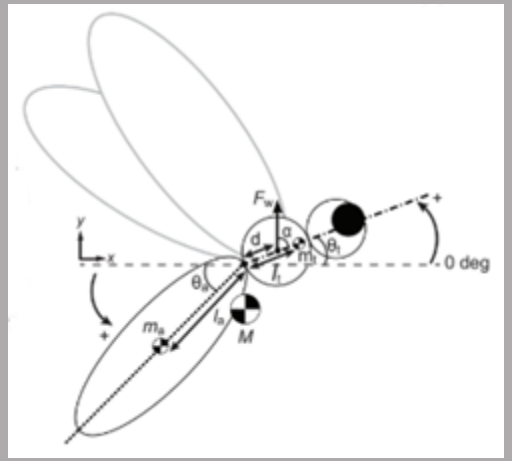
-Micro Air Vehicles or MAV systems provide opportunities to both the surveillance and small cargo industries especially in remote areas

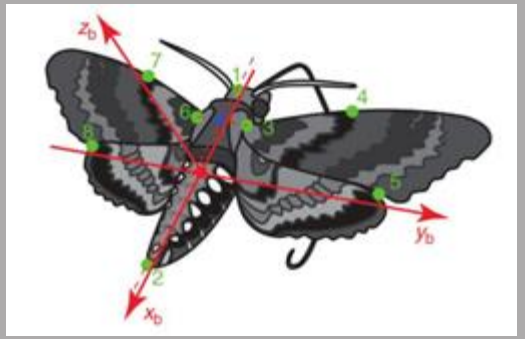
-Passive winged insects are an ideal model for Flapping Winged Micro Air Vehicles since they can carry their own body weight

-*Manducca Sexta* , The Tobacco Hawkmoth is an ideal candidate for a flapping wing model as they can perform complex maneuvers but only require one set of wings

Moth Anatomy





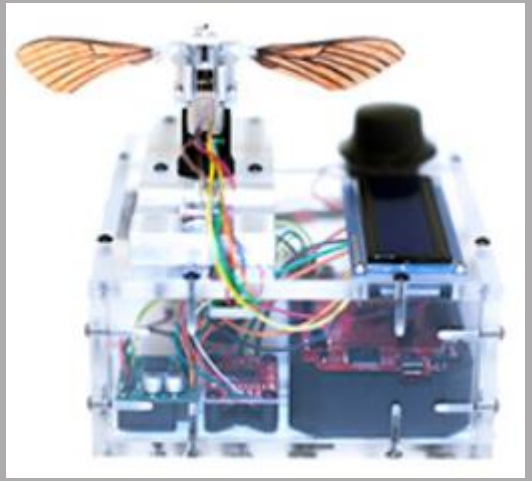


Current Research

-So far our lab has completed a series of studies into designing a mechanism to mimic the flapping frequency of the wings to generate lift

-The lab has also studied different wing materials to try to replicate the flexibility and stiffness of the moth wings in nature

-My research is aimed at understanding how moths fly and steer through the air and then replicating that motion in a mechanical system

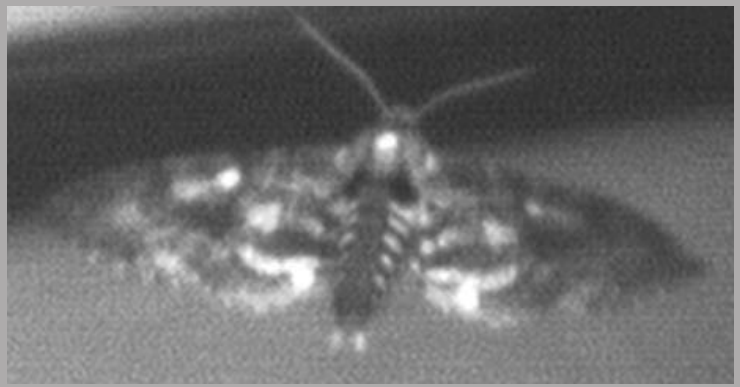


Current Research

-Research has been conducted viewing slow motion footage of moths frame by frame investigating their shape to understand turning motions

-The moths appear to rotate their abdominal sections in much the same way a fighter jet rolls to strafe quickly

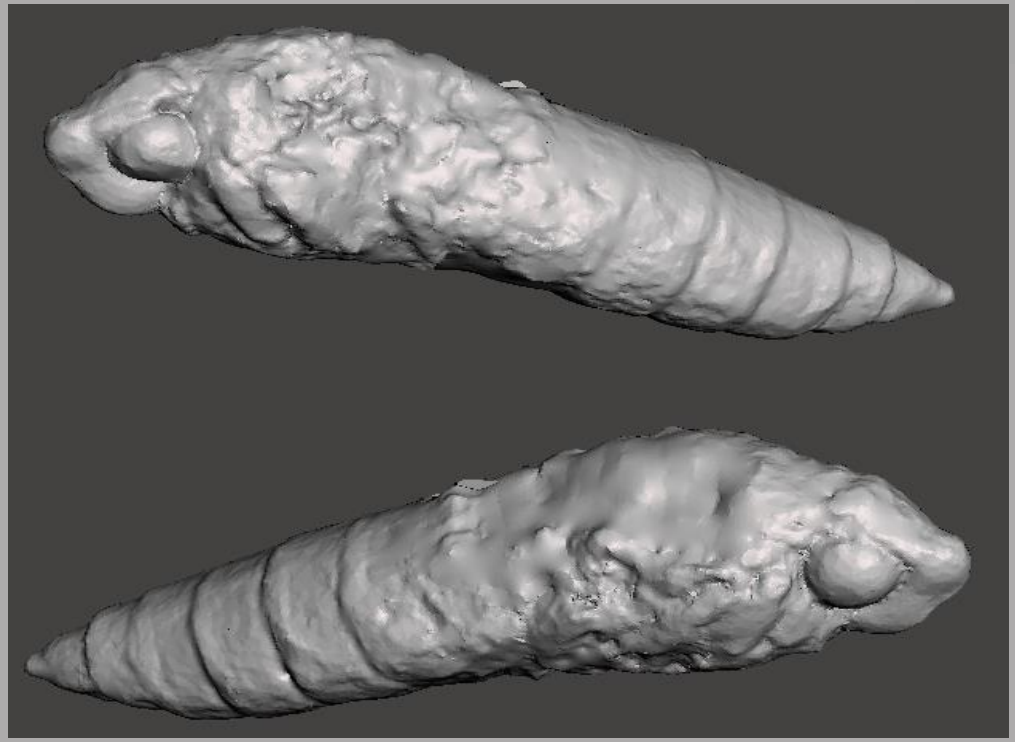
-The moths have 7 abdominal sections each of which can rotate about 5 degrees allowing the moth a fairly high degree of rotation about its neutral axis



3D scanning

AUTODESK®
MESHMIXER®

Moth models

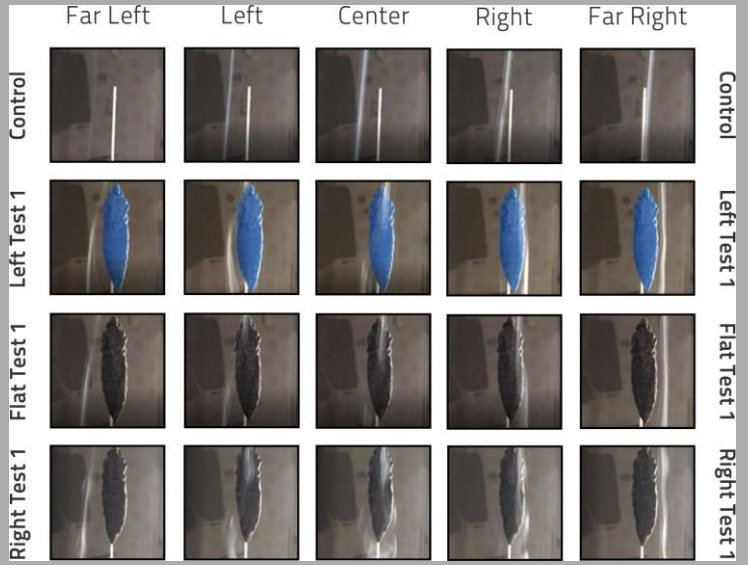


First steps

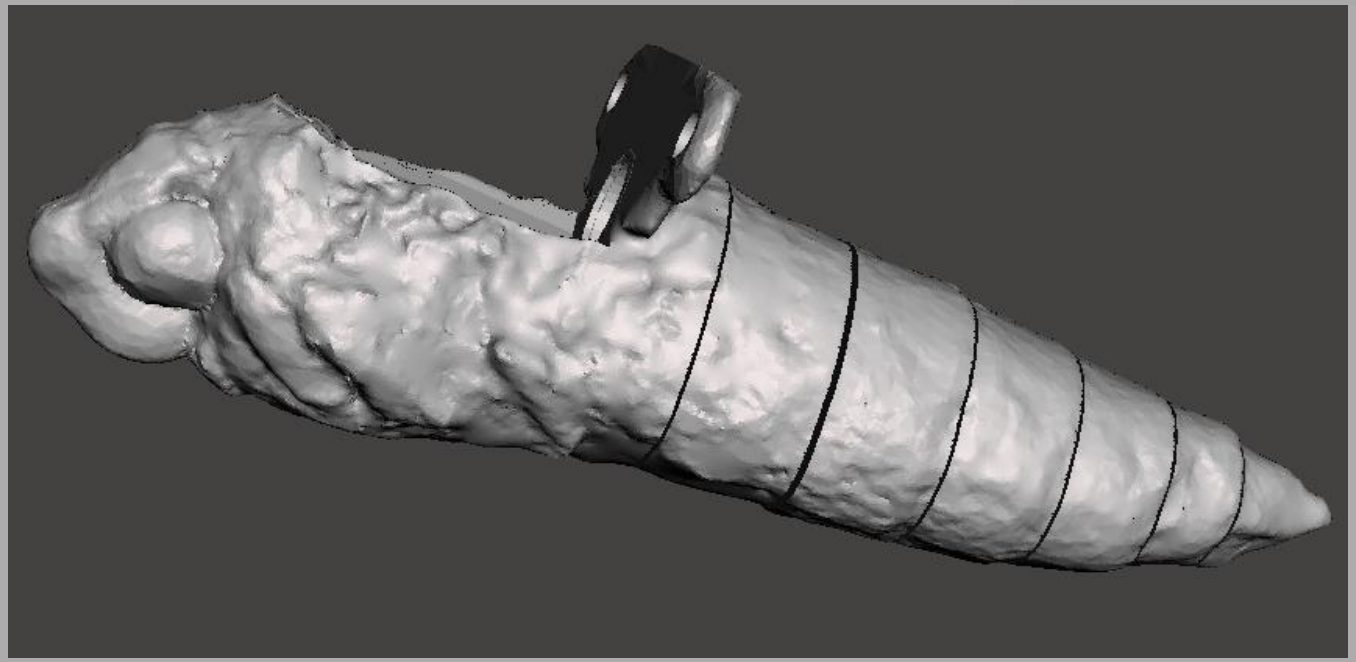
-Fixed stable wing abdomen proof of concept

-Shows definitive smoke in different ways around different abdominal shapes

-As the smoke trail transitioned from left to right a full airflow profile could be developed

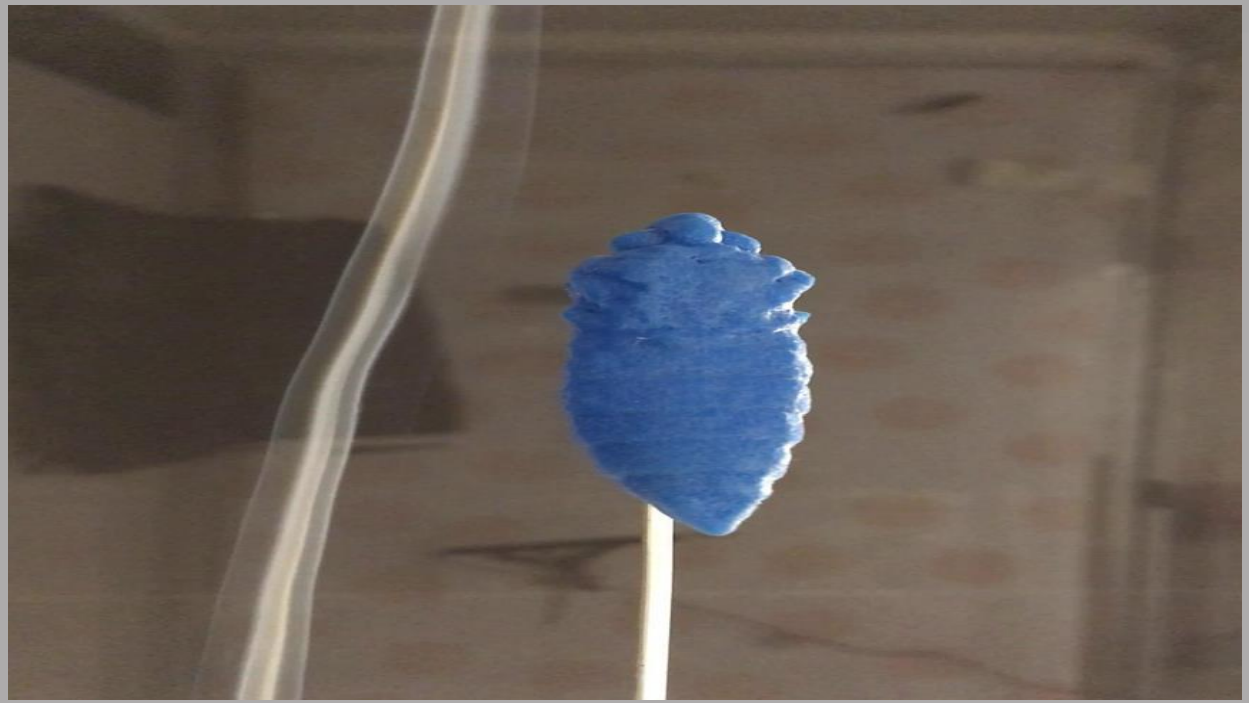


Flexible model



3D printed

Stable Wind Tunnel



Dynamic Wind Tunnel

References

[1] Moses, K. C., Michaels, S. C., Willis, M., & Quinn, R. D. (2017). Artificial Manduca sexta forewings for flapping-wing micro aerial vehicles: how wing structure affects performance. Bioinspiration & Biomimetics, 12(5), 055003. doi: 10.1088/1748-3190/aa7ea3

[2] Cranston, B., & Palazotto, A. (2014). Evaluation of the Thorax of Manduca Sexta for Flapping Wing Micro Air Vehicle Applications. International Journal of Micro Air Vehicles, 191–210. https://doi.org/10.1260/1756-8293.6.3.191

[3] “Experimental and Computational Investigation of Flapping Wing Propulsion for Micro Air Vehicles,” Fixed and Flapping Wing Aerodynamics for Micro Air Vehicle Applications, pp. 307–339, 2001.

[4] R. Sahai, “Direct Sensing of Wing Flapping and Rotation Parameters for a Hawkmoth-Sized Flapping Wing Micro Air Vehicle,” Volume 1: Advances in Aerospace Technology, Nov. 2016.

[5] Zhao, J., Wu, J., & Yan, S. (2015). Movement Analysis of Flexion and Extension of Honeybee Abdomen Based on an Adaptive Segmented Structure. Journal of insect science (Online), 15(1), 109. doi:10.1093/jisesa/iev089

[6] N. Stead, “The Abdomen: The Secret To Stabilising Flight,” Journal of Experimental Biology, vol. 216, no. 9, pp. i-ii, 2013.

[7] Hedrick, T. L. (2006). Flight control in the hawkmoth Manduca sexta: the inverse problem of hovering. Journal of Experimental Biology, 209(16), 3114–3130. doi: 10.1242/jeb.02363

[8] T. Hedrick, “Hawkmoth flight in unsteady flows,” 2016 International Congress of Entomology, 2016.

[9] Dyhr, J.P., Morgansen, K.A., Daniel, T.L. and Cowan, N.J. (2013). Flexible strategies for flight control: an active role for the abdomen. J. Exp. Biol. 216, 1523-1536.

[10] J. Gau, N. Gravish, and S. Sponberg, “Indirect actuation reduces flight power requirements in Manduca sexta via elastic energy exchange,” Jul. 2019.

[11] D. Tom, “Decoding the independent and synergistic roles of flight muscles for control of turning in the hawkmoth, Manduca sexta.,” Frontiers in Behavioral Neuroscience, vol. 6, 2012.

[12] “Correction: Robotic Moth Reveals Key to Insect Flight,” Science News, vol. 151, no. 3, p. 35, 1997.

[13] M. Fuchiwaki, T. Kuroki, K. Tanaka, and T. Tabata, “Vortex Ring Formed over the Wings of a Flapping Butterfly and a Small Flapping Robot,” 41st AIAA Fluid Dynamics Conference and Exhibit, 2011.

[14] H. Duan, Z. Li, and Q. Li, “Model and control of Micro Flapping-wing Aerial Robot,” 2010 International Conference On Computer Design and Applications, 2010.

[15] H. R. Vejdani, “Dynamics and stability of Bat-Scale Flapping Wing Hovering Robot,” 2019 IEEE 15th International Conference on Automation Science and Engineering (CASE), 2019.

[16] Sane & Dickinson, 2001, 2002; Truppel & Rossi, 2011; Usherwood & Lehmann, 2008;

[17] Cheng et al., 2011; DeLeón & Palazotto, 2011; Z. A. Khan & Agrawal, 2007, 2011; Z.

Questions?