2015台灣仿生科技協會年度活動

撲翼飛行器之仿生節能設計與生物物理解析

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台灣仿生科技與五生產業發展協會常務理事

November 28th, 2015

Research Interests of Prof. J. T. Yang

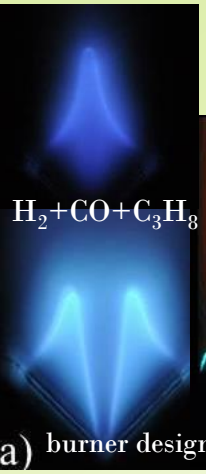
新竹中學, UW-Madison

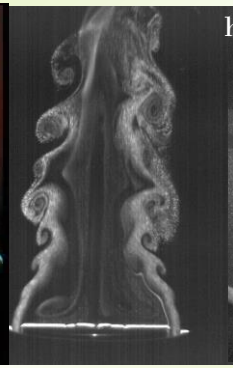
以流體力學為主軸之跨領域整合型創新研究 (次領域)

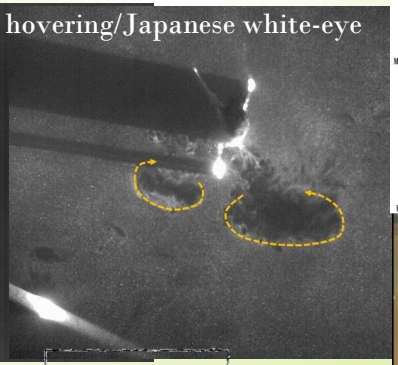
Energy and Combustion (1979~) + 強烈化學反應

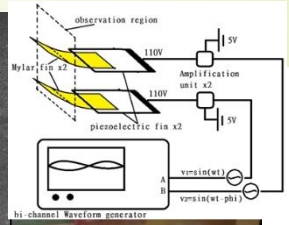
Bio-microfluidics & Lab on a Chip (2002~) + 生醫化材

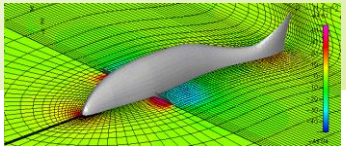
Biophysics and Biomimetics (2004~) + 生物

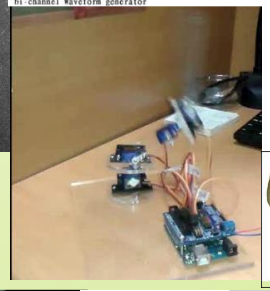


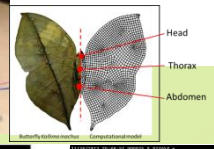


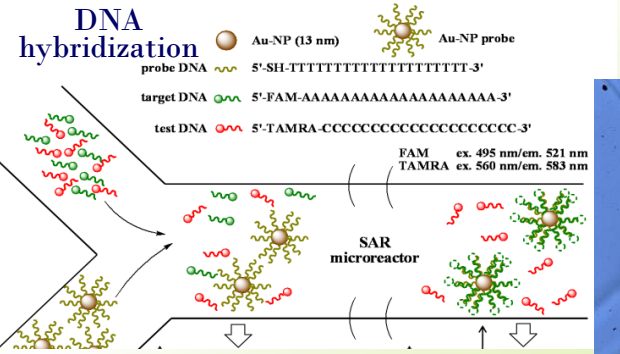




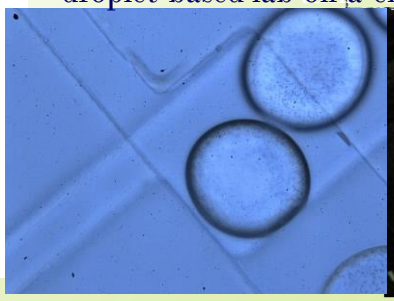


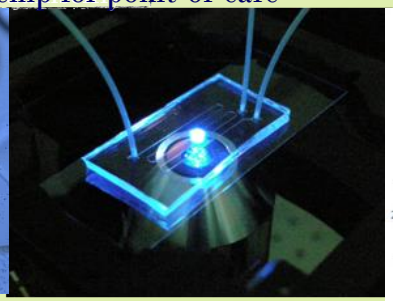


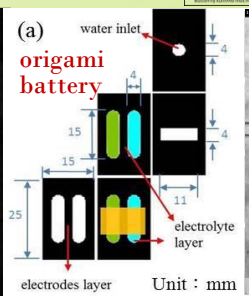




droplet-based lab-on-a-chip for point-of-care







仿生科技

快樂 + 學習

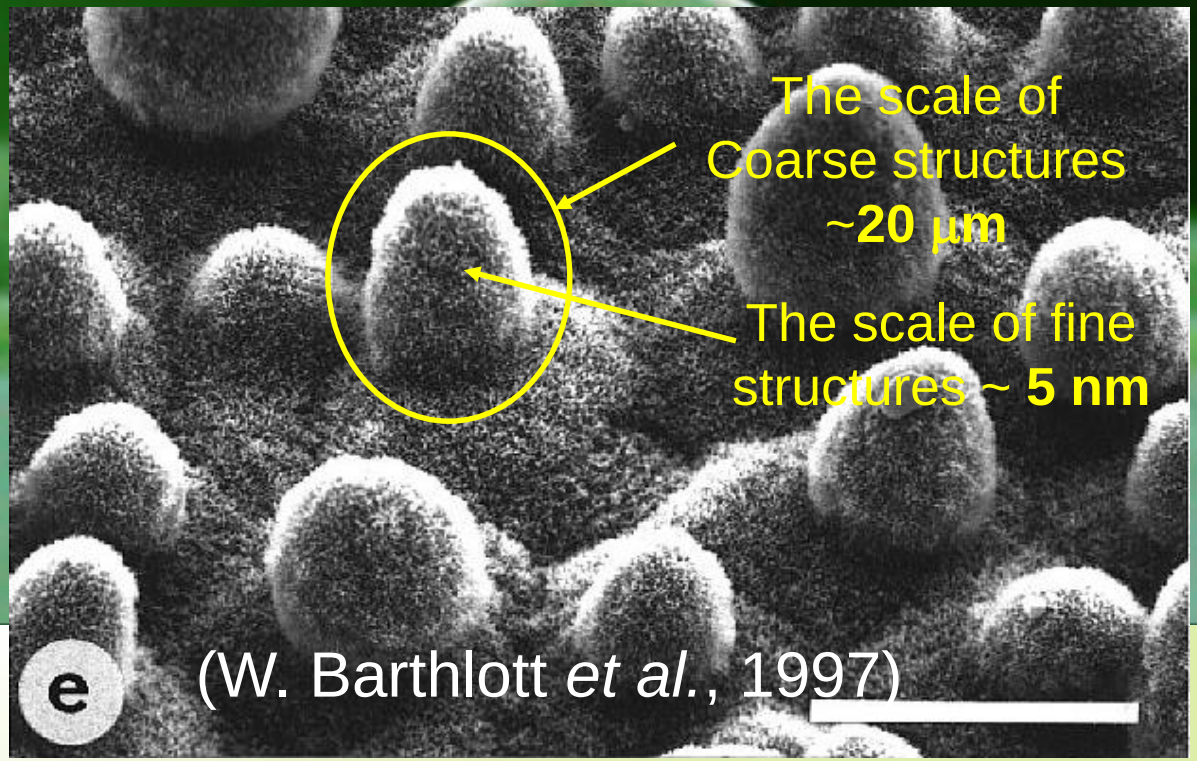
自然界中的各種動植物，在歷經千百億年的物競天擇與自然演化繁衍之後，各自發展出了能夠良好適應其生存環境的特殊生理構造、型態、功能，透過研究與借鑒動植物身上所具有的各種優點，可以獲得多元化的啟發，幫助人類提升改善現有的生存條件與生活品質，“仿生學”也應運而生。

仿生學是一門“從自然中學習進而應用在工程技術中的學科”，常見與Biomimetics同義的詞彙還包括：Biomimicry, Bionics, Biognosis

Example 1: Lotus Effect & Biochips

Lotus leaf, Super-hydrophobic surface

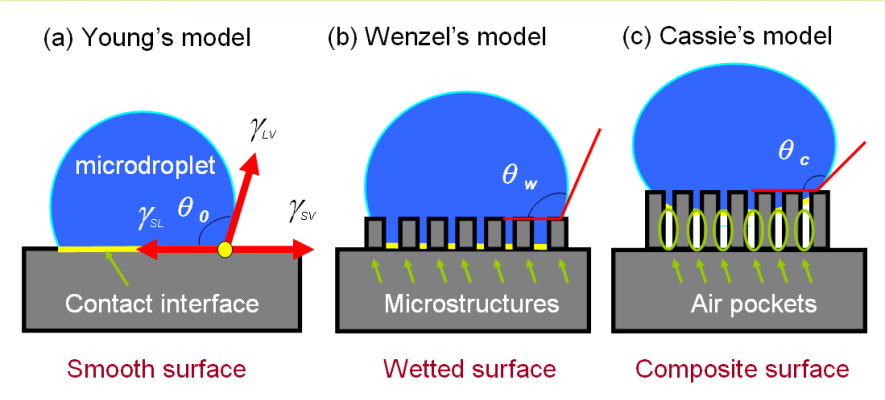
Apparent contact angle, θ_c ~160.4º

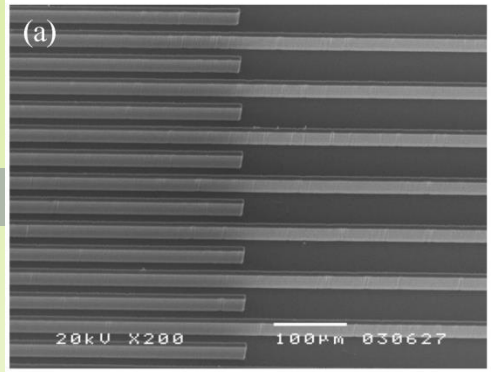


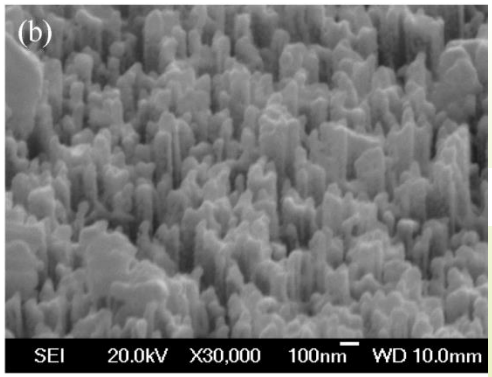
(W. Barthlott *et al.*, 1997)

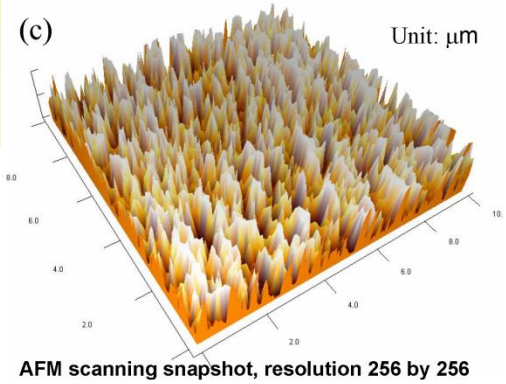
2004-2014

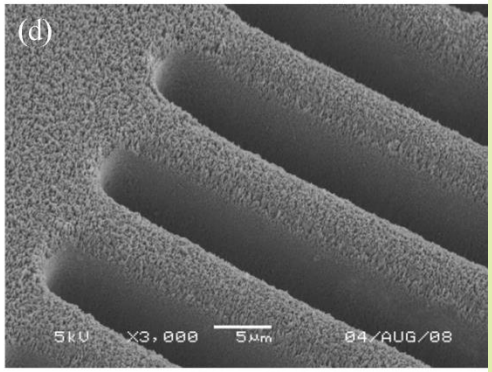
Ultra-Hydrophobic Surfaces

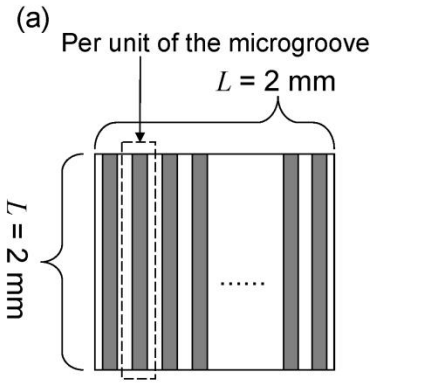


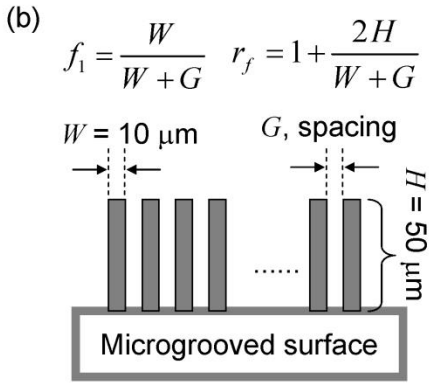


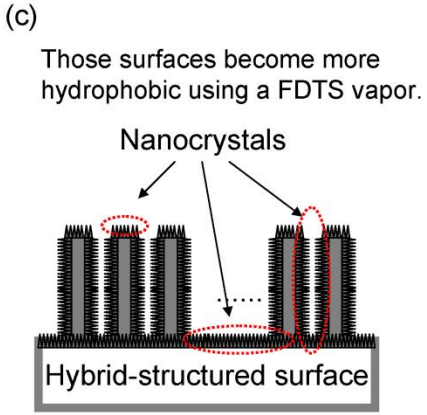


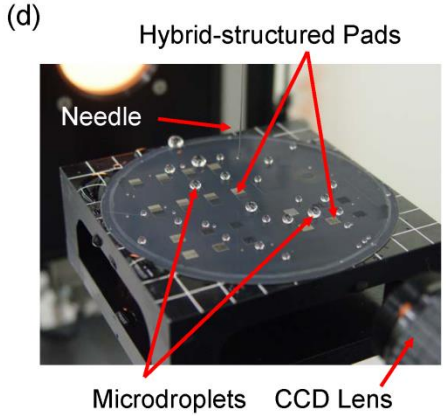


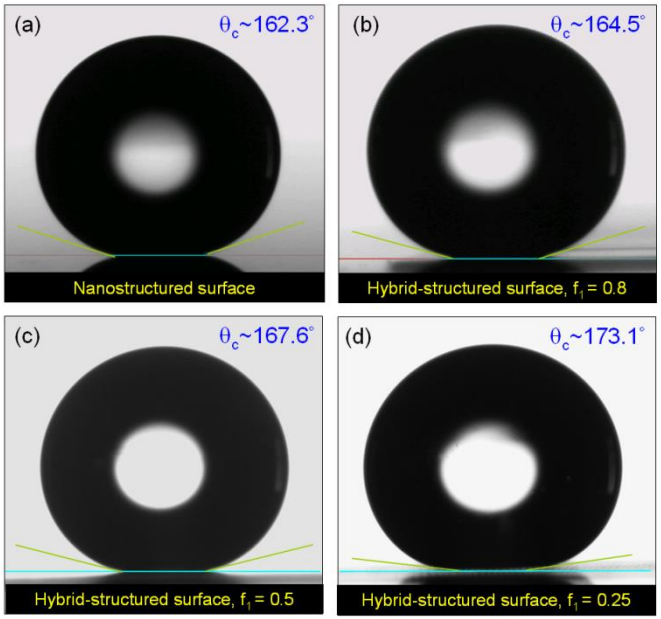












J. T. Yang
Z. H. Yang,
C. Y. Yang
Dr. M. H. Hsu
Dr. Y. H. Lai
2009

JMM, 2009

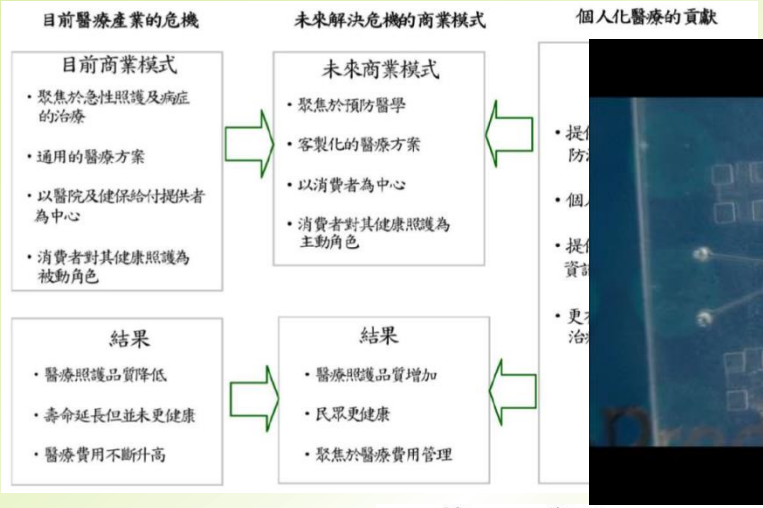
可視化液珠式基因快篩技術

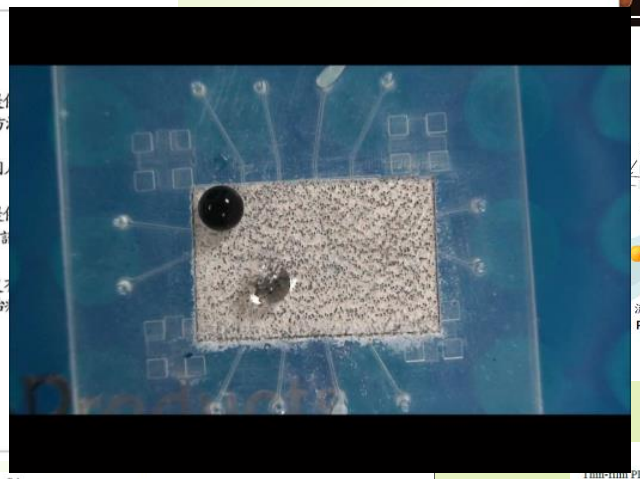
Personalized Diagnostics at Sight: Droplet-based Gene Screening

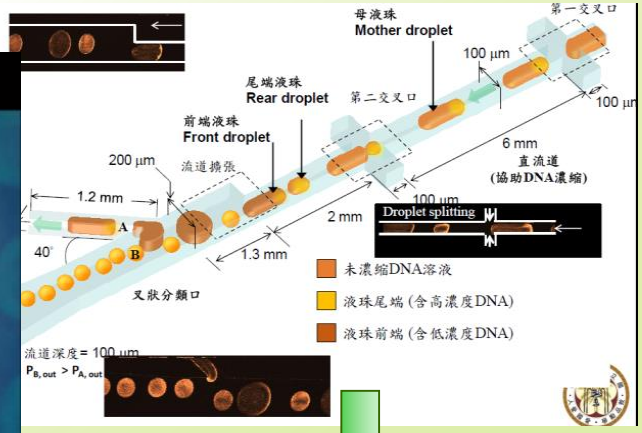
Point-of-care model

第11屆國家新創獎, 2014

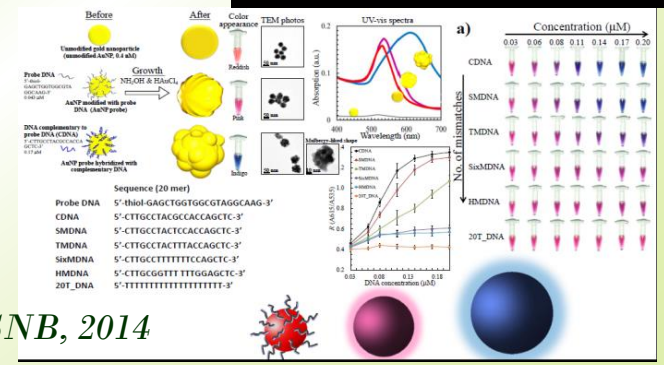
一種新的檢測技術和晶片系統，不需要昂貴的設備及複雜的步驟，即可自動化進行基因型診斷，檢測結果能用肉眼直接觀察得知，並具有可攜帶、微量藥品試劑消耗及快速篩選等優點，減少醫療資源浪費、發揮藥物的最佳藥效、針對每個人不同的體質，打造專屬個人的治療方式。本技術核心包含三大項目: (1) 發展一種利用金奈米粒子探針結合長晶方法，(2) 可攜式的液珠操控平台，(3) 被動式DNA濃縮技術。



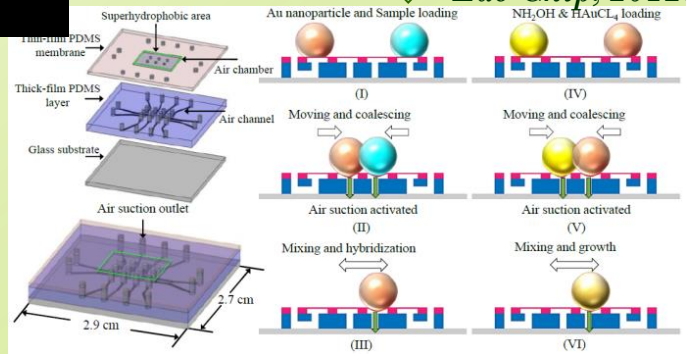




Lab Chip, 2012a



SNB, 2014



Lab Chip, 2014b

Example 2: Eyes Stabilization of Passerines

A passerine exploits tail spreading to facilitate quick recovery of body posture during hovering

2008-2012

Su, …, Yang, Physical Review E*, 2011
Su, …, Yang, J. Royal Society Interface*, 2012
Su & Yang, Bioinspiration & Biomimetics, 2013

Chicken Head Steadicam

http://www.youtube.com/watch?v=m8sNHd0

Chicken test
LG

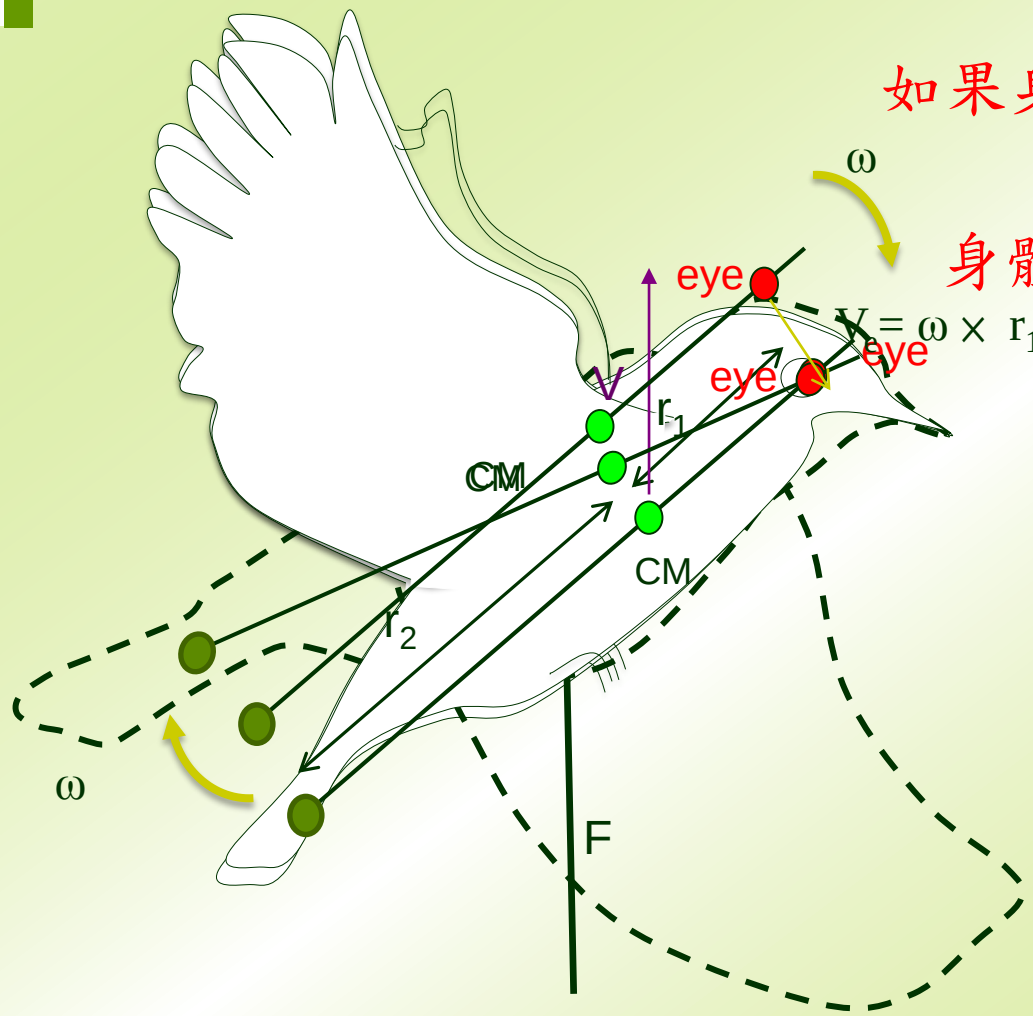
Invention

頭部包含許多重要器官，生物運動時會刻意穩定其頭部

頸部結構類似汽車之懸吊系統 ！

懸停下的視覺穩定機理

Su..., Yang,* *Physical Review E*, 2011



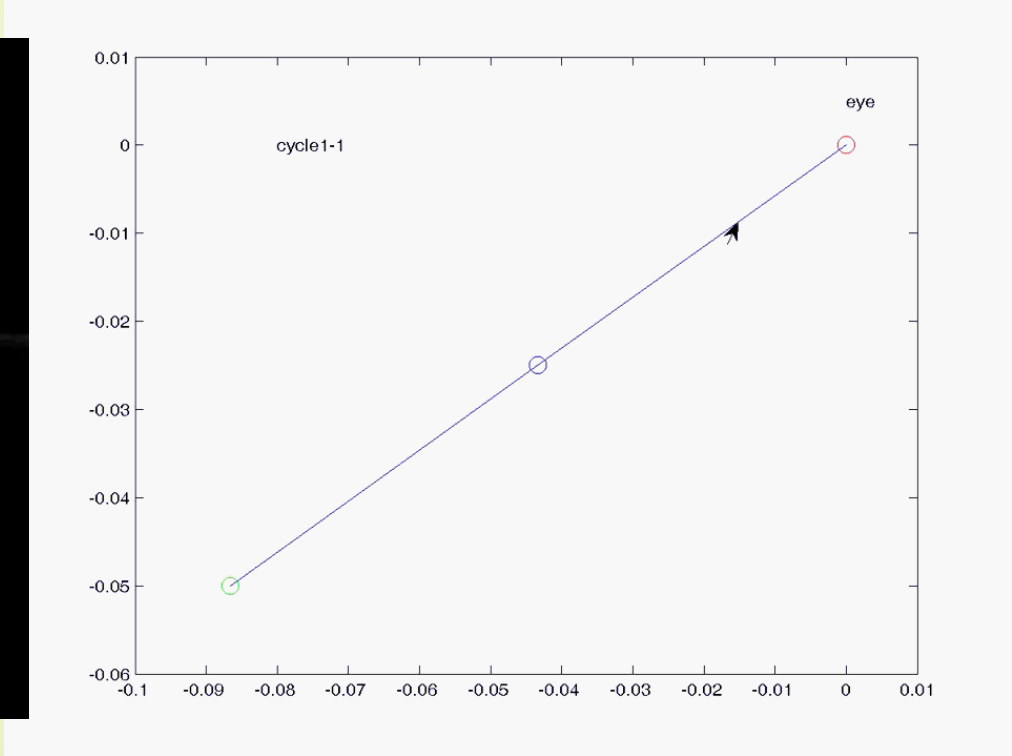
如果身體的位移與旋轉在眼睛抵銷

身體看似繞著眼睛轉 ➡ 視覺穩定

Reported by *Nature Physics*, *ScienceNews*, *American Physics Society*, 2011

The center and direction of the aerodynamic force v.s. flapping-flight

Engineering solution



Su & Yang, Bioinspiration & Biomimetics, 2013

More Examples

Pioneer of Flapping-Flight Airplane

達文西 (Leonardo Da Vinci, 1452-1519)

http://www.youtube.com/watch?v=bG52JmYfx2M

http://www.youtube.com/watch?v=aZI85oreTew

Cross-sections of various flight creatures and airplanes

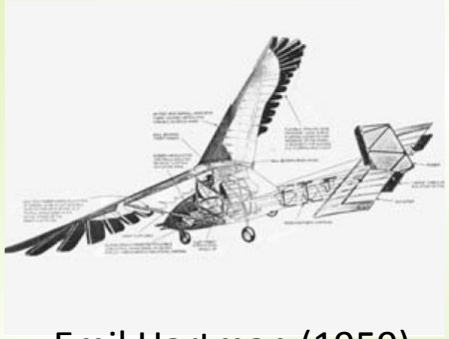
Burton, R., 1990, *Bird Flight,* England, ISBN 0-8160 2410-3

Film from discovery

楊鏡堂, 台大機械, 2011

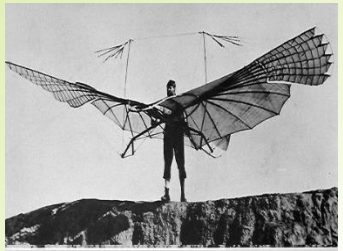
Aircraft with the Flapping Wings

Edward P. Frost (1902)



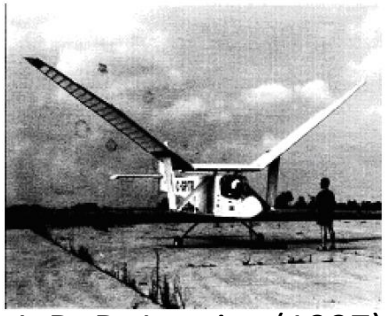
Emil Hartman (1959)

J. D. DeLaurier (2004)



Otto Lilienthal (1894)

Adalbert Schmid (1942)



J. D. DeLaurier (1997)

J. D. DeLaurier (2010)

1800	1900	1950	2000

Animal Locomotion?

Maneuvering Flight

MAV (micro aerial vehicle)

AUV (autonomous underwater vehicle)

ROV (remotely operated vehicle)

Miniaturized Winged Robots

Nature- News and Views (June, 2013)

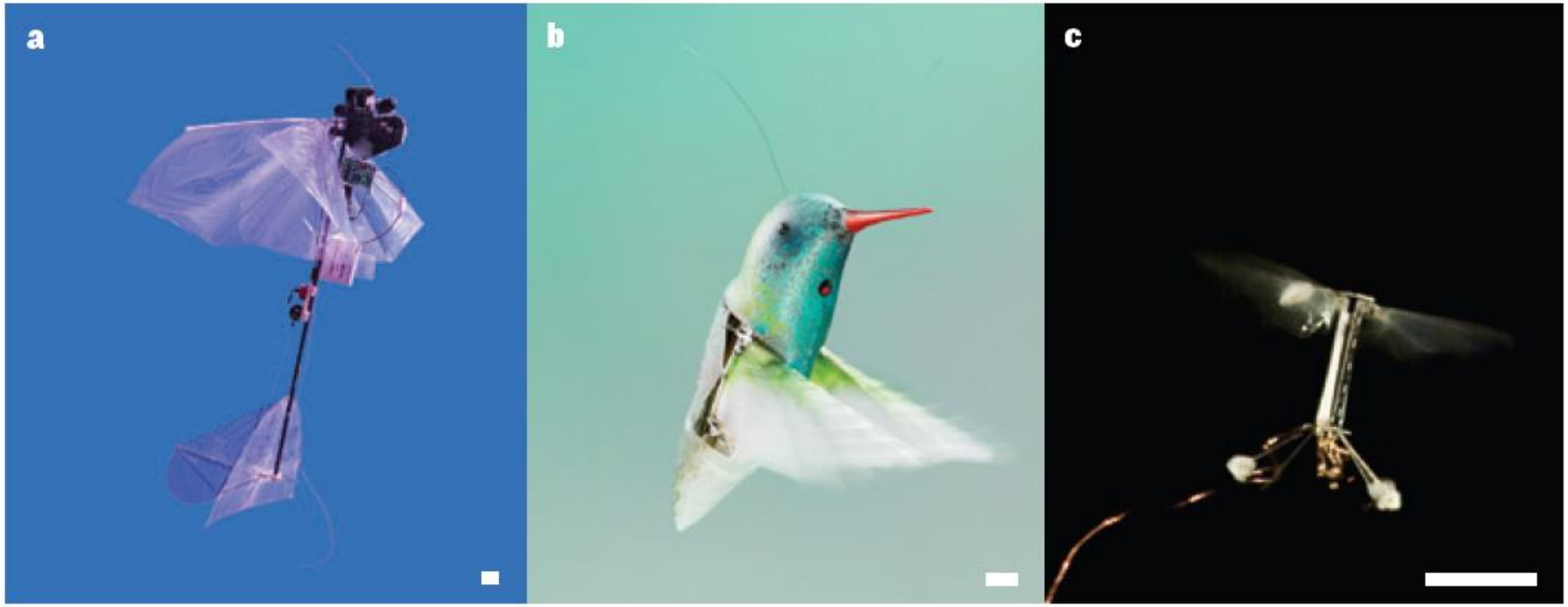


Figure 1 | Winged victories. Three successive iterations of miniaturized robots that each mimic certain aspects of animal hovering flight. **a**, The passively stable DelFly[7] hovers like an insect that is controlled by its tail. **b**, The tailless Nano Hummingbird[8] is stabilized by an on-board autopilot, which controls the wings' angle in a way analogous to that seen in real hummingbirds. **c**, Ma and colleagues' robot fly[1], shown here on its maiden flight, is controlled by a tether that provides modulated power to each flight 'muscle' of the wing. Scale bars, 10 millimetres (estimated).

The Tailless Nano Hummingbird

Nano Hummingbird
by AeroVironment Inc.
(Keennon et al., 2012)
weight 19 g
wingspan 16.5 cm
endurance 4-11 min

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

Festo—Bionic Opter (2013)

https://www.youtube.com/watch?v=nj1yhz5io20

熱流光束實驗室之研發進程

台大機械系

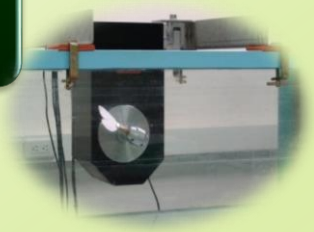
Observation, Learning, Imitation →

Inspiration → Creation

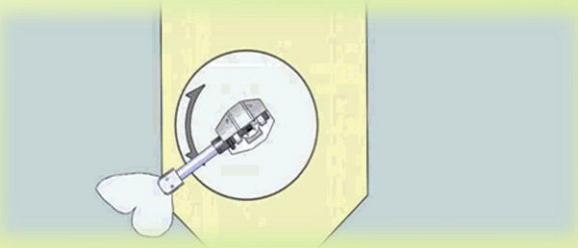
3-D Measurement & Analysis

Flight Mechanics

Artificial Design & Test



Biomimetic Vehicles

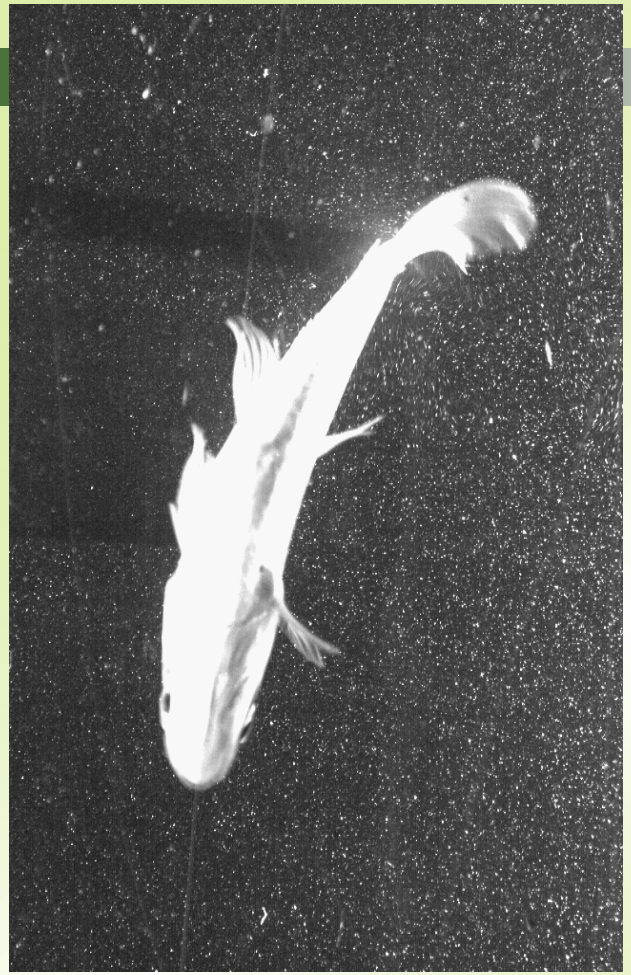


Life among the Formulae of Physics

→ Biomimetic Technology and Novel Design Concepts

→ Innovative Products

流場觀測



Swimming fish
(Crucian carp, 鯽魚)

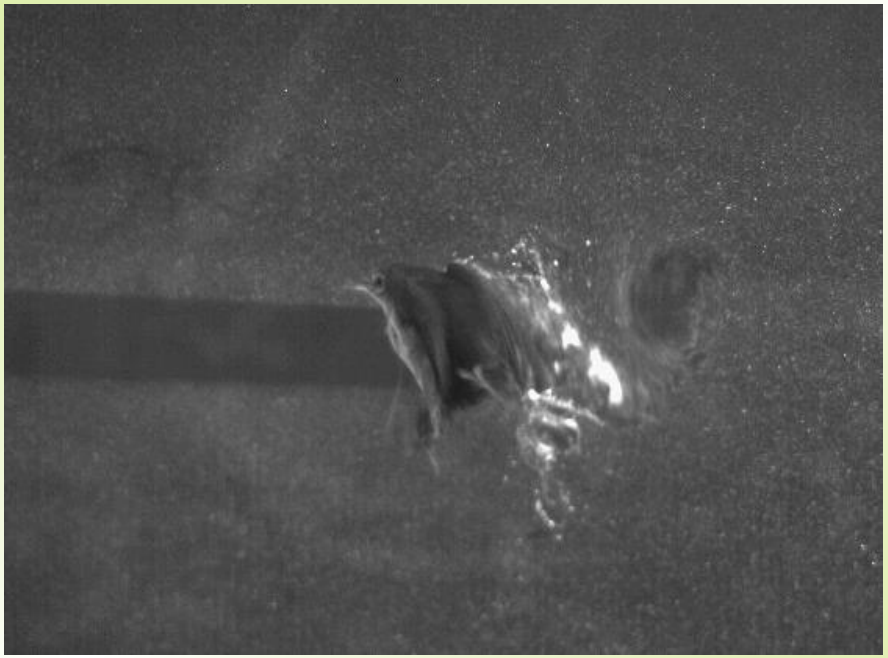
Hovering bird
(Japanese white-eye, 綠繡眼)

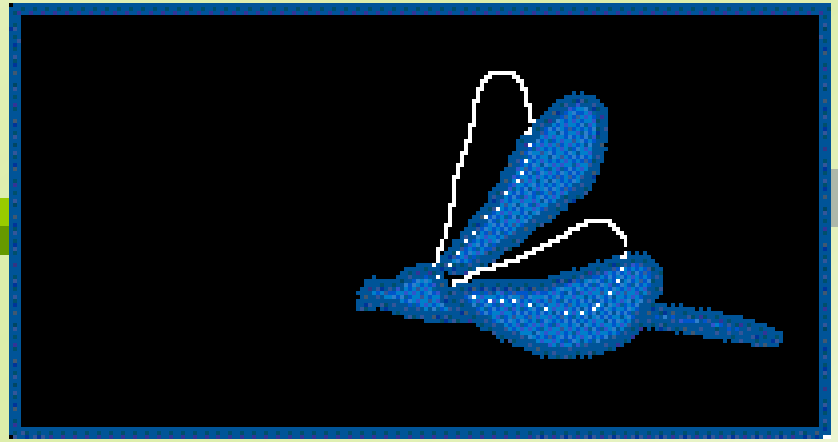
Flow Visualization

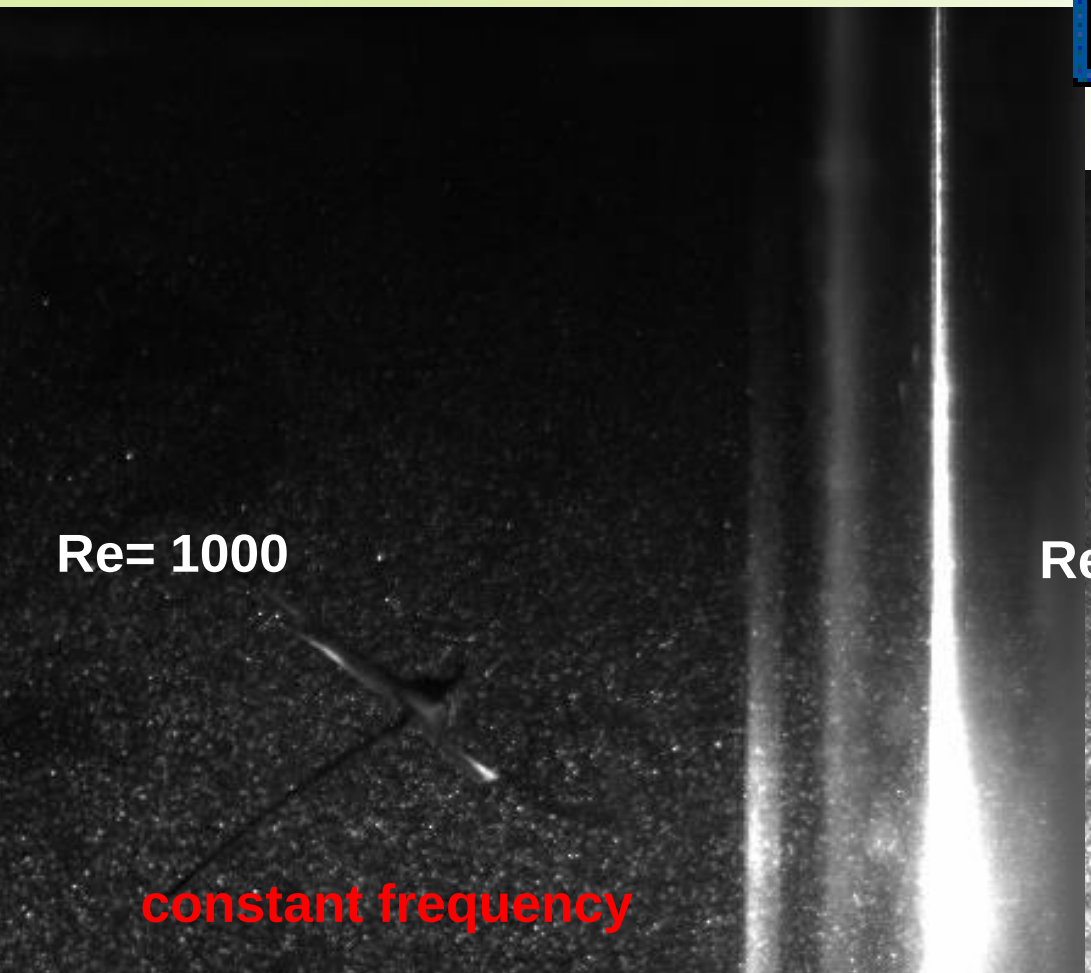
2009 拍攝於
BEAM Lab.

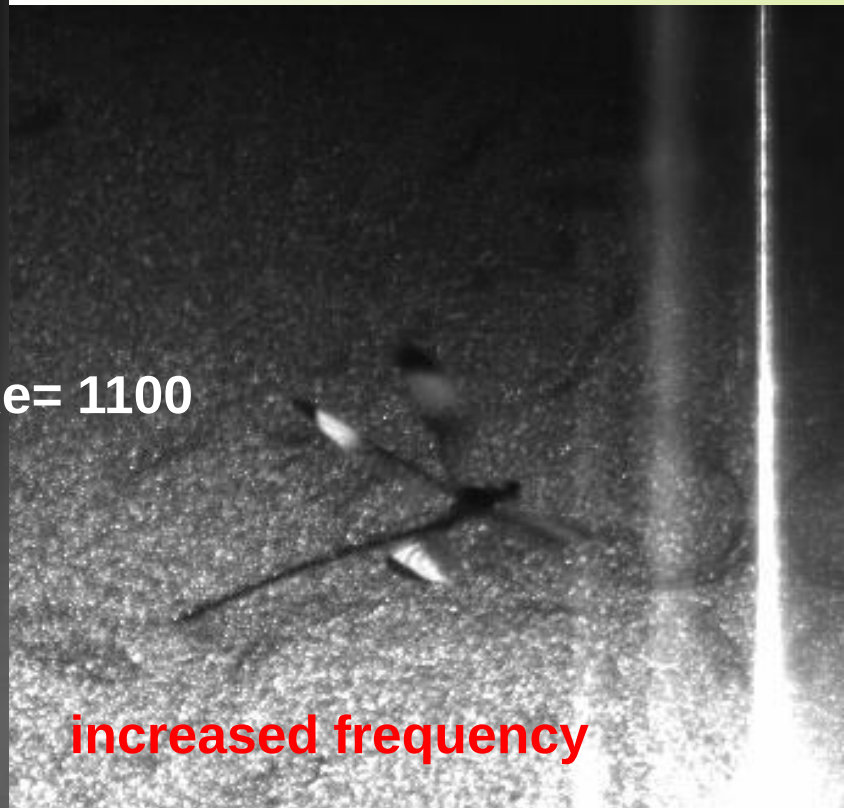
Flow Visualization

flapping flight

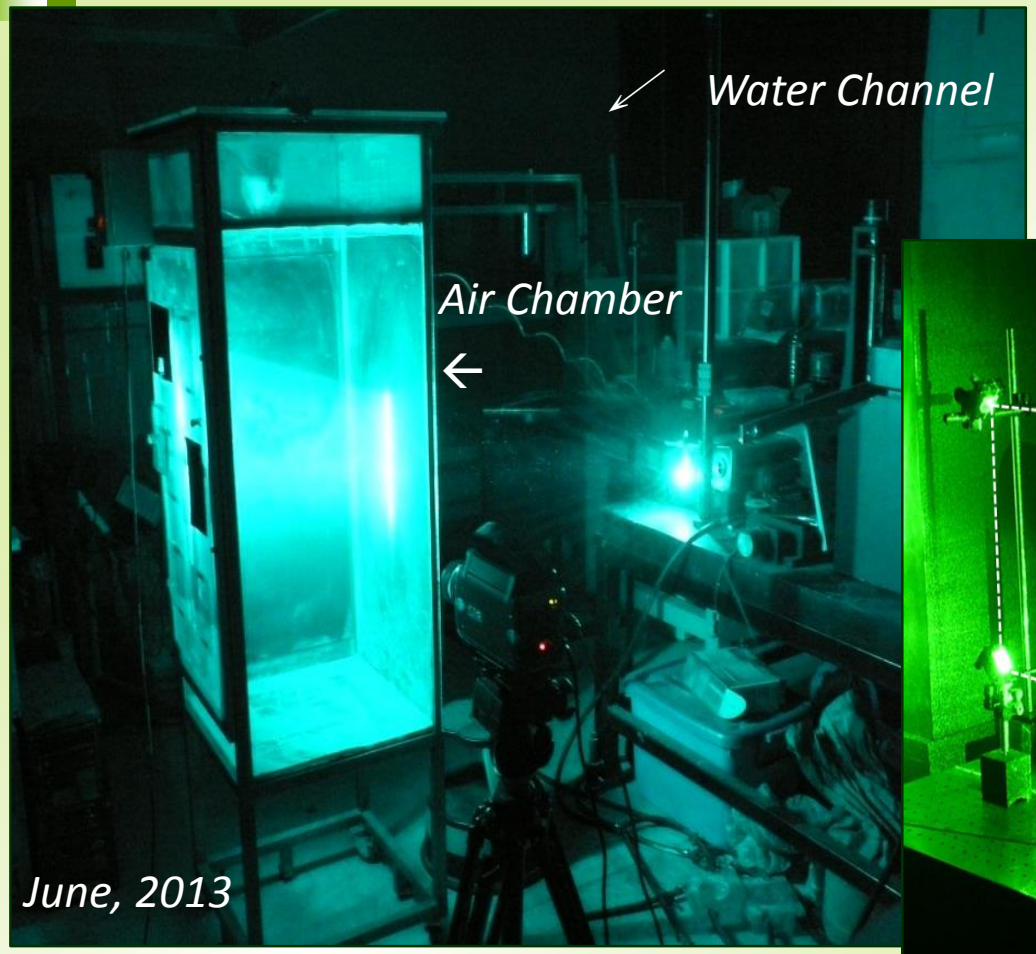


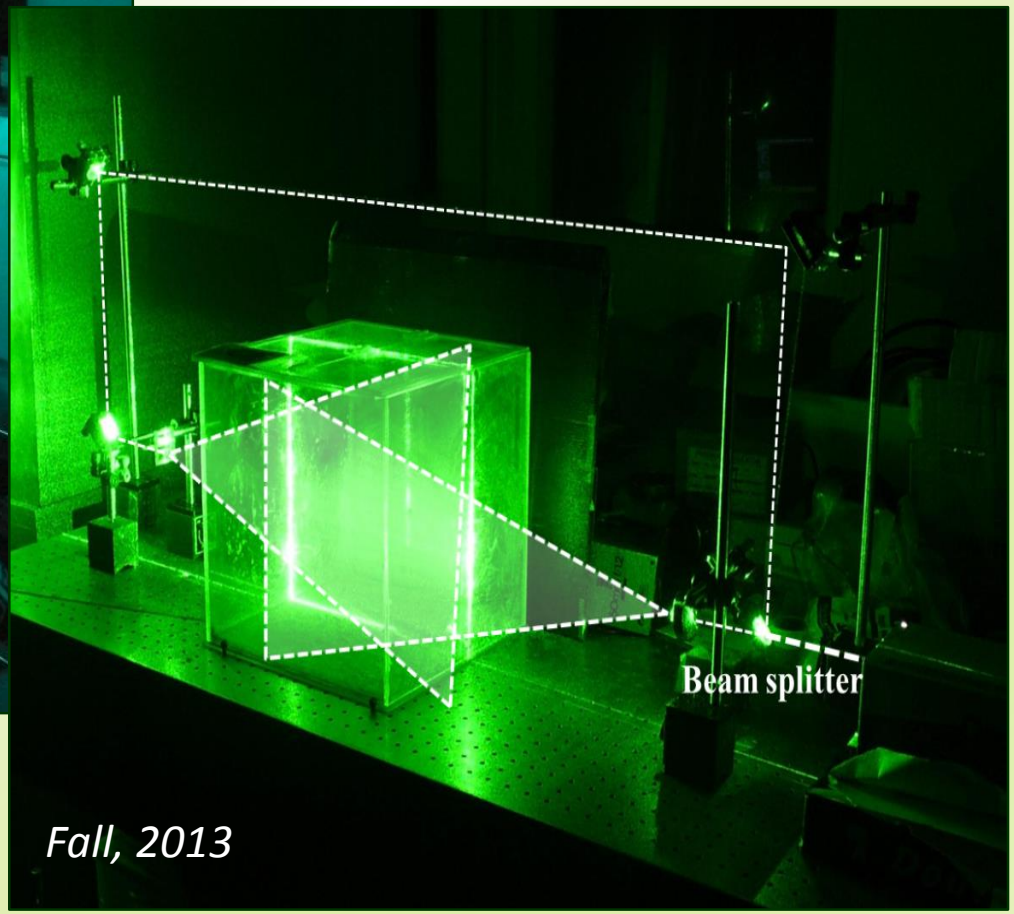



Re= 1000
constant frequency


Re= 1100
increased frequency

實驗觀測區 for birds and insects

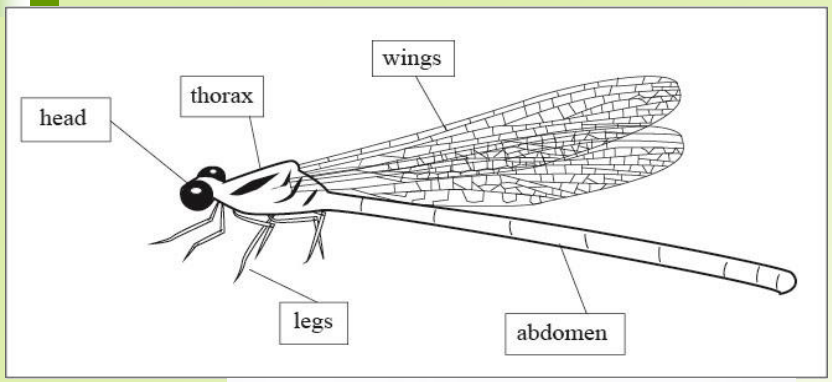


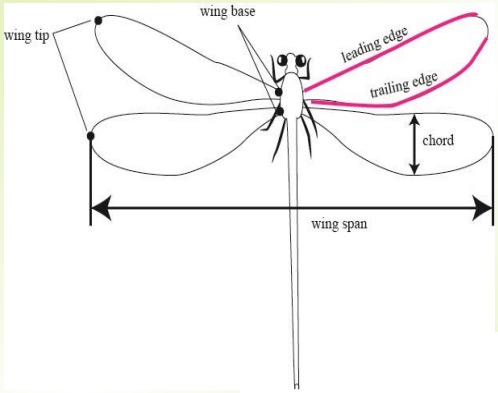


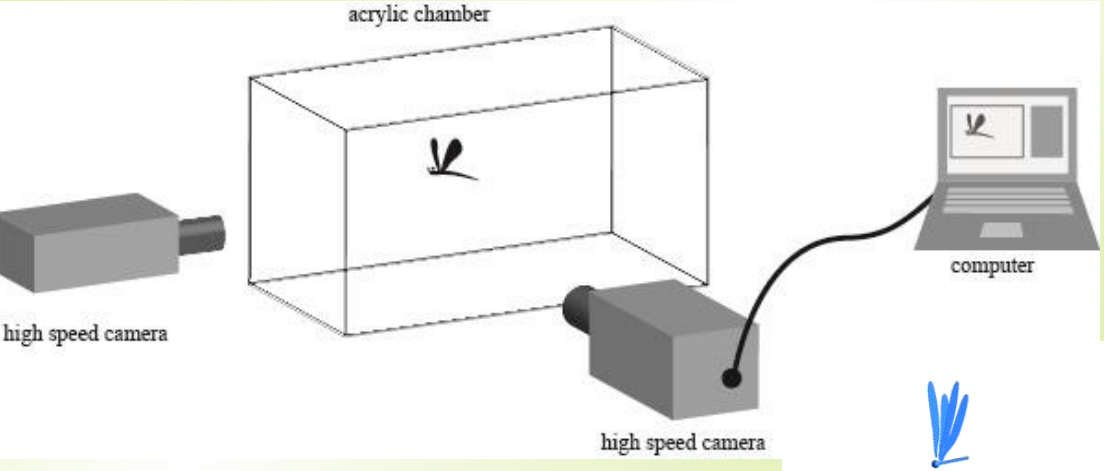
實驗測試過程 與 豆娘雙翅飛行觀測

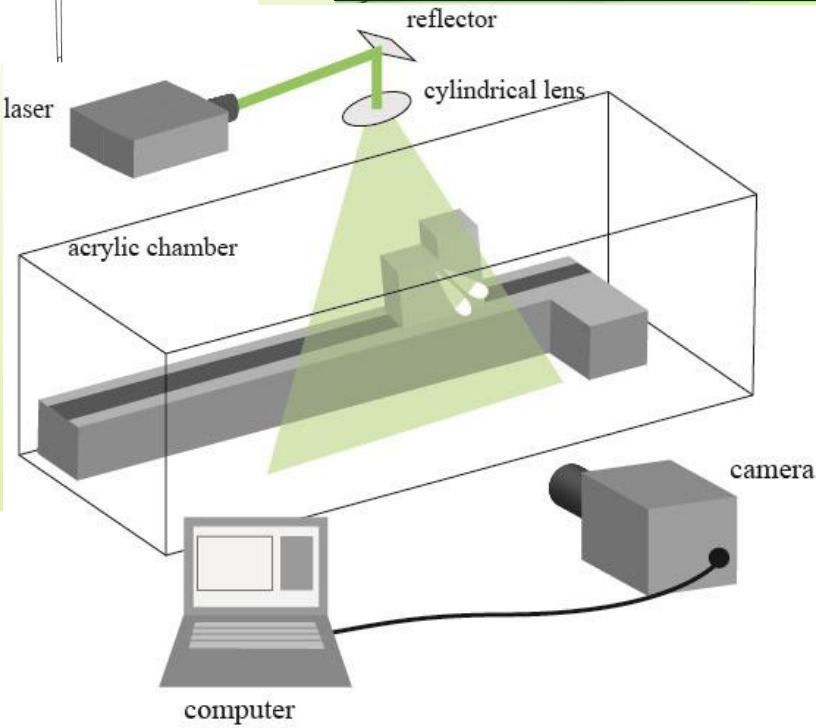
-- Damselfly

張家瑜碩士論文計畫書, 2015/12





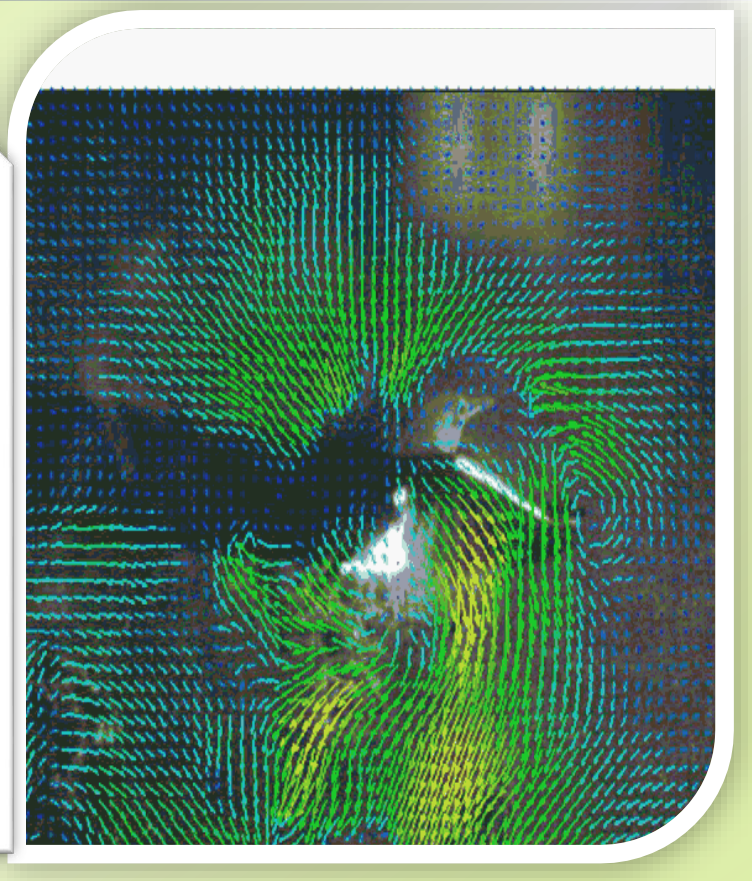




film of experiment

Flow Visualization & Kinematic Analysis

蘇健元論文, 台大機械博士, 2013



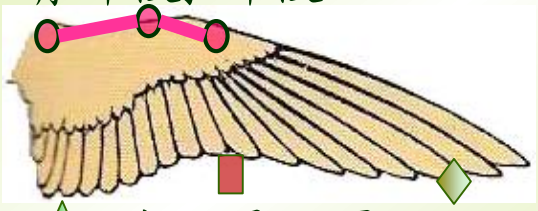
Particle Image Velocimetry (PIV)– 10,000 frame/s

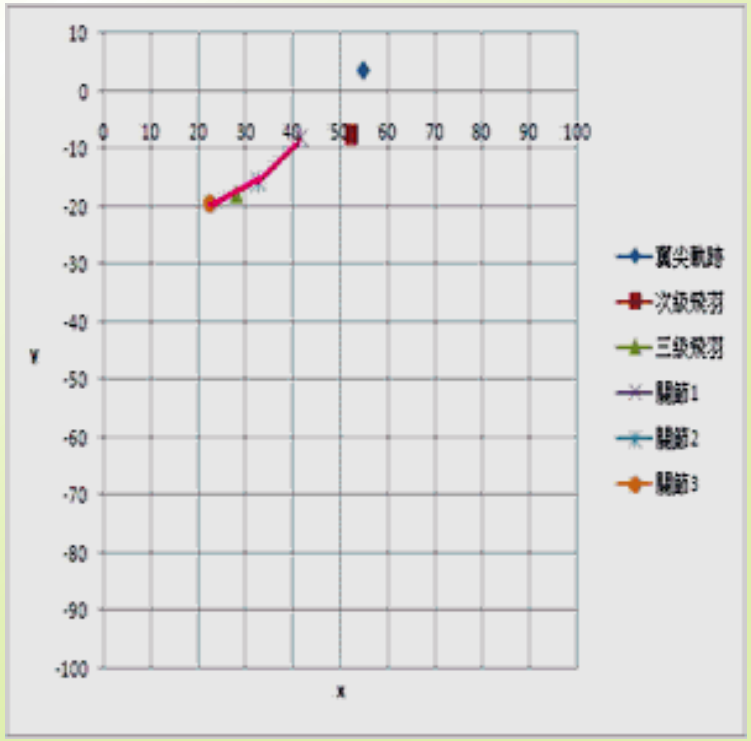
Wing Motion for Kinematic Analysis

楊鏡堂, 台大機械, 2011

綠繡眼懸停飛行↓

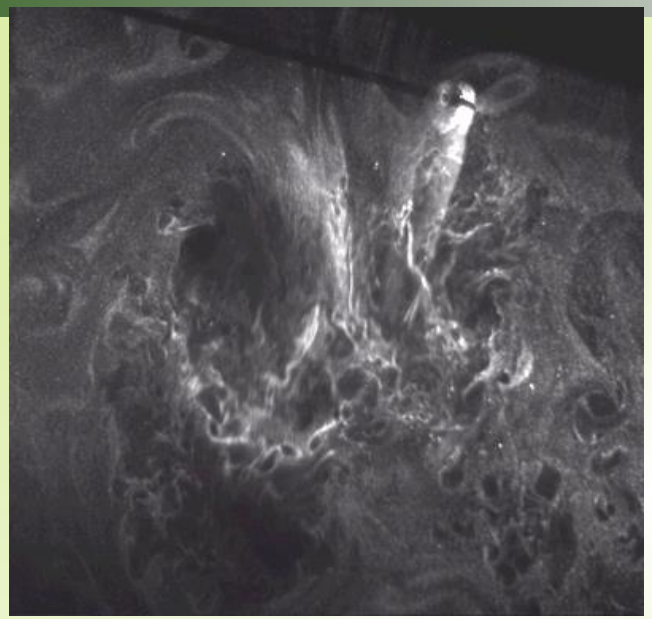
追蹤翼面軌跡作為
可摺曲翼展機構設計參考
→

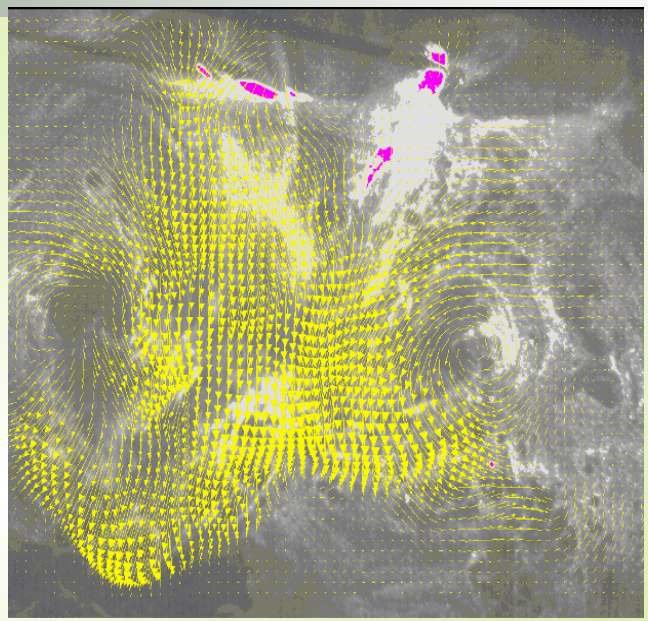


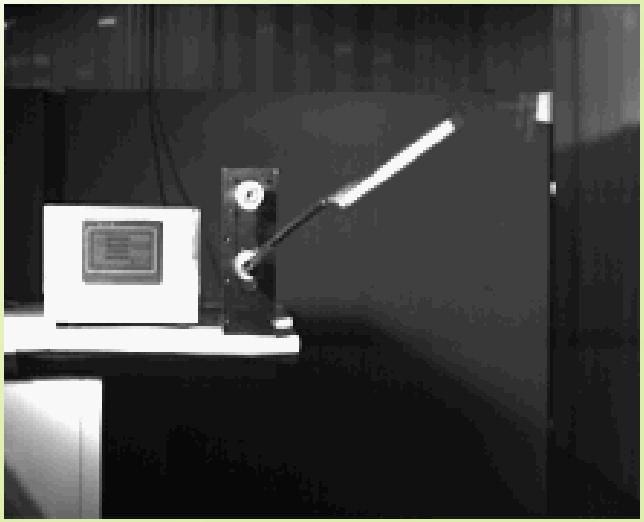


Synchronized PIV & Motion Analysis

The Complete Process of the Investigation for Passerines







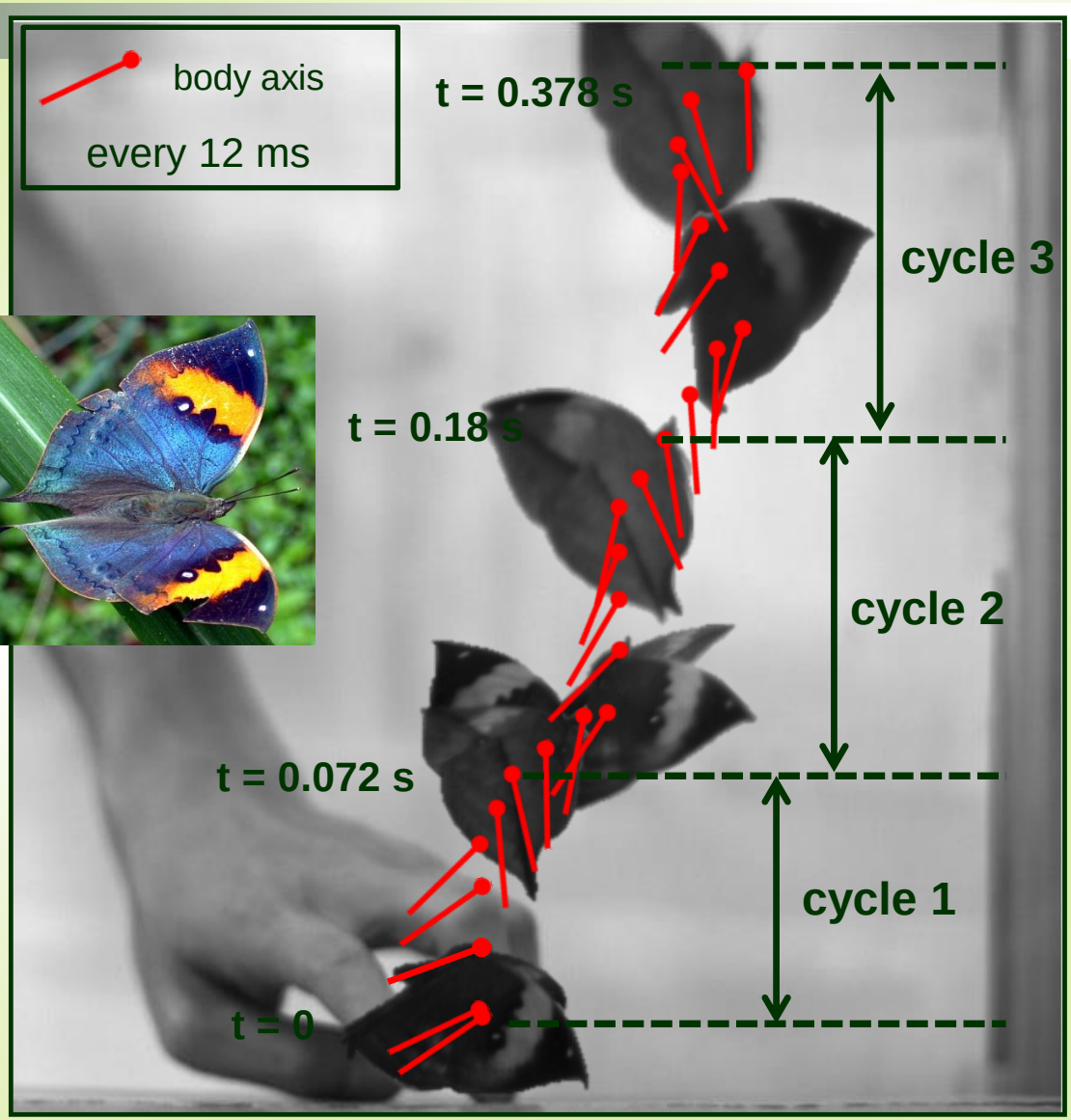
Estimation of lift force based on the vortex-ring model

翅膀身體之交互作用對蝴蝶拍撲飛行之影響

When butterflies are flying, they swing their abdomen, head, antennas or even their foots to make their body rotate regularly.

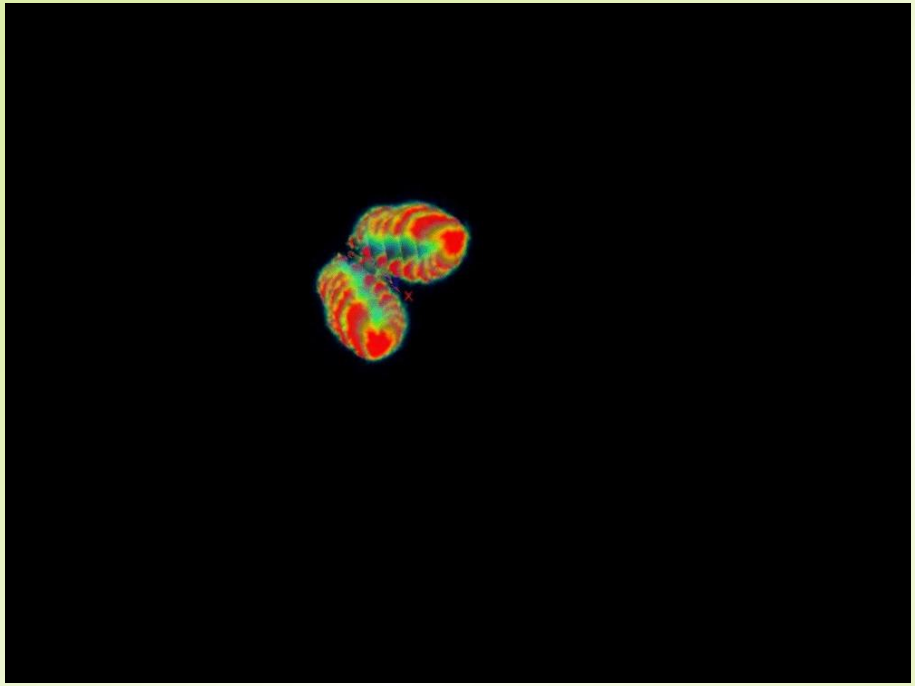
Body angle was continually changing in all species record (Ellington,1984)

Indian leaf butterfly
(Kallima inachus)

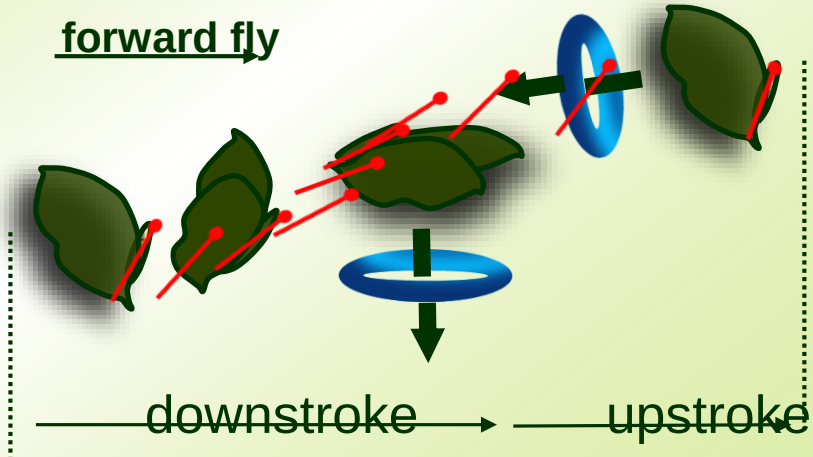


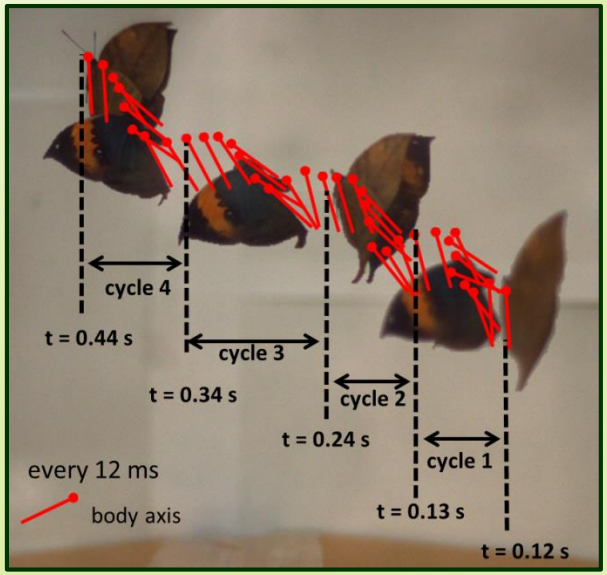
Body position in free flying butterfly

翅膀身體之交互作用對蝴蝶拍撲飛行之影響



費約翰博士論文計畫書, 2015

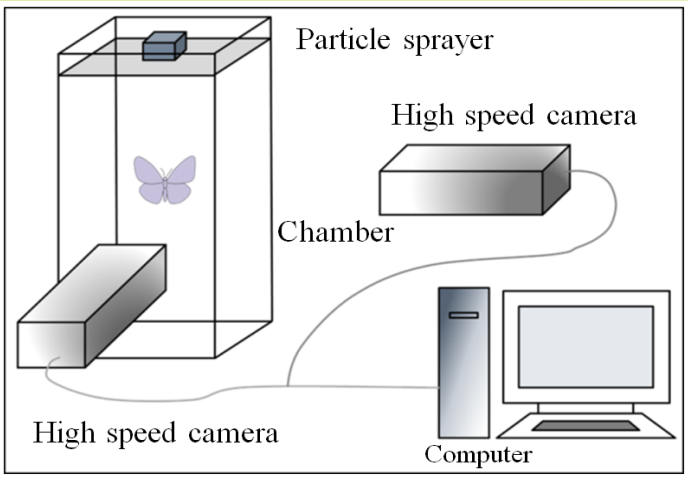




Enhanced thrust and speed revealed in the forward flight of butterflies with transient body translation

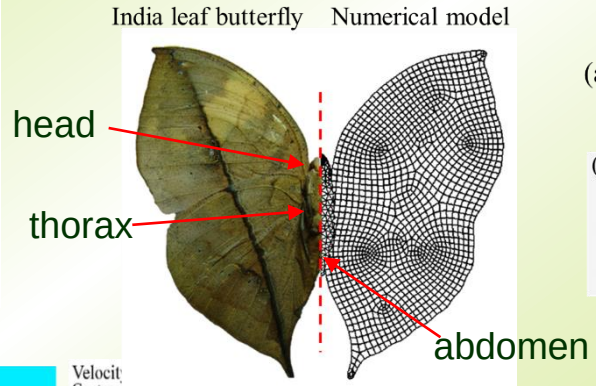
（枯葉蝶）

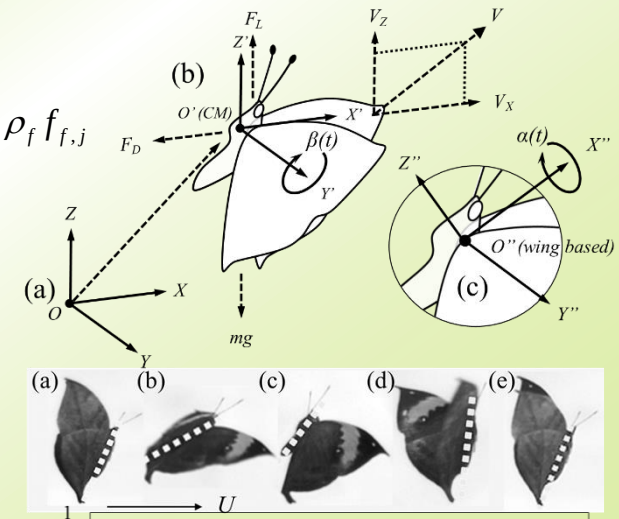
費約翰 楊鏡堂

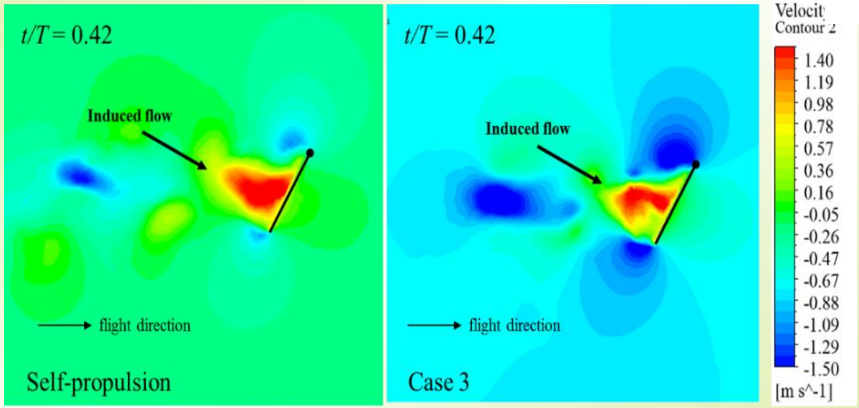


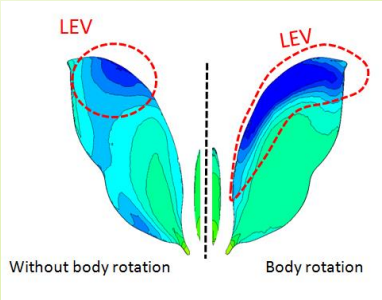
$$\frac{\partial u_{f,j}}{\partial x_j} = 0$$

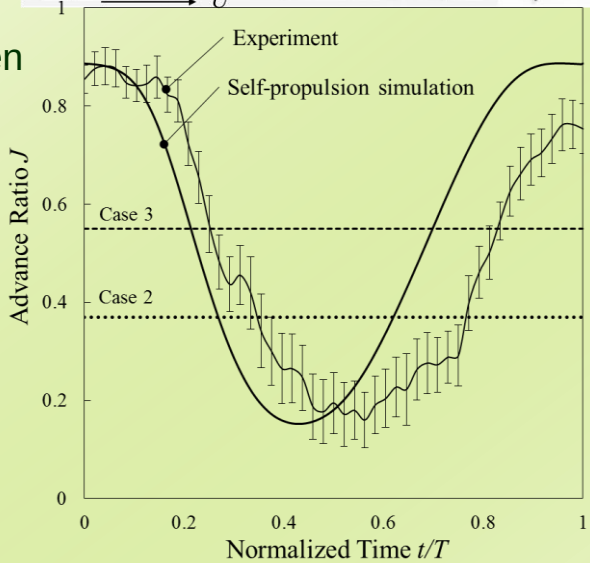
$$\rho_f\left(\frac{\partial u_{f,j}}{\partial t} + u_{f,j}\frac{\partial u_{f,i}}{\partial x_j}\right) = -\frac{\partial p_j}{\partial x_j} + \mu\frac{\partial^2 u_{f,i}}{\partial x_j^2} + \rho_f f_{f,j}$$



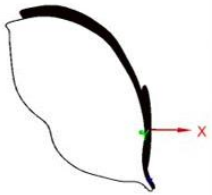




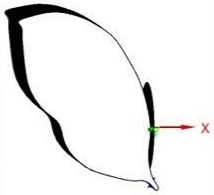




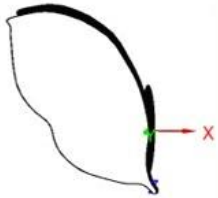
Symmetry Flapping Motion



Hovering
($\beta = 90^\circ \pm 27^\circ$)



Vertical take off
($\beta = 90^\circ \pm 30^\circ$)



Vertical take off
($\beta = 90^\circ \pm 40^\circ$)

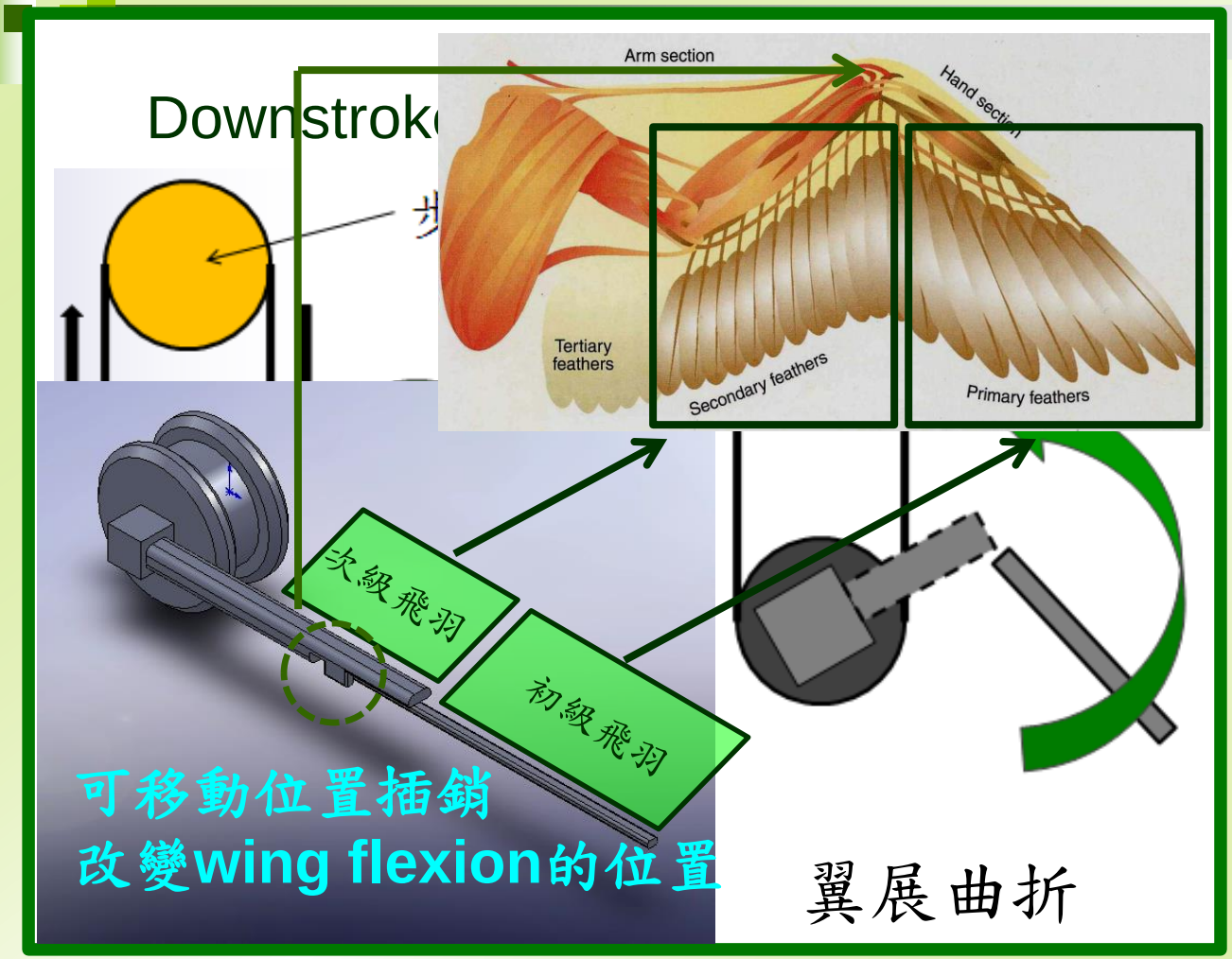
Flapping Wings Micro Air Vehicle (MAV)

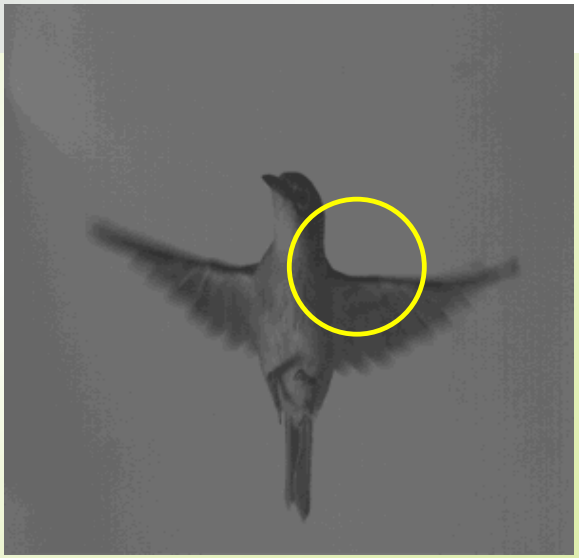
Golden Snitch

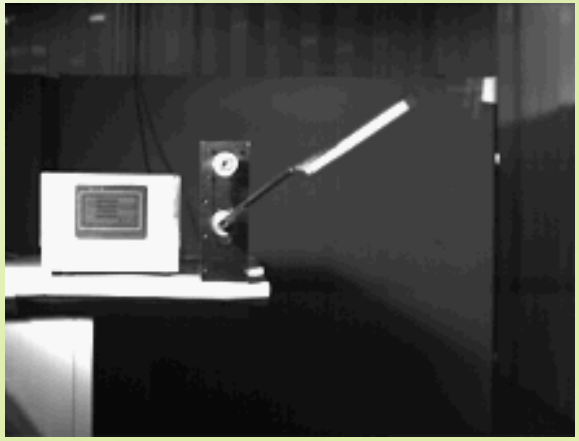
Biomimetic MAV

Butterfly

Flapping-Wing Model





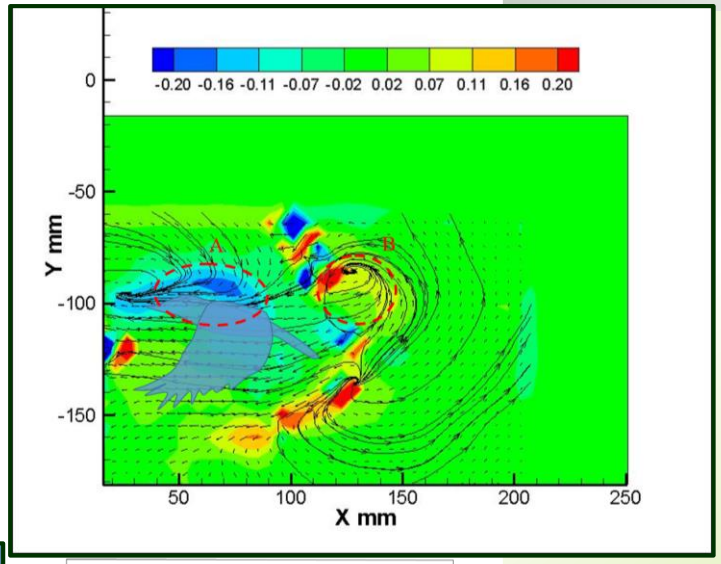


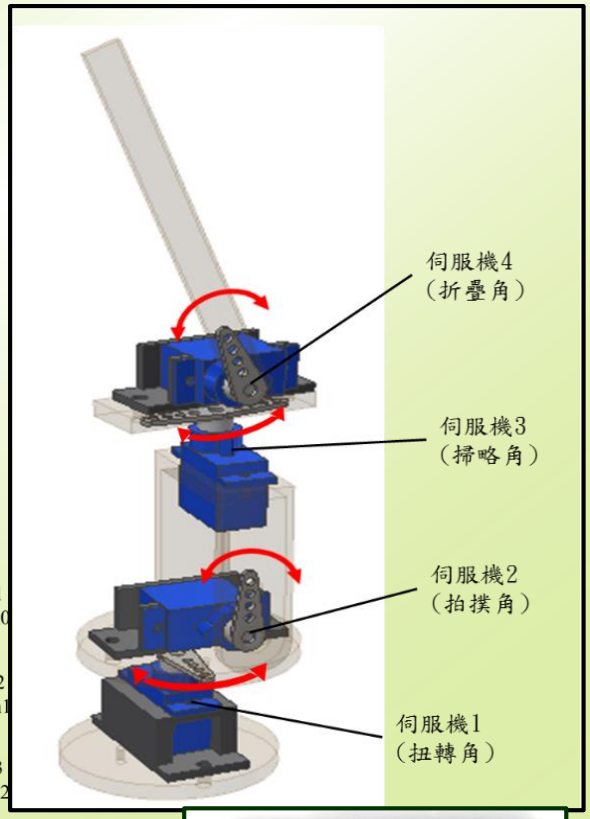
Biomimetics !

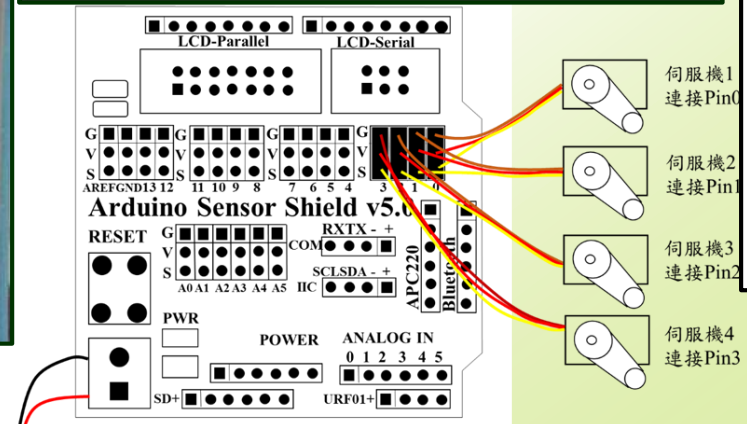
INNOVATION INSPIRED BY NATURE !

Analysis of the Mechanism of the Forward Flight in Japanese White-eye and Design a Bird-Mimicking Mechanical Flapper

黃佩儀



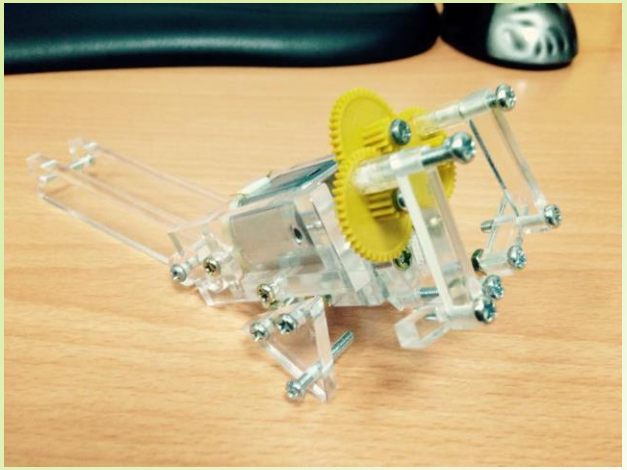


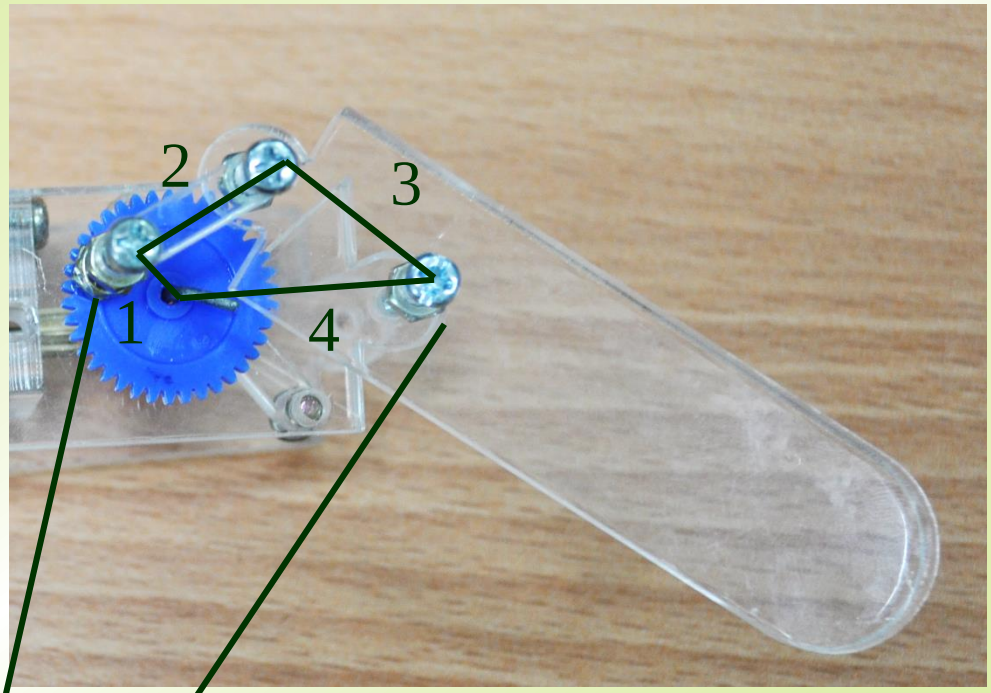


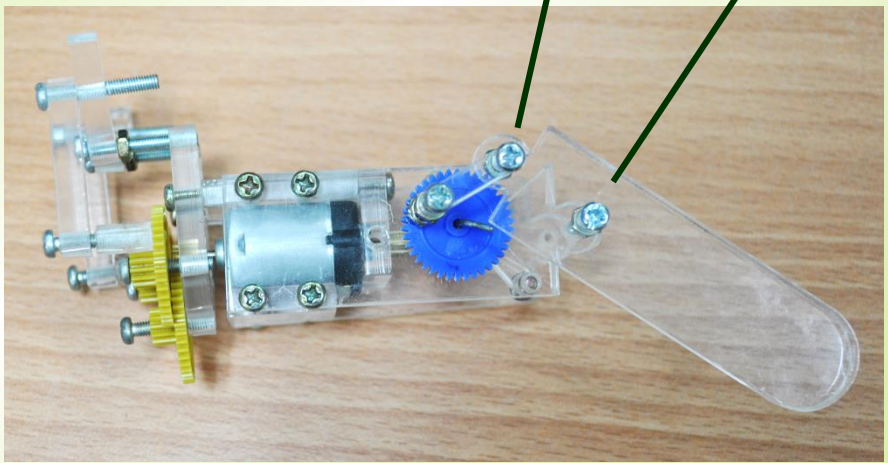
台視拍攝影片20151022 家瑜 彥傑 影片\1 翅膀下的秘密.avi

蝴蝶仿生機構(腹部)設計與測試

王彥傑碩士論文計畫書, 2015/12

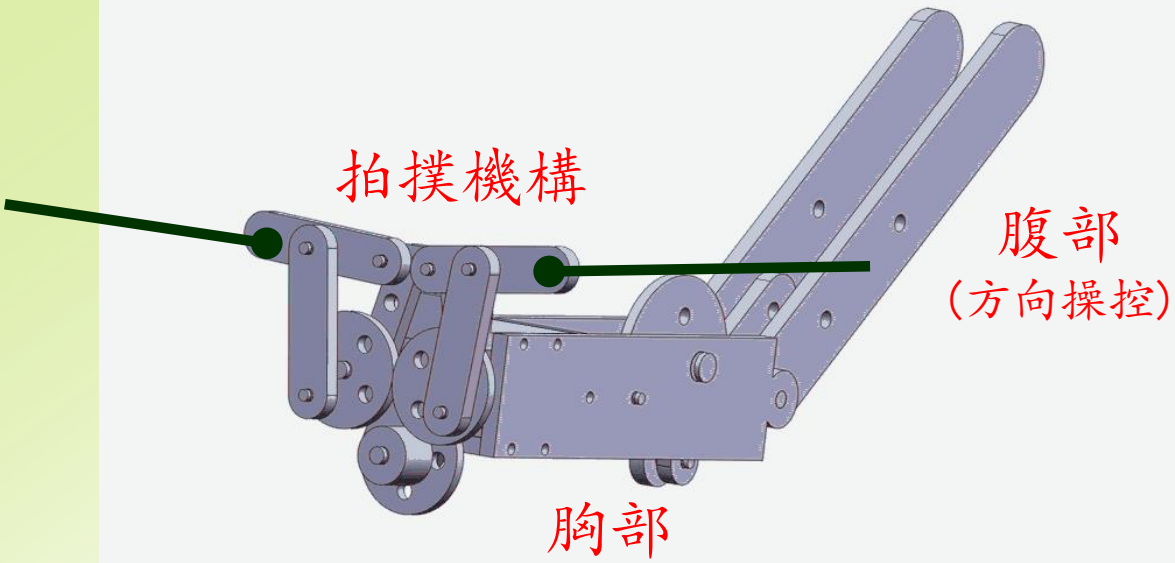






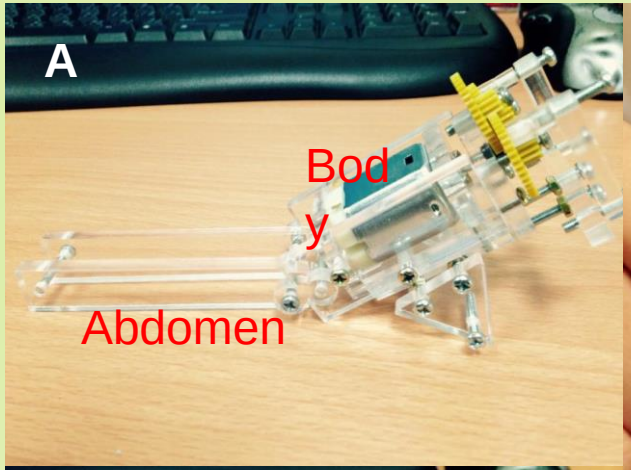
可控腹部運動之元件

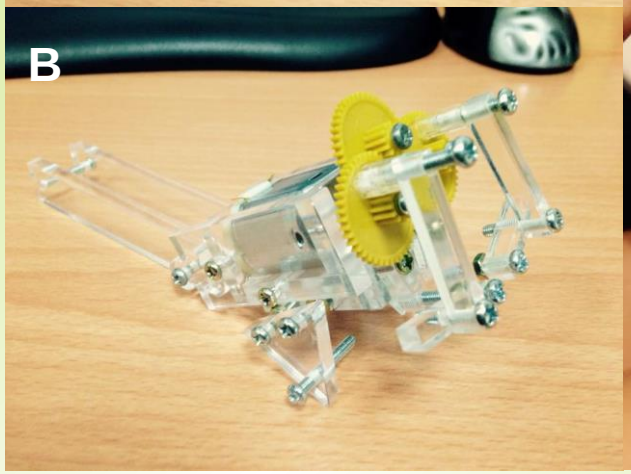
蝴蝶飛行時之特殊腹部姿態操控

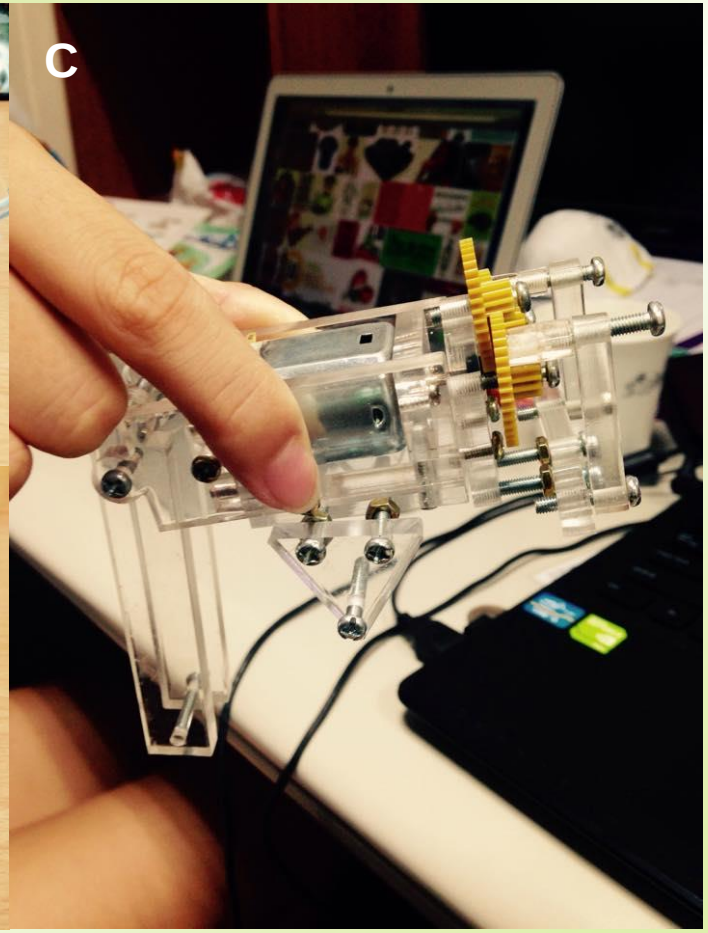


蝴蝶透過腹部的主動控制 達到飛行操控，
由此研發新型之操控微飛行器

Components of Butterfly-based MAV



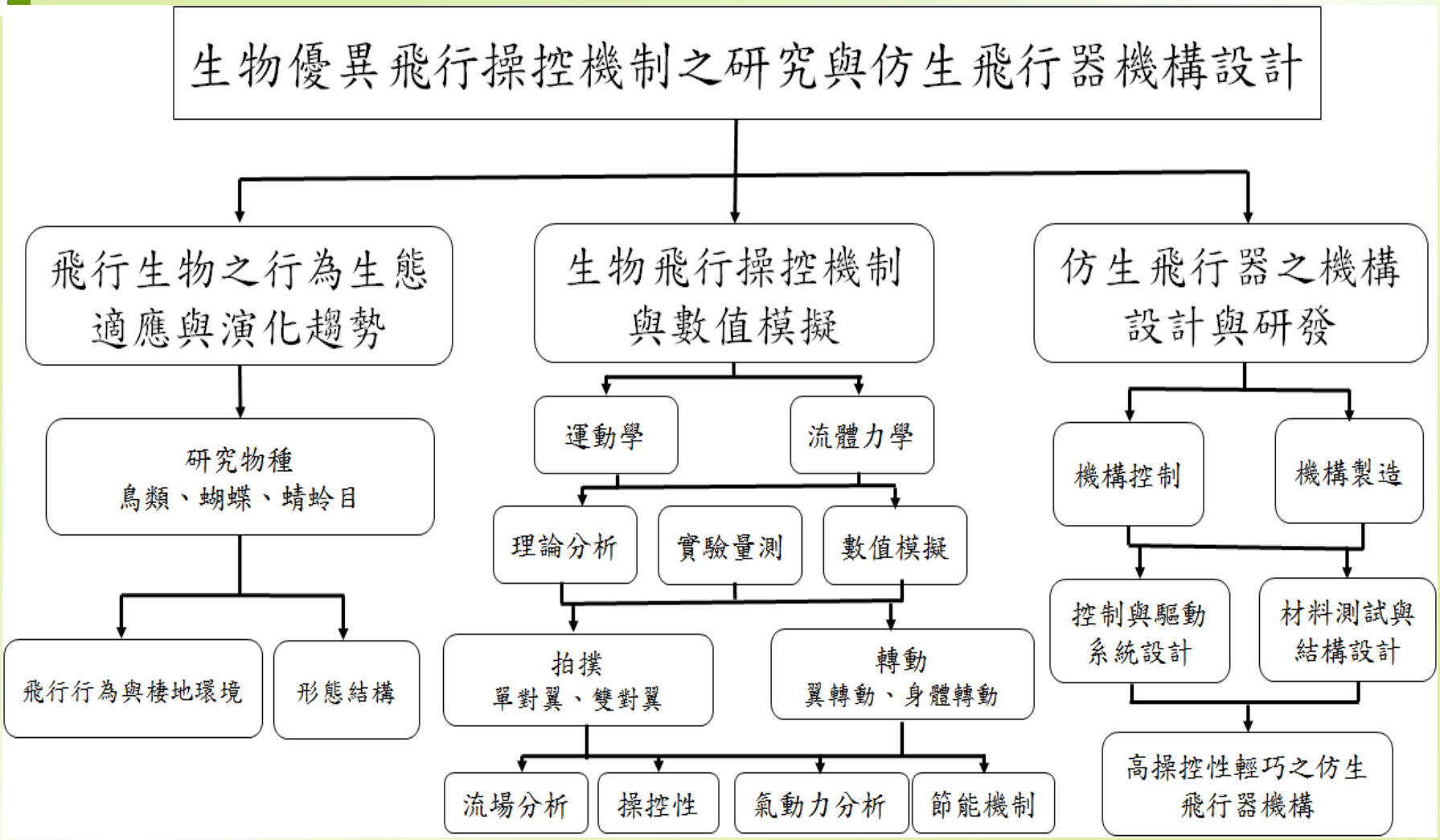




in progress….

	M.S.	graduation
費約翰	(2012/08-2014/01)	
	(2014/02-2017/01 PhD)	
王彥傑	(2014/08-2016/06)	
張家瑜	(2014/08-2016/06)	
李哲安	(2015/08-2017/06)	
侯詞軒	(2015/08-2017/06)	

生物優異飛行操控機制之研究與仿生飛行器機構設計



楊鏡堂教授主持

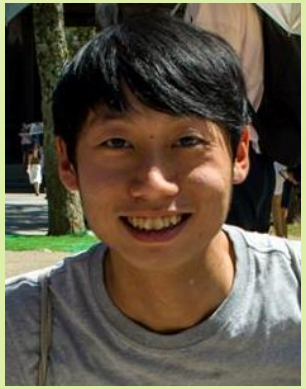
謝謝聆聽…… Q&A

費約翰

王彥傑

張家瑜

李哲安



侯詞軒