How to Photograph Birds

Frank Taylor
MIT
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FNAL

Brown Falcon
Queensland, Australia
Birds in Comparison

• Warm-blooded flying species
  – 1,000 bats
  – 9,721 birds

• Speed
  – Humans 3-4 body lengths/sec (bl/s)
  – Race Horse 7 bl/s
  – Cheetah 18 bl/s
  – SR71 (Mach 3) 32 bl/s
  – Swifts 140 bl/s

• Maneuverability roll rate
  – Stunt plane A-4 Skyhawk 720°/s
  – Barn swallow 5,000°/s

• G-forces
  – Select military aircraft 8-10 g
  – Birds up to 14 g

• Altitude record for a bird
  – 11,000 m Ruppell’s Vulture (ingested by a jet engine over Ivory Coast)

Smallest Living Bird: Bee Hummingbird (*Mellisuga helenae*) 1.6-2 g endemic in Cuba

Heaviest flying bird: Kori Bustard in Africa (*Ardeotis kori struthiunculus*), 16 to 19 kg.

Largest Living Bird: Common Ostrich (*Struthio camelus*) ~ 115 kg in Africa

‘First’ bird: *Archaeopteryx* lived during the late Jurassic period, approximately 150.8–148.5 million years ago.

**Wei Shyy et. al, “Aerodynamics of Low Reynolds Number Flyers”, Cambridge Aerospace Series**
Outline

• The Measurement problem
  – Small size, quick movement, non-proximity

• Photography Fundamentals
  – Lens
    • Focal length, aperture, vibration reduction, continuous focusing
  – Camera
    • Aperture priority, light metering and focusing, auto-ISO, burst mode, GPS tag
  – Data
    • JPEG/RAW and Image processing

• Photographing birds in different settings
  – Birds at rest
  – Birds in flight & measuring their ground speed

• Digression into a little Aerodynamics of low Reynolds numbers
  – Gliding
  – Flapping Energetics

• Obsession of an Extreme Bird
‘Measurement’ Problem

• Driven by small size and quick movements
  – Typical passerine (perching bird) size ≈ 10 cm
  – Typical distance ~ 30 m
  – Typical observation time ~ 2 seconds

\[
\frac{hi}{ho} = -\frac{i}{o} \approx -\frac{f}{o}
\]

Size of image for \( f = 300 \times 1.7 \text{ mm lens} \) 10 cm bird @ 30 m

\[ hi \approx |ho (-f/o)| = 10 (0.51/30) = 0.17 \text{ cm} \]

For Nikon D300s ((5.5 \( \mu \text{m} \))^2 pixels) image would be 310x310 pixels
Panning & Visual Acuity

To photograph a Bird flying by

Panning Function
\[ v = 17 \text{ m/s}, \quad b = 10, 20, 50 \text{ m} \]

\[ \frac{d\theta}{dt} = \frac{v}{b} \cos^2 \theta \]

To photograph a Skylark

Visual Acuity
Great Blue Heron (*Ardea herodias*) off the coast of Texas with Nikon D300s, 300x1.7 mm, f/5, 1/1250 s, ISO 200

Audubon shot (killed), then propped up his birds with wire in order to paint them. Hence none of his bird pictures is in flight.
Digital Single Lens Reflex Camera

• Speed is of the essence
  – In bird photography have no time for camera startup, focusing, exposure parameters, etc.
  – A DSLR is the (presently) only option

Nikon and Cannon are the two major companies

I have a Nikon D7200, D300s, D700 and a D80 and use the D7200 for most shots.

The technology is rapidly changing to ever-more capable cameras. I am comparatively low-end.
NIKKOR (Nikon) Lenses

• Up to 800 mm f/5.6 (Canon has a similar family)
  – Need at least 300 mm for wildlife but for birds a longer lens is better
  – I have a 300 mm f/2.8 lens that I use with a 1.4X, 1.7X and 2.0X teleconverter (equivalent to 600 mm f/5.6)
Tripod & Flash – The ‘high end’

- ‘Professionals’ use:
  - Wimberley™ Mount and sturdy tripod with long lens (600 mm prime f/4.0)
  - Flash with a Fresnel Concentrator
  - Remote/cable shutter release for low vibration
  - Enables the best shots of distance birds but is heavy and not very mobile

- I prefer hand-held lens which I can pack in backpack and carry all day @ 15 lbs
Uses of a Telephoto Lens

Galapagos Flycatcher (*Myiarchus magnirostris*)

[S 0° 14.479’, W 90° 51.707’]

Telephoto lenses are not really needed in the Galapagos! Birds are completely habituated there and will walk over your shoe or land on your head!

My lens is a Nikkor 300 mm f/2.8
Camera Settings

• Aperture Priority – lens wide open
  – Want the fastest shutter speed possible for the given light
  – Short depth of field blurs the background but makes focusing less forgiving
• Raw format 12 bit
  – Can fix many mistakes
  – 14 bit is possible but lose burst speed
• Continuous focus
  – Objects are always moving – have to track them
• Burst shutter mode (4 to 5 shots/second)
• Auto ISO
  – Minimum shutter speed 1/320 second
  – Maximum ISO 6400
• Color space
  – sRGB with auto white balance

Set up camera before going shooting
One has no time to mess with the settings
Concentrate on getting the pictures
Focus & Metering Region

• Camera menu has many options
  – Generally use spot focusing
    • Focus on the bird and not the tree limb
  – 51 point with 3D tracking possible
    • Use sometimes on a fast bird flying in a clear sky
  – Generally use spot metering
    • Want the bird to be properly exposed – don’t care about the sky or the tree

• Other settings sometimes used
  – I do a fair amount of playing with these settings
Auto ISO (International Organization of Standardization)

- ISO quantifies the sensitivity of the CMOS light sensor
  - Low ISO – least sensitive but good quality and low noise
  - High ISO – more sensitive but becomes noisy
- Auto ISO selects the optimal ISO between minimum shutter speed and the maximum ISO for the best picture quality
- EV (Exposure value) adjustments sometimes done to change the shutter speed without changing the ISO
  - Positive EV means more exposure by less shutter speed
    - +1 is one f/stop more open

From Nikon D300s

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off (default)</td>
<td>ISO sensitivity remains fixed at value selected by user, regardless of whether optimal exposure can be achieved at current exposure settings.</td>
</tr>
<tr>
<td>On</td>
<td>If optimal exposure can not be achieved at ISO sensitivity selected by user, ISO sensitivity is adjusted to compensate, to minimum approximately equivalent to ISO 200 and maximum selected using Max. Sensitivity option. Flash level is adjusted appropriately when flash is used. In exposure modes P and A, ISO sensitivity will be adjusted if photo would be overexposed at shutter speed of 1/6000 or underexposed at value selected for Min. Shutter Speed. Otherwise camera adjusts ISO sensitivity when limits of exposure metering system are exceeded (mode $S$) or when optimum exposure can not be achieved at shutter speed and aperture selected by user (mode $M$). ISO sensitivity can not be set to values over 1600 while this option is in effect.</td>
</tr>
<tr>
<td>Max. Sensitivity</td>
<td>Menu shown at right is displayed. Highlight desired ISO value and press multi selector right to return to ISO auto menu.</td>
</tr>
<tr>
<td>Min. Shutter Speed</td>
<td>Menu shown at right is displayed. Highlight desired shutter speed and press multi selector right to return to ISO auto menu.</td>
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Makes it possible to get the right exposure automatically
VR mechanism

Upon pressing the shutter-release button halfway, the built-in VR (Vibration Reduction) lens group is activated to correct blur, providing a stable image for the viewfinder, the AF sensor and the metering sensor. During exposure, it provides the image sensor with a clear, blur-corrected image.

Two lens sensors independently detect pitching and yawing, then provide instructions to two Voice Coil Motors (VCMs) that command the VR optical system to compensate blur.

Makes it possible to hand-hold telephoto lens
Continuous Autofocus

Continuous-servo AF (AF-C)
In continuous-servo AF (AF-C), the camera will continue to focus if the shutter-release button is kept pressed halfway after the camera focuses. Because the camera continues to focus up to the moment the shutter-release button is pressed all the way down, this mode is a good choice for subjects that are in motion.

From Nikon Web Site
http://imaging.nikon.com/lineup/dslr/basics/16/03.htm

Makes it possible to continuously focus on a bird as it flies pass

※ The illustration is an artist’s conception.
Hardware

Cameras: D7200, D700, D300s, D80; Lens: 300 mm VR f/2.8, 70-300 mm VR f/4.5-5.6 zoom, 18-135 DX f/3.5-5.6, 1.7X & 2.0X Teleconverter; Accessories: memory cards, extra batteries, GPS, remote release, Fresnel Flash, tripod, Laptop & external HD, logbook, backpack, Camera suitcase and many plastic bags
JPEG vs. Raw

- JPEG (Joint Photographic Expert Group)
  - Photograph is compressed in the camera according to enhanced color scale, file size etc.
  - Information of the original photo is lost forever
  - Every edit of photo can change the compressed information
  - Can not go back to original file – get creep of quality
  - Advantage is smaller file size (~ 1 to 2 Mb) and less editing needed

- Raw
  - Like the ‘negative’ of a film – with 12 or 14 bit color/intensity depth
  - All information is preserved
  - Forced to edit but original is untouched
  - Mistakes in exposure can be better corrected
  - Can experiment with different versions of the same picture without copying the original
  - Disadvantage is that each picture is large file ~ 28 Mb @ 12 bit

Shooting in RAW makes it possible to correct a variety of mistakes in original picture taking & in editing.
JPEG vs. RAW

JPEG OK if you get it right the first time

Kingfisher (*Alcedo atthis*) & ‘Flying’ Wild Boar Piglet, Obsevatoire “Loutte”, Teppes de Verbois, SZ

JPEG Picture was ‘edited to death’ – now can not easily repair
A great deal of ‘science’/effort can go into editing RAW format. Usually I do just the minimum by cropping (digital enlargement), adjusting the color temperature to 5000 and slightly increasing the contrast. I use Adobe Lightroom but the pros generally use Adobe Photoshop.

Great Egret (Ardea alba) St. Marks NWR, Florida
Nikon D300s 300 mm x1.7 f/4.8 Lens, ISO 200 Shutter 1/640

A mistake that can not be fixed is to over expose. Check the color histograms when ‘chimping’ to make sure there is no saturation. If needed, change the EV setting for a faster shutter speed.
Software to Measure Pictures

ImageJ – is an NIH Freeware
Photographing Day and Night

Frogmouth – Queensland, Australia
Night photo: 300 mm f/2.8, shutter 1/160 s, ISO 3200 illuminated with flashlight

Daytime: 300 mm x 1.7 f/4.8, shutter 1/400 s, ISO 400
Learning how to Photograph birds in flight

Good practice game: airplanes fly in predictable trajectories and at relatively slow angular speeds
Elliot’s Storm Petrel - Galapagos

Nikon D700, 300 x 1.7 mm f/4.8, 1/1250 s, ISO 800, Matrix metering, Aperture Priority
Galapagos Frigate Birds

Great Frigatebirds
*(Fregata minor ridgwayi)*

Nikon D700, 300 mm f/5.6, 1/2500s, ISO 250
Plenty of light on the equator

GPS Tag written into metadata tells where the picture was taken
Bee-eaters – Genus *Merops*

Some Genera (Genuses) can be found throughout the world

European Bee-eater – Penthaz, Switzerland  
(*Merops apiaster*)

Little Bee-eater – Okavanga Delta, Botswana  
(*Merops pusillus*)

Rainbow Bee-eater – Northern Territory, Australia  
(*Merops ornatus*)
CW: Comb-crested Jacana, White-necked Heron, Black-necked stork, Palm Cockatoo, Royal Spoonbill
India Montage

CW: Peacock, Demoiselle Crane, Hoopoe, Red-billed Leiothrix, Egyptian Vulture, Rose-ringed Parakeet
Okavango Delta - Botswana

African Leopard (*Panthera pardus pardus*)
Does not fly but climbs trees

Nikon D80 JPEG Fine, 300 mm f/3.2, 1/3200 s, ISO 100, EV -1
Local Birds

Marsh wren – Concord, White throated sparrow – Mt. Auburn, Greater Yellow legs – Parker River
Local Birds

Northern Gannet – LI Sound, Redwing Blackbird – Concord, MA, Osprey – Concord, MA – note fish
Hummingbirds

Anna’s HB (m) (*Calypte anna*), Palo Alto, CA

Ruby-throated HB (m) (*Archilochus colubris*), Ithaca, NY

Rufus HB (f) (*Selasphorus rufus*), Sisters, OR

Ruby-throated HB (f) (*Archilochus colubris*), Lexington, MA
300 mm f/8, 1/2500 s, ISO 1000 SB-700 Flash

Hovering accomplished by wrist rotation to generate lift on the wing upstroke. The camber of the wing is reversed ensuring efficient lift.
Limit @ Low Light

Barn Owl, Cley Marshes, Norfolk UK  Nikon D300s, 300 x 1.7 mm
f/4.8, 1/400 s, ISO 2800

Alula – the ‘bastard’ wing
Owls

- Daytime when they are sleepy
- Nighttime when they are resting

Verreaux’s Eagle Owl (*Bubo lacteus*), Okavango Delta, Botswana

Pel’s Fishing Owl (*Scotopelia peli*), Okavango Delta, Botswana

Great Horned Owl (*Bubo virginianus*), St. George Island, FL

Spotted Owlet (*Athene brama*), Ranthambor Park, India

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10/18/2017

Frank Taylor MIT
Aerial insectivores: House Martins

These are some of the hardest birds to photograph since they fly fast and feed on the wing.

Nikon D300s, 300 x 1.7 mm f/4.8, 1/4000 s, ISO 500, Spot Meter (Thoiry, France)
Swifts (Apus apus) in Flight

Note the thin wing and large eye. Head always turned to be parallel to the ground. Wings frequently swept back.

Camera: Nikon D700
ISO: 400
Lens: 300 mm f/2.8
Shutter: 1/6400 s in burst mode
Thoiry, France
How to Measure Bird Flight Speeds

• While waiting for a train to Edinburgh I realized that by measuring the ratio of apparent size to true size I could determine the distance of the object

• Assume bird has ‘standard’ wingspan
• Calibrate camera-lens combinations
  • Relative size vs. distance to determine distance
  • Time stamp of photo to 1/100 second
  • Several cross checks – including car & Airbus 319
• Errors from wing size variation & configuration and \( \cos \theta \)

Train \( V \approx 37 \text{ m/s} \approx 133 \text{ km/hr} \)

– Assume bird has ‘standard’ wingspan
– Calibrate camera-lens combinations
  • Relative size vs. distance to determine distance
  • Time stamp of photo to 1/100 second
  • Several cross checks – including car & Airbus 319
– Errors from wing size variation & configuration and \( \cos \theta \)
Flight speed of Swift (Apus apus)

Wing span: \( b = 38 \) to \( 40 \) cm

\[ y = -16.69x + 210.5 \]
\[ R^2 = 0.9991 \]

\( V \sim 17 \) m/s

From: *Avian Flight*, John J. Videler
Oxford University Press

Conventional lift downwash on arm-wing

Conical Leading Edge Vortex (LEV) on hand-wing contributes to lift
Bird Adaptations

• Under ‘evolutionary pressure’ bird physiology shows many remarkable adaptations
  – An efficient 2-phase respiratory system
  – Very high endurance – efficient consumption of stored fat
  – Optimized wing designs for different ecological niches

• Wings
  – Oceanic birds – high aspect ratio AR=b²/A=b/L, A = bL
    • Efficient generation of lift with lower lift-induced drag from wing tip vortices
  – Raptor & Soaring – broader chord length & lower aspect ratio
    • Less efficient generation of lift but good for taking off, low airspeed, heavy lifting and maneuverability
  – Flexible wing
    • Lift & Propulsion through Flapping and Burning of Sugar & Fat
Fig. 2.2. Relative dimensions of the skeleton of the forelimb of five species: (a) Calliope hummingbird; (b) Rock dove; (c) Blue grouse; (d) European starling; (e) Laysan albatross. The skeletons of the hand are drawn at the same length (from Dial (1992)).
Large Aspect Ratio Wings

Black Skimmer (*Rynchops niger*) Biloxi, MS  AR ≈ 10

Common Terns (*Sterna hirundo*) in nuptial flight, Teppes de Verbois, Switzerland, AR ≈ 8
Predator & Soaring Bird Wings

Northern Harrier (Circus cyaneus) Duck under tow - Delaware

Buzzard (Buteo buteo) France

Long-Eared Owl (Asio otus), Switzerland

Lower AR – Heavy Lifting with Maneuverability

Turkey Vulture (Cathartes aura) Delaware

Brown Pelican (Pelecanus occidentalis), Texas
Darwin’s Finches

Shape of Beak a profound window into natural selection
Wing pushes air downward – wing reacts upward comprising the lift

\[ L = Cl \times \frac{\rho \times V^2}{2} \times A \]

Lift = coefficient \( Cl \) \times density \( \rho \) \times velocity squared \( V^2 \) \times wing area \( A \)

Coefficient \( Cl \) contains all the complex dependencies and is usually determined experimentally.

Lindberg’s Spirit of St. Louis used the Clark Y airfoil

Very roughly \( Cl \approx 2\pi \alpha \)
Bird Aerodynamics

- Low Reynolds numbers regime
  - Viscous forces play an important part
  - Modest camber yields better L/D
- Soaring & High AR wings
  - Roughly similar to fixed airfoils
- Some smaller birds and insects utilize Leading Edge Vortex (LEV) to provide lift
  - The Swift uses this trick
- Flexible wings and flapping
  - Wing provides both Thrust and Lift, Tail provides lift at low speeds and steering for soaring birds
  - Variable deployment of arm-wing vs. hand-wing
  - There are different patterns of flapping: Wingtips of Albatross in an oval, Wingtips of a pigeon in a figure-8
- It’s a good thing that aerodynamics engineers abandoned the bird model because bird flight is quite complicated
Forces on a Bird: Lift, Weight, Drag, Thrust

Induced power (associated with lift) with wingspan $b$ and speed $V$ and air density $\rho$. It is the penalty to pay for the privilege of flight. $W = \text{weight} = L = \text{lift}$ for steady flight.

Formula:

$$P_i \approx \frac{1}{2} \frac{W^2}{\pi \left(\frac{1}{2}b\right)^2 V \rho}$$

Weight:

$$P_d = \frac{1}{2} \rho V^3 A C_d$$

Magpie Thoiry, France

**Form Drag** (the nesting stick -> effective area $A$), $C_d$ is the coefficient of drag, $\rho$ is air density.
Power Consumption – Flying Efficiently

Geese in formation-flying may use wingtip vortices to reduce effort


Canada Goose leading Greater White-fronted Geese, Lodi, CA
Nikon D80
AF-S VR Zoom Nikkor 70-300 mm @ 300 mm f/5.6, ISO 200, 1/1000 s
Mute Swans – *Cygnus olor* (Teppes de Verbois, Switzerland) require a lot of paddling and flapping to become airborne. **Weight ~ 12 kg**

Lift over water boosted by the **ground effect**: \( \Delta L = G = 2L/AR \). It is speculated that Howard Hughes’ *Spruce goose* was able to just fly by the ground effect.
 Stored energy: $E \approx 25 \text{ kJ/g}$. Extreme example - Bar-tailed Godwit record flight 8 days non-stop without eating consumed 40% of body weight for fuel.
Landings

Large angle-of-attack, configure arm-wing vs. hand-wing without stalling, bastard wing deployed, tail flared. Tufted Ducks (*Ayrthya fuligula*) on Rhone River.
Almost Everything that Flies

Adopted from Tennekes in Wei Shyy et. al, Aerodynamics of Low Reynolds Number Flyers

My measurements

<table>
<thead>
<tr>
<th>Bird</th>
<th>Speed (m/s)</th>
<th>km/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swift</td>
<td>16.7</td>
<td>60.1</td>
</tr>
<tr>
<td>Cormorant</td>
<td>17.7</td>
<td>63.7</td>
</tr>
<tr>
<td>Canada Goose</td>
<td>8.1</td>
<td>29.2</td>
</tr>
<tr>
<td>Mallard</td>
<td>17.1</td>
<td>61.6</td>
</tr>
<tr>
<td>Airbus 319</td>
<td>57</td>
<td>205.2</td>
</tr>
</tbody>
</table>

Most measurements of bird flight speeds are made with radar.

Insects: utilize (LE)Vortices
Swift (Apus apus) – The ‘ultimate’ land bird

• Extreme adaptation for flying
  – Once fledged it stays airborne for ≤ 10 months
    • Scientific name “Apus apus” means ‘without legs’
      – Can only perch on the side of a tree or building
      – Has extreme difficulty taking off from the ground
    – Performs all of life’s functions on the wing except for nesting & raising chicks
      • Sleeps in the air – often 1,000 to 2,200 m @ 8 m/s
  – Can fly as high as 3,500 m & lives within a colony
  – Flies over 500 km/day in search of insect food @ 17 m/s
  – Migrates from Europe to southern Africa
  – Lives up to 21 years
Apus apus

- Migration between Europe and sub-Saharan Africa

A. Hedenstrom, et al., Current Biology 26, 3066–3070, November 21, 2016

Migration by Soaring and Coasting

• European Stork (*Ciconia ciconia*)

Near the Dead Sea
03/09/2016

Storks have been badly affected by industrialization.

NaturOparC
ex Centre de Réintroduction
Route du Vin
68 150 HUNAWIHR - Alsace
07/09/2009

Using thermals to migrate requires a land-based route – either the Levant or Gibraltar

These are thermals – not gluons
Flying Upside Down

- Istanbul Tumbler Pigeons (*Columba livia domestica*)
Flying High

• Bar-headed Goose (*Anser indicus*)
  – Migrates over the Himalaya
  – Has to contend with lower air density and extreme cold

![Chambal River, India](image)

\[
dT/dh = (-6.5 \pm 0.1) \times 10^{-3} \, ^\circ C/m
\]

\[
L = C_L \left( \frac{1}{2} \rho V_e^2 S \right)
\]
Migration of Bar-headed Goose

Migrates over the Himalayas
Flies mostly at night when winds are calm
Has hemoglobin that can especially absorb oxygen
Powerful lungs

Why this route? Perhaps evolution – a distant ancestor started this migration when the Himalayas were less tall. From USGS: \( \frac{dH(t)}{dt} \geq 1 \text{ cm/y} \rightarrow \Delta H = 5 \text{ km in 500,000 years} \)


Northward 8 hr @ 1.1 km/h altitude gain
Southward 4.5 hr from the Tibetan Plateau
Murmurations of Starling Flocks

Starlings (*Sturnus vulgaris*) collect in large flocks - sometimes in response to predation.

~ 400 birds
Dia. ~ 11 m

Nikon D300s, 300 x 2 mm, f/5.6, 1/6400s, ISO 200, (Parker River NWR)
Murmurations - Analysis

• Movement remarkably coherent
  – Birds in flock seem to move as a ‘living blob’
  – By photographing flock in stereo can analyze the motion vectors and study correlations through the flock

• Analysis has been done – a beautiful paper on starlings in Rome
  – Developed a correlation function (average inner product of velocity fluctuations of birds separated by distance r)

Correlation lengths of orientation and speed seem to scale as size of flock.

Hence there is no intrinsic correlation length – not 10 m or 10 birds!
• What started as means to identify birds by taking their picture turned into an interesting look at bird behavior
  – I have >20ks of photographs of birds
    • On an ‘expedition’ I take 500 to 600 pictures per day
  – Many interesting aspects are captured in the pictures
    • Aerodynamic principles are evident (AoA, AR, Energetics)
    • Unexpected behaviors
    • Murmurations of starlings show remarkable coherence

• There are birds in every part of the world
  – They show a wide range of adaptations to environment as well as a stubborn will not to adapt, but rather some migrate extreme distances in order to maintain their diet, home territory and ecological niche.
  – There is much more to photograph and study – including some of the places already visited (Fermilab!)

• Birds & Aviation @ FNAL
  – Peter Kasper compiles a list of Birds of FNAL
    • http://www.fnal.gov/ecology/wildlife/list.shtml
  – David F. Anderson & Scott Eberhardt wrote a book: Understanding Flight
Time to Land this Flight of Fancy

Mute Swan – *Cygnus olor*
(Teppes de Verbois, Switzerland) D700, 500 mm f/4.8, 1/640 s

Thank You
Backup Slides
Leonardo da Vinci

Leonardo da Vinci’s Codex on the Flight of Birds

Recorded different phases of bird flight with remarkable accuracy.

Ponder how difficult it was to study bird flight before photography!

Images of Codex pages courtesy Ministry of Cultural Heritage, Activities and Tourism, Regional Administration for the Cultural Heritage of the Piemonte; Biblioteca Reale, Turin, Italy. (Ministero dei beni e delle attività culturali e del turismo - Direzione regionale per i beni culturali e paesaggistici del Piemonte - Biblioteca Reale di Torino.) Unofficial English translation prepared by Culturando and Smithsonian Institution.
Big lenses cost much more than camera body. Once invested you become a member of the ‘tribe’ (Cannon vs. Nikon is like MAC vs. PC)
Larger AR Wings have higher L/D

\[ Di = \frac{1}{2} \rho V^2 A C_{di} \]

\[ Di = \frac{L^2}{\frac{1}{2} \rho V^2 A \pi AR e} \]

Pressure difference from top to bottom of the wing causes spillage around the wing tips.

Downwash from the tips induces local angle of attack with additional drag component on a finite wing.

Aspect Ratio = AR

\[ AR = \frac{s^2}{A} \]

\[ C_{di} = \frac{C_l^2}{\pi AR e} \]

For an ellipse, \( e = 1 \)
In general \( e < 1 \)
**Reynolds Number (Newtons/Newtons)**

Re is ratio of inertial resistance to viscous resistance in fluid motion. Determines the aerodynamic regime and is useful in scaling models: \( \text{Re} = \frac{vL}{(\mu/\rho)} \), where \( \mu = \text{viscosity of air (1.79x10^{-5} \text{Nsm}^{-2})} \) and \( \rho = \text{air density (1.23 kgm}^{-3}) \)

*Swift: Re \( \sim 5 \times 10^4 \) for \( v=15 \text{ m/s}, L = 5 \text{ cm} \)

*B747: Re \( \sim 2 \times 10^9 \) at cruise*

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**Strouhal Number (Speed/Speed)**

In flapping wing dynamics the Strouhal number controls vortex formation and shedding: \( \text{St} = \frac{2f h_a}{v} \), where \( f \) is the frequency of flapping, \( h_a \) is the flapping stroke and \( v \) is the forward speed. Typically \( St \approx 0.2 \text{ to } 0.4 \Rightarrow \text{relation } f \text{ vs. } h_a \)

\( h_a \) stroke will generate trailing edge vortices
Many “YouTubes” of the phenomenon
How my D300s is Programmed

Note: For measurements here varied the light by changing f-stop. In the field almost always shoot with lens wide open.

Minimum shutter speed 1/320 s

Minimum ISO 200 (sweet spot)

Note: For measurements here varied the light by changing f-stop. In the field almost always shoot with lens wide open.

Minimum shutter speed 1/320 s

Minimum ISO 200 (sweet spot)
Bird Geography

- Nearctic
  - Families 61
  - Species 732
- Oceanic
  - Families 35
  - Species 200
- Antarctic
  - Families 12
  - Species 85
- Neotropical
  - Families 95
  - Species 3,370
- Afrotropical
  - Families 6
  - Species 1,950
- Palearctic
  - Families 69
  - Species 937
- Indomalayan
  - Families 69
  - Species 1,700
- Australasian
  - Families 64
  - Species 1,590

Example - Indian Myna (*Acridotheres tristis*)

D300s, 300 x 1.7 mm f/4.8, shutter 1/800 s, ISO 200

Metadata GPS coordinate

- GPS Latitude: 37 49.510" S
- GPS Longitude: 144 58.500" E
- GPS Altitude: 46
Geolocators

• Company near Cambridge, UK
• Longitude determined by local noon vs. standard clock
• Latitude (less accurate) determined by duration of day vs. night.
• Operates best north of Tropic of Cancer or south of Tropic of Capricorn
• Data are logged on device to be later recovered.
Flamingos at the Camargue, France

Nikon D80 with 300 mm f/2.8 Lens
ISO 200, Shutter 1/3200, Aperture Priority, JPEG Fine
Indian Peafowl (*Pavo cristatus*)
Nikon D300s, 135 mm f/5.6, 1/400s, ISO 1000
Carrier Pigeon (*Columba livia*)

**Cher Ami** helped save 194 US troops on October 3, 1918 who were being decimated by friendly fire. The field phone wires were cut and all pigeons except **Cher Ami** were killed. Shot through the breast, blinded in one eye, covered in blood and with a leg hanging only by a tendon, **Cher Ami** carried her message back to HQ 25 miles in 65 minutes with desperate message to stop shelling.

For her bravery she was awarded the **Croix de Guerre** by General Pershing and was allowed lived out her life pleasantly. Stuffed for eternity, **Cher Ami** is now on display in the Smithsonian in Washington.
Aerodynamics 101

- There are many airfoil simulation programs online
  - Can vary the airfoil shape
    - Camber
    - Aspect ratio
  - Angle of attack

- Output
  - Lift and Drag and L/D
  - Reynolds Number
  - Various plots
  - Streamline configuration
Airfoil Shape – Joukowski Transformation

• Generate an airfoil shape by conformal mapping of circle
• Develop a theory of lift by transforming a circulation around a cylinder to the airfoil while constraining the stagnation points on leading and trailing edges

\[ \zeta = z + \frac{c_1^2}{z} \]

\[ z = re^{i\theta} \]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>c1</td>
<td>1.03</td>
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<tr>
<td>x0</td>
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<tr>
<td>y0</td>
<td>0.10</td>
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<tr>
<td>R</td>
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</table>
Calculation of Induced Drag

For a wing with an elliptical lift distribution, induced drag is often calculated as follows. These equations make the induced drag depend on the square of the lift, for a given aspect ratio and surface area (while varying the angle of attack), but as the accompanying graph shows, this is only an approximation and is not valid at high angles of attack (and probably not for very high values of aspect ratio either).

$$D_i = \frac{1}{2} \rho V_e^2 S C_{Di} = \frac{1}{2} \rho_0 V_e^2 S C_{Di}$$

where

$$C_{Di} = \frac{C_L^2}{\pi e AR}$$

and

$$C_L = \frac{L}{\frac{1}{2} \rho_0 V_e^2 S}$$

Thus

$$C_{Di} = \frac{L^2}{\frac{1}{4} \rho_0^2 V_e^4 S^2 \pi e AR}$$

Hence

$$D_i = \frac{L^2}{\frac{1}{2} \rho_0 V_e^2 S \pi e AR}$$

Where:

- $AR$ is the aspect ratio,
- $C_{Di}$ is the induced drag coefficient (see Lifting-line theory),
- $C_L$ is the lift coefficient,
- $D_i$ is the induced drag,
- $c$ is the wing span efficiency value by which the induced drag exceeds that of an elliptical lift distribution, typically 0.85 to 0.95,
- $L$ is the lift,
- $S$ is the gross wing area, the product of the wing span and the Mean Aerodynamic Chord,[1]
- $V_e$ is the true airspeed,
- $V_e$ is the equivalent airspeed,
- $\rho$ is the air density and
- $\rho_0$ is 1.225 kg/m$^3$, the air density at sea level, ISA conditions.
Calibration Relative Size vs. Distance

\[ y = 2.7676x^{-1.047} \]
\[ y = 3.6994x^{-1.032} \]
\[ y = 4.4815x^{-1.032} \]
\[ y = 5.2695x^{-1.032} \]
The Train Speed

\[ y = -37.003x + 92.674 \]
\[ R^2 = 0.9708 \]

\[ V \approx 37 \text{ m/s} \approx 133 \text{ km/hr} \]
Scaling apparent fuselage to solar diameter and knowing the specification of the plane the distance to the plane can be estimated.

\[ D = 41 \text{ km.} \]

With GPS tag and UTC time stamp and position of the sun one can compute the position of the airplane.

No sunspots on this cloudy day
Bibliography
List of Books

• Photography Books
  – Pro Digital Photographer’s Handbook, Michael Freeman, Lark Books
  – Bird Photography, PIP, David Tipling
  – Photographing Birds, Rulon E. Simmons with Bates Littlehales, National Geographic

• Books on Flight
  – Understanding Flight, David F. Anderson and Scott Eberhardt, McGraw Hill
  – Avian Flight, John J. Videler, Oxford Ornithology Series, Oxford University Press
  – Aerodynamics of Low Reynolds Number Flyers, Wei Shyy, Yongsheng Lian, Jian Tang, Dragos Vieriu and Hao Liu, Cambridge Aerospace Series, Cambridge University Press
  – Basic Wing and Airfoil Theory, Alan Pope, Dover Publications, Inc.

• Finches
  – The Beak of the Finch, Jonathan Weiner, Vintage Books (Peter and Rosemary Grant)
List of Papers

• Papers on Flight