Quantitative Measurements of Forward Flapping Flight Using Image Processing

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Motivation

In bird flight research, it is important to quantitatively and accurately estimate the flapping flight kinematics (e.g. flapping frequency, wingbeat phase, and forward speed) of the bird being studied. For example, for studying the vortex wake aerodynamic of a bird using Particle Image Velocimetry, an accurate representation of the wingbeat kinematics is important for estimating the flight forces.

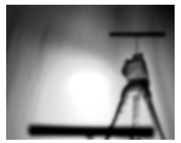
I used a high speed camera (filmed at 1000 fps) to estimate the flight kinematics of forward flapping flight of one parrotlet using image processing techniques.

Image Processing Algorithm for Obtaining Flight Kinematics

Recording of flight with high-speed camera at 1000 fps (12-bit images)

Image Processing

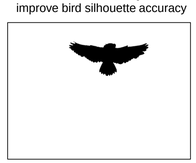
Obtain background and blur with Gaussian filter



Blur frames with Gaussian filter

Background subtraction

Threshold frames again to improve bird silhouette accuracy



Threshold frames

Canny edge detection to smooth bird outline

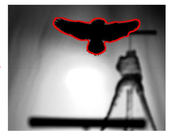
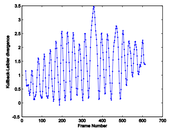


Image Matching

I compared one frame from a wingbeat phase (full wingspan) to every other frame to search for similar wingbeat phases

- Kullback-Leibler divergence – good results
- SIFT algorithm – poor results

Computed the distance between the centroid of the bird and every pixels of the bird outline. Then computed the difference of the probability distribution of one unique frame (template frame) and the probability distribution of every other frame.



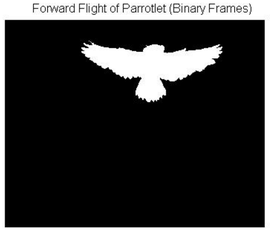
Flight parameters

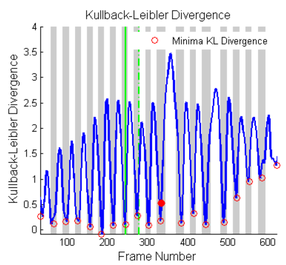
- Flapping frequency
- Forward velocity
- Forward acceleration
- Stroke phase

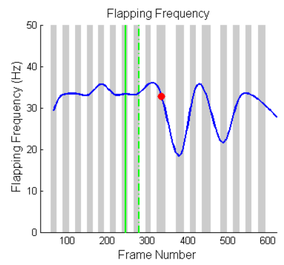
Experimental Results

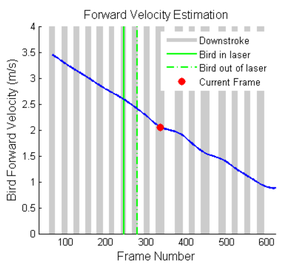
Forward Flight of Parrotlet

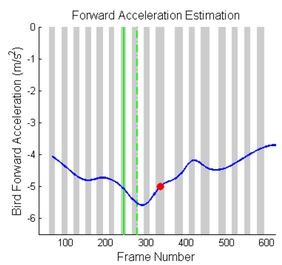
Forward Flight of Parrotlet (Binary Frames)











Three full flights with approximately 700 frames and 18 full wingbeats for each flight were tested with the algorithm.

The template frame was the bird with the largest wingspan of a given wingbeat. The algorithm was able to accurately match the template frame to every similar frame of the flight by using the Kullback-Leibler divergence method.

SIFT was not able to accurately match the template frame to frames with similar flight phases. Since SIFT describes keypoints by using gradients in the image, and the bird in each frame did not have much texture, SIFT was not able to detect keypoints on the bird.

Different template frames were tested:

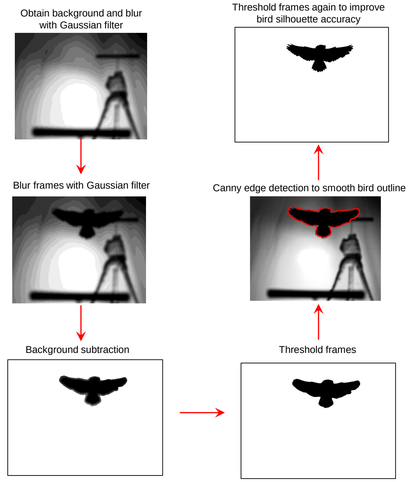
1. Beginning of downstroke (40% detection rate)
2. Largest wingspan (100% detection rate and was able to accurately distinguish between the upstroke and downstroke)
3. Beginning of upstroke (75% detection rate)

Future Work

1. Include camera distortion in the algorithm to improve the bird velocity and acceleration results.
2. Use template matching to compare with the current algorithm.
3. Position the camera more concentric to the flight direction of the bird and illuminate the background more to be able to more easily differentiate the background and the bird.

References

1. Henningsson, P., Spedding, G. R. & Hedenstrom, A. 2008. Vortex wake and flight kinematics of a swift in cruising flight in a wind tunnel. J. Exp. Bio. 211, 717 – 730.
2. Berg, A.M. & Biewener A. A. 2010. Wing and body kinematics of takeoff and landing flight in the pegion (Columba livia). J. Exp. Bio. 213, 1651 – 1658.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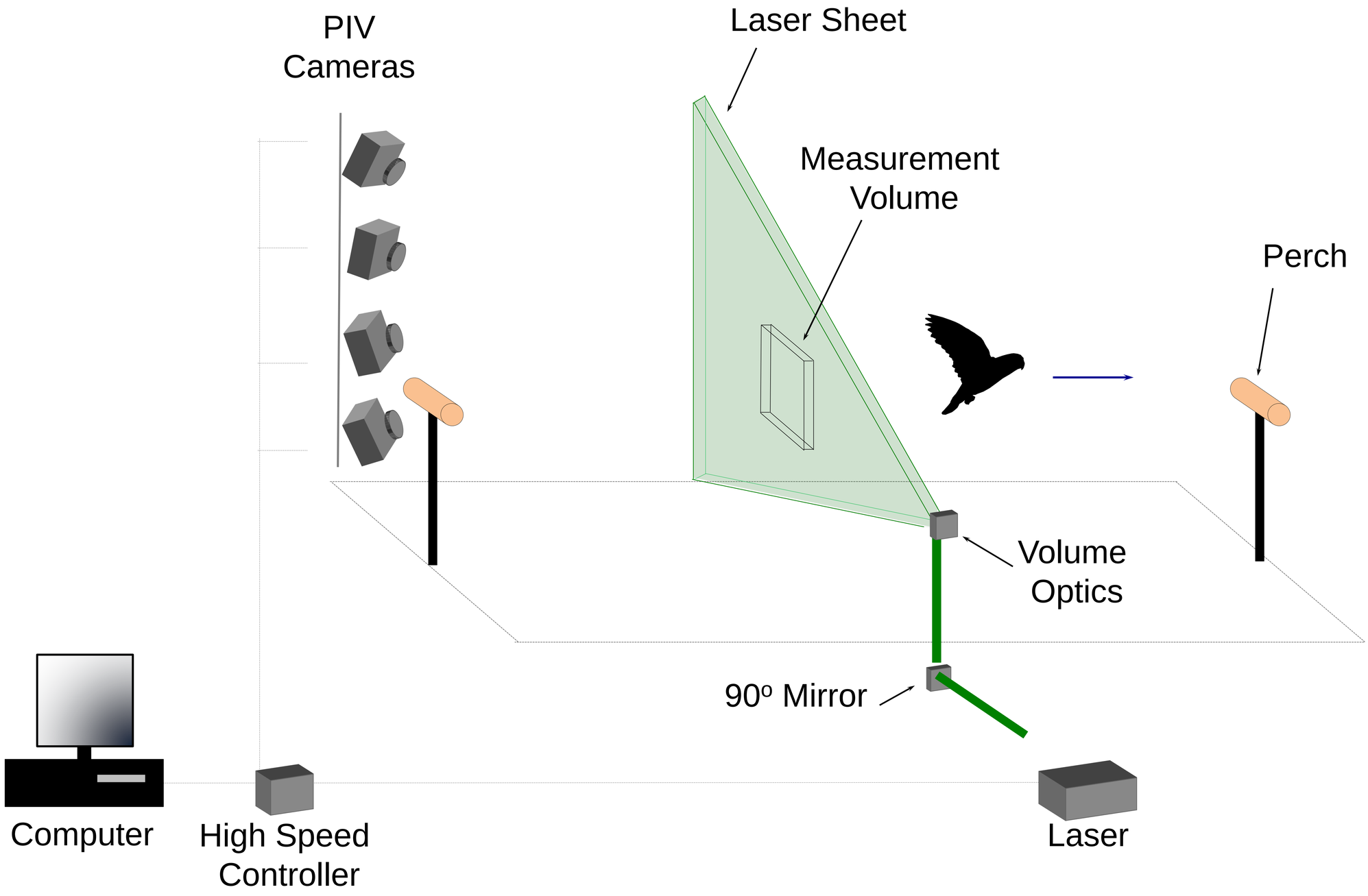
Particle Image Velocimetry (PIV)



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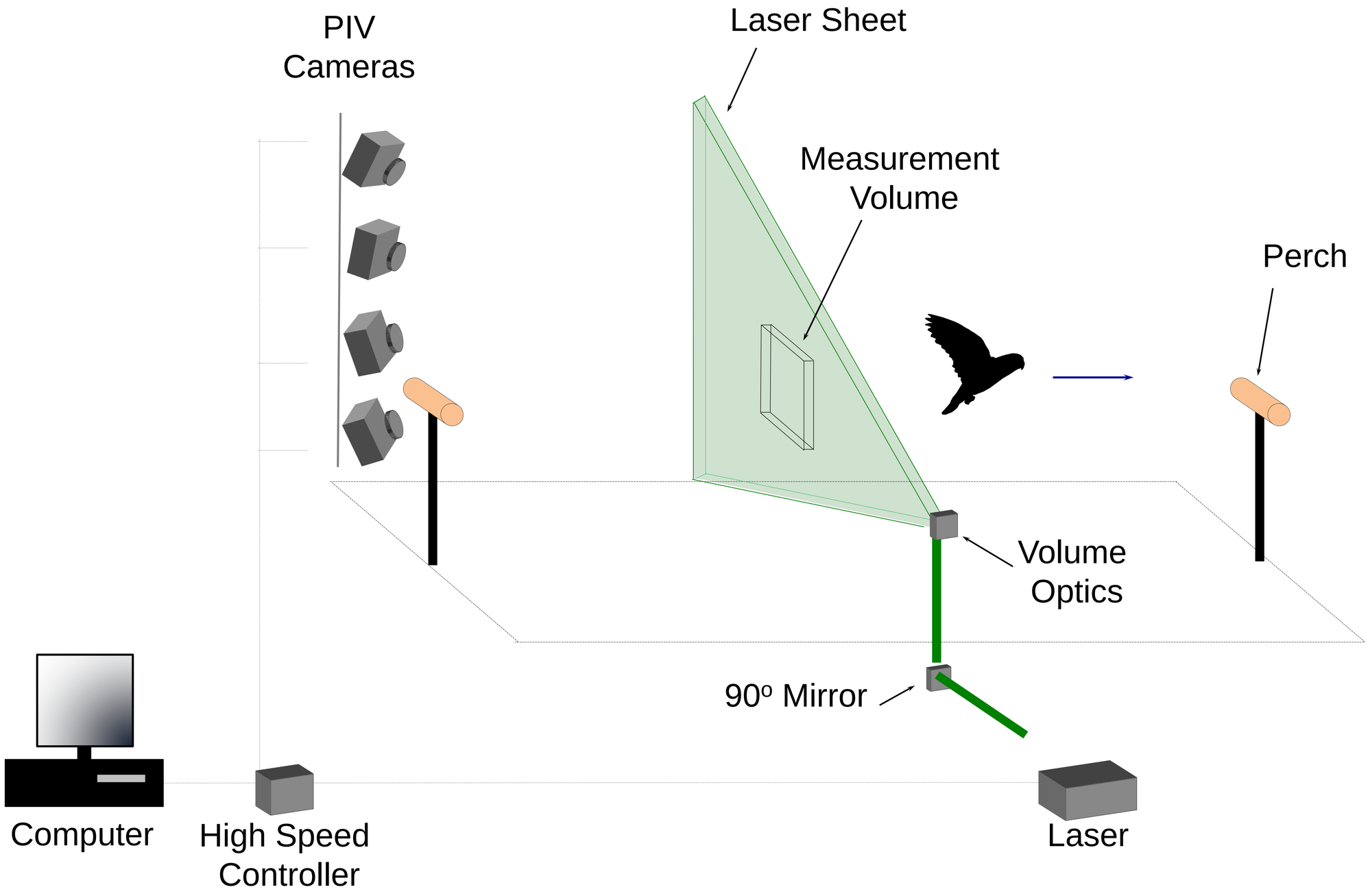

Flight of a Flapping Bird in Still Air

How does the wake of a flapping bird evolve with time?
What is the instantaneous lift of the bird from its wake?