# Energy Management of Migratory Birds through Flock Mutation

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## Abstract

This paper investigates the performance improvement of migratory birds through flock mutation. A constant number of migratory birds mutate from a big flock to small flocks and vice versa. Potential energy saving has been investigated through the entire flight time. In the present study, a drag analysis is carried out on the flocks and its sensitivity to different parameters is investigated.

## Introduction

Nature has always been the best source of inspiration for the most important scientific discoveries. The first aircraft to fly was design based on the aerodynamic characteristics of flying birds. Since then, engineers and scientists have investigated ways to make aircrafts more powerful with the least energy consumption being an important objective during the design process. Again, from a simple observation of migratory birds to the scientific investigation of their flying behavior, researchers were able to explain the hidden advantages of flight formation of migratory birds. Among these advantages are energy-saving, anti-predator mechanisms, and finding food. In 2002, Seiler et al.[1] demonstrated that large formation could lower the performance of the birds at the end position of a flock. This paper aims to investigate the optimum energy usage of migratory birds balancing from large flock to small flocks and vice versa.

## Drag Analysis during Flocking Mutation

An important way of determining the overall flight performance of birds (Canada geese) during their flocking time is the drag. Mirzaeinia et al.[2] have developed the following equation for estimating drag reduction during the swarming of migratory birds. Assuming a laminar flow, the total induced drag of flocking birds is equal to the sum of the self-induced drags of each bird and as many mutually drag as there are permutations of their wings in pairs. The total induced drag for *n* flocking migratory birds is expressed as:

$$D_I = n \times D_{I11} + \frac{4D_{I11}}{\pi^2} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \log\left[1 - \left(\frac{2a}{|i-j|(b+s)}\right)^2\right] \tag{1}$$

where $D_{I11}$, $b$, and $s$ are the induced drag of a bird, wingspan, and distance between adjacent bird perpendicular to the flight path, respectively. The total drag of each bird (bird-*k*) considering just one side of the V-shaped formation, is given by:

$$D_{Ik} = D_{I11} + \frac{2D_{I11}}{\pi^2} \log \prod_{j=1}^{n} \left[1 - \left(\frac{2a}{|k-j|(b+s)}\right)^2\right] \tag{2}$$

If *n* number of birds considered in a flock, the flock can be subdivided into two smaller flocks with $n_1$ and $n_2$ birds. The total drag for subdivided flock can be represented as:

$$D_I = D_{I11}\left[(n_1+n_2)+\frac{4}{\pi^2}\left\{\sum_{i=1}^{n_1-1}\sum_{j=i+1}^{n_1}\log\left[1-\left(\frac{2a}{|i-j|(b+s)}\right)^2\right]+\sum_{i=1}^{n_2-1}\sum_{j=i+1}^{n_2}\log\left[1-\left(\frac{2a}{|i-j|(b+s)}\right)^2\right]\right\}\right] \quad (3)$$

## Simulation and Results

Figure 1(b) shows that with increasing the size of the flock the ratio of induced drag reduction remains almost constant. Figure 1(c) indicates that the drag increase with an increase in the number of flocks.

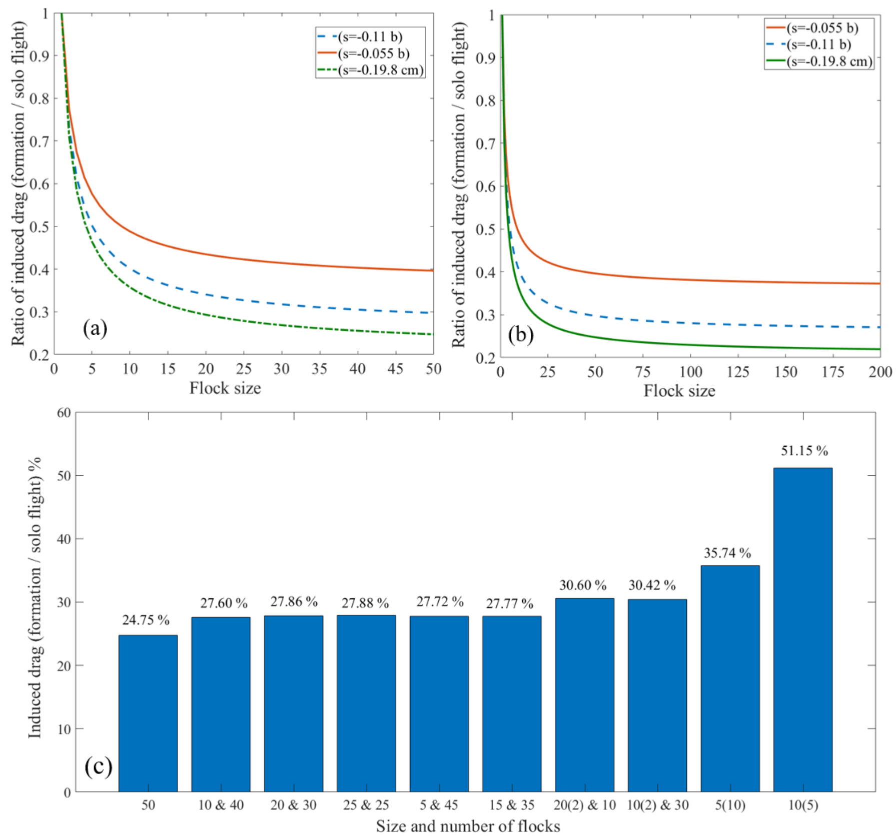


Figure 1: Views of the ratio of induced drag for (a) 50 and (b) 200 numbers of Canada geese.

## Summary and Conclusions

In summary, by investigating the flight formation and dislocation of flocks, we described the advantages associated with migratory birds. These advantages can also be implemented by drones while used for the mission like camouflage. The most important benefit of flock formation and disintegration is the least energy consumption of birds during their travel.

## References


1. Seiler, P., Pant, A. and Hedrick, K., "Analysis of bird formations", In Proceedings of the 41st IEEE Conference on Decision and Control, Vol. 1, pp. 118-123, December 2002.
2. Mirzaeinia, A., Hassanalian, M., Lee, K. and Mirzaeinia, M., "Energy conservation of V-shaped swarming fixed-wing drones through position reconfiguration", *Aerospace Science and Technology*, Vol. 94, p.105398, 2019.