

A morphogenetic exploration of bird silhouettes

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Introduction

Morphogenesis deals with the study of the development of body structures. The finer details of complex biological structures are not entirely defined in the genes, but often the result of physical forces and a chain of events during early development. While the underlying developmental rules may be encoded in the genes, these complex chains of developmental events are liable to vary and these variations may be magnified into morphologically visible differences. Such developmental differences explain the variations in fingerprints among genetically identical human twins. The earliest morphogenetic explanation of biological shapes was made by D'Arcy Wentworth Thompson in 1917. In recent times, the advances in molecular techniques and developmental biology have led to more testable hypotheses. Many of these hypotheses have been proposed using computer based models since these allow for easy experimentation. Such models have been extensively studied in the case of molluscs by Hans Meinhardt, butterflies by Nijhout and plants by Przemyslaw Prusinkiewicz and to some extent for mammalian coat patterns and bacterial colony patterns. In the case of birds, there are often wide ranges of variation in size and colouration within a species and while these can be seen to fit within a continuum of variation, it is harder to see such patterns across higher taxonomic groups. Feather colouration has recently been studied and explained using a model based on reaction diffusion (Prum and Williamson, 2001, 2002), however no models have been explored for whole bird structure.

In this article, I show how a simplistic model of bird structure can be used to study bird silhouettes. The model demonstrates variations in a small number of seemingly minor changes in factors and the resulting variety of flight silhouettes.

Method

In order to explore the effect of variables on silhouette shape, a simplistic model of the bird was chosen with a small set of parameters to describe the structure. Figure 1 illustrates the parameters used in the model.

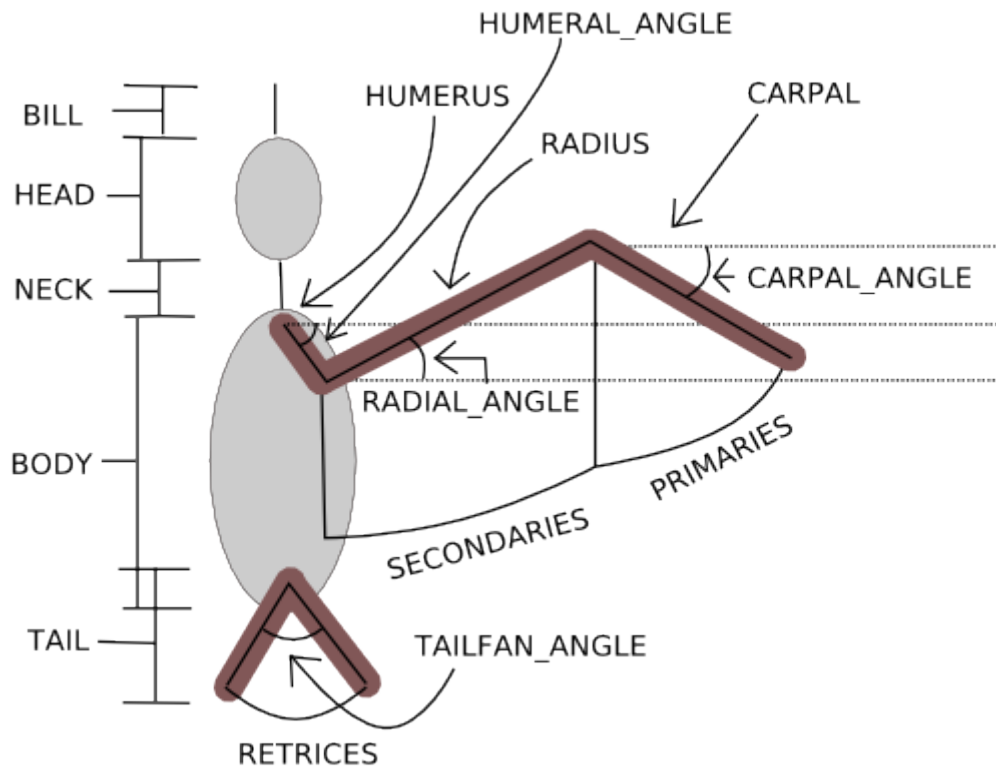


Figure 1: Parameters used to describe the structure of the model bird

Apart from the structural parameters indicated in Figure 1, a set of feather elongation factors were also used in the model. These include elongation factors for the primaries, secondaries and tail feathers. These factors decide how each the lengths of successive feathers changed in from inside outward. Varying these factors leads to significant changes and biological explanations for such factors could perhaps be in the form of blood vein branching, nutritional gradients or hormonal control. In humans the relative lengths of fingers has been shown to be modified by hormones during early development. (Mills, 2002) In addition to the actual lengths, the shape is also modified by posture and musculature. Musculature is associated with the evolutionary history of birds and adaptations to support their flight are numerous. (Gatesy and Dial, 1996)

The parameter values were then set-by-eye and a computer program generated the silhouette according to predefined rules. The values were modified to reflect recognizable silhouettes and were not based on actual morphometrics. The software (Microsoft Windows) used to generate the shapes using the parameters may be freely downloaded from the following website.

<http://www.geocities.com/muscicapa/abob.htm>

The effect of changing the tail feather elongation factor is shown in figure 2.

A range of silhouettes are shown in figure 3 and the parameter values used to generate them are provided in table 1.

Further work

These results are meant merely as pointers for further work which can be particularly fruitful for museum workers to carry out. Research based on museum specimens may help in improving the model and the parameters and can be used for the creation of virtual specimens that reflect accurate morphometrics and by incorporating models of

feather colouration, it may also be possible to create new kinds of digital field guides with flexible rendering of birds in three dimensions. Studies may also yield information on evolutionary patterns in development.

Acknowledgements

Special thanks are due to Richard Prum of Yale University for encouraging comments and pointers to relevant references.

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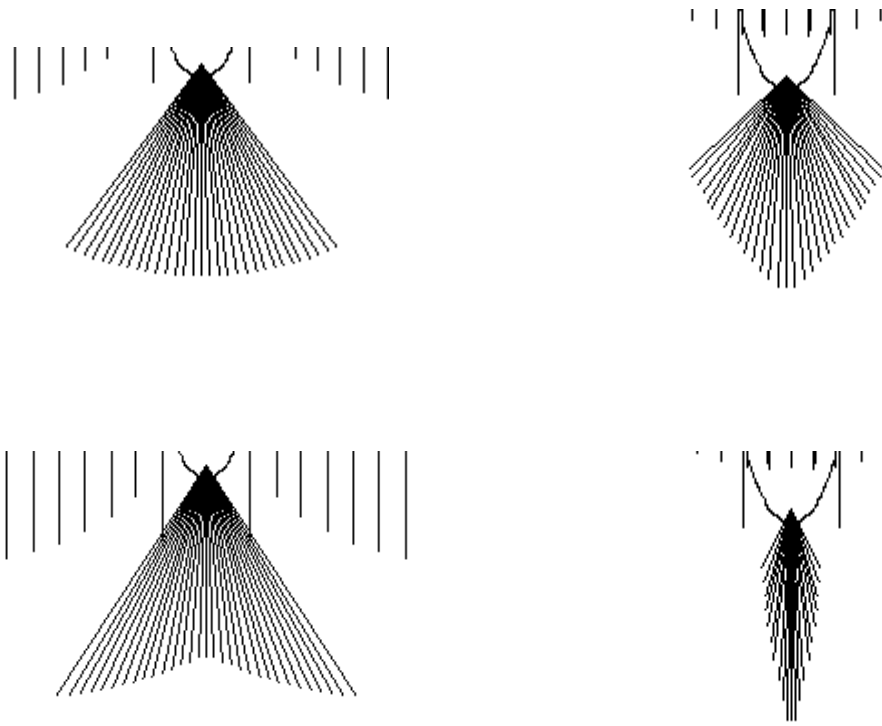


Figure 2: Elongation factor and tail shape variation
(Top-left) 1.0 – rounded tail (*Buteo*), (Top-right) 0.5 – wedge tal (*Gypaetus*)
(Lower-left) 0.5 – forked tail (*Milvus*), (Lower-right) 0.3-graduated tail (*Pica*)

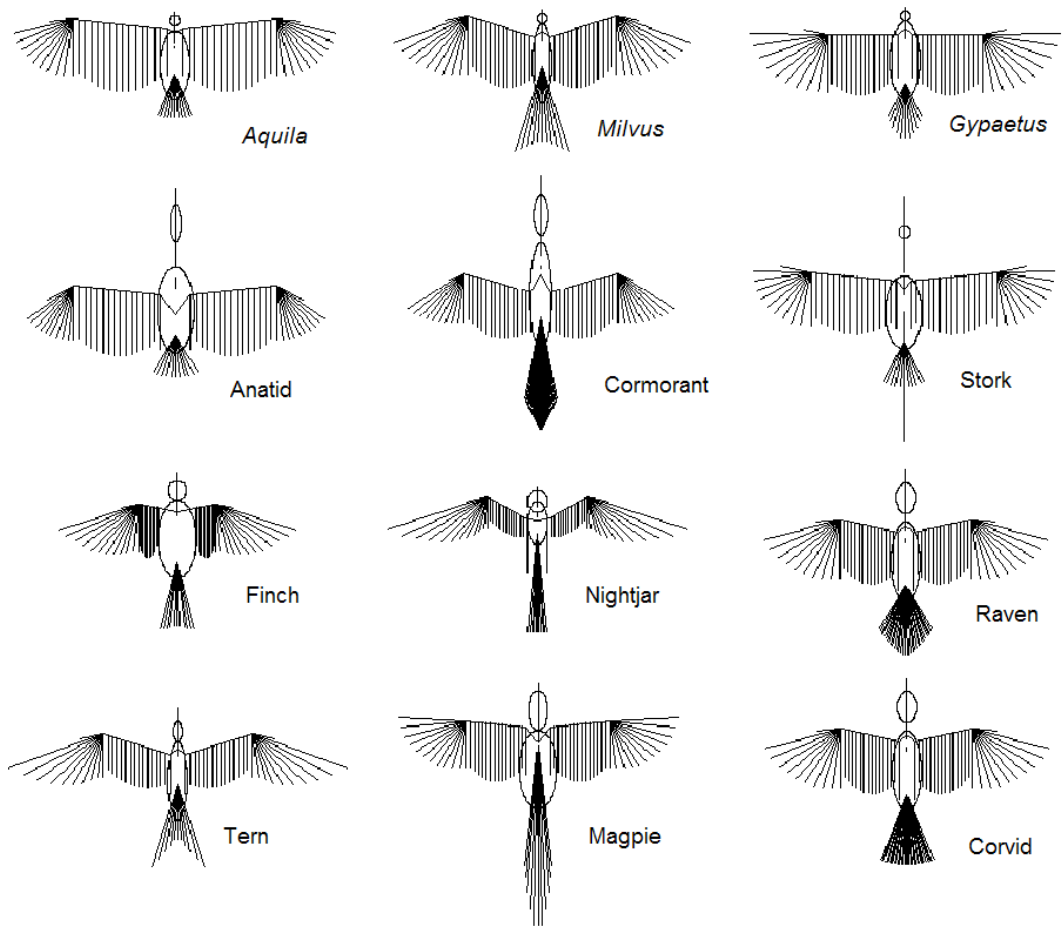


Figure 3: Silhouettes created by varying model parameters

Table 1: Parameter values used in the model to generate the silhouettes in Figure 3

	Length	Width	Head length	Head width	Neck length	Bill length	leg length	Tail length	Tailfan angle	Tail feathers	Elongation	Tailbase	Primaries	Secondaries	Wingbase	Primary Length	Elongation	Secondary Length	Elongation	Radius length	Radius angle	Carpal length	Carpal angle	Humerus length	Humeral angle
<i>Aquila eagle</i>	70	30	10	10	5	10	0	110	0.685	10	1	-0.3	10	15	0.9	120	1.05	100	1.4	190	0.1	50	-0.1	20	0.6
Cormorant	160	30	60	20	10	60	0	400	0.285	30	0.58	-0.4	10	15	0.4	150	1.33	120	1.4	190	0.3	50	-0.5	60	-1.1
Corvid	80	30	30	20	10	30	0	190	0.585	30	1	-0.6	10	15	0.9	120	1.43	120	1	120	0.2	50	-0.1	20	-0.6
Anatid	70	30	30	10	20	30	0	110	0.7	10	0.99	-0.6	10	15	-0.1	90	1.05	15	1.05	140	0.1	50	-0.5	40	0.9
<i>Milvus</i>	80	20	10	10	0	10	0	160	0.6	10	1.5	-0.1	10	15	0.8	120	1.43	90	1.4	140	0.3	50	-0.2	20	-0.6
<i>Gypaetus</i>	80	30	10	10	0	10	0	160	0.6	10	0.5	-0.6	10	15	0.8	120	1.43	90	1.4	140	0	50	0.2	20	-0.6
Magpie	40	20	20	10	0	10	0	160	0.3	10	0.3	0.6	12	15	0.7	50	1.5	50	1.2	60	0.1	0.2	0.2	20	0.9
Nightjar	20	10	10	10	-5	5	0	100	0.2	10	1	-0.5	12	15	0.1	30	4	50	0.5	40	0.5	20	-0.2	10	0.2
Raven	80	30	30	20	10	30	0	190	0.785	30	0.58	-0.6	10	15	0.9	120	1.43	120	1	120	0.2	50	-0.1	20	-0.6
Finch	40	20	10	10	0	10	0	90	0.4	10	1.1	-0.6	12	15	0.7	50	1.9	50	1.1	20	0.2	20	-0.2	20	0.2
Tern	80	20	20	10	0.1	30	0	120	0.6	10	2.9	-0.1	10	15	0.8	90	2.8	80	1.1	140	0.3	50	-0.2	20	-0.6
Stork	60	30	10	10	30	50	210	120	0.6	10	1	-0.8	10	15	0.6	90	1.05	80	1.2	140	0.1	50	0.2	20	0.9