Using Image Analysis and Mathematical Methods to Determine Species and Other Information From Biological Organisms: Research Plan

27 October 2023

Description

D'Arcy Thompson was the first person to suggest that mathematical patterns could be found in organisms and be used to describe them [1]. However, his work was limited largely to animals with clear geometric and fractal shapes such as shellfish, although he did suggest that his ideas could extend to other animals. Thanks to modern computer technology we are able to do just that, and this will be the focus of this project.

The project will focus on using the methods of PCA (principle component analysis) and elliptic Fourier transforms to extract information from images of various organisms.

The project will include a writeup explaining the methods behind both PCA and elliptic Fourier transforms, and further sections showing these being applied in practice.

The Fourier transform equation:

$$Fp(\omega) = \int_{-\infty}^{\infty} p(t)e^{-j\omega t}\,dt$$

Will be applied to processed images in order to extract key features.

The dataset will consist of images of some biological organisms. Which organisms and how exactly these images are to be analyzed remains to be decided along with the scope of the project.

Reason

I chose this topic because I'm particularly interested in the intersections of mathematics and biology, and how computers help us better understand the natural world and natural history. From a young age I've considered working in paleontology, a field which I understand needs more computational and mathematical input.

Related Modules

Some of the method used in PCA (principle component analysis) I have learned through the machine learning module. Image processing will also prove vital for preparing images for analysis via elliptic Fourier transforms. Fourier transforms, of course, I learned in the differential equations module.

Literature

The inspiration for this project comes from [1], but more modern books will inform a more modern project. Because this project will focus on computer applications of these methods, it will be informed in large part by *Feature Extraction and Image Processing for Computer Vision* [2]. Other books [3] [4] [5] will also inform the project, these books forming more of the mathematical basis for the Fourier methods used, with [5] also providing examples of computational applications.

Action Plan

W/C	Deadlines	Research
23 Oct 2023	Research plan	Finish simple C++ program
30 Oct 2023	Draft logbook submission	
6 Nov 2023		
13 Nov 2023		Begin outline of report
20 Nov 2023		Write up on Fourier transforms
27 Nov 2023		
4 Dec 2023		
11 Dec 2023		Write up on PCA
18 Dec 2023		
25 Dec 2023		Obtain dataset
1 Jan 2024		Perform analysis on dataset
8 Jan 2024		
15 Jan 2024		Finalise programming
22 Jan 2024		
29 Jan 2024	Final logbook submission	Finalise report
5 Feb 2024		
12 Feb 2024		Write up introduction and conclusion
19 Feb 2024	Draft Report	
26 Feb 2024		Work on presentation
4 Mar 2024		
11 Mar 2024		
18 Mar 2024		
25 Mar 2024		Alter report and presentation based on draft feedback
1 Apr 2024		
8 Apr 2024		
15 Apr 2024	Final Report	
22 Apr 2024		
29 Apr 2024		
6 May 2024		
13 May 2024	Viva	

References

[1] D. W. Thompson, On growth and form, Cambridge University Press, 1961.

[2] M. &. A. A. Nixon, Feature extraction and image processing for computer vision, Academic Press, 2019.

[3] P. E. Lestrel, Fourier descriptors and their applications in biology, Cambridge University Press, 1997.

[4] M. Cartwright, Fourier methods for mathematicians, scientists and engineers, Chichester: Ellis Horwood, 1990.

[5] I. L. &. M. K. V. Dryden, *Statistical shape analysis: with applications in R,* vol. 995, 2016.

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