Layered patterns in nature, medicine, and materials: quantifying anisotropic structures and cyclicity

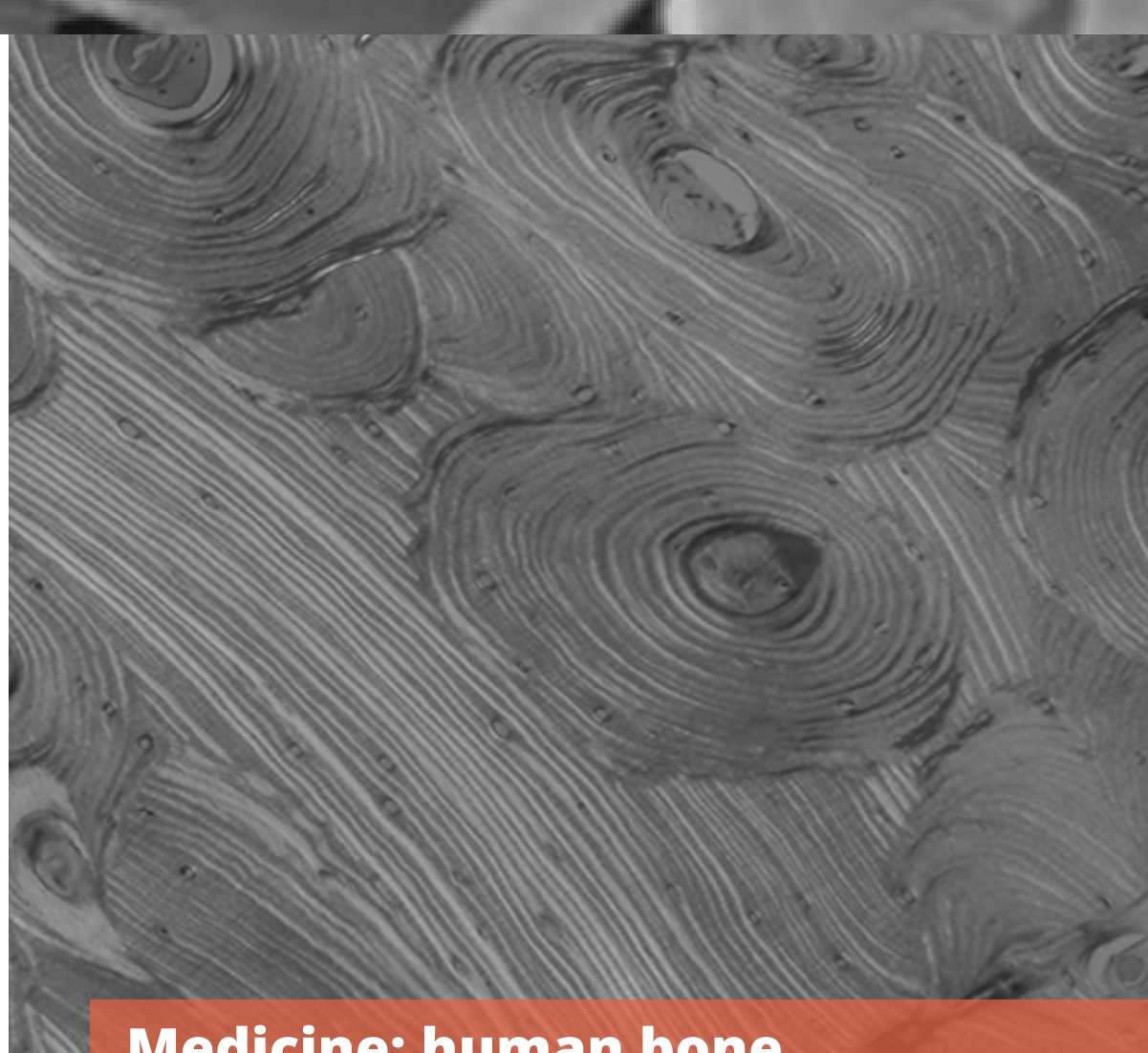
Material: abalone shell

BACKGROUND

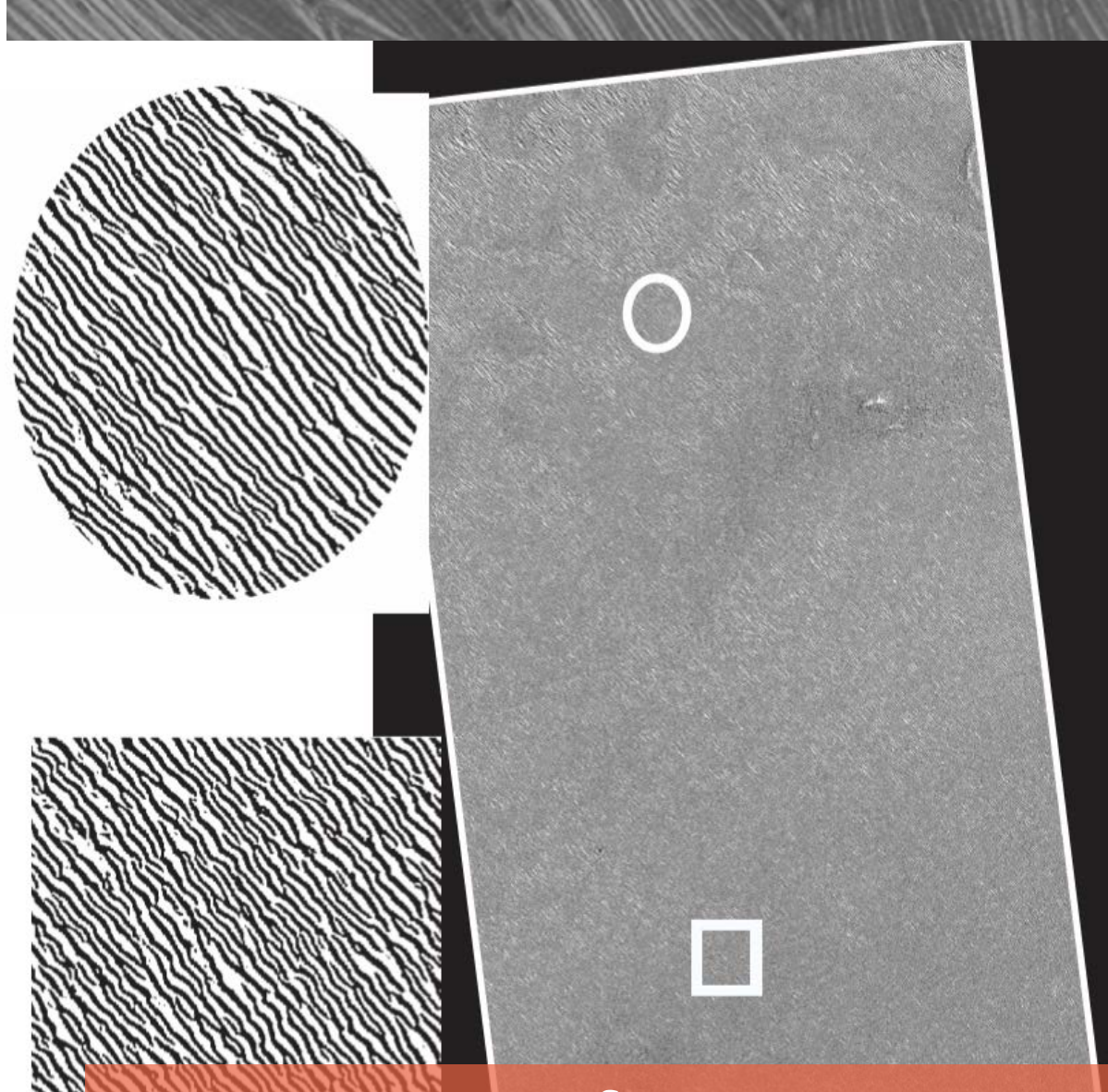
Layered patterns are broadly distributed in nature, medicine and materials.

These layered patterns form a record of internal and external factors regulating pattern formation in their various systems, making it potentially possible to recognize and identify in their incremental sequences trends, periodicities, and events in the formation history of these systems.

The structures and sizes of these patterns are characteristically *anisotropic*: That is, the number of layers and their thicknesses vary significantly in different directions.



Medicine: human bone



Nature: Mars surface

METHODS

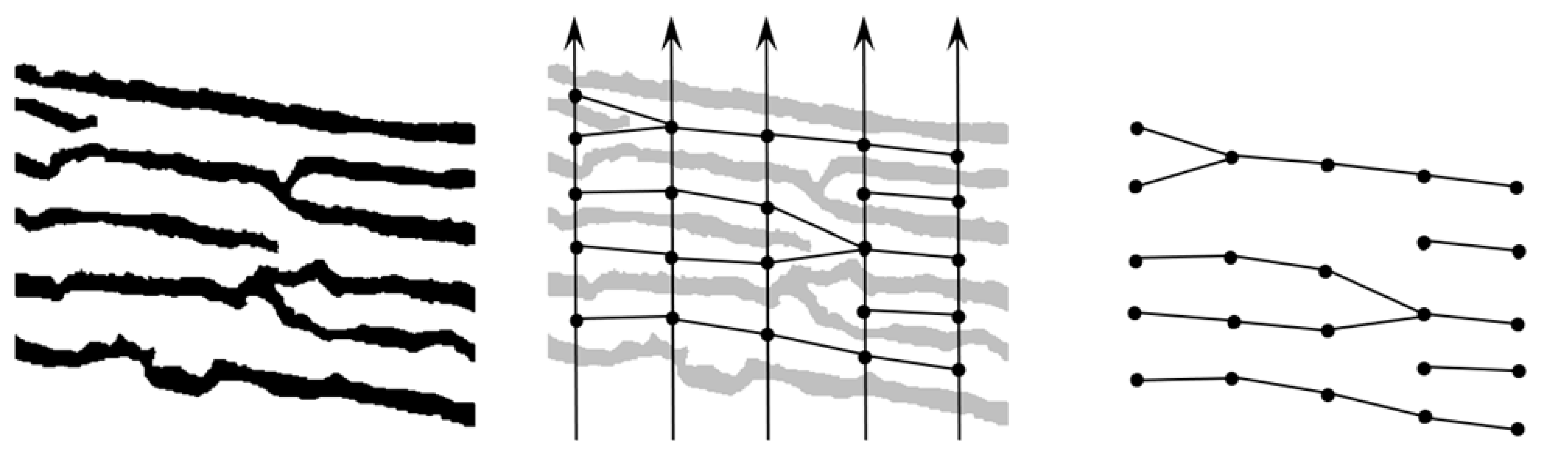
Problem statement

The study and commercial applications of various categories of layered systems requires formalizing aspects of their analysis.

Basic concepts

A Empirical model (EM) of anisotropic layered patterns (US patent 8755578). EM = {Structure of layers, Size of layers}.

Anisotropic layered structure as N-partite graph



B Disorder of layers structure (DStr)

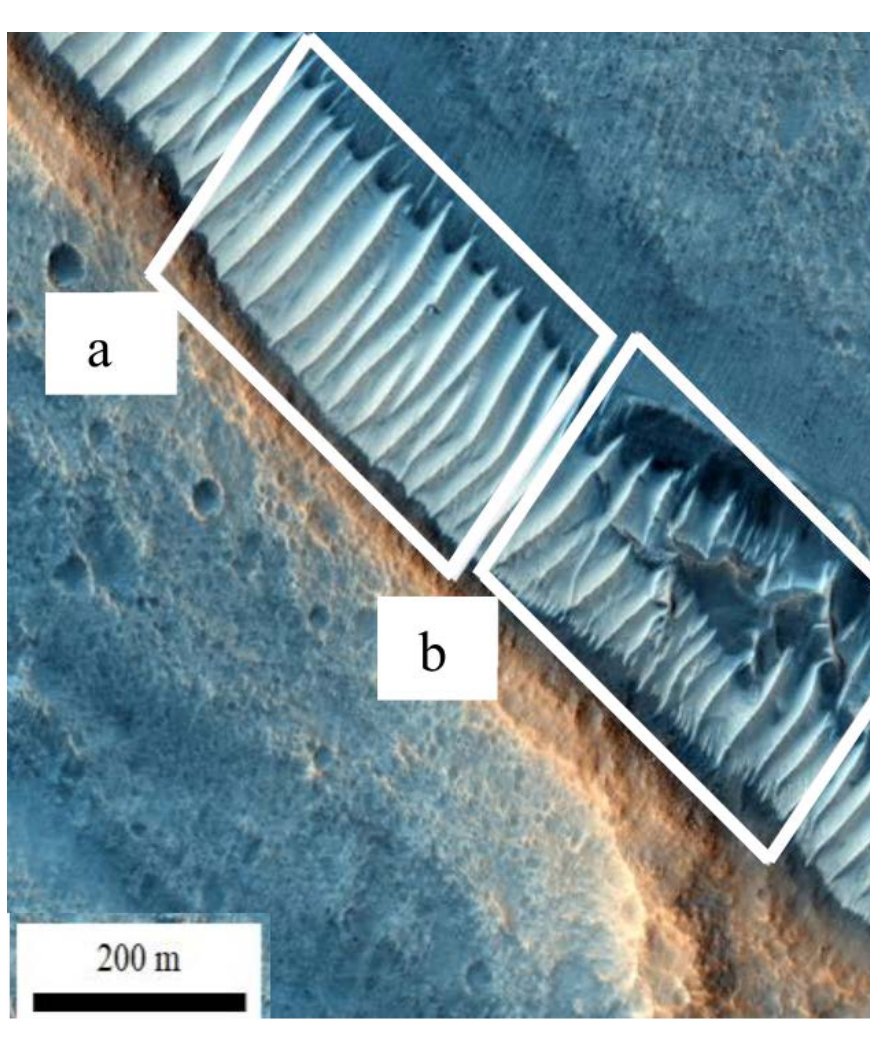
We present a parameter for structural disorder in a layered pattern (DStr) to describe the deviation of a study object's anisotropic structure from an isotropic analog.

EXPERIMENTS

Goal

Review layered patterns appearing in the realms of medicine, forensics, geology, plants, animals and materials science in order to justify describing similarities in the structural anisotropy of layers by using the Empirical model.

1 Two nearby Martian regions, a and b, with substantially different levels of structural disorder



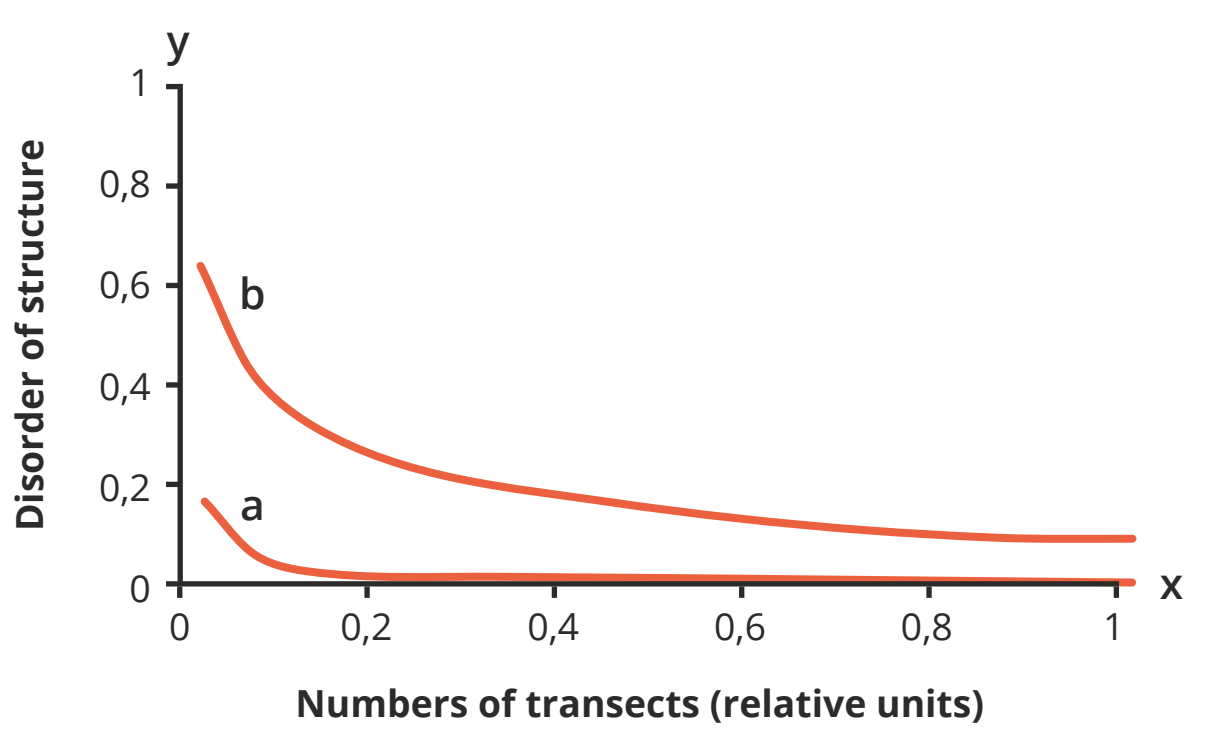


Image category	Disorder of image structure	Disorder (y) as a function of the number of transects (x)	
a	0.01851	$y = 0.0052x^{-0.957}$	R^2=0.9597
b	0.1839	$y = 0.1007x^{-0.556}$	R^2=0.976

2 Structural disorder in bird plumage patterns

Giant kingfisher

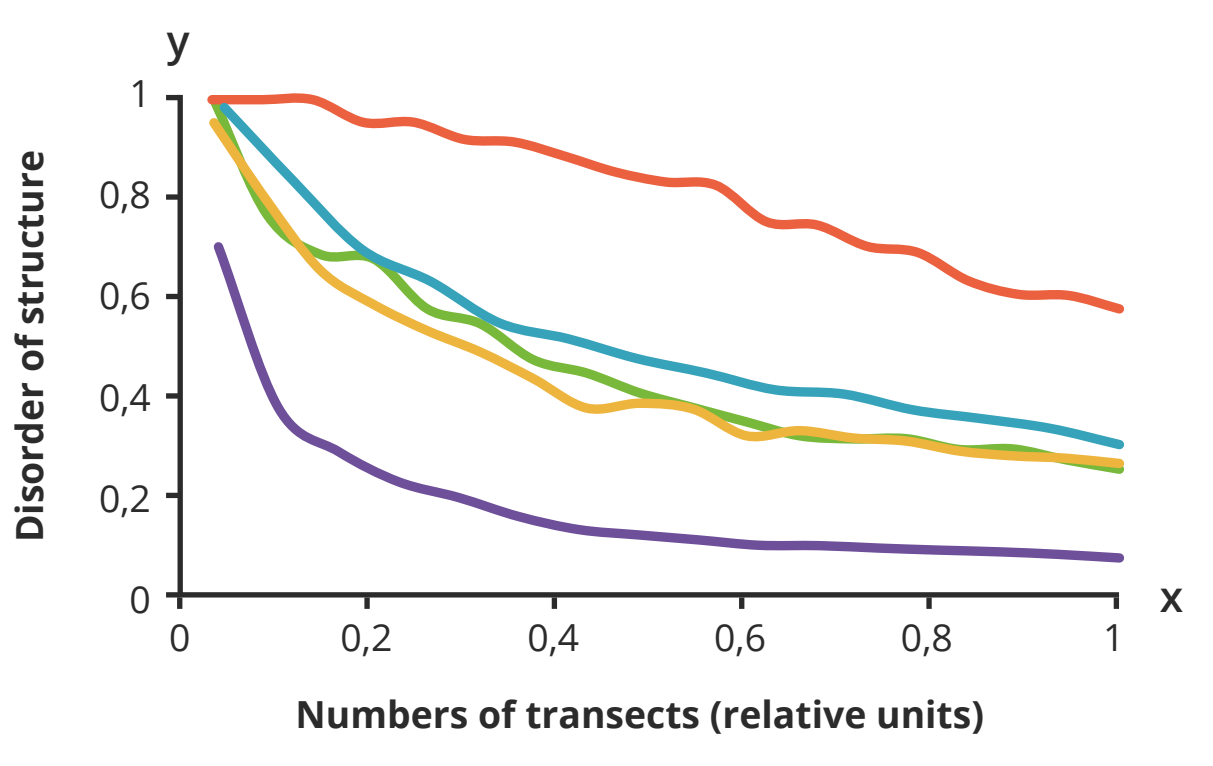
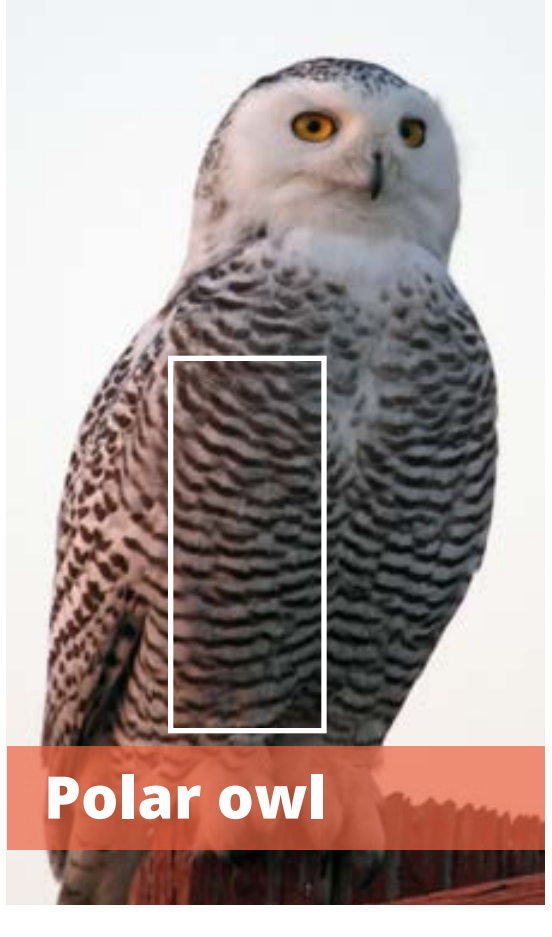


Image category	Disorder of image structure	Disorder (y) as a function of the number of transects (x)	
Giant kingfisher	0,787	y = -0.4757x + 1.0613	R^2 = 0.980
Banded pitta	0,491	y = 0.3474x-0.393	R^2 = 0.960
Harpactes 1	0,441	y = 0.2884x-0.438	R^2 = 0.945
Owl	0,419	y = 0.2805x-0.422	R^2 = 0.972
Harpactes 2	0,165	y = 0.0779x-0.709	R^2 = 0.995

Banded pitta



Polar owl

Harpactes 1

Harpactes 2

CONCLUSION

We justify the usefulness of the proposed metric by showing that the disorder of layers structure could be used to:

- reveal structural anomalies in layered patterns;
- formulate testable hypotheses by setting correspondence between properties of objects under study and the morphological characteristics of their layered patterns.

We illustrate that the disorder of layers structure is a universal characteristic applicable to any 2-D layered pattern, irrespective of nature and size, and could be used as a local and global defining characteristic of a layered pattern.

In the future, we intend to investigate the applicability of the empirical model for processing categories of patterns beyond the layered patterns discussed here.

Image credits:

- Nature. Mars surface: NASA/JPL/University of Arizona. ESP_021737_1710_RED.
- Medicine. Human bone: Norman Barker.
- Material. Abalone shell: Sylvain Deville.
- Martian region: NASA/JPL/Univ. of Arizona. PSP_008641_2105
- Birds: (A) Charles J. Sharp. Wikipedia contributor. “Giant kingfisher.” (B) Doug Janson. Wikipedia contributor. “Javan banded pitta.” (C) Phillip Anderson. (D) J.J. Harrison. Wikipedia contributor. “Harpactes.” (E) Lip Kee. Wikipedia contributor. “Harpactes.”

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