

A mathematical framework enables accurate characterization of shapes

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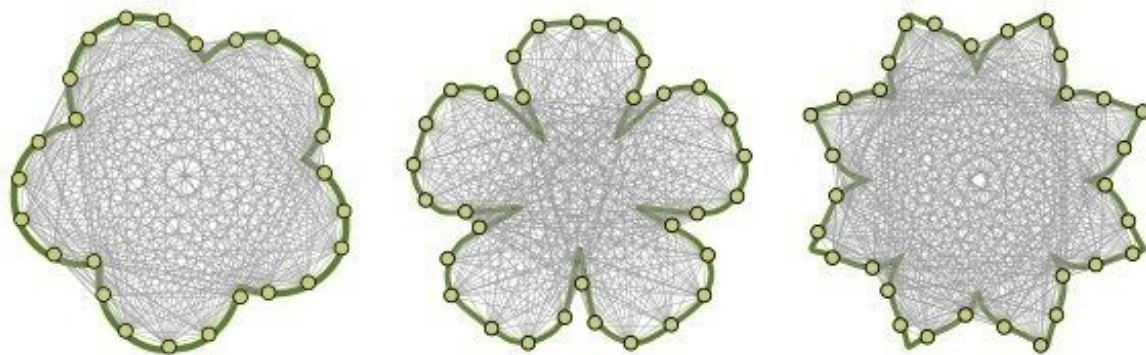


Illustration of visibility graphs for different flowers. On the contour (green), nodes are evenly spaced and connected by edges when they do not touch or intersect the contour. Credit: MPI-MP, Jacqueline Nowak

In nature, many things have evolved that differ in size, color and, above all, in shape. While the color or size of an object can be easily described, the description of a shape is more complicated. In a study now published in *Nature Communications*, Jacqueline Nowak of the Max Planck Institute of Molecular Plant Physiology and her colleagues have outlined a new and improved way to describe shapes based on a network representation that can also be used to reassemble and compare shapes.

Jacqueline Nowak designed a novel approach that relies on a network-

based [shape](#) representation, named visibility graph, along with a tool for analyzing shapes, termed GraVis. The visibility graph represents the shape of an object that is defined by its surrounding contour and the [mathematical structure](#) behind GraVis is specified by a set of nodes equidistantly placed around the contour. The nodes are then connected with each other by edges, that do not cross or align with the shape boundary. As a result, testing the connection between all pairs of nodes specifies the visibility graph for the analyzed shape.

In this study, Jacqueline Nowak used the visibility graphs and the GraVis tool to compare [different shapes](#). To test the power of the new approach, visibility graphs of simple triangular, rectangular and circular shapes, but also complex shapes of sand grains, fish shapes and leaf shapes were compared with each other.

By using different machine learning approaches, they demonstrated that the approach can be used to distinguish shapes according to their complexity. Furthermore, visibility graphs enable to distinguish the complexity of shapes as it was shown for epidermal pavement [cells](#) in plants, which have a similar shape to pieces of jigsaw puzzle. For these cells, distinct shape parameters like lobe length, neck width or cell area can be accurately quantified with GraVis. "The quantification of the lobe number of epidermal cells with GraVis outperforms existing tools, showing that it is a powerful tool to address particular questions relevant to shape analysis," says Zoran Nikoloski, GraVis project leader, head of the research group "Systems biology and Mathematical Modelling" at the Max Planck Institute of Molecular Plant Physiology and Professor of Bioinformatics at University of Potsdam.

In future, the scientists want to apply visibility graphs of epidermal cells and entire leaves to gain biological insights of key cellular processes that impact shape. In addition, shape features of different plant cells quantified by GraVis can facilitate genetic screens to determine the

genetic basis of morphogenesis. Finally, the application of GraVis will help to gain deeper understanding of the interrelation between cells and organ shapes in nature.

More information: Jacqueline Nowak et al, A network-based framework for shape analysis enables accurate characterization of leaf epidermal cells, *Nature Communications* (2021). [DOI: 10.1038/s41467-020-20730-y](https://doi.org/10.1038/s41467-020-20730-y)

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