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A closed self-organizing map of Chury

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Abstract

Standard global map projections cannot display the complete surface of a highly irregular body like Rosetta's target comet 67P/Churyumov-Gerasimenko. A self-organizing Kohonen map can be used to sample the surface of any three-dimensional shape, however, the unrolled map misses some area beyond its edges. Here, we combine two square grids into an inherently closed structure that really maps the complete surface of the comet. While this closed self-organizing map is neither exactly shape nor area preserving, it is generally well behaved. The projection has been implemented in the widely used shapeViewer software.

1. Introduction

The highly irregular shape of Rosetta's target comet 67P/Churyumov-Gerasimenko (or "Chury" for short) poses some challenges for mapping, in particular for displaying the complete comet in one map. Global map projections for the Earth (and other — more or less — spherical solar system bodies) rely on the requirement that a surface point can uniquely be identified by longitude and latitude. However, because of the large overhanging areas, there are ranges of longitude and latitude for which there are three different surface points. Therefore, a significant area of Chury — about 5 % — is not visible in a map resultant from the naive application of any standard global projection. We present an approach from the area of machine learning and self-organizing neural networks. It is based on the well known Kohonen map, but extends it by introducing a closed, limitless structure.

2. The Kohonen self adative map

A so called Kohonen map [2] is a self-organizing artificial neural network that allows it to fit a rectangular grid to any kind of data, including a closed three-dimensional surface. While this approach is straight forward, there is a shortcoming: the grid wraps itself around the shape, trying to cover it as evenly as possible with all its grid points, but there is always an uncovered gap where the edges of the grid approach each other. This gap gets narrower with increasing grid resolution, but it never closes completely.

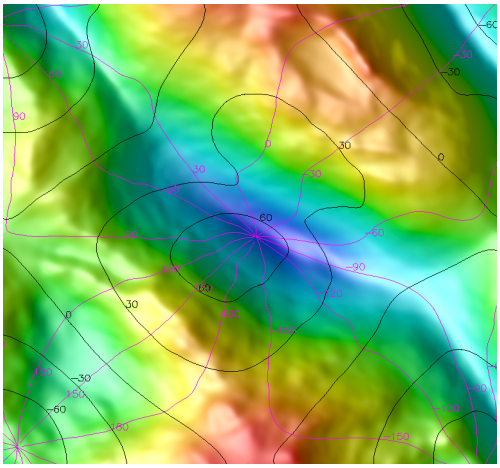

Figure 1: The closed self-organizining map of comet 67P/Churyumov-Gerasimenko in quincuncial layout. The color encodes (just to provide some example data) the distance of the surface point from the center of the comet. Latitudes are depicted black, longitudes magenta.

3. Closing the grid

Here, we create an inherently closed structure by taking two square grids and "sewing" them together at all four edges. This closed Kohonen map is then fitted to the SHAP5 shape model [1] of Chury in a similar way as the simple open map, yielding a complete map of the whole surface, see Fig. 1. Because of its construction from two squares, it exhibits the same tessellation

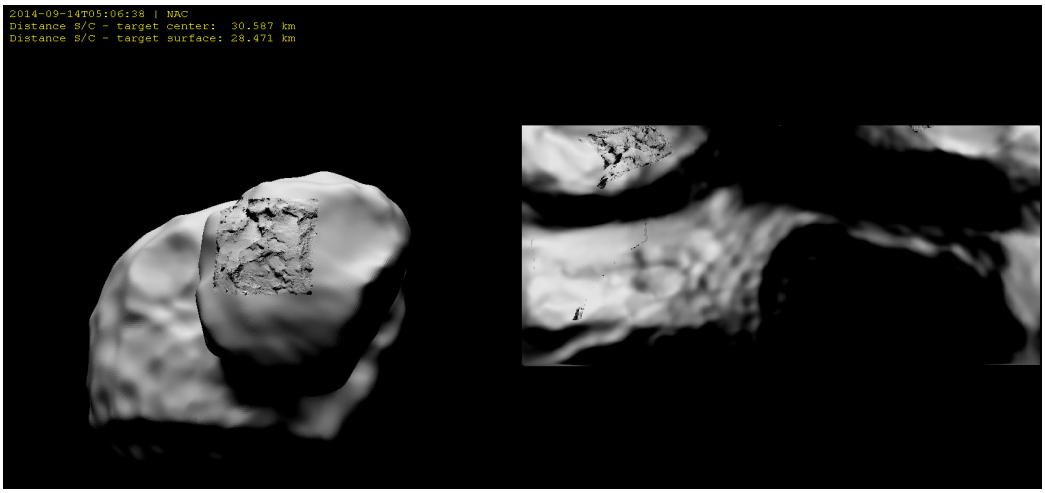

Figure 2: An example image projected onto the comet shape with shapeViewer.. *Left:* rendered 3D view. *Right:* projected onto our closed self-organizing map, here — differently from Fig. 1 — in hemispheres side by side layout.

properties as the Peirce quincuncial map projection of the Earth, which maps (in a first step) each hemisphere conformally to a square. This tessellation allows various different map layouts, e. g., in order to center a particular region of interest or for personal taste. Two of the possibilities — quincuncial and hemispheres side by side — are shown in Figs. 1 and 2, respectively.

4. The resultant map

The projection implied by the closed self-organizing map cannot be described analytically. It is neither exactly conformal (shape preserving) nor exactly area preserving, but behaves quite well over most of the surface. The projection is described by a very special shape model, which is not made of triangles — as all other shape models of Chury — but of quadrangles. It has the additional property that the vertices of the quadrangles are ordered along the lines of a two-dimensional grid, so that there is a unique relation between any point on the surface of the three-dimensional shape model and a position on the map defined by the grid.

The application of the projection given by our closed self-organizing map is more complicated than applying any of the standard global projections given by an analytic expression, however, the map projection has been implemented in the widely used shapeViewer software.[1] Fig. 2 shows the example of an actual image projected onto the comet shape and our closed self-organizing map.

5. Summary and Conclusions

We have extended the algorithm of the self-organizing Kohonen map by creating an inherently closed structure out of two rectangular grids. The resultant projection allows to display the complete surface of the highly irregular shaped comet 67P/Churyumov-Gerasimenko in one single map. The projection has been implemented in the shapeViewer software for convenient application.

References

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[2] Kohonen, T.: Self-Organized Formation of Topologically Correct Feature Maps, Biological Cybernetics, Vol. 43, pp. 59–69, 1982.

[1] `www.comet-toolbox.com/shapeViewer.html`