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Principal Components and Relief Shading

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Abstract:

Principal component analysis is often used with remote sensing to decrease the dimensionality of multi-band imagery and to realign data with new axes to maximize variance in the imagery (Campbell and Wynne, 2011). Relief shaded maps using illumination from numerous aspect directions and inclinations from the horizon can also be input to principal component analysis (PCA), resulting in principal component maps that optimize variance and mimic relief shading. Using 15° increments of azimuth and inclination to vary illumination direction yields 121 relief shadings of the Churfirsten, Switzerland at 30 m. resolution, one of the sample elevation models available from http://shadedrelief.com/SampleElevationModels/ (Kennelly et al., 2021). PCA results in the three principal component images shown in Figure 1, accounting for more than 99% of the variance found in the 121 input relief shadings. While the first two principal component maps are similar to relief shading illuminated from near the horizon and separated by 90 degrees of azimuth, the third principal component map is similar to slope shading.

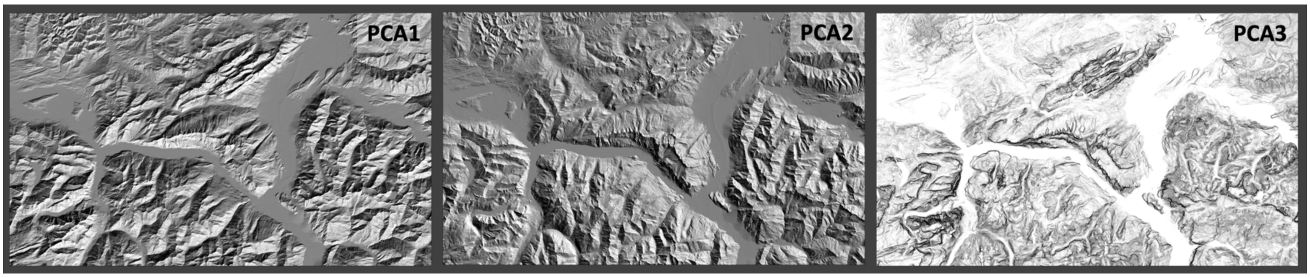

Figure 1. The first three principal component images from 121 shaded relief maps using illumination directions varying by 15° of azimuth and inclination.

PCA yields additional results when compared to mapping trends in variance of shaded relief maps created with changes in illumination directions. While both techniques identify an illumination direction from the southeast and near the horizon as the map with the maximum variance, PCA is necessary to identify other spatial patterns of shading that complement the first PCA layer in identifying additional variance.

By extracting the x, y, and z components of the surface normal vector (Trantham & Kennelly 2022, Trantham and Kennelly 2021) from the original digital elevation model (DEM), these maps serve as a more efficient input to PCA. Figure 2 shows the three principal component images resulting from analysis of the x, y, and z components of the surface normal vector. While this methodology does not use relief shading, PCA images appear similar to relief shading and yield results similar to the PCA of relief shading shown in Figure 1.

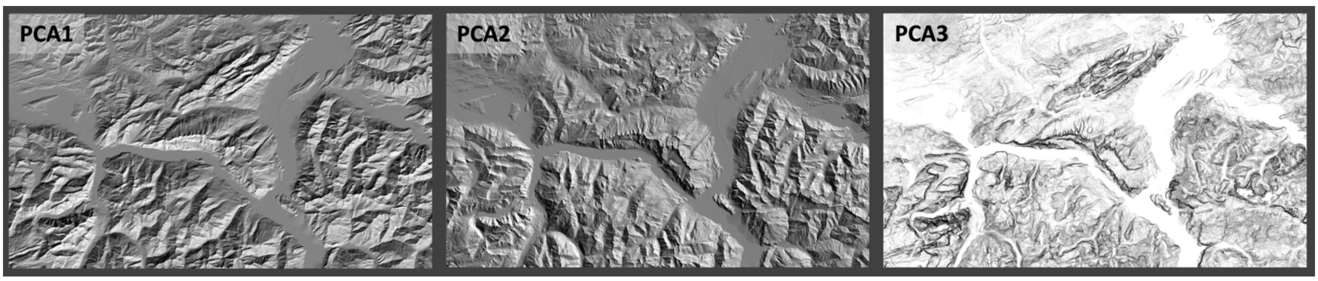

Figure 2. The three principal component images from x, y, and z components of the surface normal vector.

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Principal component maps of relief shading converge to principal components of the surface normal vector's x, y and z values when unclamped relief shading is used as input. This is because clamped output of typical relief shading assigns a brightness value of zero to all cells where the angle between the surface normal and illumination vector is greater or equal to 90°. This research demonstrates the extent to which clamped relief shading is masking variance by unnecessarily assigning the majority of grid cells to a value of zero.

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References

Campbell, J.B. and Wynne, R.H., 2011. *Introduction to Remote Sensing*. Guilford Press.

Kennelly, P.J., Patterson, T., Jenny, B., Huffman, D.P., Marston, B.E., Bell, S. and Tait, A.M., 2021. Elevation models for reproducible evaluation of terrain representation. *Cartography and Geographic Information Science*, 48(1), pp.63-77.

Trantham, G. and Kennelly, P., 2022. Terrain representation using orientation. *Cartography and Geographic Information Science*, pp.1-13.

Trantham, G. and Kennelly, P., 2021. Focus on orientation to represent terrain, *Abstr. Int. Cartogr. Assoc*., 3, 292, https://doi.org/10.5194/ica-abs-3-292-2021, 2021.

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