Fast and memory-efficient independent component analysis using Lie group techniques

Matthias Hermann
HTWG Konstanz
mhermann@htwg-konstanz.de

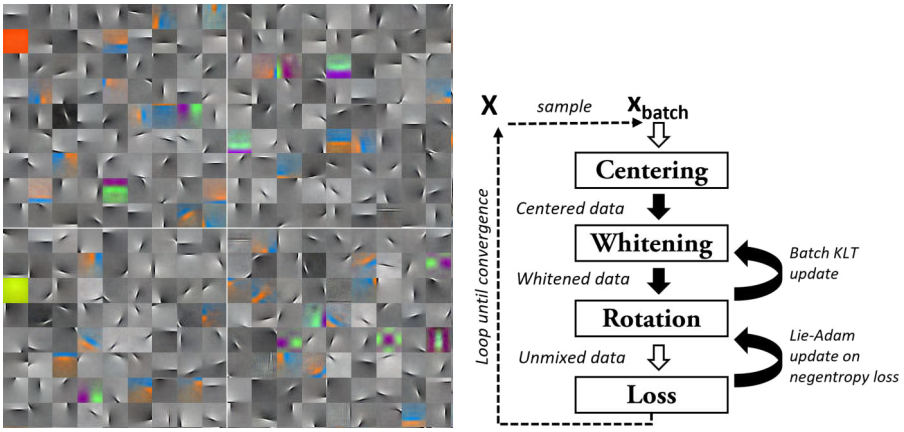

Figure 1: Examples of the first 484 independent components estimated from the ImageNet dataset ($1.2 \cdot 10^6$ examples and $d = 150528$) (left). In Lie-ADAM, we used a learning rate of 0.01 and a batch size of 484. The model was trained with three runs through the dataset which took $3h$ on standard hardware with a single GPU. A schematic overview of the algorithm is shown on the right.

We were interested in computing a mini-batch-capable end-to-end algorithm to identify statistically independent components (ICA) [1] in large scale and high-dimensional datasets. Current algorithms typically rely on pre-whitened data and do not integrate the two procedures of whitening and ICA estimation. Our online approach estimates a whitening and a rotation matrix with stochastic gradient descent on centered or uncentered data. We show that this can be done efficiently by combining Batch Karhunen-Löwe-Transformation [2] with Lie group techniques [3]. By using b-sized mini-batches the space complexity of the entire pipeline for d-dimensional inputs and k components is limited to $\mathrm{O}(d(k+b))$. Our algorithm is recursion-free and can be organized as feed-forward neural network which makes the use of GPU acceleration straight-forward. Because of the very fast convergence of Batch KLT, the gradient descent in the Lie group of orthogonal matrices stabilizes quickly. The optimization is further enhanced by integrating ADAM, an improved stochastic gradient descent (SGD) technique from the field of deep learning. We test the scaling capabilities by computing the independent components of the well-known ImageNet challenge (144 GB). Due to its robustness with respect to batch and step size, our approach can be used as a drop-in replacement for standard ICA algorithms where memory is a limiting factor.

Joint work with: Georg Umlauf, Matthias O. Franz

References

[1] P. Comon, "Independent component analysis, a new concept?" *Signal processing*, vol. 36, no. 3, pp. 287–314, 1994.

[2] A. Levy and M. Lindenbaum, "Sequential karhunen-loeve basis extraction and its application to images," in *Proceedings 1998 International Conference on Image Processing. ICIP98*, IEEE, vol. 2, 1998, pp. 456–460.

[3] M. D. Plumbley, "Geometry and manifolds for independent component analysis," in *2007 IEEE International Conference on Acoustics, Speech and Signal Processing-ICASSP'07*, IEEE, vol. 4, 2007, IV–1397.