THE UNIVERSITY OF CHICAGO

Computational and Applied Mathematics & Statistics Student Seminar

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An Approachable Approach to Nonnegative Tensor Factorization

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ABSTRACT

Nonnegative tensor factorization models, such as the canonical polyadic (CP) and Tucker decompositions, are robust methods for capturing interpretable latent structure in multiway data. The choice of factorization structure drastically affects the model's interpretability and fit; inference algorithms are typically tailored to individual models and implemented from scratch, requiring substantial implementation effort. We derive a unified majorization-minimization algorithm that works for CP, Tucker, tensor-train, and more general factorization structures by exploiting their shared multilinear form. The algorithm minimizes the beta-divergence (which includes KL divergence and squared error as special cases) between the observed tensor and specified factorization, extending classical matrix-level results to arbitrary tensor contractions. The proposed einsum-based algorithm is GPU-accelerated and extraordinarily simple: in particular, switching from CP to Tucker or tensor-train requires altering one line of code. We show the algorithm's modularity by applying it to Gibbs sampling and variational inference, enabling posterior inference in flexible Poisson–Gamma and Poisson/Multinomial–Dirichlet factorization models. Applications to international trade networks and fluid dynamics reveal that our method produces structured, interpretable tensor factorizations that fit the observed data better than the standard CP, Tucker, and tensor-train models.