

PhD subject: *Parallel Tensor Decompositions for Data Analytics*

Advisors: Suraj Kumar and Bora Ucar

Location: ROMA team, Inria Lyon, France

Context

Tensors are multi dimensional arrays and used to store data in several domains, for example, data mining, neuroscience and computer vision. Tensor decompositions help to identify inherent structure of data, achieve data compression and enable various ways of data analysis. Working with tensors is challenging due to their large computational effort and memory requirements (amount of memory and computations grow exponentially in the number of dimensions). It is therefore necessary to work with patterns of tensor data. Using low dimensional structure of high dimensional data is a powerful approach in this context. Most tensor decompositions represent data in its low dimensional structures.

CP and Tucker are the widely used tensor decompositions for data analytics. Both decompositions can be viewed as high order generalization of singular value decomposition. The data generated by many experiments is so big that it is impossible to perform a CP/Tucker decomposition without parallel computations. Therefore, it is important to design parallel and scalable algorithms for both decompositions.

Assignment

Most existing tensor decomposition algorithms work with matrix (2-dimensional) representations of tensors at each step and rely on the parallelization of matrix operations. This approach neglects high dimensional properties of tensors and may not perform the entire computations efficiently [1, 2]. The main objective of this PhD thesis is to design parallel approaches based on multidimensional properties of tensors for CP and Tucker decompositions.

This PhD thesis will be held in the ROMA Inria team at LIP, ENS Lyon under the supervision of Suraj Kumar and Bora Ucar. We will also collaborate with Grey Ballard (Wake Forest University, USA).

Main Activities

The candidate is expected to perform the following activities:

- Analyze computation and communication costs of the existing approaches for CP and Tucker decompositions
- Study minimum communication and computation costs for both decompositions
- Design new algorithms based on multidimensional properties of tensors
- Implement the proposed algorithms for large scale high performance computing systems

Skills

The candidate must have a Master's degree in Computer Science, Computational Sciences, Applied Mathematics, or a related technical field.

Familiarity with Linear Algebra computations and Parallel Programming will be much appreciated.

References

- [1] H. Al Daas, G. Ballard, L. Grigori, S. Kumar, and K. Rouse, "Communication lower bounds and optimal algorithms for multiple tensor-times-matrix computation," *SIAM Journal on Matrix Analysis and Applications*, vol. 45, no. 1, pp. 450–477, 2024. [Online]. Available: <https://doi.org/10.1137/22M1510443>
- [2] G. Ballard, N. Knight, and K. Rouse, "Communication lower bounds for matricized tensor times khatri-rao product," in *2018 IEEE International Parallel and Distributed Processing Symposium (IPDPS)*, 2018, pp. 557–567. [Online]. Available: <https://doi.org/10.1109/IPDPS.2018.00065>