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Subject : Reference letter for Mr. Ang

University of Waterloo

To whom it may concern,

By this letter, I would like to support Mr. Ang's application as a postdoctoral researcher at the University of Waterloo as a UWaterloo-Fields Postdoc fellowship.

Dr. Ang began his thesis 4 years ago (February 2017) on the use of nonnegative matrix/tensor factorisations (NMF/NTF) for the decomposition of different types of data sets, with a focus on audio data sets and hyperspectral images. NMF/NTF are central tool in the analysis of nonnegative data sets, including audio signals, documents, images, microarrays, graphs, to cite a few. The contributions of Mr. Ang are focused on algorithmic developments for these difficult non-convex optimization problems. In particular, he developed a heuristic algorithm inspired from Nesterov's accelerated gradient method but adapted to non-convex problems by tuning the extrapolation parameter automatically. Another important contribution of Mr. Ang is on the so-called minimum-volume NMF model. Not only Mr. Ang proposed new highly efficient algorithms in difficult scenarios (such as rank deficient cases), he was also able to prove the identifiability of such models (that is, their capacity to learn the true underlying factors that generated the data). Within four years, Mr. Ang published 4 papers in top journals (Neural Computation, IEEE Trans. Signal Processing, IEEE J. Sel. Top. Appl. Earth. Obs. Remote Sens., Numerical Linear Algebra with Applications), and 7 refereed conferences papers (3*ICASSP, 2*EUSIPCO, 2*GRETSI, WHISPERS). This is clearly above average.

Mr. Ang is also very active in the community and has participated to many conferences, has visited several research groups where he gave oral presentations (University of Rennes in February 2019, Hong Kong Polytechnic University in March 2019, U. of Waterloo in the summer 2019), and other events (such as PhD schools); see <https://angms.science/activityLog.html> for a comprehensive list. Mr. Ang is a highly motivated person who does not hesitate to interact and ask questions. This is exemplified with his collaborations with many different researchers. Mr. Ang is the most active PhD student I have met in my career, and

his enthusiasm is impressive and communicative. For example, he won the “poster hunter award” at the EURASIP Tensor-Based Signal Processing summer school. This is also exemplified by his website where Mr. Ang keeps all his research notes with his personal comments; see <https://angms.science/notes.html>

Moreover, Mr. Ang is a very mature researcher, and most ideas in the published papers come from him (extrapolation in the non-convex case, min-vol NMF algorithms, etc.). Mr. Ang recently came up with a new NMF model using unimodality which allows to obtain much stronger identifiability results. Mr. Ang also proposed a very efficient approach to tackle this difficult problem (the feasible set is not convex, but Mr. Ang came up with an approach to efficiently project onto it). Finally, Mr. Ang has written a very convincing research proposal on low-rank matrix and tensor approximations which are a key tool in data analysis and machine learning. They allow to automatically extract latent features in large data sets. They have been used successfully in a wide range of applications such as recommender systems, image analysis, text mining, audio source separation, community detection, clustering to cite a few. Although these techniques are rather old (such as PCA which is more than 100 years old), this is still a very active area of research because many open questions remain open. Mr. Ang, in his proposal, will address two of the most important direction of research:

- How to make algorithms faster for this type of methods? Mr. Ang will base his approach on extrapolation. Although this technique is well understood in the convex case, it remains an open question to understand better his behaviour in non-convex settings. For this part of the project, Prof. Hans De Sterck and his team will be an ideal environment as they are already working on such questions. Moreover, Mr. Ang experience on the topic is very high, because he has already designed such methods for LRMTA, and has a strong expertise in optimization.
- How can we make sure the low-rank models recover the right solution? This is called the identifiability issue. This is a crucial question in many applications: is the model able to recover the sought factors? See for example Fu, Huang, Sidiropoulos, Ma, “Nonnegative Matrix Factorization for Signal and Data Analytics: Identifiability, Algorithms, and Applications”, IEEE Signal Process. Mag., 36(2), 59-80, 2019, for a recent survey for the NMF problem. There are still many open questions on how to design proper models with identifiability guarantees. The expertise of Mr. Ang for this topic is, again, ideal: he has already proven several such results (in particular, for NMF; see his paper on minimum-volume NMF in IEEE Trans. on Signal Processing), and is currently developing a new model (dubbed unimodal NMF) that allows for stronger identifiability guarantees. To supervise this research, Prof. Vavasis would be perfect, being one of the top experts on the topic; with results on both complexity of NMF and identifiability for the separable NMF model.

In summary, Mr. Ang is a highly motivated and skilled researcher, and I recommend him as a postdoctoral researcher with no hesitation.

Prof. Nicolas Gillis

