

IBM INNOVATION AWARDS 2019

DECEMBER 3, 2019

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IBM INNOVATION AWARDS 2019

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- Cyber Security
- Cloud Computing

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► For the F.R.S. - FNRS, the Award is granted to:

Omar Seddati

PhD in engineering and technology - UMONS

Master in computer science and management - UMONS

Postdoctoral Researcher - UMONS

for his PhD thesis :

Reconnaissance et recherche de données multimedia par les réseaux de neurones profonds.

Over the past decades, available multimedia collections have seen consistent growth through easily accessible devices that we now use on a daily basis. These huge collections motivated researchers to look for more efficient approaches for multimedia data retrieval.

In this thesis, we have conducted a thorough study of multimedia recognition and retrieval. We have identified potential key parts of the classic data retrieval processing pipeline. Based on this study, we selected several key parts to make different changes that brought significant improvements to the whole process.

Most search engines assume that part of the metadata provided with multimedia data describe its visual content and are used as keywords during search phase. In order to

enhance search relevance, we introduced better recognizers for automatic metadata enrichment, providing more accurate tags (automatically generated) for multimedia retrieval.

Furthermore, in order to reduce information loss (e.g. missing metadata, wrong annotation, etc.) due to highly compressed data representation (e.g. keywords, tags, etc.) and to bring more flexibility in search querying, we introduced two query modes. The first is Sketch Based Image Retrieval, where a freehand sketch is used to describe an object and search for it. The second is Content-based image retrieval where an image is used as an example to find similar contents. We have also addressed search results diversification to make our solutions more suitable for applications like Pinterest, where the diversity of results is as important as relevance.

IBM INNOVATION AWARDS 2019

► For the FWO, the Award is granted to :

Nico Vervliet

PhD in electrical engineering - KU Leuven

Master in mathematical engineering - KU Leuven

Postdoctoral Researcher - KU Leuven

for his PhD thesis

Compressed sensing approaches to large scale tensor decompositions.

This information age is characterized by an enormous volume of data that is generated at an unprecedented velocity. These data are used, e.g., in signal processing, data analysis and machine learning, to find underlying sources, to discover patterns, to perform prediction and so on. While matrix techniques have been used successfully in many applications, they can only be used to model the interaction between two variables or modes. In this thesis, we use higher-order generalizations of matrices, i.e., with more than two modes. These so-called tensors can be imagined as multiway arrays of numbers. Thanks to milder uniqueness conditions, underlying components are easier to find by decomposing tensors instead of matrices. This means that often unnecessarily restrictive and unnatural constraints can be avoided, improving the interpretation of the models.

Tensor problems tend to be large-scale due to their higher order. However, a simple model with relatively few parameters is often enough to extract useful information. Compressed sensing techniques overcome this discrepancy: instead of measuring all data, a compressed version is used to compute the model in order to reduce time and memory requirements. This compressed version can be a sample of all data points, an efficient representation which uses fewer parameters or an implicit definition of the data. In this thesis, we propose five techniques to significantly reduce the computational and memory cost of algorithms for tensor decompositions. This is achieved by exploiting the structure in both the compressed measurement and the decomposition. More specifically, we present algorithms that deal with incomplete datasets, that use random block samples or that exploit the efficient representation of a tensor. We derive an updating algorithm for tracking varying decompositions based on streaming data. Finally, we study tensors that are given implicitly. The proposed algorithms are readily applicable in many domains, which we illustrate for a variety of applications.

MEMBERS OF THE JURY F.R.S. - FNRS 2019

MANNEBACK Pierre

Professor at UMONS

MARKOWITCH Olivier

Professor at ULB

SCHOBENS Pierre-Yves

Professor at UNamur

VANDERDONCKT Jean

Professor at UCL

MEMBERS OF THE JURY FWO 2019

DESCHRIJVER Dirk

Professor at UGent

MARQUEZ-BARJA Johann

Professor at UAntwerpen

NOWÉ Ann

Professor at VUB

Omar Seddati

UMONS

“Reconnaissance et recherche de données multimédia par les réseaux de neurones profonds”



Summary

In this thesis, our main focus is to improve multimedia data recognition and retrieval using artificial intelligence. Unlike conventional approaches based on manually designed features, we use deep learning models for feature extraction. Our models were trained on large scale datasets to learn how to extract automatically the most relevant features.

During this research, we proposed several solutions for multimedia recognition and retrieval where three types of multimedia data were considered: sketches (in the form of black lines on a white background), images, and videos. In the following, we present some of the solutions introduced in this work and the main results.

In our first publication, we were inspired by solutions proposed in the field of image recognition to improve sketch recognition. We were able to introduce the first sketch recognizer to have exceeded human performance on a large-scale benchmark, TU-Berlin. Since then, we continued to improve this model to maintain the best state-of-the-art results. We also introduced the first ConvNet for Partial Sketch Recognition. Then, we used this model to take into account the evolution of the drawing over time to enhance complete sketch recognition.

In addition to sketch recognition, we also proposed several solutions to improve multimedia retrieval. In order to do that, we dealt with both, the query paradigm and the efficiency of multimedia content encoding. We selected two different query modes to provide more flexibility to multimedia search tools:

- **Sketch Based Image Retrieval (SBIR):** This query mode allows the user to describe an object and search for it using a hand drawing. Freehand sketches are an interesting universal form of visual representation. Sketching has become easily accessible with many of the devices that we use on a daily basis. This query mode can be very useful in some cases (e.g. a visual search technology in E-commerce) where the query has many spatial details that needs a complex description when using keywords. As a first SBIR solution, we used the partial sketch recognition model to build a real-time sketch recognition and image retrieval system based on sketch-contour matching. In order to develop more effective SBIR solutions, it is necessary to face the difficulties related to the cross-modal nature of the problem. We mainly proposed two solutions to deal with these difficulties: the Quadruplets networks, inspired from Triplets networks –introduced in the field of face matching- that we adapted for SBIR to significantly improve state-of-the-art results; and the Triplets networks combined with an attention model to achieve state-of-the-art results while using short vectors (128 floats compared to 1024 floats for the Quadruplets representation). In order to evaluate our solutions, we used three large scale benchmarks: Sketchy, TU-Berlin SBIR and Flickr15k. We achieved the best results for the first two benchmarks and the second best result for the last one.

- Content-based image retrieval (CBIR): In this type of search, an image is used as an example to find similar images. We opted for a method based on the use of pre-trained models for object recognition. We proposed several improvements that do not involve any model finetuning (which is more suitable for this task since there is no publicly available training data) and we achieved the best state-of-the-art results for this kind of approaches (without finetuning). We evaluated our solution on four well known benchmarks: Holidays dataset, UKB, Oxford5k and Paris6k. We also proposed a variant of this solution that prioritizes both relevance and diversification by grouping similar contents in an intelligent fashion. We evaluated this variant during our participation to MediaEval 2017: Diverse Social Images Retrieval. We ended up at the first position for relevance and the third position for diversification.

Furthermore, we also conducted a thorough study of a state-of-the-art approach for action recognition in videos. Then, we made several changes that brought a significant accuracy improvement. This model, in addition to several others that we trained for object recognition (based on a subset of useful categories from the ImageNet), environment recognition (using Places205), sketch recognition and including our SBIR solutions are used in the IMOTION video search system (the winner of the VBS 2017 challenge). This system provides several query modes, the ones mentioned above as well as the use of keywords to retrieve contents based on tags generated with our models. These models are also used to extract spatial and temporal features needed to group similar contents and facilitate user experience when using the system interface.

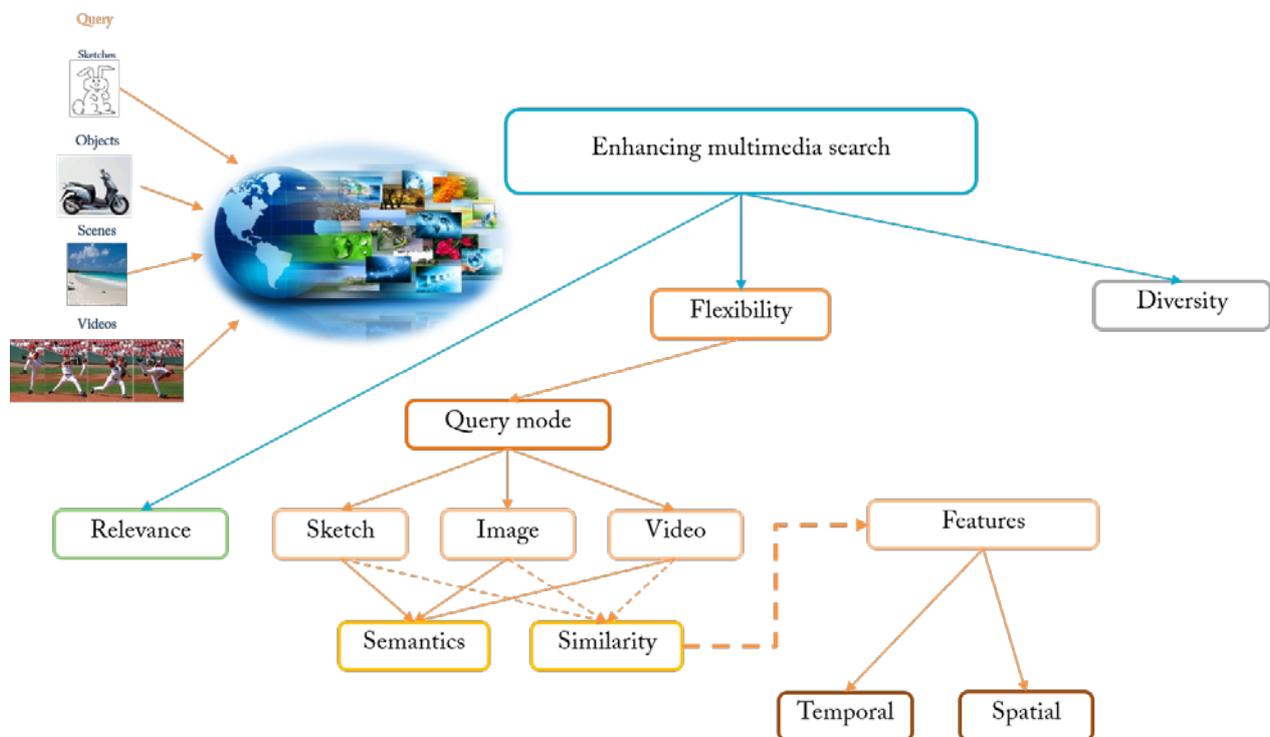


Figure 1 : this figure summarizes the different points addressed in this thesis.

To conclude, in this work we have conducted a thorough study of multimedia recognition and search. We were able to propose several improvements at different levels as shown in Figure 1. Starting with introducing better recognizers that enhance relevance by generating more accurate tags. Then, we provided more flexibility by including different multimedia data types, two query modes, spatial and temporal features. Next, we modified our CBIR approach to enhance results diversification and make our solution more suitable for applications like Pinterest, where the diversity of results is as important as relevance. Furthermore, our solutions were integrated in a larger system and proved their efficiency during the VBS 2017 challenge. Which shows that the proposed solutions could be integrated in Ecommerce websites, stock images and similar services. However, there are still many challenges to be solved to be able to apply these solutions at a web scale.

Curriculum Vitae



Omar Seddati

- Post doc -

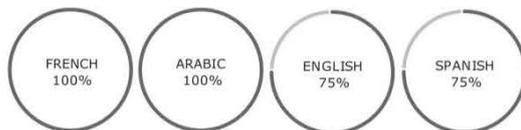
Phone : (+32) 65 37 47 36

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EXPERIENCE

- Postdoctoral Research Associate**
01.2018-12.2020 | UMONS
Member of the DigiMIR: Multimedia Information Retrieval for the Creative Industries.
- Research Assistant**
01.2014-12.2017 | UMONS
Member of the european project: IMOTION (Intelligent Multi-Modal Augmented Video Motion Retrieval System).
- Internship**
2012 | J. Delafon
Designing a full system for the production chain monitoring and analysis.
- UECE Head of cultural affairs**
09.2010-06.2011 | Polytechnic Faculty of Mons

LANGUAGES



SKILLS

- Machine Learning:**
Torch7, Tensorflow, Slim, Keras, TfLearn
- Image Processing, OpenCV, Image & Video Classification, Object Detection, Content-based Retrieval, Feature Extraction, Multimodal Retrieval**
- Programming & DB:**
C/C++, PHP, Python, LUA, HTML, SQL, JAVA, JS, CSS
- Frameworks:**
QT, Symfony

EDUCATION

- Ph. D.**
2017-2018 | UMONS
Ph. D., in engineering and technology
- M. Sc.**
2012-2013 | UMONS
M. Sc., in Computer Science and Management, specialized in information systems
- B. Sc.**
2010-2011 | UMONS
B. Sc. in engineering sciences, civil engineering orientation

Awards

- | | |
|---------------------------|------|
| VBS 2017 (MMM 2017) | 2017 |
| FNRS-IBM Innovation Award | 2019 |

RESEARCH INTERESTS

- Artificial Intelligence & Machine Learning
- Pattern Recognition
- Computer Vision
- Multimodal Interaction
- Signal Processing

INTERESTS



Complete list of publications

Seddati, Omar, DUPONT, Stephane, et MAHMOUDI, Saïd. Deepskech: deep convolutional neural networks for sketch recognition and similarity search. In : *Content-Based Multimedia Indexing (CBMI), 2015 13th International Workshop on*. IEEE, 2015. p. 1-6.

Seddati, Omar, KULAH, Emre, PIRONKOV, Gueorgui, et al. UMons at MediaEval 2015 Affective Impact of Movies Task including Violent Scenes Detection. 2015.

Seddati, O., Dupont, S., & Mahmoudi, S. (2016, June). DeepSketch 2: Deep convolutional neural networks for partial sketch recognition. In *Content-Based Multimedia Indexing (CBMI), 2016 14th International Workshop on* (pp. 1-6). IEEE.

Seddati, O., Dupont, S., & Mahmoudi, S. (2016, October). DeepSketch2Image: Deep Convolutional Neural Networks for Partial Sketch Recognition and Image Retrieval. In *Proceedings of the 2016 ACM on Multimedia Conference* (pp. 739-741). ACM.

Seddati, O., Dupont, S., & Mahmoudi, S. (2016 May). Réseaux de Neurones Convolutionnels Profonds pour la Reconnaissance d'Action dans les Vidéos. In : 18e Colloque Compression et Représentation des Signaux Audiovisuels, CORESA 2016.

Dupont, S., Seddati, O., Frisson, C., Pironkov, G., Mahmoudi, S., Giangreco, I. & Sezgin, M. Innovative Query Modes for Searching and Manipulating Video through Motion and Sound (eNTERFACE'2015–10/08-04/09/2014).

Mahmoudi, S. A., & Lecron, F. (2016). Monitoring computer vision applications in cloud platforms (movacp). In *12th Summer Workshop on Multimodal Interface*.

Tanase, Claudiu, GIANGRECO, Ivan, ROSSETTO, Luca, et al. Semantic Sketch-Based Video Retrieval with Autocompletion. In : *Companion Publication of the 21st International Conference on Intelligent User Interfaces*. ACM, 2016. p. 97-101.

Rossetto, Luca, GIANGRECO, Ivan, SCHULDT, Heiko, et al. IMOTION—a content-based video retrieval engine. In : *MultiMedia Modeling*. Springer International Publishing, 2015. p. 255-260.

Rossetto, Luca, GIANGRECO, Ivan, HELLER, Silvan, et al. IMOTION—Searching for Video Sequences Using Multi-Shot Sketch Queries. In : *MultiMedia Modeling*. Springer International Publishing, 2016. p. 377-382.

ROSSETTO, Luca, GIANGRECO, Ivan, TĂNASE, Claudiu, et al. iAutoMotion—an Autonomous Content-Based Video Retrieval Engine. In : *MultiMedia Modeling*. Springer International Publishing, 2016. p. 383-387.

Rossetto, L., Giangreco, I., Tănase, C., Schuldt, H., Dupont, S., & Seddati, O. (2017, January). Enhanced retrieval and browsing in the IMOTION system. In *International Conference on Multimedia Modeling* (pp. 469-474). Springer, Cham.

Seddati, O., Dupont, S., Mahmoudi, S., Parian, M., & Dolez, B. (2017, October). Towards Good Practices for Image Retrieval Based on CNN Features. In *ICCV Workshops* (pp. 1246-1255).

Seddati, O., Dupont, S., & Mahmoudi, S. (2017, June). Quadruplet networks for sketch-based image retrieval. In *Proceedings of the 2017 ACM on International Conference on Multimedia Retrieval* (pp. 184-191). ACM.

Seddati, Omar, Stéphane Dupont, and Saïd Mahmoudi. "DeepSketch 3." *Multimedia Tools and Applications* 76.21 (2017): 22333-22359.

Delbrouck, Jean-Benoit, Stéphane Dupont, and Omar Seddati. "Visually grounded word embeddings and richer visual features for improving multimodal neural machine translation." *arXiv preprint*

arXiv:1707.01009 (2017).

Seddati, O., Ben-Lhachemi, N., Dupont, S., & Mahmoudi, S. (2017). UMONS@ MediaEval 2017: Diverse Social Images Retrieval. In *MediaEval*.

Seddati, O., Dupont, S., & Mahmoudi, S. (2017, July). Triplet Networks Feature Masking for Sketch-Based Image Retrieval. In *International Conference Image Analysis and Recognition* (pp. 296-303). Springer, Cham.

The 3 most important:

Seddati, O., Dupont, S., Mahmoudi, S., Parian, M., & Dolez, B. (2017, October). Towards Good Practices for Image Retrieval Based on CNN Features. In *ICCV Workshops* (pp. 1246-1255).

Seddati, O., Dupont, S., & Mahmoudi, S. (2017, June). Quadruplet networks for sketch-based image retrieval. In *Proceedings of the 2017 ACM on International Conference on Multimedia Retrieval* (pp. 184-191). ACM.

Seddati, Omar, Dupont, Stephane, et Mahmoudi, Said. Deepsketch: deep convolutional neural networks for sketch recognition and similarity search. In : *Content-Based Multimedia Indexing (CBMI), 2015 13th International Workshop on*. IEEE, 2015. p. 1-6.

Nico Vervliet

KU Leuven

"Compressed sensing approaches to large scale tensor decompositions"



Summary

➤ Introduction

In data analysis, signal processing and machine learning, finding simple, interpretable models or components is key to extract information, to discover underlying sources or to make decisions. These data can take the form of images, tables, graphs, etc. and are often stored as matrices. For example, in movie recommendation the rows of a matrix model a user and the columns a movie. Each value then represents the rating a certain user gives or would give a certain movie. This matrix has two explaining variables or modes: user and movie. It is obvious that a more accurate prediction can be made by including an additional mode, for example, time. This can be done naturally by representing the data by a third-order tensor. A tensor can be seen as a multiway array of numbers and is a higher-order generalization of vectors (order one) and matrices (order two). Tensors have many attractive properties: by exploiting the multilinear relations in the data, one can achieve higher compression ratios compared to matrix techniques. Tensor decompositions are also more easily unique. This means that useful components can be extracted without the requirement of often unnatural constraints. Tensor decompositions are therefore used more and more in biomedical applications, scientific computing, data analysis and so on.

Tensor problems are often large-scale as the amount of storage and the computation time increase exponentially in the order: an N th-order tensor in which each dimension is equal to I has I^N values, and the computational cost typically scales at least linearly in the number of tensor entries. The problems associated with this exponential increase are often called the curse of dimensionality. In this thesis, I mainly focus on the computation of the decomposition into a sum of rank-1 tensors, the so-called canonical polyadic decomposition or CPD. For this decomposition, I have investigated different algorithms and techniques that fundamentally reduce computational time and memory footprint. As the goal in data analysis and signal processing is often to recover only (relatively) few simple and interpretable components, e.g., rank-1 terms, I propose techniques that exploit the rank-1 structures in the data by using only relevant parts at a time, instead of dealing with the entire dataset. In this compressed sensing spirit, the data sparsity, i.e., the low-rankness, is used to recover the interesting components using few samples, compressed data or structured representations of the data. Moreover, in contrast to the conventional alternating optimization techniques, I show that second-order all-at-once optimization algorithms can be used in practice by exploiting the multilinear structure.

➤ *Combining incomplete tensors and linear constraints to break the curse of dimensionality*

The curse of dimensionality can be broken on two levels. First, by using low-rank tensor models instead of the real data, the problems associated with the exponential dependency are removed in the analysis step. Second, when computing this low-rank model, the curse can be alleviated or broken by using incomplete tensors. In contrast to state-of-the-art methods which often replace unknowns by some value or use very basic optimization routines, we show that Gauss–Newton techniques can achieve fast convergence and are more robust w.r.t. the initial guess. One crucial addition in our algorithm is that prior information in the form of linear constraints can be included. Examples are smooth functions or dictionaries of known components. This way, highly accurate tensor decompositions can be computed using very few tensor entries.

We have applied these techniques to two materials science applications to model material properties, such as the melting temperature or the Gibbs free energy of an alloy with many compounds. These properties can be represented as higher-order tensors in which each mode corresponds to a concentration of a certain compound, e.g., the percentage of iron in steel. Storage or computational requirements are often prohibitive to construct these tensors which limits the number of compounds that can be used in analyses. We have investigated the melting temperature of an alloy with ten compounds, which results in a ninth-order $100 \times 100 \times \dots \times 100$ tensor. As computing all 10^{18} entries is unfeasible, we show that by using incomplete tensors a very accurate continuous model can be constructed using only 10^5 samples in a few minutes on a laptop. Similarly, for a four-compound alloy, we show that only 200 samples are sufficient to replace the actual property tensors in simulations, making these simulations actually feasible.

➤ *Effective stochastic tensor optimization by randomly sampling blocks*

In stochastic optimization, e.g., in stochastic gradient descent (SGD), one or a small number of samples is selected every iteration to update the variables. The samples are chosen randomly, which may not be efficient from a computational point-of-view as many or all variables are updated every iteration and the multilinear structure available in tensor decompositions is hardly exploitable. In the case of the CPD, we notice that each entry affects only few variables and that sampling random indices in each mode rather than random entries limits the number of affected variables significantly. By sampling indices in each mode, we actually select a random subtensor that is dense. This means that we can leverage well-known structure exploitation results from standard CPD algorithms, resulting in highly efficient variable updates. Moreover, this allows the algorithm to use second-order information, which also facilitates tuning hyperparameters such as the learning rate. We show that using our randomized block sampling method, we can achieve nearly the same accuracy as if the full tensor is used, while only a fraction of the data is accessed. The effectiveness of this approach is illustrated for both synthetic and real-life tensors. We are able to analyze terabytes of synthetic data on a laptop in a couple of minutes. In a real-life example, we show that we can quickly classify hazardous gasses measured at an array of sensors: the decomposition of the corresponding 12.5GB tensor takes only three minutes on a laptop.

➤ *Enabling real-time, low memory tensor analysis via updating techniques*

The effectiveness of low-rank tensor models has become apparent in countless applications. Mostly, these models are trained on a dataset that is fully available at the time of analysis. However, in practical settings such as, e.g., continuous monitoring, new data arrives constantly and the model may change over time. Moreover, datasets and therefore the computational cost may grow rapidly while a fast, real-time analysis and a corresponding action are required. To accommodate this, we have developed a novel type of updating method: instead of keeping the entire dataset, a compact, low-rank representation is saved instead to reduce the memory cost. By exploiting the structure of this low-rank approximation and updating all variables at once, a high computational efficiency is achieved. We show that, in contrast to previously proposed methods, the accuracy is close to the accuracy an algorithm using all data would achieve, requiring only a fraction of the time and storage space.

➤ *Scaling blind source separation through efficient representations*

Blind source separation is a key tool in signal processing and data analysis in order to extract meaningful sources from a noisy linear mixture. As recovering these sources uniquely without extra information is not possible, additional assumptions have to be made. Traditional techniques assume, e.g., that sources are uncorrelated or independent and rely on (higher-order) statistics which may require many samples to achieve a suitable accuracy. Moreover, these assumptions may not be applicable to many problems. Recently, methods built upon deterministic assumptions have been presented. For example, the signals can be exponential or rational functions, or can be approximated by low-rank terms. By tensorizing the data, i.e., by mapping the vector or matrix data to a tensor, sources can be separated by means of tensor decompositions under few additional restrictions, often requiring very few samples.

The tensorization step often leads to an explosion of the amount of data. This severely limits the applicability of these techniques in practice. We have therefore proposed the implicit tensorization technique: by specializing few operations, the tensor properties can be exploited while keeping a vector or matrix complexity. We illustrate this by separating exponential polynomials with 0.5 million samples, for which the tensor would consume a terabyte of memory, in minutes on a laptop. We show that using rational functions to separate a fetus' heartbeat from the mother's heartbeat becomes feasible on wearable devices as the memory consumption reduces from 60MB to 160kB.

The implicit tensorization techniques are examples of efficient representations of tensors, i.e., ways of representing the tensor with fewer parameters than its number of entries. We show that we can elegantly exploit a variety of structures in tensor computations. For example, we illustrate that it becomes possible to perform compression in combination with constrained tensor decompositions and second-order optimization techniques. This way, we can speed up computations significantly.

➤ *Linear systems with tensor structured solutions and implicitly defined tensors*

An important contribution is the concept of linear systems of equations in which the solution vector can be seen as a vectorized low-rank tensor. In essence, this generalizes linear systems to multilinear systems in a similar way as tensor decompositions generalize matrix decompositions. In the thesis, we explain and illustrate that many problems, including, e.g., face recognition, blind system identification and irregular heartbeat classification, are encompassed in our proposed LS-CPD framework. By making this connection, we can show that our simple yet efficient optimization-based algorithm can replace the current ad-hoc solutions. Moreover, we have proposed an algebraic algorithm that allows one to solve this problem relying solely on linear algebra operations. As for tensor decompositions, these algebraic algorithms are key to provide good initializations for optimization-based methods. Using the LS-CPD framework, we propose a novel technique and algorithm to do multilinear classification. This is more versatile than linear classification as we exploit multilinear relations in the data, yet easier than nonlinear techniques common in machine learning.

These linear systems with tensor structured solutions can be seen as a form of compressed sensing: the matrix is the known sensing matrix, the right hand side is the compressed measurement, and we look for a (data) sparse solution in the form of a low-rank tensor. Via generic uniqueness conditions relying on techniques from algebraic geometry, we derive a deterministic bound for how many samples are required to ensure unique recovery of the solution. This bound is a huge advantage over probabilistic bounds which only hold with high probability.

➤ *Conclusion*

In total, eight new techniques for dealing with large-scale tensor decompositions have been investigated in this thesis. All algorithms focus on fundamentally reducing the computational cost using a compressed version of the data, which enables the decomposition of large-scale tensors on regular laptops or desktops. All algorithms are made available in Tensorlab, a Matlab toolbox for tensor computations of which I am the current lead developer and maintainer.

Curriculum Vitae



Nico Vervliet

Experience

- 2018–present **Postdoctoral researcher, KU Leuven, Belgium.**
 - Started teaching of (parts of) bachelor courses on Electrical Networks and Control Theory.
 - Mentored four master students during their thesis.
- 2014–present **Lead developer and maintainer Tensorlab, KU Leuven, Belgium.**

Tensorlab is a Matlab toolbox for tensor computations and complex optimization.

 - Released Tensorlab 3.0 (www.tensorlab.net) with a focus on large-scale tensor analysis and user friendliness, while broadening the application range. This release has been download by 3500+ unique academic and industrial users since March 2016.
 - Contributed 12000 lines of code (75% of all code) and 100+ pages of documentation and demos.
 - Currently coordinating a three-person team to develop Tensorlab 4.0.
- 2013–present **Teaching assistant, KU Leuven, Belgium.**
 - Teacher for (parts of) two bachelor courses with 30-40 students since 2018.
 - Organizer of hands-on sessions during three international summer/winter schools on tensor decompositions with 40-60 participants.
 - Teaching assistant for the exercise sessions of five bachelor and master courses.
- 2013–2018 **PhD researcher, KU Leuven, Belgium.**
 - Developed various algorithms to analyze large-scale, multiway datasets or tensors using compact representations, e.g., to handle gigabyte and terabyte scale tensors on a laptop.
 - Mentored three master students during their thesis.
 - Actively collaborated as tensor expert in biomedical and material sciences applications.

Diplomas

- May 2019 **Doctor of Engineering Science (PhD): Electrical Engineering, KU Leuven, Leuven.**
Thesis: "Compressed sensing approaches to large-scale tensor decompositions."
Summa cum laude with congratulations from the Board of Examiners
- Jul 2013 **Master of Science in Engineering: Mathematical Engineering, KU Leuven, Leuven.**
Thesis: "Efficient tensor-based methods for signal separation and modeling."
Summa cum laude (86.08%)
- Jul 2011 **Bachelor of Science in Engineering, KU Leuven, Leuven.**
Major: Computer Science | Minor: Electrical Engineering
Magna cum laude (79.65%)
- Jun 2008 **Greek, Latin and Mathematics, Sint-Gummaruscollege, Lier.**
Summa cum laude (90.00%)

Honors and awards

- Dec 2019 **IBM Innovation Award**, *FWO/FNRS and IBM Belgium*.
Award for excellent PhD thesis that presents an original contribution to informatics or its applications (EUR 5000).
- June 2019 **Junior postdoctoral fellowship**, *Research Foundation—Flanders (FWO)*, Belgium.
Postdoc grant for four years.
- May 2019 **Nokia Bell Scientific Award**, *FWO/FNRS and Nokia Belgium*.
Award for excellent PhD thesis in information and communication technology (EUR 8000).
- June 2018 **Postdoctoral Mandate**, *Internal Funds—KU Leuven*, Belgium.
Postdoc grant for one year.
- Sep 2016 **Best poster award**, *Benelearn 2016*, Kortrijk, Belgium.
- June 2015 **Gene Golub SIAM Summer School on RandNLA**, *SIAM*, Delphi, Greece.
Highly selective and fully paid two-week summer school.
- June 2013 **FWO Aspirant Grant**, *Research Foundation –Flanders (FWO)*, Belgium.
PhD grant for four years.

Papers

International journal papers

- [1] N. Vervliet, O. Debals, and L. De Lathauwer, "Exploiting efficient representations in tensor decompositions," *SIAM J. Sci. Comput.*, vol. 41, no. 2, A789–A815, Mar. 2019. DOI: doi.org/10.1137/17M1152371.
- [2] F. Van Eeghem, O. Debals, N. Vervliet, and L. De Lathauwer, "Coupled and incomplete tensors in blind system identification," *IEEE Trans. Signal Process.*, vol. 66, no. 23, pp. 6137–6147, Oct. 2018. DOI: [10.1109/TSP.2018.2873545](https://doi.org/10.1109/TSP.2018.2873545).
- [3] M. Boussé, N. Vervliet, I. Domanov, O. Debals, and L. De Lathauwer, "Linear systems with a canonical polyadic decomposition constrained solution: Algorithms and applications," *Numer. Linear Algebra Appl.*, vol. 25, no. 6, e2190, Aug. 2018. DOI: [10.1002/nla.2190](https://doi.org/10.1002/nla.2190).
- [4] N. Vervliet and L. De Lathauwer, "A randomized block sampling approach to canonical polyadic decomposition of large-scale tensors," *IEEE J. Sel. Topics Signal Process.*, vol. 10, no. 2, pp. 284–295, Mar. 2016. DOI: [10.1109/JSTSP.2015.2503260](https://doi.org/10.1109/JSTSP.2015.2503260).
- [5] N. Vervliet, O. Debals, L. Sorber, and L. De Lathauwer, "Breaking the curse of dimensionality using decompositions of incomplete tensors: Tensor-based scientific computing in big data analysis," *IEEE Signal Process. Mag.*, vol. 31, no. 5, pp. 71–79, Sep. 2014. DOI: [10.1109/MSP.2014.2329429](https://doi.org/10.1109/MSP.2014.2329429).

International conference papers

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- [17] N. Vervliet, "Compressed sensing approaches to large-scale tensor decompositions," PhD thesis, May 2018.
- [18] O. Debals and N. Vervliet, "Efficiënte tensorgebaseerde methoden voor modellering en signaalscheiding," (Dutch), Master's thesis, KU Leuven, 2013.

Extracurricular activities

- 2013–2018 **Board of directors, *Academics for Companies*, Leuven.**
Coach of yearly chosen managers for IT, student consulting and (vice-)president, and part of the long-term strategy team. (AFC is a non-profit student consulting organization.)
- Summer 2012 **Research intern at the biomedical engineering department, *Materialise*, Leuven.**
My research on new and promising mathematical techniques has revealed multiple new ways to interpret and use statistical models in biomedical engineering.

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