



POEMA

H2020-MSCA-ITN-2018

**Polynomial Optimization, Efficiency through
Moments and Algebra**

PERSONAL CAREER DEVELOPMENT PLAN

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Introduction

The Personal Career Development Plan (PCDP) describes both near and long term objectives of the fellow, to reflect on their progress, plan their future development, and take actions to realize their plans. The document must be completed and updated every 12 month by the fellow and his/her advisor. It will be monitored yearly by the Educational Committee who will also provide the feedback assessment results of the training programme on the occasion of the yearly meeting. Major deviations from the plan should be reported to the Educational Committee.

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Individual Research Plan

1.1 Host Institution

Centrum Wiskunde en Informatica (CWI), Amsterdam,
Group: Networks and Optimisation (N&O).

1.2 PhD Advisor(s)

Monique Laurent and Etienne de Klerk

1.3 PhD Thesis Supervisor Committee (if applicable)

N/A

1.4 Short overall project description

This project aims to investigate hierarchies of approximations for general polynomial optimization problems. The methodology will rely on combining tools from real algebra, moment theory, operator theory, and semidefinite optimization. Examples of questions that may be addressed include:

- Convergence analysis of the approximation hierarchies;
- Genericity of finite convergence and optimality certificates;
- Exploring techniques (like sparsity and using appropriate polynomial bases) to make the computation of the non-commutative hierarchies more efficient.

1.5 First secondment

CNRS-LAAS in Toulouse, France. September to November 2020

1.6 Second secondment

Numerical Algorithms Group (NAG), Oxford, UK July to September 2021

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Research Outputs, Dissemination and Mobility

2.1 Research results

I have conducted a literature review that includes the following publications:

1. A Course on Semidefinite Optimization (Draft Lecture Notes): M. Laurent, F. Vallentin.
2. Approximate Volume and Integration for Basic Semialgebraic Sets (SIAM Review), D. Henrion, J. B. Lasserre, C. Savorgnan.
3. An Introduction to Polynomial and Semi-Algebraic Optimization, J.B. Lasserre, Cambridge University Press, 2015.

2.2 Research publications

Not yet applicable since my employment at CWI in 15 Oct. 2019

2.3 Dissemination and networking

I now list and briefly describe the conferences I have participated in:

1. LNMB Lunteren, Netherlands 13 Jan. 2020 (This is an annual conference of the Dutch network on the mathematics of Operations Research.)
2. 1st POEMA Workshop, Florence, Italy 15-17 Jan. 2020

I have also participated in the following seminars all provided under CWI

1. N&O Group seminars
2. Reading group on Random Matrices (Studying proofs used in the topic of Random Matrices.) <https://makrandsinha.github.io/reading/>
3. QuSoft Seminar (CWI) (A seminar concerned with algorithms and protocols for quantum computers.)
4. CWI Lectures on Programming and Cryptology 2019 (21 - 22 Nov 2019) (An annual event hosted by CWI with varying topic.)
5. CWI Scientific Meeting 29 Nov 2019 (An event hosted by CWI where new CWI researchers present some of their work.)

I have presented a lecture on the topic:

1. Concentration of Empirical Spectra Distribution, Herbst Method, Talagrand's inequality (26 Nov 2019) (This was part of my involvement with the Reading group on Random Matrices.)

I plan to attend the following events.

1. POEMA learning week, Konstanz, Germany, 23-27 Mar. 2020.
2. 2nd POEMA Workshop, Konstanz, Germany, 30 Mar. - 4 Apr. 2020.
3. 56th Dutch Mathematical Congress (NMC), Utrecht, Netherlands, 14-15 Apr. 2020.
4. SDP day CWI Amsterdam, Netherlands, 6-7 May 2020.
5. (Tentatively) Summer School: Topics in real algebraic geometry, Nordfjordeid, Norway, 22-26 Jun 2020.

I also plan to participate in a reading group on Polynomial optimisation hosted in CWI, Amsterdam, Netherlands. I plan to present a lecture on: Approximate Volume and Integration for Basic Semialgebraic Sets, 29 Jan. 2020.

I hope to broaden my network by interacting more with the following networks.

1. *DIAMANT: 'Discrete, Interactive and Algorithmic Mathematics, Algebra and Number Theory.'* One of the four mathematical clusters of the Netherlands of which CWI is a participant. DIAMANT organises a semi-annual DIAMANT symposium usually in May and November. <http://websites.math.leidenuniv.nl/diamant/>
2. *LNMB: 'Landelijk Netwerk Mathematische Besliskunde'* This network is an inter university co-operation in which all Dutch universities and the Centre for Mathematics and Computer Science (CWI) in Amsterdam participate. LNMB offers courses in Mathematics of Operations Research for PhD and Master students. <https://www.lnmb.nl/pages/home/>
3. *MINOA (contact via ESR): 'Mixed Integer Non-Linear Optimisation Algorithms and Applications'* . This is EU-ITN which has CWI and Tilburg University as participants. I am in contact with ESR's part of this network. <https://minoa-itn.fau.de/>

2.4 Software, Data, other

Not yet available.

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Personal Training Plan

3.1 Scientific training courses

I followed master's level courses in optimisation offered by LNMB (<https://elo.mastermath.nl/>). I did so as a brief refresher on many of the commonly used topics.

Continuous Optimization - M1 - 6EC (Attended most of the classes), Utrecht University, Netherlands.

Discrete Optimization - M1 - 6EC (Attended most of the classes and exam, results pending), Utrecht University, Netherlands.

I am currently taking the following PhD Courses closer to my field of research:

IntPM: Integer Programming Methods -4 EC ,Utrecht University, Netherlands.

NCG: Noncooperative Games -4 EC ,Utrecht University, Netherlands.

Further details available at: <https://www.lnmb.nl/pages/courses/>

For the future I plan to take the following course

Semidefinite Optimization - M1 - 8EC, Vrije Universiteit, Netherlands, starting Feb. 2020.

This course is given by my supervisor and is directly applicable to the topics of our research.

3.2 Complementary training courses

Under CWI I have benefited and will benefit from the following complimentary courses.

1. Scientific Integrity I & II 20, 27 Nov. 2019
2. Taking Charge of your PhD project 19 May and 2 Jun 2020

I hope in the near future to acquire training in the following:

3. Learning French in anticipation of my secondment in Toulouse (Date to be established).
4. Becoming proficient in Julia programming language.

3.3 Professional skill development

I plan to develop the following professional skills:

1. *Journaling: to better keep track of my research efforts.*
2. *Active recall: a technique to better retain what I have studied.*
3. *Being more inquisitive concerning the work of my colleagues at CWI and POEMA.*

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Personal Career Development

4.1 Plan for the next period

For the foreseeable future I plan on investigating hierarchical bounds for:

1. Matrix factorization ranks e.g. nonnegative rank, positive semidefinite rank and binary factorization rank.
2. Separable decomposition of tensors.
3. Noncommutative polynomial optimization.

Many of the above topics have been inspired by quantum information optimization problems. These problems have also been proven to be hard and as such require approximation techniques to become tractable.

As I encounter the above mentioned topic I will apply my growing knowledge of approximation hierarchies and attempt to derive results concerning convergence, optimality certificates and the effect of sparsity. I seek to explore the differences between hierarchies through these problems.

To start my investigation I have joined a reading group containing these topics in its focus. In this reading group I will also present the above mentioned topics.

Lastly I would like to note that there is a postdoctoral student here at CWI well versed in these topics. I intend to draw upon his knowledge as well as that of my supervisor.

4.2 Career objectives (Postdoctoral project, ...)

My objectives can be summarized as follows.

- *Publish scientific papers in reputable Journals.*
- *Build a network of motivated mathematicians and benefit from their knowledge.*
- *Possible create a startup based on innovations discovered during this PhD.*
- *Foster symbiotic connections with industry that will last beyond my PhD.*
- *Finnish my PhD program in the allocated 3 years.*