



POEMA

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**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.

1 Individual Research Plan

1.1 Host Institution

LAAS-CRNS, Toulouse, France

1.2 PhD Advisor(s)

Milan Korda, Pierre Weiss

1.3 PhD Thesis Supervisor Committee (if applicable)

1.4 Short overall project description

Polynomial Optimization: Some challenges from applications

Many problems in nonlinear dynamical systems and control can be cast as infinite-dimensional linear programming problems in the space of Borel measures. The Lasserre's moment-sum-of-squares hierarchy can then be deployed to obtain a sequence of finite-dimensional convex semidefinite programming problems whose solutions approximate, and typically converging to, the solution of the original problem (e.g., [5, 1, 3]). The broad aim of this project is to develop this framework further. There are two concrete directions to investigate. The first direction will try to develop this framework for analysis and control of nonlinear partial differential equations. Here, preliminary results already exist [2, 6] but without convergence guarantees in the most general setting [2] and with only preliminary numerical results. The second direction will try to leverage spectral theory of linear operators with the aim to gain theoretical understanding as well as computational advantage within the moment-sum-of-squares framework for nonlinear systems. The starting point would be the close connection to the Koopman and Perron-Frobenius operator frameworks (e.g., [7]).

1.5 First secondment

CWI, Amsterdam, Monique Laurent's group. The secondment will take place when it is possible, presumably late 2021 or beginning of 2022.

1.6 Second secondment

IBM, Dublin. The secondment will take place in 2022, presumably from May to July.

2 Research Outputs, Dissemination and Mobility

2.1 Research results

- *Converging outer approximations to global attractors using semidefinite programming:*

Characterization of global attractors by a linear program on the space of Borel measures. For polynomial systems a corresponding hierarchy of semidefinite programs, whose solutions give outer approximations of the global attractor with guaranteed convergence, is formulated.

- *Sparse moment-sum-of-squares relaxations for nonlinear dynamical systems with guaranteed convergence*

We exploit specific sparse structures in dynamical systems which allow decompositions into smaller systems. This approach is combined with methods for computing several interesting objects for dynamical systems, as the region of attraction, the maximum positively invariant set and global attractors, based on hierarchies of semidefinite programs.

2.2 Research publications

-<https://arxiv.org/abs/2005.03346>

-<https://arxiv.org/abs/2012.05572>

2.3 Dissemination and networking

- *presentations at conferences/workshops (network events, other events): POP Brainstorming day*
- *Internal POEMA day, November 27th 2020, talk on computing global attractor based on sum-of-squares relaxations.*
- *presentation at the 18th Workshop on advances in continuous optimization (EUROPT 20) canceled.*
- *participation to conferences/workshops (network events, other events, research visits, etc): Online POEMA workshops, POP Brainstorming day, seminars and workshops at LAAS-CNRS.*
- *list the anticipated networking opportunities for the new period: Unclear due to current situation*

2.4 Software, Data, other

Code accompanying the paper “*Converging outer approximations to global attractors using semidefinite programming*” available from: <https://homepages.laas.fr/mkorda/Attractor.zip>

3 Personal Training Plan

3.1 Scientific training courses

Taken courses:

POEMA online learning weeks

List of courses that are planned to be taken:

-Courses at the University of Toulouse, Paul Sabatier

-Learning weeks, as part of the POEMA program

-Summer/Winter schools

-Workshops

Dates and specific information unclear due to the current situation.

3.2 Complementary training courses

3.3 Professional skill development

4 Personal Career Development

4.1 Plan for the next period

-Exploiting sparse structures for problems obtained by dynamical systems, as for example for global attractors. Some of such sparse structures can be translated to sparse structures in corresponding moment or sum-of-squares problems.

-Investigating particle flows obtained as gradient flows (with respect to the Wasserstein metric for example) as a possible approach to (linear) optimization problems on measures.

4.2 Career objectives (Postdoctoral project, ...)

- *Getting in contact with researchers, groups and their work hopefully creates possibilities to apply for further projects and to learn more.*
- *The POEMA network therefore is a great starting point and I am sure the secondments will provide me with more insights towards my career objectives.*