ANR
Programme non thématique 2005

I - FICHE D'IDENTITE DU PROJET

N° dossier : `:NT05-1 43039 :Noll :Dominikus :`

Secteur disciplinaire principal : *STIC*

Autre secteur disciplinaire facultatif : *Mathématiques et interactions*

Titre du projet
Nouvelles stratégies pour le guidage et la commande de systèmes

Acronyme ou titre court	Guidage

Mots-clés
Commande en rétroaction, systèmes de l'aéronautique et de l'espace, systèmes mécaniques, systèmes de puissance, optimisation non-linéaire, analyse non-lisse, problèmes NP-difficiles en automatique, synthèse de lois de commande, suivi de trajectoires

Coordinateur du projet (Partenaire 1)

Civilité	Nom	Prénom	Laboratoire	Type
Mr	Noll	Dominikus	Université Paul Sabatier Mathématiques pour l'Industrie et la Physique	UMR 5640

Autres partenaires

Civilité	Nom	Prénom	Laboratoire	Type
Mr	Brogliato	Bernard	INRIA Rhône-Alpes	

Nombre de personnes impliquées dans ce projet
(en équivalent temps plein : ETP) :

Chercheurs et enseignants-chercheurs permanents 11, Post-doctorants déjà recrutés 0, Etudiants 3, Ingénieurs et techniciens 0

Durée du projet : ☐ 24 mois ⊗ 36 mois

Montant total de l'aide demandée : 430560

Estimation (pour information) du coût de la demande : 448560

Résumé du projet (maximum 3000 caractères) (objectifs, résultats attendus, méthodologie)
Dans ce projet, nous proposons de développer de nouvelles stratégies en automatique pour le suivi de trajectoires et la synthèse de lois de commande en feedback. Grâce à des techniques de l'optimisation et de l'analyse non-lisse nous comptons résoudre un certain nombre de problèmes difficiles de l'automatique, considérés comme hors d'atteinte avec les techniques existantes. Cela concerne la commande et le guidage de systèmes discontinues et de grande taille, la commande de systèmes avec incertitudes paramétriques, la commande de systèmes sous-actionnés ou fortement non-linéaires, la synthèse de compensateurs structurés, d'ordre réduit ou décentralisés, et la stabilisation simultanée pour des systèmes sécurisés. Ce projet conduira à une plate-forme informatique de calcul efficace. Les applications visées concernent les systèmes de l'aéronautique et du spatial, de la robotique ou de la mécanique avec frottement, des systèmes électriques ou des systèmes de puissance.

Abstract (not more than 3000 characters) (objectives, expected results, methods)
We develop new strategies and software tools for challenging problems in automatic control, including tracking and feedback controller synthesis for systems with parametric uncertainties, systems with discontinuities, highly nonlinear and underactuated systems, control of systems with a large number of states, structured, decentralized and reduced order control, and simultaneous stabilization to enhance system security. Applications include control and tracking of aeronautic and space systems, electrical power networks, robotics and mecanical systems with Coulomb friction. We develop and apply new ambitious nonsmooth optimization techniques for tracking and control of these systems, which allow us to solve challenging but practically important problems in automatic control for which existing techniques are not appropriate. We will create a new software platform which expands on existing tools based on algebraic Riccati equations and linear matrix inequalities.

Je déclare exactes les informations contenues dans ce document
Visa du directeur du laboratoire

Lu et approuvé, date et signature du coordinateur du projet
Noll, Dominikus 08/06/2005

II - PRESENTATION DETAILLEE DU PROJET

A - Identification du coordinateur et des autres partenaires du projet

Acronyme ou titre court du projet : Guidage

A-1 - Partenaire 1

Civilité	Nom	Prénom
Mr	Noll	Dominikus

Grade | Professeur	
Mail | noll@mip.ups-tlse.fr	
Tél.| 05.61.55.86.22	**Fax.** | 05.61.55.83.85
Laboratoire| Mathématiques pour l'Industrie et la Physique	
N^O Unité | UMR 5640	
Adresse du laboratoire | 118, route de Narbonne	
Ville | Toulouse | code postal| 31062 | Région | 31	
Organisme de tutelle | Université Paul Sabatier	

Principales publications :

1. **D. Noll, M. Torki and P. Apkarian**, Partially augmented Lagrangian method for matrix inequalities. SIAM Journal on Optimization, vol. 15, no. 1, 2004, pp. 161 – 184.
2. **D. Noll and P. Apkarian**, Spectral bundle methods for non-convex maximum eigenvalue functions I + II, Math. Programming Series B, (2005), à paraître.
3. **P. Apkarian and D. Noll**, Controller design via nonsmooth multi-directional search. SIAM J. on Control and Optimization, (2005), à paraître.
4. **P. Apkarian, P. Pellanda, H.D. Tuan**, Mixed H_2/H_∞ multi-channel linear parameter-varying control in discrete time, Systems and Control Letters, vol. 41, pp. 333-346, 2000.
5. **D. Alazard and P. Apkarian**, Exact observer-based structures for arbitrary compensators, International J. of Nonlinear and Robust Control, no. 9, 1999, pp. 101 – 118.

Coordinateur (Partenaire 1)

Coordinateur	Noll	Dominikus	Professeur UPS, MIP, Toulouse	100%

100% de temps consacré au projet. Chercheur principal. Spécialité : Optimisation non-linéaire et non-lisse. Développement de stratégies algorithmiques. Automatique.

Membre	Apkarian	Pierre	Ingénieur chercheur ONERA Toulouse PAST UPS	80% 20%

100% de temps consacré au projet. Chercheur principal. Spécialité : Automatique, systèmes aéronautiques et spatiaux. Développement d'algorithmes pour la synthèse.

Membre	Pellanda	Paulo	Instituto Militar de Engenharia Rio de Janeiro	100%

60% de temps consacré au projet. Spécialité : Commande LPV. Interlocuteur pour des applications de nos méthodes aux systèmes et réseaux de puissance.

Membre	Alazard	Daniel	Professeur Supaero, Toulouse	100%

60% de temps consacré au projet. Spécialité : Applications aux systèmes aéronautiques et spatiaux. Interlocuteur pour des projets industriels.

Membre	Swevers	Jan	Professor KU Leuven, Belgique Dep. of Mechanical Engineering	100%

20% de temps consacré au projet. Spécialité : Applications de la commande en feedback aux systèmes mécaniques. Plusieurs études permettant de tester nos méthodes sont envisagées en coopération avec le groupe de Swevers : contrôle actif de bruit, réduction de vibrations, poursuite robuste, commande paramétrique robuste pour fraiseuses de grande vitesse (control of high speed milling).

Consultant	Vacher	Pierre	ingénieur de recherche ONERA, Toulouse	100%

10% de temps consacré au projet. Consultant pour les aspects d'identification et de réduction de systemes.

Consultant	Bes	Christian	Professeur de Mécanique Université Paul Sabatier	100%

20% de temps consacré au projet. Consultant pour le milieu industriel aéronautique et interlocuteur avec Airbus Industries.

Membre	Diehl	Moritz	Assistant Professor IWR Universität Heidelberg	100%

30% consacré au projet. Spécialité : commande optimale et commande prédictive. Participera sur deux thèmes, l'intégration de contraintes simulées (par méthode de tir multiple) dans la synthèse de compensateurs, et deuxièmement, commande de système périodiques non-linéaires.

Membre	Bompart	Vincent	thésard ONERA, Toulouse	100%

100% consacré au projet. Développement de méthodes non-lisses. Méthodes du second ordre. Optimisation de la norme H_∞.

Membre	Thevenet	Jean-Baptiste	thésard ONERA, Toulouse	100%

100% consacré au projet. Développement de méthodes non-lisses. Optimisation de valeurs propres. Logiciel *specSDP*.

Curriculum vitae - Dominikus Noll

−48 ans, nationalité allemande

- Dr. rer. nat. Universität Stuttgart (Allemagne) 1983
- Habilitation à diriger des recherches (HDR) à Stuttgart 1989
- Assistant (MCF) Universität Hohenheim, Dep. of Statistics, Allemagne 1982 - 83
- Assistant (MCF) Universität Stuttgart, Dep. of Mathematics, 1983 - 89
- Professeur (C2) Universität Stuttgart, Dep. of Mathematics, 1989 - 1995
- Professeur à Halifax (Canada), Dalhousie University, Dep. of Mathematics, Statistics, and Computer Science, 1990-91
- Professeur à Waterloo (Canada), Dep. of Combinatorics and Optimization, 1993-94
- Professeur de Mathématiques Appliquées à Toulouse depuis 1995

Intérêts scientifiques : Optimisation numérique, recherche opérationnelle, automatique, imagerie médicale.

1. **D. Noll, P. Apkarian**, Spectral bundle methods for nonconvex maximum eigenvalue functions. Part I : first order methods, part II : second-order methods,
   Math. Programming, Series B, à paraître.
2. **D. Noll, M. Torki, P. Apkarian**, Partially augmented Lagrangian method for matrix inequalities,
   SIAM J. Optimization, vol. 15, no. 1, 2004, pp. 161 – 184.
3. **P. Apkarian, D. Noll, H.D. Tuan**, Fixed-order $\mathcal{H}_\infty$ control design via an augmented Lagrangian method,
   Int. Journal of Robust and Nonlin. Control, vol. 13, no. 12, 2003, pp. 1137 – 1148.
4. **P. Apkarian, D. Noll**, Controller design via nonsmooth multi-directional search,
   SIAM J. Control and Optimization, à paraître.
5. **B. Fares, D. Noll, P. Apkarian**, Robust control via sequential semidefinite programming,
   SIAM Journal on Control and Optimization, vol. 40, no. 6, 2002, pp. 1791 – 1820.

- Prix pour la thèse par les *Freunde de Universität Stuttgart*.
- Editeur associé du Journal of Convex Analysis.
- Membre de 3 commissions de spécialistes de la 26ème section (INSA Toulouse, Limoges, Perpignan).
- Membre du CNU 26ème section.
- Membre du conseil du laboratoire MIP et résponsable du groupe optimisation et interaction du labo.
- Partenaire universitaire externe du projet *Algorithmes de Calcul pour l'Automatique de Dimension Elevée* (ALCADE) de l'ONERA Toulouse.

Curriculum Vitae - Pierre Apkarian, 45 ans

- APKARIAN Pierre, 14.01.1960
  Nationalité Française, célibataire, 1 enfant. Adresse personnelle :
  2, chemin Clair Bois, Bat. N, 31500 - Toulouse
  Tel : 05 61 80 49 37
- Profession : Ingénieur de Recherches, ONERA-CERT, 2, av. Edouard Belin, 31055 - Toulouse - Tel : 05 62 25 27 84
- Adresse electronique : apkarian@cert.fr
- Page internet : http ://www.cert.fr/dcsd/cdin/apkarian/

Formation

- 1979–82 **Classes Préparatoires** – Lycée P. de Fermat Toulouse
- 1982–85 **Diplome d'Ingénieur de l'ESIEA**
  (Ecole Supérieure d'Informatique, Electronique, Automatique - PARIS)
  - Major Promotion 1985
- 1984 **Maitrise de Mathématiques Pures**
  (Université Paris VII)
  - Mention Bien
- 1985 **D.E.A Automatique et Traitement du Signal**
  (Université Paris VII / Ecole Supérieure d'Electricite-LSS)
  - Mention Bien
- 1986–1987 **Doctorat en Automatique de l'ENSAE**
  (Ecole Nationale Supérieure de l'Aeronautique et de l'Espace/CERT)
  - Mention Très Honorable
  - Prix Meilleure Thèse AFCET 88 en Automatique - Catégorie Théorie
- 1997 **Habilitation à Diriger des Recherches**
  (Université Paul Sabatier - Toulouse III)
- 1999 Qualification aux fonctions de professeur des universités
  section CNU 61 - genie informatique, automatique et traitement du signal (effet 09/03/99).
- 2001 Qualification aux fonctions de professeur des universités
  section CNU 26 - mathématiques appliquées et applications des mathématiques (effet 24/01/2001).

Sélection de 5 publications

1. **P. Apkarian and D. Noll**, Controller design via nonsmooth multi-directional search 2nd IFAC Symposium on System, Structure and Control, Oaxaca, Mexico, 2004. Also to appear in SIAM Journal on Control and Optimization
2. **P. Apkarian and D. Noll and J.B. Thevenet H.D. Tuan**, A spectral quadratic-SDP method with applications to fixed-order H_2 and H_∞ synthesis Asian Control Conference, Melbourne, Australia, 2004. European J. of Control, vol. 10(6), pp. 527-538, 2004.
3. **P. Apkarian and D. Noll and H.D. Tuan**, Fixed-Order H_∞ Control Design via a Partially Augmented Lagrangian Method International Journal of Robust and Nonlinear Control., vol. 13, no. 12, pp. 1137-1148, 2003.
4. **P. Apkarian, P. Pellanda, H.D. Tuan**, Mixed H_2/H_∞ multi-channel linear parameter-varying control in discrete time Systems and Control Letters, vol. 41, pp. 333-346, 2000.
5. **P. Apkarian, H.D. Tuan, J. Bernussou**, Continuous-time analysis and H_2 multi-channel synthesis with enhanced LMI characterizations IEEE Trans. Automatic Control, vol. 46, no. 12, pp. 1941-1946, 2001.

Curriculum vitae - Alazard Daniel, 42 ans

Professeur d'automatique, SUPAERO
2, av Ed. Belin, Toulouse
Tel : +33 5 62 17 80 94
Fax : +33 5 62 17 83 45

2003 : Habilitation a Diriger les Recherches, Universite Paul Sabatier
1986 : Ingenieur de l'Ecole Nationale Superieure des Arts et Métiers (medaille d'Or).

1. **C. Cumer, F. Delmond, D. Alazard and C. Chiappa.** Tuning of observer-based controllers. Journal of Guidance Control and Dynamics (AIAA), Vol 27, No. 4, july-august 2004.
2. **S. Alazard, O. Voinot and P. Apkarian.** A new approach to multi-objective control design from the viewpoint of the inverse optimal control problem. IFAC Symposium on System Structure and Control SSSC'04, 8-10 décembre 2004, Oaxaca (Mexique).
3. **S. Alazard, N. Imbert, B. Clément and P. Apkarian.** Launcher attitude control : some additional and optimization tools. CNES/EADS Conference on Launcher Technology, novembre 2003, Madrid.
4. **D. Alazard.** Comments on the benchmark for "Design and optimization of restricted complexity controllers" : towards a non-parametric model based solution. European Journal of Control - Special Issue, Vol.9, No. 1, 2003
5. **D. Alazard.** Cross Standard Form for generalized inverse problem : application to lateral flight control of a highly flexible aircraft. ICNPAA 2002 (International Conference on Nonlinear Problems in Aviation and Aerospace), Melbourne (Florida), mai 2002.

CURRICULUM VITAE - PELLANDA Paulo César, 42 ans

• Né le 13 Novembre 1962 à CURITIBA, Paraná, Brésil
Adresse professionnelle : Instituto Militar de Engenharia -IME, Departamento de Engenharia Elétrica, Praça General Tibúrcio, 80, Praia Vermelha, 22.290-270 - Rio de Janeiro - Brésil Tél : +55 21 25 46 70 30

Formation

• 1999–2001 : **Doctorat en Automatique de l'ENSAE**

École Nationale Supérieure de l'Aéronautique et de l'Espace/ONERA-DCSD, TOULOUSE, France.
- Mention très honorable avec félicitations et Prix meilleure thèse automatique CNRS-France

• 1992–93 : **"Master of Science" en Automatique de l'IME**

Instituto Militar de Engenharia, RIO DE JANEIRO, Brésil.
- Dissertation : mention très bien - Moyenne globale 4.0/4.0.

• 1989 : **Diplôme d'Officier Ingénieur Militaire**
Instituto Militar de Engenharia, RIO DE JANEIRO, Brésil.
- Mention finale : très bien - Moyenne globale 18.6/20.0.

• 1981–85 : **Diplôme d'Ingénieur Électricien Industriel**

Centro Federal de Educação Tecnológica do Paraná, CURITIBA, Brésil.
- Mention finale : bien - Moyenne globale 15.2/20.0.

Publications principales

1. **P.C. Pellanda, A. M. Simões, P. Apkarian and D. Alazard.**, Synthesis of missile gain-scheduled autopilots using an H_∞-LPV technique, Journal of Nonlinear Studies, Special Issue on Control in Defense Systems, I&S Publishers, Daytona Beach, FL, USA, Vol. 11, no. 2, pp. 243-276. 11(2) :243-276, 2004.
2. **P.C. Pellanda and P. Apkarian.** Synthesis of controllers for modal shaping in linear parameter-varying systems via the implicit model following formulation, Proceedings of the American Control Conference-ACC, vol. 6, pages 5161-5166, Denver, Colorado, June 4-6, 2003.
3. **P.C. Pellanda et P. Apkarian.** Une méthode d'interpolation de structures estimation/commande pour des compensateurs H_∞ et μ. Dans le livre : Conception de Commandes Robustes, édité par J. Bernussou et A. Oustaloup. Hermès Science Publications, Paris, pages 269-315, 2002.
4. **P.C. Pellanda and P. Apkarian.** Missile autopilot design via a multi-channel LFT/LPV control method, International Journal of Robust and Nonlinear Control, John Wiley & Sons, Ltd. 12(1) :1-20, January 2002.
5. **P. Apkarian, P.C. Pellanda and H.D. Tuan.** Mixed H_2-H_∞ multi-channel linear parameter-varying control in discrete time, System & Control Letters, Elsevier Science B.V., 41(5) :333-346, 2000.

CV Moritz Diehl, 32 ans

Education and Employment :

2001-	C1 assistant within Interdisciplinary Center for Scientific Computing (IWR), Heidelberg Univ.
Jan-Mar 2003	Long term fellow within "Optimization Year", Institute for Mathematics and its Applications, Minneapolis
1999-2001	Ph.D., Heidelberg Univ. "Real-Time Optimization of Large Scale Processes", summa cum laude
1993-1999	"Diplom" (Master) in Physics, Heidelberg Univ., with distinction
1995-1996	Univ. Cambridge, Mathematical Tripos, Part II B, first class pass
1991-1993	Civilian service at office for environmental affairs, Hamburg
1991	"Abitur" (A-Level), Gymn. Lerchenfeld, Hamburg (1.0)

Awards and Honours :

– invited plenary speaker at "German Polish Conference in Optimization", 2005
– winner of "Klaus Georg and Sigrid Hengstberger Prize" (Euro 15.000, with K. Mombaur) to organize the 1st Ruperto Carola Symposium, after Heidelberg university wide competition in 2004
– outstanding reviewer of IEEE Transactions on Automatic Control in 2004
– winner of "Prix Dodu" for best presentation of a young researcher at "journees MODE", Montpellier, 2002
– invited lecture at official Ph.D. celebration ceremony for the natural sciences in Heidelberg university in autumn 2001

Recent Journal Articles :

1. **M. Diehl, H. G. Bock, and J. P. Schlöder**, A Real-Time Iteration Scheme for Nonlinear Optimization in Optimal Feedback Control, SIAM J. Con. & Optim., Vol 43, No 5, pp. 1714-1736 (2005)
2. **M. Diehl and Jakob Björnberg**, Robust Dynamic Programming for Min-Max Model Predictive Control of Constrained Uncertain Systems, IEEE Trans. Aut. Cont., Vol 49, No 12, pp. 2253-2257 (2004).
3. **M. Diehl, L. Magni, G. De Nicolao**, Efficient NMPC of Unstable Periodic Systems using Approximate Infinite Horizon Closed Loop Costing. IFAC Annual Reviews in Control, Vol 28, No 1, pp. 37-45, (2004).
4. **M. Diehl, R. Findeisen, F. Allgöwer, H.G. Bock, J.P. Schlöder**, Nominal Stability of the Real-Time Iteration Scheme for Nonlinear Model Predictive Control. IEE Contr. Theory and Appl. (in print).
5. **M. Diehl, H.G. Bock, J.P. Schlöder, R. Findeisen, Z. Nagy, and F. Allgöwer**, Real-time optimization and nonlinear model predictive control of processes governed by differential-algebraic equations. Journal of Process Control, Vol. 12, No. 4, pp. 577-585 (2002).

Curriculum vitae - Bes Christian, 48 ans

Né le 24 décembre 1956 à Aubin (12).
84,Avenue des Pyrenées, 31600 Muret.
Tél : 05 61 51 17 59
Fax : 06 62 11 23 79
e-mail :`cbes@cict.fr`

Expérience professionnelle

- 1982-1984 : Laboratoire d'Automatique et d'Analyse des Systèmes (L.A.A.S), Toulouse, Préparation d'une thèse de 3ème Cycle.
- 1984-1986 : Faculty of Management Studies, University of Toronto, Canada, Post-doc
- 1986-2000 : EADS/AIRBUS, Chef de Service/Expert Scientifique .
- 2000——— : Université Paul Sabatier. Professeur de Mathématiques Appliquées et de Mécanique.

Formation

- 1984 : Doctorat de 3éme cycle, Spécialité : Automatique, Université Paul Sabatier, Toulouse.
- 1995 : Diplôme d'Habilitation à Diriger des Recherches, Spécialité : Mathématiques Appliquées, Université Paul Sabatier, Toulouse.

Principales activités de recherche

Modélisation et conception de systèmes dans les domaines suivants : Analyse des données, commande optimale, identification, fiabilité, optimisation,

Principaux contrats de recherche en cours

- Optimisation multidisciplinaire au stade avant projet avion (AIRBUS)
- Optimisation multidisciplinaire de l'architecture des commandes de vol (AIRBUS)
- Modélisation de la disponibilité et de la fiabilité en phase de conception (AIRBUS)
- Définition de stratégies de maintenance optimales (AIRBUS)

Publications les plus significatives

1. **M. Mongeau, C. Bes** Aircraft maintenance jacking problem via optimization. IEEE Transactions on Aerospace and Electronic Systems, vol 41,no. 1,2005
2. **S. Segond, J. M. Redonnet, C. Bes, Y. Landon, P. Lagarrigue**, Characterisation of the workpiece dilatation phenomenon during machining using the neural network method : Application to NC Turning. International Journal of Advanced Manufacturing Technology, January, 2005.
3. **M. Mongeau, C. Bes,** Optimization of aicraft container loading. IEEE Transactions on Aerospace and Electronic Systems, vol. 39, no. 1, 2003.
4. **C. Bes, S. P. Sethi,** Solution of a class of stochastic linear-convex control problems using its deterministic equivalent. Journal of Optimization Theory and Applications, vol. 62, no. 1, July 1989.
5. **C. Bes, S. P. Sethi,** Concepts of forecast and decision horizons : applications to dynamic stochastic optimization problems. Mathematics of Operations Research, vol. 13, no. 2, May 1988.

Curriculum Vitae - Jean-Baptiste Thevenet, 27 ans

– Doctorant, ONERA-CERT, 2, av. Edouard Belin, 31055 - Toulouse
– Né le 03.05.1978, Nationalité Française
Adresse personnelle : 65, rue Lucien Cassagne, Bat. B, 31500 - Toulouse
Tel : 06 62 49 25 84 - Email : thevenet@cert.fr
Page internet : http ://www.cert.fr/dcsd/THESES/thevenet/

Formation

– 2002 **Diplome d'Ingénieur de l'ENSEEIHT**
(Ecole Nat. Sup. d'Electrotechnique, Electronique, Informatique, et Hydraulique, Toulouse)
– 2002 **D.E.A Systèmes Automatiques**
(Institut National Polytechniques (INP) de Toulouse)
- Mention Très Bien
– 2002 – à ce jour **Doctorat en Mathématiques Appliquées de l'UPS**
(Université Paul Sabatier et ONERA - CERT, Toulouse.)
- SIAM Student Award, SIAM Conference on Optimization, Stockholm, May 2005

Sélection de 5 publications

1. **P. Apkarian and D. Noll and J.B. Thevenet H.D. Tuan**, A spectral quadratic-SDP method with applications to fixed-order H_2 and H_∞ synthesis
European J. of Control, vol. 10(6), pp. 527-538, 2004.
2. **J.B. Thevenet, D. Noll, P. Apkarian.** Non linear spectral SDP method for BMI-constrained problems : applications to control design. ICINCO proceedings, 1 :237-248, Portugal, 2004. Informatics in Control, Automation and Robotics, Kluwer Academic Publishers, 2005.
3. **J.B. Thevenet, P. Apkarian, D. Noll.** Reduced-order output feedback control design with specSDP, a code for linear / nonlinear SDP problems. A paraître dans ICCA05 proceedings, Budapest, 2005.
4. **J.B. Thevenet, P. Apkarian, D. Noll.** Description and User's guide of specSDP, a Matlab-interfaced Fortran code to solve linear / nonlinear SDP constrained optimization problems. Rapport technique MIP - UPS, 2005.
5. **D. Noll, J.B. Thevenet.** Augmented Lagrangian methods with smooth penalty functions. Rapport technique MIP - UPS, 2005.

Vincent BOMPART - 27 ans
ONERA Centre de Toulouse
Département Commande des Systèmes et Dynamique du Vol (DSCD)
2 avenue Edouard Belin - BP4025
31055 TOULOUSE CEDEX 4

Adresse personelle :
Résidence Les Héliades, appt. 32
30 chemin de Fages
31400 TOULOUSE

tel. : 05 61 53 54 06 – 06 85 72 46 24
e-mail : *bompart@onera.fr*

27 ans, célibataire (né le 24 juillet 1977 à Rabat, Maroc).

Situation actuelle

Depuis 2004 **Doctorat en Mathématiques Appliquées**
Optimisation non-lisse pour la commande des systèmes de l'aéronautique.
Université Paul Sabatier (Ecole doctorale Mathématiques et Applications),
Laboratoire MIP (Mathématiques pour l'Industrie et la Physique),
Office National d'Etudes et de Recherches Aérospatiales.

Formation

2003-2004	**DESS Modèles Mathématiques et Méthodes Informatiques**, mention Bien Université Paul Sabatier, Toulouse.
2002-2003	**Maîtrise d'Ingénierie Mathématique**, mention Bien Université Paul Sabatier, Toulouse.
1999-2001	**CAPES de Mathématiques**, rang 118 sur 990 en liste principale Institut Universitaire de Formation des Maîtres Midi-Pyrénées, Toulouse.
1997-1998	**Licence de Mathématiques fondamentales** Université Paul Sabatier, Toulouse.
1995-1997	**DEUG MIAS**, mention Assez Bien Université Paul Sabatier, Toulouse.
Juin 1995	**Baccalauréat S**, mention Très Bien, Félicitations du Jury Lycée Gabriel Fauré, Foix.

Stages, expérience professionnelle

Avril-Sept. 2004	**RENAULT S.A.S.** (Direction de la Recherche, Guyancourt) *Optimisation appliquée à la mise au point dynamique des moteurs Diesel.* *Développement en C++ de métaheuristiques pour la réduction des émissions (norme antipollution EURO4).*
Mai-Août 2003	**LAAS** (laboratoire Méthodes et Algorithmes en Commande, Toulouse) *Programmation entière : validation de méthodes itératives pour la résolution de problèmes de type « sac-à-dos » en variables binaires et avec contraintes d'égalité.* *Mise en œuvre en C++ (bibliothèques Xpress-MP et Cplex) sur station Sun.*
2001-2002	**Professeur stagiaire certifié de Mathématiques** Collège Anatole France (Toulouse) : *stage en responsabilité.* Lycée polyvalent Pierre-Paul Riquet (Saint-Orens) : *stage de pratique accompagnée.*

Acronyme ou titre court du projet : Guidage

A-2 : Autres partenaires du projet

Civilité	**Nom**	**Prénom**
Mr	Brogliato	Bernard

Grade |	Directeur de Recherche
Mail |	bernard.brogliato@inrialpes.fr
Tél.| 04.76.61.53.93	**Fax.** | 04.76.61.54.77
Laboratoire|	INRIA Rhône-Alpes
N^o Unité |	
Adresse du laboratoire |	655, avenue de l'Europe, Montbonnot
Ville | St. Ismier | code postal| 38334 |	Région | Rhône-Alpes
Organisme de tutelle |	INRIA

Principales publications :

1. **B. Brogliato, D. Goeleven,** The Krakovskii-LaSalle invariance principle for a class of unilateral dynamical systems,
   Mathematics of Control, Signals and Systems, vol.17, pp.57-76, 2004.
2. **D. Goeleven, B. Brogliato,** Stability and instability matrices for linear evolution variational inequalities, IEEE Transactions on Automatic Control, vol.49, no 4, pp.521-534, 2004.
3. **S. Adly and D. Goeleven** A stability theory for second-order nonsmooth dynamical systems with applications to friction problems. J. Math. Pures Appl., vol. 83, 2004, pp. 17 – 51.
4. **B. Brogliato,** Some perspectives on the analysis and control of complementarity systems, IEEE Transactions on Automatic Control, vol.48, no 6, pp.918-935, 2003.
5. **J. Malick**, A dual approach to semi-definite least-squares problems,
   SIAM Journal of Matrix Analysis and Applications, Volume 26, Number 1, pp.272-284, 2004

Partenaire 2

Coordinateur	Brogliato	Bernard	Directeur de Recherche, INRIA Rhône-Alpes	100%

100% de temps consacré au projet. Chercheur principal. Spécialité : Mécanique, automatique, systèmes avec discontinuités, systèmes hybrides.

Membre	Théra	Michel	Professeur Université de Limoges	100%

80% de temps consacré au projet. Chercheur principal. Spécialité : Optimisation, analyse non-lisse.

Membre	Goeleven	Daniel	Professeur Université de la Réunion	100%

100% de temps consacré au projet. Spécialités : Mécanique, analyse non-lisse, systèmes discontinus, in-équations variationnelles.

Membre	Adly	Samir	MCF, Université de Limoges	100%

100% de temps consacré au projet. Spécialité : analyse non-lisse, mécanique et frottement de Coulomb.

Membre	Malick	Jérôme	thésard, INRIA Rhône-Alpes	100%

100% de temps consacré au projet. Implication : méthodes numériques pour la co-positivité. Méthodes efficaces pour la programmation matricielle non-linéaire.

Consultant	Lemaréchal	Claude	Directeur de Recherches, INRIA Rhône-Alpes	100%

20% de temps consacré au projet. Consultant pour les aspects théoriques et informatiques de l'optimisation non-lisse.

Curriculum vitae - Bernard Brogliato 42 ans

- **a)** Brogliato, Bernard ; 42 ans ; doctorat INP Grenoble (11 janvier 1991) ; Habilitation à diriger de recherches de l'INPG Novembre 1995 ; Directeur de Recherche INRIA
- **b)** Chargé de Recherche au CNRS de Octobre 1991 à Aout 2001.
- **c)**

  1. **B. Brogliato, D. Goeleven,** The Krakovskii-LaSalle invariance principle for a class of unilateral dynamical systems, Mathematics of Control, Signals and Systems, vol.17, pp.57-76, 2004.
  2. **B. Brogliato,** Absolute stability and the Lagrange-Dirichlet theorem with monotone multivalued mapppings, Systems and Control Letters, vol.51, pp.343-353, 2004.
  3. **B. Brogliato,** Some perspectives on the analysis and control of complementarity systems, IEEE Transactions on Automatic Control, vol.48, no 6, pp.918-935, 2003.
  4. **D. Goeleven, B. Brogliato,** Stability and instability matrices for linear evolution variational inequalities, IEEE Transactions on Automatic Control, vol.49, no 4, pp.521-534, 2004.
  5. **B. Brogliato,** Some results on the controllability of planar variational inequalities, Systems and Control Letters, vol.54, pp.65-71, 2005.

- **d)** Prix, distinctions : Prix de thèse INPG 1991, Prix du conseil scientifique du pôle Européen Universitaire et Scientifique de Grenoble, 1996.

Curriculum vitae - Claude Lemaréchal 61 ans

- **a)** 61 ans. Doctorat d'État en Mathématiques à l'Université de Paris-Dauphine ; Directeur de recherche INRIA
- **c)** Publications :

  1. **G. Cornuéjols, C. Lemaréchal,** A convex-analysis perspective on disjunctive cuts, Rapport de recherche INRIA numero 5317, to appear in Mathematical Programming.
  2. **J.-B. Hiriart-Urruty, C. Lemaréchal,** Fundamentals of Convex Analysis, Springer Verlag, 2001
  3. **C. Lemaréchal, F. Oustry,** SDP relaxations in combinatorial optimization from a Lagrangian point of view, Advances in Convex Analysis and Global Optimization (Editors N. Hadjisavvas and P.M. Pardalos), Kluwer, pp. 119-134, 2001
  4. **C. Lemaréchal, F. Oustry, C. Sagastizábal,** The $\mathcal{U}$-Lagrangian of a convex function, Transactions of the American Math. Society, vol. 352, number 2, pp.711-729, 2000
  5. **J.F. Bonnans, J.Ch. Gilbert, C. Lemaréchal, C. Sagastizábal,** Numerical Optimization, Springer Verlag, 2003

- **d)** 1994 Dantzig Prize awarded jointly by Mathematical Programming Society and Society of Industrial and Applied Mathematics (SIAM).

- Thèse en 1978, université de Pau.
- HDR 1988, université Paris I, Panthéon-Sorbonne.

- Professeur (CE) à Limoges depuis 1989.
- Visiting professor université de Pise 1997
- Visiting professor université de Milan 1992
- Visiting professor university of California (Davis) 1990
- Visiting professor university of California (Santa Barbara) 1987
- Visiting professor California State university 1986

Publications :

1. **S. Adly, D. Goeleven, M. Théra,** Recession mappings and noncoercive variational inequalities, Nonlinear Analysis, Theory Methods and Applications, (1996), Vol 26, Nř 9, 1573-1603
2. **V. H. Ngai and M. Théra,** On necessary conditions for non-Lipschitz optimization problems, SIAM J. on Optimization, vol. 12, no. 3, pp. 656-668, 2002.
3. **A. Moudafi and M. Théra**, Finding the zero of a sum of two maximal monotone operators, Journal of Optimization Theory and Applications, Vol 94, no. 2, pp. 425-448, 1997
4. **J. Revalski, M. Théra,** Enlargements and sums of monotones operators, Nonlinear Analysis, Theory, Methods and Applications, 48, 505-519, 2002
5. **S. Adly, E. Ernst, M. Théra,** Stability of non-coercive variational inequalities, Communications in Contemporary, Mathematics, Vol 4, 1, 145–160, 2002

- Editeur associé, Positivity, Kluwer Academic
- Editeur associé, Journal of Convex Analysis,Hedelman-Verlag
- Editeur associé, Journal of Nonlinear and Convex Analysis,Yokohama Publishers
- Editeur associé, Communications on Applied Nonlinear Analysis
- Editeur associé, Acta Vietnamica

- 2000 - 2004 Président de la SMAI
- 2001- Membre du Conseil Scientifique de l'université de Limoges
- 1997 – Membre élu du conseil d'administration de la SMAI
- Membre du conseil d'administration du CIRM
- Membre du conseil d'administration du CNFM
- Membre du conseil d'administration du CIMPA
- Vice-Président de l'université de Limoges depuis 2005.

Curriculum vitae - Daniel Goeleven 40 ans

a) Goeleven, Daniel ; 40 ans ; doctorat en sciences mathématiques, université de Namur (Belgique), 1993 ; Habilitation à diriger des recherches de l'université de Limoges, 1997 ; Professeur à l'université de la Réunion (IREMIA).

b) Assistant FNRS du 01/09/1994 au 31/08/1996 facultés universitaires N-D. de la Paix de Namur ; Boursier RWTH Aachen du 01/09/1996 au 31/08/1997, fondation Alexander von Humboldt (D).

c) Publications :

1. **D. Goeleven, B. Brogliato,** Necessary conditions of asymptotic stability for unilateral dynamical systems, Nonlinear Analysis, Theory, Methods and Applications, vol.61, pp.961-1004, 2005.
2. **B. Brogliato, D. Goeleven,** The Krakovskii-LaSalle invariance principle for a class of unilateral dynamical systems, Mathematics of Control, Signals and Systems, vol.17, pp.57-76, 2004.
3. **D. Goeleven, B. Brogliato,** Stability and instability matrices for linear evolution variational inequalities, IEEE Transactions on Automatic Control, vol.49, no 4, pp.521-534, 2004.
4. **S. Adly and D. Goeleven** A stability theory for second-order nonsmooth dynamical systems with applications to friction problems. J. Math. Pures Appl., vol. 83, 2004, pp. 17 – 51.
5. **D. Goeleven, D. Motreanu, Y. Dumont, M. Rochidi**, Variational and hemivariational inequalities, theory, methods and applications : unilateral analysis and unilaterla mechanics. Kluwer, Nonconvex Optimization and its Applications, Dordrecht, 2003.

Curriculum vitae - Samir Adly 36 ans

Nom : ADLY
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Fonction : Maître de conférences.
Etablissement actuel : Université de Limoges.
- **Doctorat de l'Université de Limoges.**
Titre de la thèse : *Analyse variationnelle appliquée aux problèmes unilatéraux.*
Thèse soutenue le 5 octobre 1995 à la Faculté des Sciences de Limoges.
Directeur de thèse : Michel Théra.
- **D.E.A. d'Ingénierie Mathématique** (Cryptographie & Optimisation)
obtenu en 1992 à la Faculté des Sciences de Limoges.

Intérêts mathématiques

Analyse non-linéaire, analyse convexe et optimisation, analyse numérique, équations aux dérivées partielles, méthodes variationnelles, problèmes de la mécanique unilatérale, stabilité de Lyapunov des systèmes dynamiques.

Publications

1. **S. Adly and E. Ernst and M. Théra**, Stability of non-coercive variational inequalities, Communications in Contemporary Mathematics Vol. 4, 1, 145-160 (2002).
2. **S. Adly and E. Ernst and M. Théra**, On the closedness of the algebraic difference of closed convex sets, Journal de Mathématiques Pures et Appliquées, Vol. 82, **9**, pp 1219-1249 (2003).
3. **S. Adly and E. Ernst and M. Théra**, Norm closure of the barrier cone in normed linear spaces, Proc. Amer. Math. Soc., **132** no. 10, pp 2911–2915 (2004).
4. **S. Adly and E. Ernst and M. Théra**, Well-positioned closed convex sets and well-positioned closed convex functions, Journal of Global Optimization, **29** (4) pp 337-351, (2004).
5. **S. Adly and D. Goeleven**, A stability theory for second-order nonsmooth dynamical systems with application to friction problems, Journal de Mathématiques Pures et Appliquées, Vol. 83, pp 17-51 (2004).

Curriculum vitae - Jérôme Malick 26 ans

- **a)** Malick, Jérôme ; 26 ans ; ancien élève de l'ENS Cachan en thèse à l'Université Joseph Fourier de Grenoble et à l'INRIA.
- **b)** Moniteur l'Université Joseph Fourier à dans le cadre de la thèse.
- **c)** Publications :

  1. **J. Malick**, A Dual Approach to Semi-definite Least-Squares Problems, SIAM Journal of Matrix Analysis and Applications, Volume 26, Number 1, pp.272-284, 2004
  2. **V. Beck, J. Malick, G. Peyré,** Objectif agrégation, Éditions H&K, 2004
  3. **A.Daniilidis, J.Malick**, Filling the gap between lower-C^1 and lower-C^2 functions, Journal of Convex Analysis, Volume 12, Number 2, 2005
  4. **J.Malick, S. Miller**, U-Newton methods for nonsmooth convex minimization, Mathematical Programming, to appear.

- **d)** Distinctions : Agrégation de mathématiques (classé 33ième).

Programme non thématique 2005
B - Déscription du projet

Acronyme ou titre court	Guidage

B-1 - Objectifs et contexte :(2 pages maximum en arial 11, simple interligne)
On situera le projet dans le contexte international en y précisant les objectifs et les enjeux.

We are leaders in developing nonlinear and nonsmooth mathematical programming techniques for challenging problems in feedback control synthesis, where traditional methods in automatic control like LQG, H_2 or H_∞ control, based on solving algebraic Riccati equations (AREs) fail. This inludes difficult design problems like parametric robust control, simultaneous stabilization problems, multi-objective control, design of reduced-order and static controllers, decentralized control, controllers with structural contraints like sparsity, controllers with finite precision arithmetics, and control and tracking of mechanical systems with discontinuities. In contrast with conventional strategies we apply highly efficient nonlinear and nonsmooth mathematical programming techniques, which allows us to address a wide range of challenging problems, where current methods cannot be brought to work.

In this project we propose to create a new software platform for design of high performance feedback controllers and for system design, `noFee`, which expands on currently available software in control such as the MATLAB control toolbox, the SLICOT environment, PENNON, or our own code *specSDP*. The `noFee` platform will be complementary to SICONOS, a European project to which members of team from INRIA Rhône-Alpes contribute, and whose objective is the simulation and control of nonsmooth dynamical systems. `noFee` will be useful and made available to design engineers and researchers in the fields of aeronautics and space navigation, control of vehicles and mechanical systems.

We are experienced in designing small and medium size output feedback controllers for very large systems with several hundred states. We use nonlinear and nonsmooth mathematical programming methods to design such controllers without extensive use of system reduction techniques. This is because we have realized that overly reduced systems bear the risk of failure to control the closed-loop system, by unnecessarily introducing uncertainty into the system modeling. This ultimately leads to control laws with unsatisfactory performance and failure to achieve the necessary robustness of the design. Our new optimization techniques are versatile in difficult situations, where controllers with good performance are subject to challenging structural constraints. This includes sparse controllers, reduced order controllers, decentralized control, PID control, observer based controllers, feed forward controllers. We plan to continue and extend this line of investigation, called *nonsmooth optimization framework for synthesis*. In this project we plan to introduce new design elements within the optimization process. This includes finding good performance specifications (today done by hand via trial and error), incorporating several concurring performance channels into a sole optimization step using multi-objective or multi-disk control.

Systems with discontinuities arise frequently in applications. Electrical circuits with ideal diodes have jump discontinuities, hybrid dynamical systems lead to discontinuous models, and mechanical systems with Coulomb friction or unilateral contact, or systems with impulse effects fall in this class. We have shown that Lyapunov stability theory may be extended to such systems, so that matrix inequality tests and nonsmooth methods based on Hamiltonian tests can be applied in open and in closed loop. However, due to the set-valued character of the tranfer function, linearizing changes of variables as used in classical H_∞ or H_2 theory cannot be brought to work, and genuine bilinear matrix inequalities (BMIs) have to be accepted even in the nominal case. In this situation the MATLAB control toolbox and other existing tools are not suited. We plan to address these problems, referred to as the *nonsmooth analysis framework for tracking and control*, in our new software tool `noFee`.

We use advanced nonlinear and nonsmooth analysis and optimization techniques to synthesize feedback controllers with improved performance specifications in different high technology fields including aeronautics and space navigation, power plant network control, mechanical systems with friction, robotics and systems with discontinuities. Our techniques allow us to address challenging problems such as robustness against system uncertainties, simultaneous stabilization to safeguard systems against possible failures or aging, reduced order and static output feedback control design to avoid system reduction techniques, which tend to degrade the performance of feedback laws. We have developed and tested gain-scheduling methods to control time-varying systems such as helicopters, launchers (Ariane 5) and industrial robots.

We measure the success of our work by comparing our innovative techniques to existing approaches via extensive numerical testing. We use challenging benchmark examples to test the limits of performance of our methods. We use industrial projects with ONERA Toulouse, EADS, INRIA Rhône-Alpes and the department of mechanical engineering at KULeuven (Belgium) to validate our approaches to LTI and LPV control, and to control and tracking for mechanical systems and systems with discontinuities. We publish our results in leading journals of applied mathematics, optimization and automatic control. Our platform `noFee` will be made available to design engineers and researchers for further testing, validation and improvement.

B-2 - Déscription du projet et résultats attendus : (8 pages maximum en arial 11, simple interligne) On décrira le déroulement prévisionnel et les diverses phases intermédiaires ainsi que les méthodologies employées. L'originalité et le caractère ambitieux du projet devront être explicités.

1 Algebraic Riccati equations and beyond

It was recognized during the 1990s that algebraic Riccati equations (AREs) and linear matrix inequalities (LMIs) were not practical for a variety of challenging and NP-hard problems in automatic control. Since many of these problems are of great practical importance, heuristic approaches were used, and even several rigorous methods were proposed to solve these difficult classes of problems. This included for instance methods from concave programming or global optimization. However, these methods were of very limited success due to serious size limitations, and many of these important problems could not be addressed appropriately.

Since the late 1990s our group has systematically developped strategies for these challenging problems, using local optimization techniques. See [28, 29, 8, 9] and subsequently [7, 43, 46, 47]. Approaches known from classical nonlinear mathematical programming like the augmented Lagrangian method (AL) and sequential quadratic programming (SQP) were successfully extended to optimization programs with bilinear matrix inequality constraints (BMIs). See also [38, 40, 39, 35, 36, 37].

The limitations of this new approach to BMIs was still in the size of the optimization programs, even though much less severe than for global optimization techniques. The reason is that the number of Lyapunov variables grows quadratically with the order of the systems. Around the year 2000, Burke, Lewis and Overton [23, 24, 25, 26] proposed a new method for synthesis, which completely avoided the use of Lyapunov variables. The price to pay for this was that optimization programs became nonsmooth and needed special optimization techniques. Our own approach to optimization without Lyapunov variables [44, 45, 3, 4, 5, 6], inspired by but different from that of Burke et al., is at the basis of the new tool `noFee`, which we will develop in this projet. Nonsmooth analysis and optimization methods for tracking and synthesis will therefore be discussed in the sequel.

2 Bilinear matrix inequalities (BMIs)

Linear matrix inequalities (LMIs) and bilinear matrix inequalities (BMIs) have been intensively studied since the 1990s. Stephen Boyd and his research group [17] put forward the idea to cast a large set of problems in automatic control as LMIs, and to solve them via interior point methods. This program has indeed led to significant progress, and various problems from different fields have been solved accordingly.

We have been among the first [28, 29, 9, 8, 7, 47, 43] to stress the need for new optimization techniques for several difficult (and even NP-hard) control problems, which are intrinsically non-convex and could not be addressed within the framework of LMIs or AREs. Problems of the form

$$\begin{array}{ll} \text{minimize} & c^\top x + d^\top y, x \in \mathbb{R}^r, y \in \mathbb{R}^s \\ \text{subject to} & \mathcal{B}(x,y) = A_0 + \sum_{i=1}^r A_i x_i + \sum_{j=1}^s B_j y_j + \sum_{i=1}^r \sum_{j=1}^s C_{ij} x_i y_j \preceq 0 \end{array} \tag{1}$$

are referred to as BMI optimization programs, and $\mathcal{B}(x,y) \preceq 0$ is called a BMI constraint or simply a BMI, and $\preceq 0$ means negative semidefinite. BMIs arise for instance from the bounded real lemma or the Kalman-Yakubovic-Popov lemma. Typically, in controller synthesis, x regroups the true decision parameters (controller gains K), while y stands for the Lyapunov matrix Y.

Example. The bounded real lemma asserts that the tranfer matrix $G(s) = C(sI - A)^{-1}B + D$ of the system

$$\begin{cases} \dot{x} = Ax + Bw \\ z = Cx + Dw \end{cases}$$

is stable and has H_∞-norm $\|G\|_\infty < \gamma$ if and only if a Lyapunov matrix $Y \succ 0$ exists such that

$$\begin{bmatrix} A^\top Y + YA & YB & C^\top \\ B^\top Y & -\gamma I & D^\top \\ C & D & -\gamma I \end{bmatrix} \prec 0. \tag{2}$$

If $A = \mathcal{A}(K)$, $B = \mathcal{B}(K)$, $C = \mathcal{C}(K)$, $D = \mathcal{D}(K)$ are closed-loop data, depending on an unknown feedback controller K, then (2) is a special case of (1), where $x = (K, \gamma)$, while y stands for Y. □

Software for BMIs using local optimization strategies is currently developed by several research groups [46, 7, 47, 29, 35, 40, 40, 33]. We mention for instance PENNON by Kocvara and Stingl [36, 37, 33], Compl$_e$ib by Leibfritz [40, 39], *specSDP* by our own group [47, 46], YALMIP by [51] or GlobiPoli by Henrion et al. [34]. Not surprisingly, since BMI programs are too general as a class [1], the success is limited, and it is necessary to exploit special structure. For instance, our group [8, 9, 28, 29, 43] has systematically exploited cases where BMIs may be simplified using the projection lemma [2, 17]. This class of problems is typically of the form

$$\begin{array}{ll} \text{minimize} & c^\top y, y \in \mathbb{R}^s \\ \text{subject to} & \mathcal{A}(y) \preceq 0 \\ & g_1(y) = 0, \ldots, g_p(y) = 0 \end{array} \tag{3}$$

where $\mathcal{A}(y) \preceq 0$ is now a LMI, $g_j(y) = 0$ are nonlinear equality constraints, and y means Lyapunov variables, $s = \dim(y)$.

Despite the advantages of (3) over the general (1) it needs to be stressed that there is a principal difficulty with *any* algorithmic approach based on (1). Namely :

The number s of Lyapunov variables in (1), (2) and (3) grows quadratically with the number of states n of the system.

In consequence, problems (1), (2) and also (3) grow quickly in size, which causes failure of most solvers even at moderate system sizes.

Since 2003, our group is investigating a new approach to BMI optimization using methods from eigenvalue optimization [44, 45, 48]. Such techniques have been pioneered by Overton, Cullum et al., Fletcher, Oustry and others since the 1980s. Using this new line, we are able to stabilize and control benchmark systems with up to 300 states, which as a program of the form (1) may amount to 50,000 unknown variables (see table 1).

This approach is promising and shall be further developed and extended to be ultimately integrated in the platform `noFee`. Testing and further validation is still under way and will be continued in the project.

All the options of this section (that is, keeping Lyapunov variables : smooth or nonsmooth) will be included in the new software tool `noFee`. The line developed in *specSDP* will be continued, and successive semidefinite programming as well as augmented Lagrangian methods will be made available within `noFee`. Nonsmooth methods will play the central role in solving (1), (2) and (3).

[1]For instance, every integer quadratic program is equivalent to a BMI program

Problem	states	n_K	var	cpu	α_{ol}	α_{cl}
CM1_IS	20	2	213	2	5e-3	-4e-3
Boeing	55	4	1545	1.6	0.1	-0.02
CM2 _IS	60	2	1833	-	5e-3	-
CM3 _IS	120	3	7263	-	5e-3	-
heat2D_1	256	4	32901	33	1.1	-0.54
heat2D_2	324	4	52655	47	1.9	-0.60

TAB. 1: *Eigenvalue optimization used for several benchmark test examples. Acronymes refer to the* Compl$_e$ib *test bench [38].* n_K = *order of controller,* α_{ol} = *spectral abscissa in open loop,* α_{cl} = *in closed loop,* var = $\dim(x, y)$. *For certain problems, disparities of several orders of magnitude between controller gain variables* $x = (K, \gamma)$ *and Lyapunov variables* $y = Y$ *may lead to numerical difficulties and failure. Nonetheless, the approach is highly promising and shall be developed in this project.*

3 At the core : optimization without Lyapunov variables

The main impediment in the BMI based synthesis program (1) is the presence of Lyapunov variables y. It is possible to *avoid* their use and optimize the true decision parameters x only. Such a strategy has been proposed by Burke, Lewis and Overton in a series of publication around 2000, [23, 24, 25, 26], who use the spectral abscissa $\alpha(A)$ of a square matrix A to compute stabilizing feedback controllers for large systems. Their gradient sampling algorithm [25] allowed them to solve for the first time around 2000 the Boeing 767 benchmark problem (Boeing in Tables 1 and 2). Since then, the nonsmooth approach has become the most promising strategy to solve the most difficult synthesis problems. It is based on the following basic result.

LEMMA 1 *The following are equivalent :*

1. $\dot{x} = Ax$ *is exponentially stable.*
2. **Lyapunov condition**. *There exists a symmetric* Y *such that*

$$\begin{bmatrix} YA + A^\top Y & 0 \\ 0 & -Y \end{bmatrix} \prec 0.$$

3. **Spectral abscissa.** $\alpha(A) := \max\{\text{Re}\lambda : \lambda \text{ eigenvalue of } A\} < 0.$
4. H_∞**-norm.** *The transfer function* $s \mapsto G(s) := (sI - A)^{-1}$ *belongs to the Hardy space* RH_∞ *of stable rational transfer functions. In particular,* $\|G\|_\infty < +\infty$.

As one can see, condition 2 leads to matrix inequalities, condition 3 is the approach of Burke et al., while our own method is based on condition 4. We use the following scheme for synthesis

General scheme for synthesis

1. **Stabilization**. Compute a closed loop stabilizing controller K_1 as follows. Choose initial K_0 and $\alpha > \alpha\,(A + BK_0C)$ and optimize the spectral abscissa or the shifted H_∞ norm
$$\min_K \|(sI - A + BKC - \alpha I)^{-1}\|_\infty$$
until K_1 stabilizing the open loop system is found.
2. **Performance**. Introduce performance and tracking specifications $w^i \to z^i$ and obtain so-called LFT.
3. **Optimization**. Optimize (4) with performance channels $w^i \to z^i$ using nonsmooth optimization. Use K_1 as initial and maintain closed-loop stability during optimization. Solution is optimal feedback controller K_2.
4. **Simulation**. Test K_2 via simulation. If unsatisfactory, change performence specifications and go back to step 2. Otherwise accept K_2.

As we observed [44, 45, 3, 4], using the shifted H_∞-norm in step 1 avoids difficulties with the spectral abscissa and leads to an initial stabilizing controller, K_1. In the main step, where performance specifications and tracking are introduced, the controller is then optimized, while closed-loop stability of the iterates is maintained during optimization. This step is the central part of the entire approach, and it is here where our approach is the most innovative. We intend a general multi-objective optimization program of the form :

$$\begin{array}{ll} \text{minimize} & \|T_{w^i\to z^i}(K)\|,\ i = 1,\ldots,p \\ \text{subject to} & K \text{ stabilizes closed loop system} \\ & \text{structural constraints on } K \\ & \text{simulated constraints in closed loop} \end{array} \tag{4}$$

Here $s \mapsto T_{w^i\to z^i}(K,s)$, $i = 1,\ldots,p$ are suitable closed-loop transfer functions modeling performance and tracking specification [16], which have to be optimized simultaneously.

Multi-objective synthesis, where several concurring stability and tracking specifications have to be optimized simultaneously, is a difficult design problem. The multi-objective optimization program (4) can be addressed by several strategies. One may for instance introduce weights δ_i and optimize

$$\sum_{i=1}^{p} \delta_i \|T_{w^i\to z^i}(K,\cdot)\|_i,$$

where $\|\cdot\|_i$ usually means the H_2, the H_∞, the peak-to-peak gain norm or other useful performance indices or norms. A second possibility, used for instance in H_2/H_∞ control, is to optimize one of the performance channels, while putting constraints on the remaining ones :

$$\begin{array}{ll} \text{minimize} & \|T_{w^0\to z^0}(K)\|, \\ \text{subject to} & \|T_{w^i\to z^i}(K)\| \le \gamma_i, \\ & i = 1,\ldots,p \end{array}$$

A third possibility is the so-called multi-disk synthesis, where the worst case is optimized :

$$\min_K \max_{i=1,\ldots,p} \|T_{w^i\to z^i}(K)\|.$$

This has been proposed by Helton [32]. Recently we have shown [5] how this approach may be put to work, and that it offers advantages over single-channel optimization.

problem	(n, m, p)	order	iter	cpu (sec.)	nonsmooth H_∞	H_∞ AL	FW	H_∞ full
AC8	$(9, 1, 5)$	0	20	45	2.005	2.02	2.612	1.62
HE1	$(4, 2, 1)$	0	4	7	0.154	0.157	0.215	0.073
REA2	$(4, 2, 2)$	0	31	51	1.192	1.155	1.263	1.141
Boeing	$(55, 2, 2)$	0	15	294	13.11	$*$	$*$	3.23
AC10	$(55, 2, 2)$	1	46	408	10.21	$*$	$*$	3.23
BDT2	$(82, 4, 4)$	0	44	1501	0.8364	$*$	$*$	0.2340
HF1	$(130, 1, 2)$	0	11	1112	0.447	$*$	$*$	0.447
CM4	$(240, 1, 2)$	0	2	3052	0.816	$*$	$*$	$*$

TAB. 2: *H_∞ synthesis via nonsmooth optimization. Acronym refers to Compl$_e$ib testbench [38]. The gain achieved by our nonsmooth method in column 'nonsmooth H_∞' was compared to augmented Lagrangian method from specSDP in column 'H_∞ AL' and to the Franck & Wolfe method in column 'FW' (also used for DK-iteration in MATLAB control toolbox [12]). The column 'H_∞ full' gives the lower bound obtained for the full order controller. Column '(n, m, p)' gives plant characteristics. Column 'order' gives the order of the controller, $*$ means failure. The results show that the nonsmooth techniques can control systems with several hundred states within minutes of CPU. If several hours of CPU are acceptable, we can currently control systems with up to 1000 states, if the number of controller gains K, that is, the dimension of the decision vector x, is of moderate size.*

Structural constraints include fixed pattern (sparse) controllers, decentralized controllers, and many possible parametrization $K = \Phi(\kappa)$. This could be PID controllers, feed forward or two degree of freedom controllers, lead lag, Youla parametrization, and much else. Simulated constraints $g(K) = 0$, or $g(K) \leq 0$, are classical inequality or equality constraints, where $g = (g_1, \dots, g_q)$ is some function of the closed loop system trajectory $x(t)$ in response to a suitable input signal $w(t)$. Simulated constraints combine the linearizing framework with multiple shooting techniques to compute function values and gradients of the g_j.

What are the difficulties of the nonsmooth approach without Lyapunov variables? As table 2 shows, our method is particularly well suited if small controllers for large systems are sought. If controllers get more sizeable, numerical difficulties may appear. To improve this situation is one of the objectives of this project.

The size of the central optimization program in step 3 of the synthesis scheme depends on the number of actuators and sensors, m, p and on the order of the controller, k, but not *directly* on the order n of the system. However, function evaluation for the H_∞ and also for the H_2 norm depend on n. In particular, we compute the H_∞ norm with the superlinearly convergent iterative method by Boyd et al. [14, 15]. We have rendered this algorithm functional for systems with up to 1000 states, and we plan to upgrade it further to cope with systems of up to 3000 states. This would bring our method within reach of controlling systems of that size without any (open or closed loop) system reduction techniques. In particular, this is a promising new approach to control of distributed parameter systems and control of PDEs, which suffer from the lack of good techniques for synthesis.

A difficulty which is independent of the size of the system n sometimes arises when extremely sharp peaks in the frequency curve $\omega \mapsto \lambda_1 (T_{w \to z}(K, j\omega))$ occur. This does not happen as a rule, but we have observed it for instance in the control of CD-players. In that situation the peak detection in the algorithm of Boyd et al. needs to be extremely accurate, which may cause numerical difficulties or lead to failure. We are currently investigating in which way second order methods for program (4) may help in this situation.

4 Methods for discontinuous systems

Feedback control, tracking and design of discontinuous systems can be treated with techniques similar to those in the continuous case, because a suitable Lyapunov theory has been developed by our group ; cf. [30, 22, 1, 18, 19, 20]. Consider for instance a system with transfer function $G(s) = C(sI - A)^{-1}B$ with an additional static nonlinearity, known as a sector nonlinearity :

$$\begin{aligned} &\dot{x}(t) = Ax(t) - By_L(t) \\ &y(t) = Cx(t) \\ &y(t) \in \mathcal{K} \\ &y_L(t) \in N_{\mathcal{K}}(y(t)) \end{aligned} \tag{5}$$

for all $t \geq 0$, where $\mathcal{K}$ is a convex cone containing 0, $N_{\mathcal{K}}(y)$ the normal cone to $\mathcal{K}$ at $y \in \mathcal{K}$. If the triplet (A, B, C) is positive real, (5) can be equivalently cast as a so-called linear evolution variational inequality (LEVI)

$$\langle \dot{z}(t) - RAR^{-1}z(t), v - z(t) \rangle \geq 0 \text{ for every } v \in \tilde{\mathcal{K}}, \tag{6}$$

where $z = Rx$, $R^{-2}C^T = B$, $R = R^T \succ 0$, $\tilde{\mathcal{K}} = \{h \in \mathbb{R}^n : CR^{-1}h \in \mathcal{K}\}$. The solutions $z(\cdot)$ of (6) are then continuous and differentiable to the right. The following fundamental result is obtained.

Theorem 1. [cf. [30]] *The origin $x = 0$ is asymptotically stable for (5) provided there exists a symmetric Lyapunov matrix Y which is positive definite on $\mathcal{K}$, noted $Y \succ_{\mathcal{K}} 0$, and an invertible matrix R with $R^{-2}C^T = B$ such that (i) $\left(RAR^{-1}\right)Y + Y\left(RAR^{-1}\right)^T \succ_{\mathcal{K}} 0$ and (ii) $(I - Y)(\partial\mathcal{K}) \subset \mathcal{K}$.*

These conditions reduce to the standard Kalman-Yakubovic-Popov conditions (2) for $\mathcal{K} = \mathbb{R}^n$. In that case, R is the square root of the Lyapunov matrix Y. As part of the current project, we plan to investigate these conditions further to identify situations, where they are algorithmically useful. This leads to interesting problems. For instance, if $\mathcal{K} = \mathbb{R}^n_+$, then $Y \succeq_{\mathcal{K}} 0$ means $x^TYx \geq 0$ for every $x \geq 0$, a property known as *copositivity*. Ways to check copositivity algorithmically are known in specific cases [13]. As a part of this project, we will investigate useful algorithmic approaches in related situations.

LEVI theory applies to unilateral contact problems, hybrid control systems, electrical circuits with jump discontinuities, mechanical problems with Coulom friction, and much else.

In what cases do optimization problems arise in connection with Theorem 1 ? One may wish to apply the result in closed-loop, with $A = \mathcal{A}(K)$, etc. depending on an unknown (to be designed) feedback controller, K, which as in the traditional case is expected so satisfy performance specifications, including stability. Or the result may be applied in open loop, with $A = A(q)$, $B = B(q)$, $D = D(q)$ and $\mathcal{K} = \mathcal{K}(q)$ depending smoothly on certain design parameters q, in which case stability should be one among several constraints. Such problems could then be addressed via smooth or nonsmooth methods. The decision variables are $(x, y) = (K, Y)$ respectively $(x, y) = (q, Y)$.

5 Conclusion

We design and implement nonlinear and nonsmooth optimization methods to compute feedback controllers for LTI and LPV systems. We develop methods for challenging problems like design of static, reduced order, decentralized or structured controllers, where methods based on algebraic Riccati equations (AREs) or linear matrix inequalities (LMIs) fail. We develop new strategies and tools for tracking and control of dynamical systems with discontinuities. We use sophisticated nonsmooth analysis and optimization techniques to address difficult but practically important problems in automatic control. We create a new platform `noFee` for tracking and feedback synthesis expanding on existing software tools.

Références

[1] S. Adly and D. Goeleven *A stability theory for second-order nonsmooth dynamical systems with applications to friction problems.* J. Math. Pures Appl., vol. 83, 2004, pp. 17 – 51.

[2] P. Apkarian and P. Gahinet, *A convex characterization of gain-scheduled H_∞ controllers*, IEEE Trans. Aut. Control, 40 (1995), pp. 853–864.

[3] P. Apkarian and D. Noll, *Controller design via nonsmooth multi-directional search.* SIAM J. on Control and Optimization. `http ://mip.ups-tlse.fr/perso/noll/PAPERS/POLYTOPE.pdf`

[4] P. Apkarian and D. Noll, *Nonsmooth H_∞ synthesis.* Submitted.
`http ://mip.ups-tlse.fr/perso/noll/PAPERS/frequency.pdf`

[5] P. Apkarian and D. Noll, *Nonsmooth optimization for multidisk H_∞ synthesis.* Submitted.

[6] P. Apkarian, D. Noll, and D. Alazard, *Controller design via nonsmooth multi-directional search*, in IFAC Conf. on System Structure and Control, Oaxaca, Mexico, Dec. 2004.

[7] P. Apkarian, D. Noll, J. B. Thevenet, and H. D. Tuan, *A spectral quadratic-SDP method with applications to fixed-order $\mathcal{H}_2$ and $\mathcal{H}_\infty$ synthesis*, Asian Control Conference, Melbourne, AU, 2004.
`http ://mip.ups-tlse.fr/rapp/rapp04/04.25.ps`

[8] P. Apkarian, D. Noll, and H. D. Tuan, *Fixed-order $\mathcal{H}_\infty$ control design via an augmented Lagrangian method* , Int. J. Robust and Nonlinear Control, 13 (2003), pp. 1137–1148. `http ://mip.ups-tlse.fr/rapp/rapp02/02.13.ps`

[9] P. Apkarian, D. Noll, and H. D. Tuan, *A prototype primal-dual LMI-interior point algorithm for nonconvex robust control problems,* Rapport Interne 01-08, MIP, UMR 5640, `http ://mip.ups-tlse.fr/rapp/rapp01/01.08.ps.gz`

[10] P. Apkarian, P. Pellanda, H. D. Tuan, *Mixed H_2/H_∞ multi-channel linear parameter varying control in discrete time*, System Control Letters, 2000, pp. 333 – 346.

[11] P. Apkarian and H. D. Tuan, *Robust Control via Concave Minimization - Local and Global Algorithms*, Transaction of Autom. Control, vol. 45, no. 2, 2000, pp. 299 – 305.

[12] G. J. Balas and J. C. Doyle and K. Glover and A. Packard and R. Smith, *μ-analysis and synthesis toolbox : user's guide*, The MathWorks, Inc., April 1991.

[13] I.M. Bomze, *Linear-time copositivity detection for tridiagonal matrices and extension to block-tridiagonality*, SIAM J. on Matrix Anal. Appl., vol. 21, no. 3, 2000, pp. 840 – 848.

[14] S. Boyd and V. Balakrishnan, *A regularity result for the singular values of a transfer matrix and a quadratically convergent algorithm for computing its $\mathbf{L}_\infty$-norm*, Syst. Control Letters, 15 (1990), pp. 1–7.

[15] S. Boyd, V. Balakrishnan, and P. Kabamba, *A bisection method for computing the $\mathbf{H}_\infty$ norm of a transfer matrix and related problems*, Mathematics of Control, Signals, and Systems, 2 (1989), pp. 207–219.

[16] S. Boyd and C. Barratt, *Linear Controller Design : Limits of Performance*, Prentice-Hall, 1991.

[17] S. Boyd, L. El Ghaoui, E. Feron and V. Balakrishnan, *Linear matrix inequalities in system and control theory*, SIAM Studies in Applied Mathematics, vol. 15, 1994.

[18] B. Brogliato, *Some perspectives on the analysis and control of complementarity systems*, IEEE Trans. Autom. Control, vol. 48, no. 6, 2003, pp. 918 – 935.

[19] B. Brogliato, *Absolute stability and the Lagrange-Dirichlet theorem with monotone multivalued mappings*, Systems & Control letters, vol. 51, 2004, pp. 343 – 353.

[20] B. Brogliato, *Some results on the controllability of planar variational inequalities*, Systems & Control Letters, vol. 54, 2005, pp. 65 – 71.

[21] B. Brogliato, A. Daniilidis, C. Lemarechal, V. Acary, *On the equivalence between complementarity systems, projected systems and differential inclusions*, Systems and Control Letters, in press.

[22] B. Brogliato and D. Goeleven, *The Krakovskii-LaSalle invariance principle for a class of unilateral dynamical systems.* Math. Control Signals Systems, vol. 17, 2005, pp. 57 – 76.

[23] J. Burke, A.S. Lewis and M.L. Overton, *Optimizing matrix stability*, Proc. Amer. math. Soc, vol. 129, no. 6 (2000), pp. 1635 – 1642.

[24] J. Burke, A.S. Lewis and M.L. Overton, *Two numerical methods for optimizing matrix stability*, SIAM J. Matrix Anal. and Applications, 2001.

[25] J.V. Burke and A.S. Lewis and M.L. Overton, *A Robust Gradient Sampling Algorithm for Nonsmooth, Nonconvex Optimization*, SIAM J. Optimization, vol. 15, no. 3, 2005, pp. 751 – 779. .

[26] J.V. Burke and A.S. Lewis and M.L. Overton, *Robust stability and a criss-cross algorithm for pseudospectra*, IMA Journal of Numerical Analysis, vol. 23, 2003, pp. 1-17.

[27] H. Dym and J. W. Helton and O. Merino, *Multidisk problems in H_∞ optimization : a method for analyzing numerical algorithms*, Indiana Univ. Math. J., vol. 51, no. 5, 2002, pp. 1111-1160.

[28] B. Fares, P. Apkarian and D. Noll, *An augmented Lagrangian method for a class of LMI constrained problems in robust control theory.* Int. J. Control, 74, 2001, 348 – 360. `http ://mip.ups-tlse.fr/rapp/rapp00/00.38.ps.gz`

[29] B. Fares, D. Noll and P. Apkarian, *Robust control via sequential semidefinite programming,* SIAM J. Control. Optim., 40, 2002, 1791 – 1820. `http ://mip.ups-tlse.fr/rapp/rapp99/99.40.ps.gz`

[30] D. Goeleven and B. Brogliato, *Stability and instability matrices for linear evolution variational inequalities*, IEEE Trans. Autom. Control, vol. 49, no. 4, 2004, pp. 521 – 534.

[31] D. Goeleven, B. Brogliato, *Necessary conditions of asymptotic stability for unilateral dynamical systems*, Nonlinear Analysis, vol. 61, 2005, pp. 961 – 1004.

[32] J. W. Helton and O. Merino, *Coordinate optimization for bi-convex matrix inequalitites*, Proc. IEEE Conf. on Decision and Control, San Diego, CA, 1997, pp. 3609-3613.

[33] D. Henrion, M. Kocvara, and M. Stingl, *Solving simultaneous stabilization BMI problems with PENNON*, in IFIP Conference on System Modeling and Optimization, vol. 7, Sophia Antipolis, France, July 2003.

[34] D. Henrion, J. B. Lasserre, *Solving Global Optimization Problems over Polynomials with GloptiPoly 2.1,* LAAS Research Report No. 02289, July 2002. Proceedings of the International Workshop on Global Constrained Optimization and Constraint Satisfaction (Cocos'02), Sophia Antipolis, France, October 2-4, 2002. Journal version appeared in C. Bliek, C. Jermann, A. Neumaier (Editors). Global Optimization and Constraint Satisfaction. Lecture Notes on Computer Science, Volume 2861, pp. 43-58, Springer Verlag, Berlin, 2003.

[35] F. Jarre, *Some aspects of nonlinear semidefinite programming*, System Modeling and Optimization, 2001, pp. 55 - 69.

[36] M. Kocvara, and M. Stingl, *PENNON - a code for convex, nonlinear and semidefinite programming.* Optim. Meth. Software, vol. 18, no. 3, 2003, pp. 317 – 333.

[37] M. Kocvara, and M. Stingl, *Solving nonconvex SDP problems of structural optimization with stability control.* Optim. Meth. Software, 2004.

[38] F. Leibfritz, *COMPL$_e$IB, COnstraint Matrix-optimization Problem LIbrary - a collection of test examples for nonlinear semidefinite programs, control system design and related problems*, Tech. Report, Universität Trier, 2003.

[39] F. Leibfritz and E. M. E. Mostafa, *An interior point constrained trust region method for a special class of nonlinear semi-definite programming problems*, SIAM J. on Optimization, 12 (2002), pp. 1048–1074.

[40] F. Leibfritz and E. M. E. Mostafa, *Trust region methods for solving the optimal output feedback design problem*, International Journal of Control, 76 (2000), pp. 501 – 519.

[41] J. Malick, *A Dual Approach to Semi-definite Least-Squares Problems,* SIAM Journal of Matrix Analysis and Applications, Volume 26, Number 1, pp.272-284, 2004

[42] J.Malick, S. Miller, *U-Newton methods for nonsmooth convex minimization,* Mathematical Programming, to appear.

[43] D. Noll, M. Torki and P. Apkarian, *Partially augmented Lagrangian method for matrix inequalities.* SIAM Journal on Optimization, vol. 15, no. 1, 2004, pp. 161 – 184.
`http ://mip.ups-tlse.fr/rapp/rapp02/02.31.ps.gz`

[44] D. Noll and P. Apkarian, *Spectral bundle methods for non-convex maximum eigenvalue functions : First-order methods*, Math. Programming Series B, (2005).
`http ://mip.ups-tlse.fr/perso/noll/PAPERS/03.43.pdf`

[45] ——, *Spectral bundle methods for non-convex maximum eigenvalue functions : Second-order methods*, Math. Programming Series B, (2005).
`http ://mip.ups-tlse.fr/perso/noll/PAPERS/04.20.pdf`

[46] J.-B. Thevenet, P. Apkarian, D. Noll, *Reduced-order output feedback control design with specSDP, a code for linear/nonlinear SDP problems.*

[47] J. Thevenet, D. Noll, and P. Apkarian, *Nonlinear spectral SDP method for BMI-constrained problems : Applications to control design*, in ICINCO Proceedings, Portugal, 2004.
`http ://mip.ups-tlse.fr/perso/noll/PAPERS/04.25.pdf`

[48] J. Thevenet, D. Noll, and P. Apkarian, *Nonsmooth methods for large bilinear matrix inequalities : Applications to feedback control.*

[49] K. Zhou, J. C. Doyle, K. Glover, *Robust and optimal control*, Prentice Hall, 1996.

[50] European project IST2001-37172.*Simulation and Control of Nonsmooth Dynamic Systems (SICONOS).* `http ://siconos.inrialpes.fr`

[51] `http ://control.ee.ethz.ch/~joloef/yalmip.php`

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C - Moyens financiers et humains demandés par chaque équipe partenaire du projet

On présentera une brève justification scientifique des moyens demandés pour chacune des équipes impliquées dans le projet

Responsable scientifique - coordinateur : Dominikus Noll

- 2 postdocs sur 3 ans.
- Frais de mission pour visites de conférences, comme SIAM Control Conference, American Control Conference (ACC), European Control Conference (ECC), Conference on Decision and Conrol (CDC).
- Frais de mission pour invitation de membres extérieurs, de l'équipe de Swevers à Toulouse, de Diehl à Toulouse. Echange entre les equipes de MIP et de l'INRIA.
- Equipement. 3 ordinateurs pendant 3 ans.

Responsable scientifique - partenaire 2 : Bernard Brogliato

- 1 postdoc sur 3 ans.
- Frais de mission pour visites de conférences.
- Frais de mission pour invitation de membres extérieurs. Echange entre Limoges, la Réunion et Grenoble.
- Equipement. 3 ordinateurs pendant 3 ans.

Programme non thématique 2005

Fiche de demande d'aide - Laboratoire public/Fondation

Acronyme ou titre court Guidage

Responsable scientifique - coordinateur : **Dominikus Noll**

Estimation du coût marginal du projet pour le laboratoire
MIP UMR 5640 : 10000

	Année 1	Année 2	Année 3	Total
Dépenses personnel † Postdoc 1	37000	37000	37000	111000
Dépenses personnel † Postdoc 2	37000	37000	37000	111000
Equipements	4000	4000	4000	12000
Prestations de service				
Petits matériels	500	500	500	1500
Frais de mission	9000	9000	9000	27000
Frais généraux (4%)				10500
Total				273000
Aide demandée				283000

† 38h 30 par semaine donc 1607 h par an

Programme non thématique 2005

Fiche de demande d'aide - Laboratoire public/Fondation

Acronyme ou titre court	Guidage

Responsable scientifique - Partenaire 2 : **Bernard Brogliato**

Estimation du coût marginal du projet pour le laboratoire
INRIA Rhône-Alpes : 8000

	Année 1	Année 2	Année 3	Total
Dépenses personnel † Postdoc 3	37000	37000	37000	111000
Equipements	4000	4000	4000	12000
Prestations de service				
Petits matériels	500	500	500	1500
Frais de mission	9000	9000	9000	27000
Frais généraux (4%)				6060
Total				157560
Aide demandée				165560

† 38h 30 par semaine donc 1607 h par an

Programme non thématique 2005

D-Récapitulatif global de la demande financière pour le projet

Acronyme ou titre court	Guidage

a-Total de l'aide demandée

	Aide demandée
Coordinateur	273000
Partenaire 2	157560
Total à reporter sur la 1ère page du dossier	430560

b-Estimation du coût complet de cette demande

	Coût complet
Coordinateur	283000
Partenaire 2	165560
Total à reporter sur la 1ère page du dossier	448560