Groupe de réflexion "Automatique et IA" du GDR MACS

Bilan du groupe de réflexion
(composition en annexe)

GdR-MACS du CNRS & COMET-SCA
juin 2021

Initiative du GDR Macs

Contacts : Isabelle QUEINNEC et Dimitri PEAUCELLE
avec le GDR MACS

Objectifs du groupe de réflexion: répondre aux questions suivantes

- Qu'est ce que l'IA ?
- Quelques points importants sur l'IA et Automatique ?
- Pourquoi ces liens sont importants pour l'automatique ? Pour l'IA ?
- Quels sont les succès dans ce domaine ?
- Quelles actions pourrait-on entreprendre ?

Remarque: composition et organisation sont en annexe de cette présentation

Avertissement

Présentation dynamique. Vos retours sont les bienvenus.

En particulier des références peuvent être oubliées.
Ce document ne prétend pas être exhaustif.

C'est une initiative du GDR Macs, discussions avec la communauté STP en cours. D'autres initiatives communes seront menées.

Automatic control issues and solutions

Classical issues in automatic control

1. identification, model learning
2. simulation
3. observation, estimation
4. diagnostic
5. control and performance

for dynamical systems, in presence of uncertainties, heterogeneities, constraints...

Proposed solutions

1. reduced-order modeling
2. performance and robustness certifications
3. observation and control *could be* done separately
4. cascade, **feedback** and series are possible

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AI

Opportunities

1. scientific computation
2. big data, sensors are everywhere
3. optimization and efficient algorithms
4. recording of long time-scale signals is possible

Proposed solutions

1. large neural networks
2. efficient applications
3. automatic learning and processing
4. transfer learning

Already many successes that were not possible a few years ago.

What can control gain from AI?

A lot:

- Algorithmic

  Control design using Reinforcement learning / real time optimization

  Automatic differentiation

  Model reduction using AI

  System identification or parameter calibration

  Fictious measures for observation with machine learning

  Links with adaptative control
- Practical solutions to address control problems
- Hardware and architectures

  Tailored hardware and software with AI (e.g., Tensor Processing Units)

  New design control algorithms with such architectures

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Some examples of AI in Control

- Recent works on AI tools for modeling of complex systems[1]
- Some works on diagnosis and fault detection[2]
- Many new contributions in identification of dynamical system using AI elements[3]
- Contributions also for observations, and optimization of filters in tracking[4]
- Computation of adaptive controls with Machine Learning[5]

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[1] I. Mezic, Data-driven Analysis and forecasting of Highway Traffic Dynamics; K. Wilcox, nonlinear model reduction and PDE lifting

[2] K. Tidriri, data-driven fault diagnosis and health monitoring; K. Goebel, A survey of artificial intelligence for prognostics, 2007

[3] T. Schön, Deep learning and system identfication. IFAC World Congress, 2020 AI4Research; Automatic diagnosis of ECG. Nature Communications, 2020. R. Vidal, Subspace clustering, 2011

[4] S. Bonnabel, AI for Covariance Estimation; C. Prieur, LSTM and Kalman filtering

[5] H. Sandberg, Adaptive Control of Linear Quadratic Regulators and Regret lower bounds; R. Sutton, A. Barto, Reinforcement learning: An introduction; M. Abeille, A. Lazaric, "LQ@Facebook"; D. Bertsekas, Reinforcement learning and optimal control, 2019

What can control give to AI?

A lot, as well!

- Some AI problems are control problems
  e.g., robot walking, or human-robot collaborative tasks, or robots catching flying objects
- Some AI problems have an intrinsic dynamical component
  e.g., video processing (Kalman filter, consensus approach)
  System theory for recurrent neural networks, reservoir computing
  Why persistance of excitations in AI could help?
- Some AI tools need verification (safety, stability)
  e.g., Lyapunov techniques, barrier certificates, randomized algorithms and uncertainty quantification

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Some examples of control in AI

- Training seen as a control problem:
  Controllability of nonlinear systems[6]
  Training (as image processing) is a least-squares regression[7]
- Some ML-based objectives are control problems
  e.g., robot walking, or human-robot collaborative tasks, or robots catching flying objects[8]
- Stability proof in Reinforcement Learning
  Robustness is a difficult issue[9]
  Ensuring the stability (or the safety) in a region of attraction[10]

[6] P. Tabuada, Universal approximation power of deep residual neural networks via nonlinear control theory, ICLR, 2021; arxiv:2007.06007; P. Tabuada, Training deep residual networks for uniform approximation guarantees, submitted

[7] F. Bach, Distributed machine learning over networks, plenary lecture, CDC'19

[8] A. Billard, Recent advances in robot learning from demonstration, see also ICRA 2020

[9] P. Seiler, Recovering robustness in model-free reinforcement learning, ACC'19

[10] P. Seiler & M. Arcak, arxiv:2006.07579; arxiv:2012.09293

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Correspondance between AI and Automatic control

IA	Control theory
Data, Learning	Modelling, Identification, Observation
Policy	Control
Neural network	Systems with isolated nonlinearities
Heuristic	Proof, numerical certificate
Decision making	Control
...	...

Need of a multidisciplinary approach AI+Control
(+ math, physics and information science)

AI-in-the-loop gives new problems for (AI+Control)

There are new problems for (AI+Control) when AI-elements in the loop

For instance, how can we ensure safety when AI algorithms are in closed-loop systems?

Some examples

- Self-driving cars: can we use AI system in a closed-loop fashion[11]
- Failure modes of machine learning algorithms[12]
- Autoencoders and dimensionality reduction[13]

[11] See the study of adversarial examples (theoretical aspects, and also detection methods), as done by E. Dohmatob in particular.
See also J. Sifakis Why is it so hard to make self-driving cars?

[12] K. Goebel, Degradation modeling and remaining useful life prediction of aircraft engines using ensemble learning, 2019

[13] Dan Yang, arxiv:2101.07976

Actions? What to do?

Targeted audience:
academic AND industrial partners

Short term actions, urgent

1. Publish our notes and present these slides
2. Pedagogical school for the French community.
   See 2021 Summer School. Other possible events?
3. **Organize a tutorial-level conference**
   Some AI techniques could be presented for newcomers within control community first.
4. Attend conferences, and submit papers there. E.g. [14] CAp, L4DC, ICML, ESA GNC, EuroGNC where industrial partners could be met as well
5. Attend seminars. In particular COMET.[15]

[14] WebPages: CAp. L4DC, ICML, ESA GNC, Euro GNC

[15] Contact: Hélène Evain

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Challenge type hackathon

Target: master and young engineers, during 2 days e.g. with a subject mixing AI and Control.

Example: tower with built with cubes. How to predict the final position of the cubes when it falls?
Could AI be useful for that? How to exploit the dynamics for that?

Quite easy to organize, need to find 2-3 "mentors"[16]

[16] see the past experience of M. Gilson. Contact: V. Andrieu as well

Mid-term actions

Opportunities and stimulate

1. Organize meetings/actions in the context of GDR MACS to develop links with IA. E.g.:
   - Identification with machine learning;
   - Optimal control design and AI;
   - Closed-loop systems and AI;
   - Adaptive control, LQ control and AI.
2. Joint working group between GDRs? GDR Isis, GDR AI. See also AfIA Association française pour l'Intelligence Artificielle.
3. Apply for PhD with CNES. Apply to industrial call for solutions[17]
4. Vall for applications with CNRS (PEPS?)? ANR? Not sure that a devoted call Control+AI could be organized
5. National conference? difficult to get attention of AI+Control.

[17] contact: Hélène Evain

Benchmark

Many interests for benchmarking problems

Control of attitude-orbite of satellites when using AI[18]

More specifically, one possibility is the plane drag with wind tunnel in Valenciennes.

Other possible benchmarks related to aerospace

- AI for position and attitute of satellites using cameras;
- Rendezvous problem with AI;
- Sloshing mode control in orbital phase (modelling, identification and control).

Example of successful benchmark:
robotised 3D-printer with reinforcement learning, Univ. Delft[19]

[18] Contacts: J.-A. Perez Gonzalez and M. Ganet-Schoeller

[19] R. Babuska et al, Reinforcement learning based compensation methods for robot manipulators, 2019

Others?

1. Europe? ESA?
2. Press review on top-research papers and new results? Seems to be hard to do during weeks/months.[20]

[20] Maybe the example of *Event-based Vision Resources on Github* could be used

Annexe

en annexe : composition du groupe de réflexion et organisation

Participants au groupe de réflexion

3 animateurs

- Marion GILSON,
- Franck PLESTAN,
- Christophe PRIEUR.

Pour 3 groupes

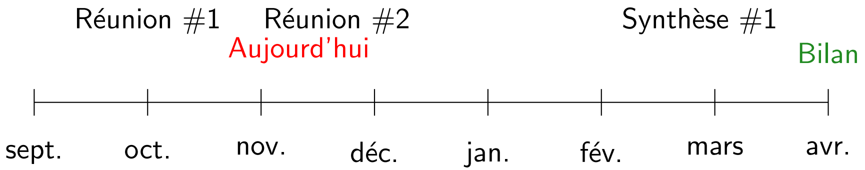
- Thierry GUERRA (LAMIH), Jose-Alvaro PEREZ-GONZALEZ (Thales), Franck PLESTAN (LS2N), Romain POSTOYAN (CRAN), Sophie TARBOURIECH (LAAS),
- Sylvain DURAND (ICube), Héléne EVAIN (CNES), Milan KORDA (LAAS), Mihaly PETRECSZKY (Cristal), Christophe PRIEUR (Gipsa),
- Vincent ANDRIEU (Lagep), Martine GANET-SCHOELLER (Groupe Ariane), Marion GILSON (CRAN), Antoine GIRARD (L2S), Guillaume MERCÉRE (LIAS).

Organisation

Fonctionnement

- 2 réunions en sous-groupe
- puis réunion plénière avec synthèses successives
- synthèse avril 2021

Calendrier



Bilan à mi-parcours

Expérience très enrichissante.

Réunions:

- en sous-groupe non-thématique
- échanges informels, courts, *chacun présente à tout le monde*
- courte échéance