

# What is Control Theory in 2021?

## Can AI do Better?

Olivier Pironneau

March 16, 2022

### Abstract

Until the twentieth century it was assumed that knowledge means control. Automatic control came in the sixties for electronics with Bellman's *dynamic programming* and Kalman's *filter* and received a boost in the eighties with *robust* and  $H^\infty$  control. Will artificial intelligence algorithms change the practice of control drastically [4],[1].

Parallel Optimal Control [2], which dates from the calculus of variations of Hadamard and the Pontryagin principle [7], is a more functional approach to the optimization of systems. It is heavily used for the design of mechanical devices like airplanes (optimal shape design [6]) and the topological optimisation of materials [3].

Stochastic control [8] remained up to now a mathematical field except for the rare semi-analytical solutions as in the case of linear quadratic control. It is now computationally feasible and its applications to finance for instance. – though challenged by deep neural networks – are in daily use for risk assessment of bank's portfolios.

Finally, perhaps the most mathematically demanding is the mean-field type control [5] and its application to the Monge-Ampere problem.

As this is a colloquium talk, the problems and the main results will be stated only, without assuming any prior knowledge of these sometimes difficult fields. Yet the talk is for a mathematically trained audience.

## References

- [1] D. Bertsekas. *Reinforcement Learning and Optimal Control*. Athena Scientific, 2019.
- [2] D.P. Bertsekas. *Dynamic Programming and Stochastic Control*. Athena Scientific, 2005.
- [3] François Jouve Anca-Maria Toader Grégoire Allaire, Frédéric De Gournay. Structural optimization using topological and shape sensitivity via a level set method. *Control and cybernetics*, 2005.
- [4] Simon Haykin. *Kalman Filtering and Neural Network*. 2001.
- [5] J.M. Lasry and P.L. Lions. Mean field games” (pdf). *japanese journal of mathematics*. 2: 229–260. *Japanese Journal of Mathematics.*, 2:229–260, 2007.
- [6] O. Pironneau. *Optimal Shape Design for Elliptic Systems*. Springer, 1982.
- [7] L. Pontryaguine, V. Boltianski, R. Gamkrélidzé, and E. Michtchenko. *Théorie Mathématique des Processus Optimaux*. Mir, 1974.
- [8] Jiongmin Yong and Xun Yu Zhou. *Stochastic Controls*. Springer Verlag, NY, 1999.