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A finite-difference based variational approach for solving Hamilton-Jacobi equations in high-dimensional domains

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It is well-known that the value function associated to a given optimal control problem or differential game can be characterised as the viscosity solution of an associated Hamilton-Jacobi equation. Numerical methods based on finite-differences are guaranteed to approximate the viscosity solution, provided the numerical scheme has the correct monotonicity. However, these grid-based methods suffer from the curse of dimensionality when the dimension of the domain is high. In this talk, I will present a variational approach to approximate the viscosity solution, consisting in the minimisation of a functional involving a Lax-Friedrichs discretisation of the Hamiltonian. I will show that, by choosing an appropriate numerical scheme, one can ensure uniqueness of a critical point for the functional. This in turn implies that the gradient flow associated to this functional converges to the unique global minimiser, which additionally can be proven to be close to the viscosity solution. In practice, the solution to the minimisation problem can be approximated by means of a Neural Network, trained through stochastic gradient descent, which simulates the gradient flow associated to the functional.

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