

Thesis proposal: Stochastic differential equations and (diffusion) generative AI

A typical state-of-the-art image generator works by a surprising trick: it starts from pure random noise and gradually transforms it into a realistic image.

Mathematically, the method rests on a pair of stochastic differential equations. A forward equation, which in simple models is of Ornstein–Uhlenbeck type, gradually transforms a complicated probability distribution (for instance, the distribution of natural images) into a simple Gaussian distribution. A classical result on the time reversal of diffusion processes then shows that this transformation can be run backwards by an associated second stochastic differential equation, whose characteristics can be learned from data. Generating a new sample (i.e., a *new* image similar to given empirical sample of images) thus amounts to simulating this reverse equation, starting from Gaussian noise.

The underlying mathematical theory of the project relies on stochastic differential equations, which are also a central tool in, for example, financial mathematics.

There are several possible directions for a thesis in this area, and the interested student should have a solid background in probability theory and stochastic processes.

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