GAN and Lotka-Volterra equations in machine learning

I. A. Lopatin[1]

Overfitting is a common problem in machine learning. We investigate the reduction of overfitting effects by drawing analogies between machine learning procedures and biological processes. Specifically, we interpret well-known Generative Adversarial Networks (GAN) framework [1] as a predator-prey model from biology. We demonstrate that the gradient descent process for solving the main minimax problem of GANs [1]:

$$\min_y \max_x V(x,y),$$
$$V(x,y) = \frac{1}{L}\sum_{l=1}^{L} \log D(z_l, x) + \int_Z p_{\text{gen}}(z,y)\log(1 - D(z,x))dz,$$

where $\{z_l\}$ is a sample, $D(z,x)$ and $p_{\text{gen}}(z,y)$ are parametric families of probability distributions on the space Z, called the *discriminator* and the *generator* with learning parameters x, y, respectively (assuming $x, y \in \mathbb{R}^d$), can be interpreted as a dynamical system analogous to the Lotka-Volterra equations. Building on this interpretation we propose a new machine learning algorithm [2]. For minimization problem $\mathcal{L}(x) \to \min$ (e.g., regression problem), we introduce modified Lotka-Volterra equations

$$\frac{dx}{dt} = -\nabla\mathcal{L}(x) + U(x-y),$$
$$\frac{dy}{dt} = -W(x-y),$$

where U and W are special vector functions (forces) describing the interaction between the prey and the predator. We analyze how this new model helps reduce overfitting.

[1]Steklov Mathematical Institute of Russian Academy of Sciences.
Email: lopatin.ia@phystech.edu

References

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