Progressively Growing GAN-aided High-Resolution Microscopy for Live Cell Dynamics Study

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Problem Statement and Motivation

- Currently there exist several super-resolution microscopy methods to study small cellular structures such as structured illumination microscopy (SIM) and stimulated emission depletion microscopy (STED). However, they often require slow frame rate, unhealthy environment for live cells and complicated optical setup. We want to utilize GAN to enhance resolution of microscopy images, which could aid the study of the dynamics of live cells. In particular, we will use progressive GANs because both efficiency and stability are important to the large-size noisy microscopy data.
- Inputs and outputs will be paired microscopy images with low resolution and high resolution. For example, we can acquire microscopy images with low and high exposure time alternatively and use them as low resolution inputs and high resolution outputs.

Previous and Related Works

- The original progressive GANs paper (ICLR 2018): https://arxiv.org/pdf/1710.10196.pdf
- Resolution enhancement in scanning electron microscopy using deep learning. de Haan, Kevin et al. Scientific reports vol. 9,1 12050.
- cellSTORM—Cost-effective super-resolution on a cellphone using dSTORM. Diederich, Benedict et al. PloS one vol. 14,1 e0209827.

Dataset

- We will use microscopy images from Kural Lab at Ohio State University and public microscopy data such as ISBI dataset. We have access to fluorescence microscope and other variants in the lab. To ensure input and output are aligned, we can use beads or metal coating on the surface as a reference point.

Methodology and Experiments

- Based on the progressive GANs paper, we first implement the progressive growing of GANs by incrementally adding layers to generator and discriminator pairs that are mirror images of each other so that finer details of image distribution could be gradually learned. The layers added will be smoothly faded with residual-block nature to avoid sudden shock to existing layers.
- Although progressive GANs architecture has been successful on tasks such as face-recognition, micrographs differ from ordinary images greatly, thereby requiring algorithmic modification for it to work. There are many types of microscopy images so different modifications are needed, but in general we want to exploit the fact that a large portion of microscopy image is background and put extra emphasis on the high resolution layers because we need the high resolution sharp enough for us to study things like curvature of small cellular structures.

Evaluation

- We will compare our model with published super-resolution generative models. We expect our trained images to achieve better pixel-wise resolution than non-GAN models such as U-Net. We plan to track each individual detected structures and analyze distribution statistics of these individual units (for example, if it is fluorescence image, we would count number of spots detected and missed, and analyze the distribution of FWHM of the detected PSFs.)

Other information:

- The image data and microscopes to obtain images are supported by Tianyao Wu's lab at Ohio State University. Note that this is not a published study.