Multi-StyleGAN: Towards Image-Based Simulation of Time-Lapse Live-Cell Microscopy

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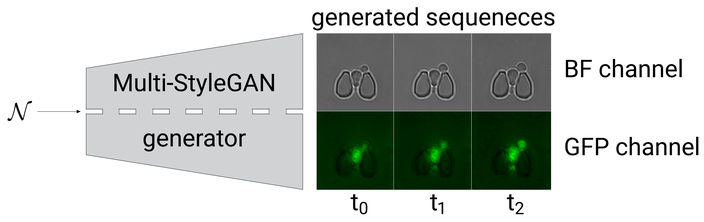
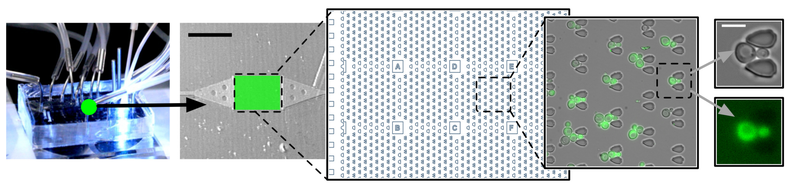
Introduction & Motivation

- Time-lapse fluorescent microscopy (TLFM) is a powerful tool to study living cells, with multiple aligned channels.
- TLFM imagery contains information not routinely extracted.
- No method available to generate realistic multi-domain sequences.
- Mult-StyleGAN synthesises multi-domain image sequences *in silico*.



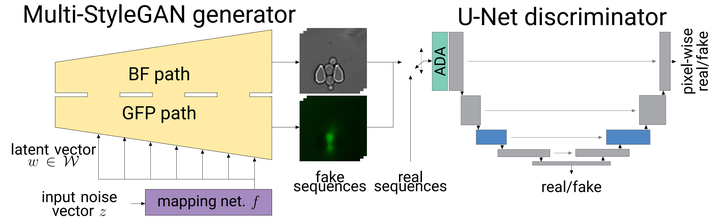
Dataset & Data Acquisition

- TLFM image sequences of living yeast cells recorded in our lab.
  - 9696 multi-domain images
  - brightfield channel (BF)
  - fluorescent channel (GFP)
  - 256 × 256 resolution
  - training sequences length 3
  - timestep △t=10min
  - 8148 training sequences
  - from a single TLFM experiment
- Microfluidics based microscopy of multi-domain sequences.

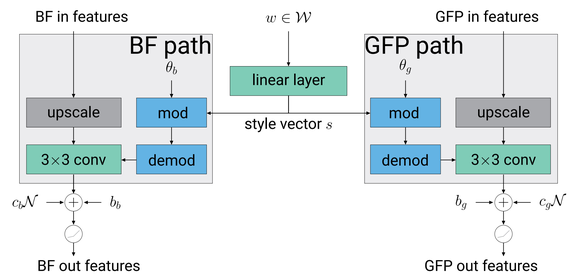


Methodology & Architecture

- Multi-StyleGAN extends StyleGAN2 [2] to multi-domain sequences.
- Two separate convolutional paths to generate each domain separately.

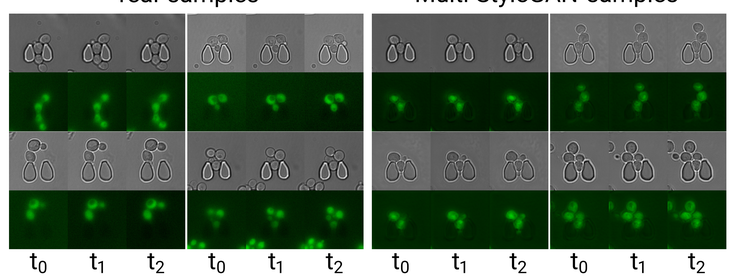


- The novel dual-style-convolutional block is the main component.
- Single style vector s enforces consistency between domains.



Results

- Qualitatively, Multi-StyleGAN samples capture underlying biophysical factors and time dependencies realistically (baselines are unrealistic).



- Quantitatively, Multi-StyleGAN outperforms the baselines significantly.

	FID ↓		FVD ↓	
Method	BF	GFP	BF	GFP
Multi-StyleGAN (ours)	**33.37**	**207.84**	**4.46**	**30.16**
StyleGAN2 + ADA [1] + U-Net dis. [3]	200.54	224.79	45.63	35.22
StyleGAN2 3D + ADA + U-Net dis.	76.03	298.75	14.75	31.48

- Multi-StyleGAN captures the dataset well and transitions smoothly through the latent space (see supplementary video).

References

[1] Karras, T., Aittala, M., Hellsten, J., Laine, S., Lehtinen, J., Aila, T.: Training generative adversarial networks with limited data. In: NeurIPS. vol. 33, pp. 12104–12114 (2020)
[2] Karras, T., Laine, S., Aittala, M., Hellsten, J., Lehtinen, J., Aila, T.: Analyzing and Improving the Image Quality of StyleGAN. In: CVPR. pp. 8110–8119 (2020)
[3] Schonfeld, E., Schiele, B., Khoreva, A.: A U-Net Based Discriminator for Generative Adversarial Networks. In: CVPR. pp. 8207–8216 (2020)

Conclusion

- Multi-StyleGAN synthesises multi-domain image sequences.
- Dual-styled-convolutional block enables high-quality synthesis of multi-domain images.
- Multi-StyleGAN showcased on time-lapse fluorescent microscopy sequences of yeast.
- The simulations realistically capture spatio-temporal organisation of multiple living yeast cells, as well as other biophysical factors, cell fluorescence and time-dependencies.

Paper (preprint): `https://arxiv.org/pdf/2106.08285.pdf`
Code: `https://git.rwth-aachen.de/bcs/projects/tp/multi-stylegan`
Dataset: `https://tudatalib.ulb.tu-darmstadt.de/handle/tudatalib/2880`
Project Page: `https://christophreich1996.github.io/multi_stylegan/`

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