Technische Universität München – Faculty of Informatics
Chair for Computer Aided Medical Procedures (Prof. Nassir Navab)
Practical Course: Machine Learning in Medical Imaging SS24

Deep Generative Models for Growing Structures

1 General Info

Project Title: Deep Generative Models for Growing Structures
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2 Background and Motivation

In the last few years, research in the domain of synthetic image generation has increased. This surge is particularly impactful in the area of medical imaging, where data scarcity poses a substantial challenge. Among the various approaches, Generative Adversarial Networks (GANs) and Diffusion Models [3] have gained prominence due to their abilities to represent the data. Nonetheless, these methods sometimes fail to adhere to the underlying physical or geometrical constraints, which is crucial for realistic image synthesis. Early non-DL approaches [5] have shown that simple mathematical functions are able to generate biological structures in a growing manner. However, this area of research has been underexplored after the advent of deep learning-based methods.

3 Project Abstract

In this project, we aim to address this limitation by grounding our approach in fundamental physical models. We draw inspiration from Turing pattern generators [5] and growing neural cellular automata [2], which are instrumental in simulating the development of complex structures such as vascular networks. Then, we integrate these foundational models with cutting-edge generative models like diffusion models to create biologically plausible synthetic images. We will tackle the generation of data in both 2D and 3D vessels [4, 1] using the proposed method.

4 Technical Prerequisites

- Good background in machine learning and deep learning
- Experienced in PyTorch
- Experienced in Python
- Experience with Generative Models

5 Benefits

- Weekly supervision and discussions
- Possible novelty of the research
- The results of this work are intended to be published in a conference or journal

6 Work packages and Time-plan

	Description	# Students
WP1	Familiarizing with the literature.	4
WP2	Implementing the baselines	4
WP3	Improving the baselines and validation on relevant datasets	4
	Midterm Presentation	4
WP4	Implementing the model	4
WP5	Finalizing the results and evaluation	4
	Final Presentation	4

Table 1: Project Timeline

References

[1] Muhammad Moazam Fraz, Paolo Remagnino, Andreas Hoppe, Bunyarit Uyyanonvara, Alicja R. Rudnicka, Christopher G. Owen, and Sarah A. Barman. Chase db1: Retinal vessel reference dataset, 2012.

[2] Alexander Mordvintsev, Ettore Randazzo, Eyvind Niklasson, and Michael Levin. Growing neural cellular automata. *Distill*, 5(2):e23, 2020.

[3] Robin Rombach, Andreas Blattmann, Dominik Lorenz, Patrick Esser, and Björn Ommer. High-resolution image synthesis with latent diffusion models. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pages 10684–10695, 2022.

[4] Amber L Simpson, Michela Antonelli, Spyridon Bakas, Michel Bilello, Keyvan Farahani, Bram Van Ginneken, Annette Kopp-Schneider, Bennett A Landman, Geert Litjens, Bjoern Menze, et al. A large annotated medical image dataset for the development and evaluation of segmentation algorithms. *arXiv preprint arXiv:1902.09063*, 2019.

[5] Alan Mathison Turing. The chemical basis of morphogenesis. *Bulletin of mathematical biology*, 52:153–197, 1990.