Medical image synthesis using deep learning

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Introduction

Medical image analysis tasks
E.g. segmentation, detection, classification, registration

Clinical applications
E.g. radiotherapy, image guided surgery, diagnosis, risk prediction

Problems
- Large clinical datasets needed
- Privacy and ethical concerns
- Imbalanced datasets
- Models not always robust against changes in acquisition protocol

How to overcome these problems?
The use of artificial data can overcome these issues. Artificial medical images can be created in two ways: using simulation or synthesis.

Simulation uses complex models to model the underlying structure and to simulate a medical scan. Whereas synthesis is data driven, and no underlying models need to be known.

Many studies are done on generating deep fakes for e.g. political attacks or generating non-existent faces. These models can be translated to medical images to potentially improve automated medical image analysis tasks.

Methods & possible applications

Possible directions this research is heading:

Non-existing patients

Generate images of non-existent patients with for example the use of a style-based generator [1].
- Create an anonymous variant of an existing dataset
- Controlled data augmentation to obtain a balanced dataset that includes rare pathologies

Non-existent features in real patients

Generate images of existent patients, with non-existent features using e.g. image-to-image translation model [2].
- Generate images showing future progression of disease
- For example for early diagnosis of Alzheimer's disease
- Large public datasets available from Alzheimer studies
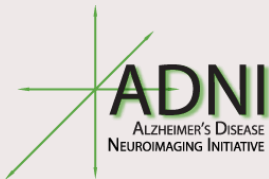
Points of discussion

- Many 3D tasks, will hardware allow for 3D image synthesis?

- How to evaluate the quality of synthetic data?
    - Metric based on comparing feature distributions of real versus synthetic images

    Realistic images ← ⚖ → Large amount of variation

    → How to evaluate when synthetic dataset contains more variation than original?
    - Evaluate deep learning task trained on real versus synthetic data.
    → Do the images need to be realistic in this case?

- Are synthetic images completely anonymous, or can they be traced back to a patient?

[1] Karras, T., et al.. "A style-based generator architecture for generative adversarial networks. "*Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2019.
[2] Isola, P., et al. "Image-to-image translation with conditional adversarial networks. "*Proceedings of the IEEE conference on computer vision and pattern recognition*. 2017.