PhD Thesis Proposal

Title: Computational Visual Perception and Learning Framework for Quality-Driven Medical Imaging.

Summary

We are witnessing a proliferation of deep learning-based solutions in medical imaging technologies. Most of the current developed algorithms for medical image processing and interpretation are based on Deep Neural Networks (DNNs). For many computer vision problems, the DNNs are trained and validated based on the assumption that the input images/videos are pristine (i.e., artifact-free). However, in medical imaging, video-guided surgery and image-guided radiotherapy systems, for example, different signal processing stages like image acquisition and reconstruction can affect the acquired image quality. These factors reduce the visibility of relevant features and hence are a cause of concern in the context of diagnosis. It is then important to develop efficient solutions to generate good quality images in order to facilitate high level tasks in the field of medical imaging and clinical diagnosis and especially in the case of low-dose (LD) protocols more and more used especially in radiotherapy.

The main goal of this research project is to contribute to the reformulation of new approaches, based on DNNs, for the processing and analysis of visual information. The main idea is to combine the perceptual approach, based on the modelling of retino-cortical mechanisms, with deep learning techniques. The originalities and contributions will be highlighted through several concrete actions on both the theoretical and application levels. One of the objectives of this work is to redefine the loss functions and the different connectionist architectures by drawing on sufficiently established knowledge on the architecture and functioning of the visual cortex. In terms of targeted applications, two major fields will be considered: LD imaging enhancement and tumor identification for image-guided Radiotherapy (IGRT) using multi-modality imaging techniques. The deep learning based multimodal learning approaches can improve the accuracy, efficiency, robustness, interpretability, and generalizability of low-dose imaging enhancement and tumor segmentation/classification which is a promising way to manage patients' follow-up and post-surgical tasks. The developed methods will be more particularly evaluated and validated on concrete cases of Low-dose CT (LDCT) and PET (LDPET) images.

The mentioned objectives can be achieved through the three main research questions listed below.

1. **How to go beyond the physical limits of low-dose medical image acquisition systems**: Development of new DL-based methods particularly new multimodal learning-based approaches for high quality image acquisition and reconstruction from LDCT and LDPET data.
2. **How to automatically identify malignant lesions**: Development of a suitable DL-based image processing and analysis tools to automatically segment malignant lesions from combined low-dose PET/CT images and organs at risk from LDCT images.
3. **How to measure image quality both at the acquisition and processing levels**: It is important to have reliable and consistent Image Quality Metrics (IQMs) with the evaluation of clinicians to access image quality at acquisition and pre-processing. Development of diagnostic oriented IQMs based on the modelling of retino-cortical mechanisms, with explainable and justified deep learning models, for multimodal medical imaging.

In summary, in this thesis, we will introduce a new framework by building a bridge between computational modeling of perceptual vision and machine learning paradigm for solving real-world problems in the context of medical imaging and clinical diagnosis.

Contacts

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