Degree project 30 credits in Biomedical Engineering

Hyperbolic Deep Learning in medical imaging

Biomedical Engineering R&D (MT-FoU) is a research and development department at the Center for Information Technology and Biomedical Engineering at Norrland University Hospital, Region Västerbotten. The department conducts international research, development and education in the field of biomedical engineering, with expertise in, for example, sensors and measurement systems, image and signal analysis and biomechanical models. MT-FoU is also a part of the competence center AI for Medicine in Northern Sweden, AIM North, which supports clinical research projects with technical method expertise in machine learning and AI.

Background

To date, deep representation learning has been the central component that drives modern computer vision problems, medical imaging included. In short succession, many differentiable layers and network architectures have been proposed to tackle visual research problems. While different in structure, all are based on Euclidian operators and therefore assume that data is best represented on grids. However, this assumption does not fit all types of data. Medical imaging often contains hierarchical anatomical structures or exhibits complex relationships between different modalities, such as CT, MRI, and PET scans. In this regard, Euclidian geometry struggles to capture the exponential complexities of hierarchies, thus leading to suboptimal data representations. Unlike Euclidean space, hyperbolic space has two attractive properties, i.e., exponential expansion, and hierarchical, tree-like structure. **Hyperbolic Deep Learning (HDL)** provides a powerful framework for capturing hierarchical and nuanced relationships within high-dimensional, non-Euclidian data. Through hyperbolic embeddings, HDL offers improved performance in tasks such as classification and segmentation. With the growing need for more accurate and interpretable medical imaging analysis, exploring the application of HDL in this domain offers the potential for significant advancements in diagnostic accuracy, early disease detection, and personalized treatment planning.

Aim of the project

This project aims to explore the potential of HDL in medical imaging, focusing on its ability to represent hierarchical and non-Euclidean structures within high-dimensional data. Specifically, the goal is to investigate how hyperbolic embeddings can enhance performance in downstream tasks such as medical image classification or segmentation. Particular focus will be given to integrating hyperbolic learning techniques at the embedding or classification level, using exponential mapping layers to ensure seamless compatibility and synergy with existing state-of-the-art network architectures. With the increasing demand for more accurate and interpretable diagnostic tools, this project seeks to demonstrate how HDL can significantly improve diagnostic accuracy, facilitate early disease detection, and contribute to personalized treatment planning in the medical field.

Work description

The key objectives and tasks for this project include:

1. **Literature Review**: research techniques in HDL and explore its possible application in medical imaging.
2. **Algorithm Development:** develop and implement HDL methods that enable synergetic integration with existing pre-trained backbones.
3. **Model training and testing:** train models and evaluate their performance (we plan to use in-house data from the Umeå University Hospital).
4. **Performance Evaluation:** i) conduct quantitative and qualitative assessments to measure how well the HDL models generalize to new data and capture hierarchical information in the data; ii) compare against traditional Euclidian-based models to highlight the improvements in generalization.
5. **Reporting and Documentation:** document all stages of the project, including methods, results, and insights gained, producing a final report.

If your program has 15 credits rather than 30, we will adapt the scope of the thesis to fit within the credits.

Supervisor at MT-FoU
Paolo Soda and Francesco Di Feola
CIMT, Medicinsk teknik – FoU, Region Västerbotten
E-post: paolo.soda@umu.se, francesco.feola@umu.se
Web: https://www.regionvasterbotten.se/medicinsk-teknik-forskning-och-utveckling, https://www.umu.se/en/staff/paolo-soda/