PhD research project 2024-2027

Graph neural network, informed deep learning and entropy for image analysis using multiview structural information: application to medical imaging and early brain lesion

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Place: ISISV teams of the « Laboratoire Angevin de Recherche en Ingénierie des Systèmes » (LARIS), Angers University
Collaboration: University Hospital of Angers
keywords: deep learning, graph neural networks, multiview/multigraph, informed deep learning, entropy, computer vision, medical imaging.
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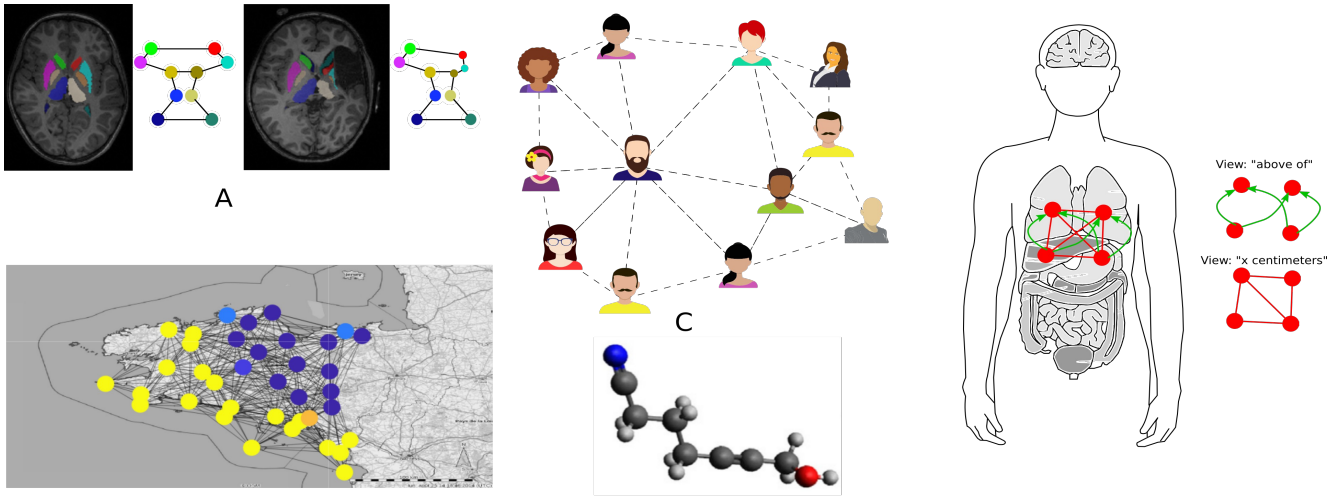

Figure 1: A few examples of how graphs are used: in healthcare, with relationships between anatomical structures (A, E), in meteorology with networks of weather stations (B), in social networks (C), in chemistry (D), including multiviews (E).

Context

Graph Neural Networks (GNNs) are powerful tools to analyze irregularly structured data (as illustrated in Figure 1: people relationships in social networks, bio-chemical associations in chemistry/material sciences, spatial relationships between regions in computer vision [wan23]) [bac20]. The proposed research study mainly focuses on GNNs using multiview and informed deep learning concepts. Multiviews allow to model rich and heterogeneous information, that are challenging to exploit, as underlined by recent works related to multigraphs (each graph being a particular view) [cha22,cha23]. In computer vision, this can refer to various heterogeneous relationships leading to various graph topologies (Figure 1-E – with oriented and non-oriented edges). Informed deep learning is a new and interesting topic in artificial intelligence regarding the ability to integrate physics knowledge/expert knowledge in data-oriented-deep-learning-based methods [ben24,che23,lop23,mor23]. In medical imaging, this can be used with knowledge of anatomy (i.e. spatial relationships between organs in medical imaging - Figure 1-A, E). The integration of such kind of knowledge into the design of GNNs could help to constrain and simplify their training, to improve their generalization and accuracy, and to allow training on smaller datasets. Such a knowledge can be integrated at message passing level or in the loss function of a GNN. Note that such knowledge can also be used during inference, to modulate the decision taken by a GNN (avoiding trivial errors that can occur in data-only-guided deep learning).

Objective, proposed approach, and positioning versus researches of the ISISV team.

The main objective of this research is to find out a method allowing to combine multiview information and expert knowledge in relationships guided image analysis [ben24,wan23]. Two tasks will be considered: node classification for image segmentation and graph regression. Concerning graph regression, two objectives are considered. The first objective deals with the prediction of the hand motor function of children after neonatal stroke [cou24b]. The second objective is related to the quantification, by a GNN, of the irregularity of a graph (Figure 1-A: right side graph is less regularly than the left side one). This corresponds to its entropy computation. The underlying application is linked with the correlation between this GNN-guided entropy measure and hand motor function previously mentioned. This work will be based on the state of the art as well as on recent research works of the ISISV research team, on graph-guided segmentation using graph matching and GNNs [cho23,cou24a], on GNN-based regression for the prediction of motor hand motor function after neonatal stroke [cou24b], and on entropy measures [gau22,gau23]. Using GNN-based entropy computation, one expects, in particular, to reduce computation time. Although this research work aims at providing generic methods to be evaluated on various synthetic and public datasets, the main targeted application is linked with the previous mentioned prediction of the hand motor function from various imaging modalities (MRI, DTI, fMRI in our case). Regarding this application, the

dataset is already available, as well as preliminary codes, resulting from recent works [cou24b]. This part of this work will be performed in collaboration with the medical doctors of the ISISV team that are also members of the University Hospital of Angers.

Skills: computer vision, deep learning, graphs, Python, Pytorch.

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