Comparison between CNN and GNN pipelines for analysing the brain in development

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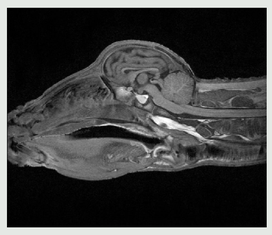
Abstract : In this study, we present a novel pipeline designed for the analysis and comparison of non-conventional animal models, such as sheep, without relying on neuroanatomical priors. This innovative approach combines an automatic MRI segmentation (histogram-based algorithm or ”split and merge” algorithm) with graph neural networks (GNNs) to overcome the limitations of traditional methods. Conventional tools often depend on predefined anatomical atlases and are typically limited in their ability to adapt to the unique characteristics of developing brains or non-conventional animal models. By generating regions of interest directly from MR images and constructing a graph representation of the brain, our method eliminates biases associated with predefined templates. Our results show that the GNN-based pipeline is more efficient in terms of accuracy. GNNs offer notable advantages, including improved interpretability and the ability to model complex relational structures within brain data. Future research will focus on refining graph construction techniques, incorporating edge features, and exploring various GNN architectures to enhance the pipeline’s performance. Overall, our approach provides a promising solution for unbiased, adaptable, and interpretable analysis of brain MRIs, particularly for developing brains and non-conventional animal models

Experiments made on 197 sheep brains

GNN pipeline

(Our proposition)

1 – PRETREATMENTS:



Z-score normalisation
Skull stripping

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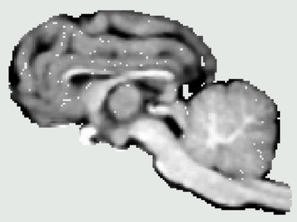

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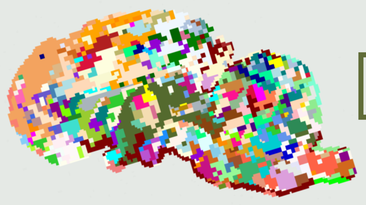
2 – BRAIN SEGMENTATION:

Split and merge algorithm

Histogram-based algorithm

(github link: https://scm.univ-tours.fr/lifat/splitandmerge3d)



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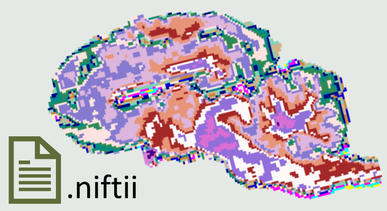

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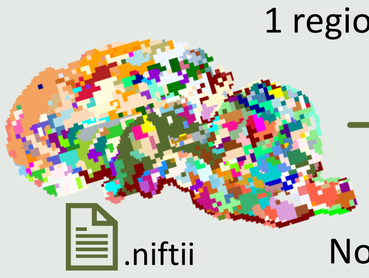
3 – GRAPH CREATION: (github link: https://scm.univ-tours.fr/projetspublics/lifat/3dbrainminer)

Node creation:
1 region = 1 node

Edge creation:
2 adjacent regions => edge



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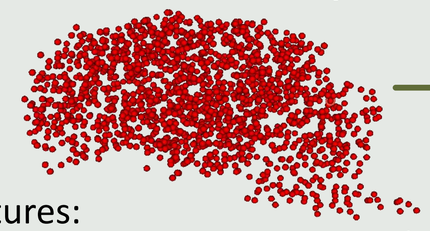

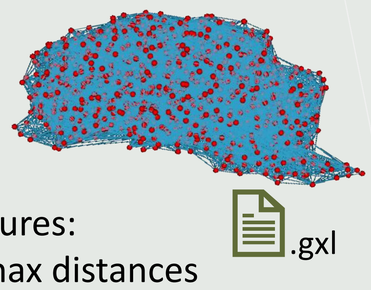

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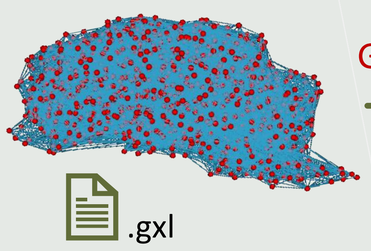
Node features:
Volume, surface, intensity (mean and std), position

Edge features:
Mean, min and max distances

4 – GRAPH CLASSIFICATION:

Task: Age prediction via graph classification across 7 classes



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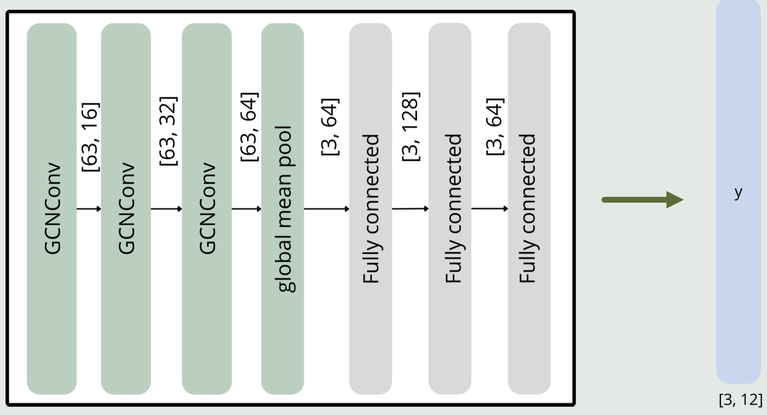
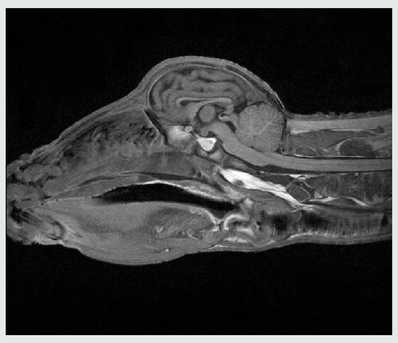
GNN4



CNN pipeline

1 – PRETREATMENTS:



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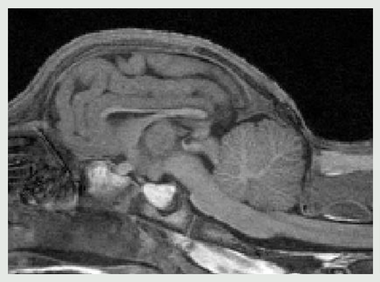
Z-score normalisation
Cropping



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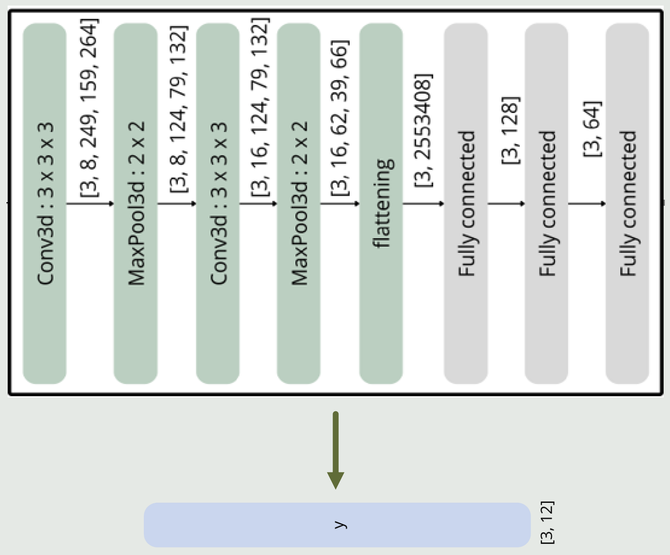
2 – IMAGE CLASSIFICATION:

Task: Age prediction via image classification across 7 classes



GNN RESULTS:

	Convs	Pooling	Accuracy (%)
GNN1	8, 16, 32	Maxpool	59.20 ± 8.15
GNN2	8, 16, 32	Meanpool	48.28 ± 2.98
GNN3	16, 32, 64	Maxpool	54.60 ± 7.18
GNN4	16, 32, 64	Meanpool	**63.22 ± 5.27**

Results using different GNN architectures with the split and merge algorithm (split = 10, merge = 40)

Segmentation Method	Accuracy (%)
Histogram-based, $n = 6$	41.95 ± 1.99
Histogram-based, $n = 20$	40.81 ± 6.53
Histogram-based, $n = 30$	43.10 ± 6.90
Split = 10, Merge = 40	**63.22 ± 5.27**
Split = 20, Merge = 60	41.51 ± 5.33

Results using GNN4 and different segmentation parameters

CNN RESULTS:

Accuracy of the CNN architecture:
59.77%

Conclusion:

- Automatic segmentation to model brains as graphs yields better results than traditional image pipeline for age classification tasks
- No biological prior is needed, as it could bias the results

Future works:

- Better graphs creation methods: Test with other parameters, connect two nodes considering an intensity threshold etc.
- Testing other GNN architectures: GAT layers, VGAE etc.