A glimpse of ClinicaDL, an open-source software for reproducible deep learning in neuroimaging

Elina Thibeau-Sutre* ELINA.TS@FREE.FR
Mauricio Díaz* MAURICIO.DIAZ-MELO@INRIA.FR
Ravi Hassanaly RAVI.HASSANALY@GMAIL.COM
Olivier Colliot OLIVIER.COLLIOT@CNRS.FR
Ninon Burgos NINON.BURGOS@CNRS.FR
Sorbonne Université, Institut du Cerveau - Paris Brain Institute - ICM, CNRS, Inria, Inserm, AP-HP, Hôpital de la Pitié Salpêtrière, F-75013, Paris, France

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Abstract

This paper presents ClinicaDL, a deep learning software for neuroimaging processing. Its aim is to provide a concrete solution to methodological flaws often found in our field (the difficult use of neuroimaging data sets, data leakage and insufficient reproducibility), but also to raise awareness and discuss these issues with our community. The corresponding journal paper has recently been accepted in Computer Methods and Programs in Biomedicine.

Keywords: Deep learning, Neuroimaging, Data leakage, Reproducibility, Open-source

1. Introduction

In addition to facing a reproducibility crisis (Hutson, 2018), many deep learning studies include methodological flaws, especially in the field of neuroimaging in which deep learning contributors may not be aware of the specificities of the domain. In a previous study (Wen et al., 2020) we identified and quantified the occurrence of some of these flaws (data leakage) in the literature. The effect of data leakage was further studied in (Yagis et al., 2021). With ClinicaDL (Thibeau-Sutre et al., 2022), we propose a concrete solution to methodological flaws in addition to two other pitfalls encountered by deep learning users working on neuroimaging data.

2. Avoiding common pitfalls in deep learning studies with ClinicaDL

ClinicaDL allows its users to easily handle a great diversity of neuroimaging data sets as it interacts with a neuroimaging standard, the Brain Imaging Data Structure (Gorgolewski et al., 2016) (BIDS). This structure can be easily preprocessed by Clinica (Routier et al., 2021), the companion project of ClinicaDL, to prepare images (structural MRI or PET) in a standard way and store them in the ClinicA Processed Structure (CAPS).

Secondly, ClinicaDL implements a set of technical solutions to avoid the main methodological issues causing data leakage found in the literature. One of them consists in providing feature extractors ensuring that the data partitioning between train and test is at the subject level, and not at the patch or slice level (Figure 1), as it was already witnessed in several studies (Wen et al., 2020).

* Contributed equally

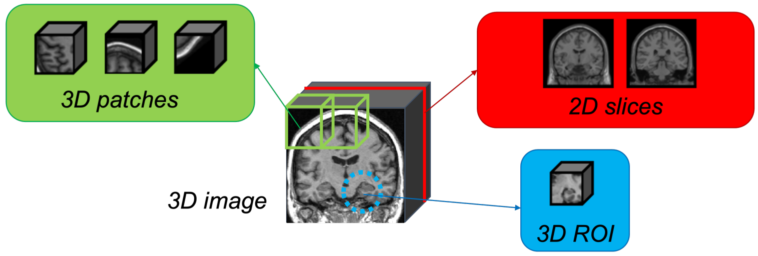

Figure 1: ClinicaDL users can handle their 3D images in different ways. They can use the whole 3D image, extract 3D patches, 2D slices or 3D regions of interest (ROI) according to a binary mask (not necessarily cubic) manually designed by users.

Finally, ClinicaDL ensures the reproducibility of deep learning experiments by storing all information necessary to replicate them. Moreover, it has adopted standard practices for software development and distribution to enhance its usability. The open-source code is available on Github[1] and is automatically tested thanks to continuous integration. The software is distributed as a Python package on PyPI. Finally, we provide a documentation[2] and tutorials[3] that can be run online to help newcomers to familiarize with the software.

3. ClinicaDL overview

ClinicaDL includes a set of tools to prepare data for deep learning tasks (such as quality check, label definition, generation of synthetic data), architecture search, network training, as well as result inference, model evaluation and interpretation (Figure 2). Different tasks can be learnt by the network trained by ClinicaDL, such as classification, regression and image reconstruction. Moreover, the framework is meant to be flexible as it can be easily enriched with new features of external contributors: this way new tasks can be added by creating a new class following a template. This process is described in the documentation to encourage new contributions to the software on several levels: tasks learnt by networks, architectures, validation settings, metrics and feature extractors.

4. Conclusions

ClinicaDL helps deep learning researchers to produce reliable studies in neuroimaging. It has been developed to overcome three issues specific to our field: (1) the difficult use of neuroimaging data sets by users with little expertise, (2) data leakage in validation and evaluation methods and (3) insufficient reproducibility. Some issues remain open for further contributions, such as exploiting optimally multi-GPU workspaces. To answer them, we plan to integrate in the future standard tools of the deep learning or neuroimaging communities, such as MLflow[4] or TorchIO (Pérez-García et al., 2021).

1. ClinicaDL repository: `https://github.com/aramis-lab/clinicadl`
2. ClinicaDL documentation: `https://clinicadl.readthedocs.io/en/stable/`
3. ClinicaDL tutorial: `https://aramislab.paris.inria.fr/clinicadl/tuto/intro.html`
4. MLflow: `https://mlflow.org`

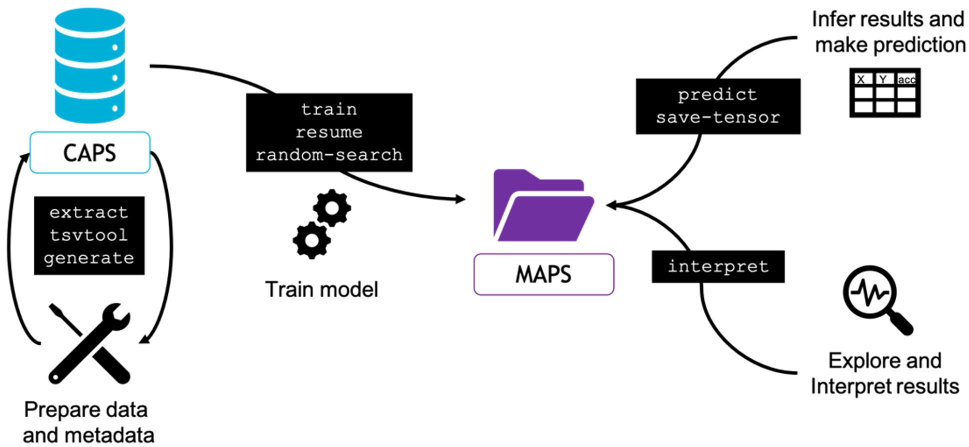

Figure 2: ClinicaDL main functionalities. `extract`, `tsvtool` and `generate` functionalities read and write in the ClinicA Processed Structure (CAPS) which contains preprocessed neuroimaging data. ClinicaDL writes its outputs in the Model Analysis and Processing Structure (MAPS), which contains the results of the training phase as well as inference on new data or the results of interpretability methods.

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