PhD Thesis Proposal

Deep Learning for Multivariate Textures: Synthesis, Classification, Robustness - Applications to Art and Biomedicine Applications.

Requirements :	Solid background in Math & Statistics ; MATLAB &Python	*Location :*	Ecole Normale Supérieure de Lyon Laboratoire de Physique

Research team and supervision.

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Scientific context: Deep Learning, reproducibility, robustness and confidence. Along the years, Deep Learning has become a reference tool massively used for several different tasks (classification, segmentation,...) in image processing. However, besides the commonly referred to lack of theoretical understanding in the principles underlying its use, deep learning, when confronted to real-world applications, further suffers from significant drawbacks (lack of reproducibility and robustness, issues in producing quantified confidence measures for the relevance of the produced outputs), that often, preclude their real use by "experts" in applications.

Along another line, despite the "data deluge" (massive datasets are available for analysis), labeled datasets grow far more slowly, yielding issues, such as severe unbalance in the sizes of tagged categories, or even absence of tags for some categories, weak reliability of the "labeling" process... This also significantly impairs the use of deep learning for real world applications.

Goals and spirit of the proposed PhD Thesis: The issues of reproducibility, robustness and confidence assessment in deep learning architectures will be investigated in the context of two fundamental, crucial and related tasks in information extraction from empirical data:

1 - **Similarity assessment** between pairs of object in large size databases remains a central building block for numerous inference problems (classification, clustering, diagnostic,...).

2 - **Spatiotemporal dynamics synthesis** is also crucial to address issues such as class unbalance, oversampling and surrogate data production issues.

Reproducible and open science: The proposed work will seek nurturing interactions between tentative methodological developments, aiming to better understand the theoretical foundations of deep learning approaches for similarity assessment and texture synthesis, and contributions in real-world applications (biomedicine and art investigations), aiming to produce significant advances in the targeted fields. It will be organized around reproducible-research/open-science strategies (toolbox, website, github repository, large audience scientific mediations...).

Research directions. The proposed work will combine several lines of thoughts:

1 - Complexity matching: a first goal will be to review and expand on the ways complexities of a task to achieve have been quantified. In classification, for instance, a bound has been proposed in the literature quantifying (for well-specified models) the levels on intra-class resemblance and inter-class-dissemblance that permit unsupervised clustering. Along another line, tools such as Vapnik-Chervonenkis dimension, were used to quantify deep learning architecture complexities. A first research direction will consist in matching architecture complexity to task complexity.

2 - Synthesis quality assessment: often, when using deep learning architectures to synthesize spatiotemporal dynamics, the quality of achieved textures is assessed by visual inspections. It will be investigated how indices can actually be constructed that assess synthesis quality in quantified and reproducible manners. In the context of textures produced by real-world applications or natural complex phenomena (e.g., hydrodynamic turbulence, intrapartum fetal baroreflex regulation), little is known in advance on what statistics characterize best the textures. Therefore, indices will be looked for with the rationale that they should not rely on a priory known properties. Multiscale statistics will

be used here. However, such indices are a posteriori i.e., they are measured after training has been completed and neural network textures synthesized. A priori indices, relying on the status of the network (e.g., the values of Loss Functions) will be investigated.

3 - Confidence assessment: Often when interacting with experts of real-world application, it becomes clear that they are not only interested in an output (e.g., clustering) but also and equally importantly by confidence levels in the outputs (how much should one trust the chosen number of clusters ? How much should one trust that a given subject is in a cluster rather that in another one). While classical in statistics and in machine learning, this critical question will be revisited in the context of deep learning, exploring the possibilities of repeating the training from scratch as well as of reinforcement strategies.

4 - Labels and supervision: When analyzing proposed results, an expert often focuses on one or a few samples only on which he/she provides a solid feedback, validating/rejecting some resemblance between pairs or small subsets of objects. One goal will then to be incorporate such feedback in a reinforcement strategies. This will require to investigate relations between unsupervised and weakly supervise strategies. This is where Point2 (texture synthesis for upsampling) and Point3 (quality assessment for sample selection) will meet Point4.

5 – Applications: While the work directions described above are methodological in nature and do not depend on the specificity of a particular application, the tools developed will be motivated by and applied to two major categories of problems, biomedicine and art investigations. First, in intrapartum fetal heart rate monitoring, focus has been so far on computing medicine driven or signal processing based features, used to feed classical machine learning strategies. However, the availability of large and documented databases of intrapartum fetal heart rate recordings makes it possible to investigate the potential of deep learning approaches in such context (Collaboration with the Femme-Mère-Enfant hospital (HFME, Hospices Civils de Lyon)). In art investigations, art photographic paper textures similarity assessment constitutes an important challenge, where constructive means and tools to foster interactions between art scholars and image processing teams is critical. Deep learning tools may permit to better contribute to these interdisciplinary sciences, by easing art scholar incorporation into automated similarity assessment tools (Collaboration with the Medialab at Yale University).

Application. All applications must be sent via email (minimum: motivation letter, CV, M2 marks).

References.

MultiScaleAnalysis: **http://perso.ens-lyon.fr/patrice.abry/18EUSIPCO.pdf**

Deep Learning: **http://perso.ens-lyon.fr/patrice.abry/20DLtextureSynthesis.pdf**

Art Investigations**:** **http://perso.ens-lyon.fr/patrice.abry/15Abryetal_SPMAG.pdf**

Further details and references are available upon request.