Multi-marginal Optimal Transport and Statistics for Fine-Grained Change-Point Detection

PhD subject

Expected starting date: September/October 2021

Key-words Machine Learning, Optimal Transport (OT), Change-Point Detection, Multi-marginal Optimal transport, signal segmentation.

Topic Sciences de l'Ingénieur (3)

Context Many tasks in machine learning often attempt to align or match real-word entities, based on computing distance between pairs of corresponding probability distributions. Recently optimal transport (OT) based data analysis has proven a significant usefulness to achieve such tasks [1, 2]. Distances based on OT are referred to as the Monge-Kontorovich or Wasserstein distance [3, 4, 5]. OT tools allow for a natural geometric comparison of distributions, that takes into account the metric of the underlying space to find the most cost-efficiency way to transport mass from a set of sources to a set of targets. The success of machine learning algorithms based on Wasserstein distance is due to its nice properties [5] and to recent development of efficient computations using entropic regularization [6, 7, 8].

Similarity and anomaly detection are widely researched problems in complex systems whose underlying state changes, possibly several times. Such situations occurs when one aims at segmenting frames of audio clips [9], in order to perform audio scene analysis. It may prove relevant for segmenting videos frames for action recognition [10] or road scene surveillance. Change-point detection is the task of estimating the location of changes in statistical properties of a signal, or more broadly, a time series [11]. Recent change-point detection methods demonstrated the potential of using OT [12, 13, 14, 15]. To expand this potential, our pursued goals are many-fold and concern the design of statistical tests based on Wasserstein distance or Gromov-Wassertein distance [16, 17] (when signals to be compared are not registered). Another intended goal is to develop efficient algorithms to integrate the statistical tests into joint signals segmentation and classification procedures. Such approaches allow to strongly label, in an unsupervised way, the constituent frames of a signal. Developed methods will be applied on audio and videos analysis for home and road surveillance applications.

So far we are interested in detecting local changes in each frame, namely its intra-constituents considered as marginal distributions. Once this is done, we can finely investigate the changes between frames, in particular we compare these intra-constituents between two consecutive frames. To tackle this problem, we refer to a multi-marginal generalization of OT, known as multi-marginal OT (MOT). MOT was first proposed in [18] as a theoretical extension to OT. It has found applications in signal processing [19], density functional theory [20], labeling for classification [21] and probabilistic graph models [22]. Our ambition is to extend MOT framework to change detection in order to finely characterize the changes in “classes“ (for instance cat, dish washer, speech sounds in home audio clips) across time. To the best of our knowledge, this is the first application of MOT in the context of change-point detection. Scientific challenges in that regard are: can we derive sufficient statistics based on MOT? How to assess the detection consistency? How to combine intra-and-inter-frame detection to reach relevant fine-grained labelling of the signals?

Scientific objectives and expected achievements The successful candidate will pursue a PhD project at the intersection of statistics, machine learning and optimal transport. We will first investigate the role of OT to deal with change-point detection problem. A second step consists in investigating multi-marginal OT problem for fine-grained signal segmentation. As OT is notoriously computationally expensive, we will devote efforts to design new efficient computation algorithms, able to handle large scale datasets and to work in an online learning setting. Applications to fine-grained audios and videos joint segmentation and classification will serve as test-beds. Scientific achievements are expected to be published in major conferences and journals of the machine learning community.

Research environment/Location The research will take place within the LITIS laboratory located at INSA Rouen, France. Strong fruitful collaborations with Mokhtar Z. Alaya (LMAC - Université Technologique de Compiégne) are envisioned and will involve several collaboration meetings. The PhD will be supervised by Gilles Gasso (LITIS) with the involvement of Mokhtar Z. Alaya (LMAC - UTC).

Candidate profile

- Prerequisites: candidates are expected to be graduated in computer science and/or applied mathematics/statistics and/or machine learning and show an excellent academic profile.
- Work environment: the PhD thesis subject requires skills on software development tools, preferably Python language programming with machine learning packages.
- Candidates must have a good level on written English for the production of scientific papers in international conferences and journals.

For more details Feel free to contact by sending an email to Gilles Gasso (`gilles.gasso@insa-rouen.fr`) and Mokhtar Z. Alaya (`elmokhtar.alaya@utc.fr`).

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