STCD: Models and Algorithms for Spatially and Temporally Correlated Data

Special Track within MMEDIA 2017, April 23-27, 2017 - Venice, Italy
http://www.iaria.org/conferences2017/MMEDIA17.html

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***Abstract*— Correlated data is a hot topic in many research fields. In fact, compression, detection, estimation, and transmission of correlated data arise in many practical applications, e.g., environmental monitoring, communication systems, image processing, etc. Identifying and properly managing such correlations may be important, especially when a very large amount of data, yet compressible, must be transmitted across the network. The aim of this special track is to collect the most recent advances in modeling and algorithm design for compression, detection, and transmission of spatially and temporally correlated data in various application domains.**

***Index Terms*— Correlated data, communication systems, sensor networks, Cyber-Physical System (CPS), image processing.**

I. Introduction

Modern Information and Communication Technology (ICT) is nowadays characterized by a plethora of different solutions, either "classical" or emerging, for various real-world applications. New trends, however, revolve around the strict interaction between the technological platform and the surrounding environment. Therefore, people are more and more interested, at different levels, in the interaction between classical communication, signal processing, and networking aspects with sensor and actuator systems. This can be indeed found in the concept of Cyber-Physical System (CPS) [1].

The interaction between ICT and the physical world can be of benefit in various fields, e.g., smart home, automation, medical, etc. Understanding the physical world behind a technology can be also very useful in the design of effective, efficient, and powerful CPS. In fact, all the technological and algorithmic aspects can be enforced by relying on the characteristics of data conveyed by the system itself. However, this comes at the price of a higher complexity, which the designed system should be able to manage.

The high complexity of modern systems calls for new approaches that can manage the huge amount of data generated by the environment to be processed by the interacting system. In fact, data should be efficiently detected, processed, and transmitted in an optimized way. In this context, identifying spatial and temporal correlations among data can play a key role to design effective CPSs.

II. The Most Recent Advances

Correlated sources and their role in modern communication, networking, and signal processing can be analyzed from different perspectives. A first hot topic in this field is proper (probabilistic) modeling which can realistically characterize correlated sources. The resulting models can effectively help a system designer by shedding light onto the effectiveness of the model itself, as well as the ultimate achievable system performance.

From the algorithmic point of view, models for correlated sources can affect performance at different levels, e.g., both at physical or higher levels. A first possible application of models for correlated sources relies in the design of detection and estimation algorithms of the correlated data. Feature extraction through possible big data analysis can be a key factor in designing a system (communication and/or network) capable to efficiently manage an extremely huge amount of data. Possible applications are in the field of data compression and reconstruction, compressive sensing, distributed source coding, image and video processing.

Modeling correlated sources is also important from the transmission point of view. In fact, one can design energy-efficient transmission schemes for correlated data. Moreover, multiple access can be also optimized by resorting to correlated source modeling. In fact, one network node may be silent if it falls inside a very dense area with strong correlations in the environment observation. Last, but not least, correlation may be exploited to guarantee system security through identification of fault node behaviors.

This special track gathers 5 contributions covering different aspects related to modeling and system design in the presence of correlated data. The track is organized into two sessions, the first one covering physical layer-based aspects (papers [2], [3]) and the second one covering algorithm design for specific applications related to image and video processing (papers [4]–[6]). The proposed approaches come from very different backgrounds, both from communication and computer scientists, thus making the track very attractive due to its interdisciplinary feature.

In [2], the authors propose a comprehensive review of probabilistic models for binary correlated data, which can be applied to realistic networking scenarios, e.g., in wireless sensor networking. In particular, they show how to derive relevant statistical quantities of interest and to easily adapt the model to various communication and networking scenarios. This allows to shed light on the achievable performance limits, as well as giving guidelines on algorithm design in the presence of binary correlated information sources.

In [3], the authors analyze the interesting problem of secure communications under a physical layer-based vision. In particular, the authors deal with fusing observations coming from different honest and malevolous nodes, with the aim of detecting the latter. The key contribution is in the derivation of a specific message passing-based detection algorithm characterized by attractive performance.

In [4], the authors focus on the use of temporal correlations in video event retrieval problems. In fact, modeling of such temporal correlations allow them to apply proper graph-based processing and improve results for existing datasets in the literature.

In [5], the authors deal with another image processing applications, where low-resolution Earth thermal images are improved to obtain corresponding high-resolution. In particular, this article proposes to exploit both temporal and spatial correlation, possibly dealing with the presence of clouds in the acquired images.

In [6], the authors discuss the direct application of the canonical Maximum Likelihood (ML) criterion to extract periodic features possibly present in a video stream. In fact, periodic features impose a specific space-time correlation on the video sequence, which can be properly modeled and exploited.

III. Open Issues

Although very broad, the special track STCD does not cover all the aspects related to the presence of correlated sources. In fact, also access and routing protocols can benefit from the inherent data characteristics. For instance, the overall traffic load may be drastically reduced by leveraging on the fact that dense portions of a network may convey similar data related to the same physical quantity of interest. Therefore, it is expected that, beyond improving the physical layer performance in the communication of correlated sources, also other aspects related to higher levels may be investigated, e.g., resorting to the probabilistic models presented in the track. Moreover, the presented algorithms can open interesting research directions in the design of efficient detection algorithms more thoroughly exploiting the nature of correlated data.

References

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