Introduction to the Issue on Gossiping Algorithms Design and Applications

AN inevitable consequence of the scaling of electronics is that in today's world it is hard to think of sensing problems that do not involve a multitude of networked platforms. Perhaps this explains why, in recent years, distributed consensus and gossiping algorithms have received considerable attention in many disciplines, and spurred a number of new research results on distributed signal processing.

These algorithms provide solutions to important problems in sensor networks, localization, robotics, distributed systems' calibration, and distributed compressive field sensing. Unlike data aggregation schemes that concentrate raw data to be processed in a central server, gossip algorithms are iterative and blend communications and computation as a network diffusion process. They provide simple and instructive abstractions of decentralized signal processing, involving key features of this class of problems, such as interaction among many terminals, subject to a model of the cost of communication and to connectivity constraints. The most appealing feature of gossiping algorithms is that in most of them very little information about the network beyond the immediate neighborhood is available at each node, and many methods are naturally resilient to link and node failures. The performance of gossip algorithms allow to make many novel connections to mathematical tools pertaining to graph theory, that are enriching the research in signal processing.

The objective of this special issue is to highlight some of the interesting directions this research has taken.

One prolific research direction is to cast an important class of classic inference problems and optimization, as network gossiping algorithms. Many of the papers in this special issue fall in this class and stretch the boundaries of what can be computed by network diffusion. Interestingly, these efforts provide increasing evidence that networks can exhibit emergent cognitive behavior, even if the data exchanged and computations performed are relatively simple.

For example, "Mobile Adaptive Networks" by S.-Y. Tu and A. H. Sayed, investigate the self-organization and cognitive abilities of adaptive networks to pursue a target, fusing local information via a gossip based adaptive filter. Another important instance of sensor fusion via gossiping is demonstrated in the paper "Gossip-Based Algorithm for Joint Signature Estimation and Node Calibration in Sensor Networks" by N. Ramakrishnan *et al.* "Convergence Rate Analysis of Distributed Gossip (Linear Parameter) Estimation: Fundamental Limits and Tradeoffs" by S. Kar and J. M. F. Moura, also includes important results on the convergence of linear estimators via network diffusion. Gossip-based estimation maximization and maximum likelihood are the topics investigated in "Gossip Algorithms for Simultaneous Distributed Estimation and Classification in Sensor Networks" by A. Chiuso *et al.*. The paper "Distributed Clustering using Wireless Sensor Networks," by P. A. Forero *et al.* shows that unsupervised learning can be attained by network diffusion. Also in this class is "Distributed Principal Subspace Estimation in Wireless Sensor Networks" by L. Li *et al.* which also shows how it is possible to decentralize the well known Oja's learning rule and learn the sample covariance principal subspace via gossiping.

Papers that are focused on using gossiping to solve a wide class of important optimization problems are: "Distributed Asymptotic Minimization of Sequences of Convex Functions by a Broadcast Adaptive Subgradient Method" by R. L. G. Cavalcante *et al.* "Performance Evaluation of the Consensus-based Distributed Subgradient Method Under Random Communication Topologies" by I. Matei and J. S. Baras, and "Distributed Asynchronous Constrained Stochastic Optimization" by K. Srivastava and A. Nedić.

A third group of papers is focused on analyzing or improving the performance of average consensus focusing on its ability to broadcast a function of the data under different sources of distortions and constraints. This has been one of the most prolific topics of investigation, and many authors have researched the design and analysis of resilient communication protocols over wireless networks supporting average consensus gossiping. New advances are still made especially in considering compression, finite precision in the states and interactions and noise in the communication links. Others consider the effect of mobility and interference in wireless communications. Important contributions are made in this issue also on these fronts.

A notoriously difficult problem in gossiping algorithms, it to study convergence properties of gossiping algorithms with exchanges and updates of discrete values. Significant advances on this topic are made in the paper "The Distributed Multiple Voting Problem" by F. Bénézit *et al.*.

In "Efficient Decentralized Approximation via Selective Gossip" by D. Üstebay *et al.*, instead, the authors examine a specific instance of the algorithm that works of vectors, which is useful for compression and distributed transform coding. The paper "A Token Based Approach to Distributed Computation in Sensor Networks" by V. Saligrama and M. Alanyali analyzes also a different form of selectivity in the interaction, based on a token that gives permission to specific agents to exchange and update their states. The issue of precision is revisited in "Non-Asymptotic Analysis of an Optimal Algorithm for Network-Constrained Averaging With Noisy Links" N. Noorshams and M. J. Wainwright.

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"Distributed Averaging in Dynamic Networks" by S. Rajagopalan and D. Shah gives new insights on what are the effects on gossip based computations when there are changes in the network topology in terms of communication links, or changes in the values of numbers present at nodes, with nodes joining or leaving.

The papers "Convergence Speed of the Consensus Algorithm with Interference and Sparse Long-Range Connectivity," by S. Vanka, M. Haenggi, and V. Gupta and "Broadcast Gossip Averaging: Interference and Unbiasedness in Large Abelian Cayley Networks," by F. Fagnani and P. Frasca improve our understanding of the performance of consensus protocols over wireless networks plagued by interference and packet collisions.

Interestingly, "Local Interference Can Accelerate Gossip Algorithms" by B. Nazer *et al.* shows that interference can be transformed from foe to friend in average consensus gossiping, if one adopts appropriate channel codes.

We thank the many researchers that have contributed to this issue. The creativity and sophistication shown in their papers attests that signal processing has fully embraced network science and will contribute for many years to come novel solution to process distributed data in scalable and resilient fashions.

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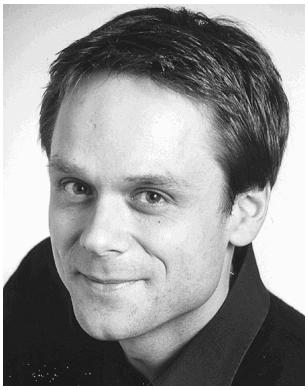

Michael Gastpar (S'99–M'04) studied engineering and philosophy in Zürich, Edinburgh, Lausanne, and Urbana-Champaign, IL, USA. He received the Dipl.El.-Ing. degree from ETH Zürich, Zürich, Switzerland, in 1997, the M.S. degree from the University of Illinois at Urbana-Champaign in 1999, and the Dr. ès sc. from Ecole Polytechnique Fédérale, Lausanne, Switzerland, in 2002.

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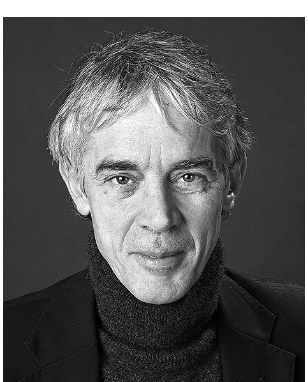
He was a recipient of an IBM Faculty Development Award (1983), an NSF Presidential Young Investigator Award (1986), an Outstanding Paper Award by the IEEE Control Systems Society (1986), the MIT Edgerton Faculty Achievement Award (1989), the Bodossaki Foundation Prize (1995), and the INFORMS Computer Science Technical Section prize (1997). He is a Fellow of INFORMS (2007). In 2007, he was elected to the National Academy of Engineering. In 2008, he was conferred the title of Doctor *honoris causa*, from the Universite Catholique de Louvain (Belgium).



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