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DISTRIBUTED FUSION ESTIMATION IN THE PRESENCE OF MEASUREMENT QUANTIZATION AND MIXED ATTACKS

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ABSTRACT

Over the past years, distributed fusion estimation algorithms have emerged as important tools in the field of networked systems, providing profound significance and practical utility in various domains (see, e.g., [1]–[3]). These algorithms play an essential role in processing information collected from different sensors or sources, to make estimations about the underlying system state or the signal of interest. One of the key advantages of distributed fusion estimation is its ability to efficiently handle large and decentralized networks. By distributing the computational burden across multiple nodes or agents within the network, these algorithms mitigate the challenges associated with centralized processing, such as computational complexity, communication bandwidth constraints, and vulnerability to single points of failure.

The consideration of quantized measurements in signal estimation problems is becoming a topic of great importance in many real-world scenarios, such as wireless sensor networks or communication systems, where the processing of continuous-valued data packets results in significant energy consumption and bandwidth usage. Quantization, which involves discretizing continuous measurements into a finite number of levels, offers a viable solution to alleviate these challenges by reducing the amount of data that must be processed. Despite the loss of information inherent in quantization, properly designed signal estimation algorithms can effectively recover accurate estimates from quantized measurements. In addition, incorporating quantization into signal estimation frameworks promotes the development of more efficient and robust algorithms that can operate effectively in resource-constrained environments (see [4] and references therein).

In today's interconnected world, where critical infrastructure, communication networks, and cyber-physical systems are increasingly vulnerable to malicious activity, understanding and mitigating the impact of eventual attacks is essential for safeguarding against potential disruptions or compromises. Random deception attacks involve adversaries injecting false information into the system, leading to erroneous estimations and eventually compromising the integrity of decision-making processes. On the other hand, denial-of-service (DoS) attacks aim to disrupt the normal operation of the system by overwhelming it with a flood of malicious requests or traffic, thereby affecting the availability and performance of estimation algorithms. Due to the limitations of existing algorithms in this scenario, the study of the estimation problem in networked systems exposed to different types of attacks has received great attention in the last few decades (see [5], [6] and references therein, among others).

This paper addresses the distributed fusion estimation problem of stochastic signals from quantized measurements with random parameter matrices and time-correlated additive noises. These measurements are assumed to be exposed to mixed network attacks, including both random deception attacks and denial-of-service (DoS) attacks and the stochastic nature of these attacks is aptly modeled through Bernoulli random variables. Using a covariance-based methodology and a prediction compensation strategy to counteract the random loss of information caused by DoS attacks, recursive algorithms are designed for the distributed fusion filtering and fixed-point smoothing problems.

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Numerical simulation results are presented to underscore the broad applicability of using random parameter matrices, which effectively cover different kinds of network-induced uncertainties and random failures, thus providing a more realistic representation of engineering environments. Furthermore, the obtained results validate the efficiency of the proposed estimation scheme and provide insights into the influence of random attack probabilities on the estimation accuracy.

The proposed algorithms contribute significantly to the advancement of signal processing and network security research, particularly in contexts involving quantized measurements, mixed uncertainties, and network attacks. This comprehensive investigation enhances the understanding and mitigation strategies in complex networked systems, facilitating advances in both theoretical research and practical implementations.

Keywords Distributed fusion estimation · quantized measurements · mixed attacks · random parameter matrices · time-correlated noise

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References

[1] Caballero-Águila R., Hermoso-Carazo A., and Linares-Pérez J., Networked fusion estimation with multiple uncertainties and time-correlated channel noise, Inf. Fusion, 54, 161–171, 2020.

[2] Shen Y., Wang Z., Dong H., Liu H., Multi-sensor multi-rate fusion estimation for networked systems: Advances and perspectives, Inf. Fusion, 82, 19–27, 2022.

[3] Zou L., Wang Z., and Liang J., Communication-Protocol-Based Filtering and Control of Networked Systems, Springer Nature Switzerland AG, 2022.

[4] Reddy B.N.B., Pardhasaradhi B., Srinath G., and Srihari P., Distributed Fusion of Optimally Quantized Local Tracker Estimates for Underwater Wireless Sensor Networks, IEEE Access, 10, 38982–38998, 2022.

[5] Sánchez H.S., Rotondo D., Escobet T., Puig V., Quevedo J. (2019). Bibliographical review on cyber attacks from a control oriented perspective. Annu. Rev. Control, 48, 103–128, 2019.

[6] Tao F., and Ye D., Distributed resilient fusion estimation for resource-limited CPSs under hybrid attacks, Inf. Sci., 648: 119527, 2023.