Asymptotic Theory of Sequential Change Detection and Identification

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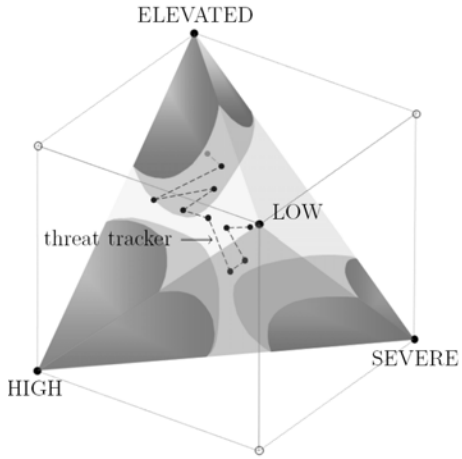

PROJECT SCOPE/ RELEVANCE TO LISTED RESEARCH AREAS: We study the joint problem of detection and identification of a sudden and unobservable change in the statistical pattern of an information sequence to one of several alternative patterns. This problem has applications in sensor management, bio-surveillance, threat detection and identification. We propose a practical online change detection and identification strategy that is asymptotically optimal under Bayesian and fixed-error formulations.

Suppose that we observe an information sequence, and it is crucial to detect a change in the threat level as early as possible and identify its cause as accurately as possible. The inferred threat is initially low, but at some unknown and unobservable time, the threat level jumps suddenly to one of three pre-described categories, e.g., elevated, high, and severe threat levels. To maintain the public safety, it is important to detect this change as early as possible, and at the same time, assess the nature of the change as accurately as possible in order to take the most appropriate countermeasures. This boils down to solving optimally the tradeoff between the detection delay cost and the false alarm and misdiagnosis costs to the society.

RECENT PROGRESS: We consider two formulations: in the *Bayesian formulation*, we want to minimize a linear combination of the expected detection delay, false alarm, and misdiagnosis costs; in *the fixed-error formulation*, we want to minimize the expected detection delay cost subject to a predetermined low upper bound on the false-alarm and misdiagnosis costs. The figure depicts in the Bayesian formulation an optimal sequential detection and identification strategy for a sample simulation. It shows the tracking of a decision statistic (dotted line) before it triggers an appropriate new warning level (indicated by its entrance into a shaded corner of the tetrahedron) and sets in motion the proper counteractions.

Unfortunately, unless the number of alternative patterns is small, obtaining optimal detection and identification strategies is computationally intractable in either formulation. Therefore, we proposed a new sequential decision strategy, which triggers an alarm when the posterior probability of a certain type of change exceeds some fixed threshold for the first time. This strategy is easy and quick to evaluate online. We show that it is also asymptotically optimal under both formulations for small sampling costs or for large misdiagnosis and false-alarm costs. We verified the results on some numerical examples.

FUTURE WORK: We will apply the strategy in bio-surveillance problems using real data.