Combining Detection with Other Tasks of Information Processing

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Classical detection theory, based on the Neyman–Pearson theorem provides the optimal rule for deciding between two hypotheses concerning the distribution or density of a given observation or sequence of observations. It tells us that best trade-off between the two kinds of probability of error is achieved by the likelihood ratio test (LRT). In certain situations, however, this decision between the two hypotheses might be only one of the tasks to be carried out. For example, consider a scenario where under hypothesis $H_0$, the sequence of observations that we receive is just pure noise (or useless/irrelevant for any other reason), which contains no useful information that may interest us, whereas under hypothesis $H_1$, the data that we have at hand has emerged from a desirable information source, and in this case, further processing is called for, such as lossless or lossy data compression, parameter estimation channel decoding encryption, further classification, etc.

The straightforward approach to this problem would be to first apply Neyman–Pearson hypothesis testing, and then, if hypothesis $H_1$ is accepted, perform the corresponding task using the best strategy available. This approach separates between optimal decision and the optimality of the subsequent task. A more sophisticated approach, however, is to solve the two problems jointly, namely, to devise a decision rule that takes into account also the cost of the subsequent task (in case it is to be carried out), and on the other hand, optimize the strategy of the following task, taking into account that the data belongs to the decision region of $H_1$.

In this talk, I will present a unified approach of optimally combining the detection problem with the second information processing task, which is based on a simple extension of the Neyman–Pearson lemma. It minimizes the relevant cost of the second task subject to constraints on the false alarm and misdetection probabilities. We then apply this generalized Neyman–Pearson lemma to three different problems: (i) joint detection and source coding [1], (ii) detection of codeword vs. pure noise, followed by channel decoding in case a signal was detected [2], and (iii) combined channel detection and channel decoding [3].

In all three problems, we derive the optimal solution and assess the asymptotic performance. It turns out that in problems (ii) and (iii) there is an asymptotic separation principle in the sense that the same error exponents are achieved by separating the detection from the second task. This is not the case, however, in problem (i).

References

