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Non-standard boundary behaviour arising in binary mixture problems

Consider a binary mixture model of the form $\pi(x) = \pi_1(x) + \pi_2(x)$, where π_1 is standard normal and π_2 is a completely specified heavy-tailed distribution with the same support. Gaussianity of π_1 reflects a reduction of the raw data to a set of pivotal test statistics at each site (e.g. an energy level in a particle physics context). For a sample of independent and identically distributed values x_1, \dots, x_n , the maximum likelihood estimator $\hat{\theta}_n$ is asymptotically normal provided that θ is an interior point. This paper investigates the large-sample behaviour for boundary points, which is entirely different and strikingly asymmetric for $\theta = \theta_1$ and $\theta = \theta_2$. On the right boundary, well known results on boundary parameter problems are recovered, giving $\hat{\theta}_n - \theta_2 = O_p(n^{-1/2})$. On the left boundary (which corresponds to no new physics) $\hat{\theta}_n - \theta_1 = O_p(n^{-1/2})$, where θ_1 indexes the domain of attraction of the density ratio when $\theta = \theta_1$. For $\theta = \theta_1$, which is the most important case in practice, the tail behaviour of π_2 governs the properties of the maximum likelihood estimator and related statistics. Most notably, conditional on the event $\{\hat{\theta}_n = \theta_1\}$, the likelihood ratio statistic has a conditional null limit distribution that is not the usual χ^2 . In the talk I will omit technical details and focus on the conceptual points with a view to ascertaining whether the formulation is reasonable in a particle physics context. This is joint work with Peter McCullagh and Daniel Xiang at the University of Chicago.

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