

# Near-consistent robust estimations of moments for unimodal distributions

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This manuscript was compiled on June 10, 2023

orderliness | invariant | unimodal | adaptive estimation |  $U$ -statistics

**A. Congruent distribution.** In the realm of nonparametric statistics, the relative differences, or orders, of robust estimators are of primary importance. A key implication of this principle is that when there is a shift in the parameters of the underlying distribution, all nonparametric estimates should asymptotically change in the same direction, if they are estimating the same attribute of the distribution. If, on the other hand, the mean suggests an increase in the location of the distribution while the median indicates a decrease, a contradiction arises. It is worth noting that such contradiction is not possible for any  $LL$ -statistics in a location-scale distribution, as explained in the previous article on semiparametric robust mean. However, it is possible to construct counterexamples to the aforementioned implication in a shape-scale distribution. In the case of the Weibull distribution, its quantile function is  $Q_{Weib}(p) = \lambda(-\ln(1-p))^{1/\alpha}$ , where  $0 \leq p \leq 1$ ,  $\alpha > 0$ ,  $\lambda > 0$ ,  $\lambda$  is a scale parameter,  $\alpha$  is a shape parameter,  $\ln$  is the natural logarithm function. Then,  $m = \lambda \sqrt[\alpha]{\ln(2)}$ ,  $\mu = \lambda \Gamma(1 + \frac{1}{\alpha})$ , where  $\Gamma$  is the gamma function. When  $\alpha = 1$ ,  $m = \lambda \ln(2) \approx 0.693\lambda$ ,  $\mu = \lambda$ , when  $\alpha = \frac{1}{2}$ ,  $m = \lambda \ln^2(2) \approx 0.480\lambda$ ,  $\mu = 2\lambda$ , the mean increases as  $\alpha$  changes from 1 to  $\frac{1}{2}$ , but the median decreases. Previously, the fundamental role of quantile average and its relation to nearly all common nonparametric robust location estimates were demonstrated by using the method of classifying distributions through the signs of derivatives. To avoid such scenarios, this method can also be used. Let the quantile average function of a parametric distribution be denoted as  $QA(\epsilon, \gamma, \alpha_1, \dots, \alpha_i, \dots, \alpha_k)$ , where  $\alpha_i$  represent the parameters of the distribution, then, a distribution is  $\gamma$ -congruent if and only if the sign of  $\frac{\partial QA}{\partial \alpha_i}$  remains the same for all  $0 \leq \epsilon \leq \frac{1}{1+\gamma}$ . If  $\frac{\partial QA}{\partial \alpha_i}$  is equal to zero or undefined, it can be considered both positive and negative, and thus does not impact the analysis. A distribution is completely  $\gamma$ -congruent if and only if it is  $\gamma$ -congruent and all its central moment kernel distributions are also  $\gamma$ -congruent. Setting  $\gamma = 1$  constitutes the definitions of congruence and complete congruence. Replacing the QA with  $\gamma mHLM$  gives the definition of  $\gamma$ - $U$ -congruence. Chebyshev's inequality implies that, for any probability distributions with finite second moments, even if some  $LL$ -statistics change in a direction different from that of the sample mean, the deviations are bounded.

**Data Availability.** Data for Table ?? are given in SI Dataset S1. All codes are attached.

**ACKNOWLEDGMENTS.** I gratefully acknowledge the constructive comments made by the editor which substantially improved the clarity and quality of this paper.