

Stochastic representations and a geometric parametrization of the two-dimensional Gaussian law

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Abstract

Using different types of polar and elliptical polar coordinates, different stochastic representations of the axis-aligned and the regular two-dimensional Gaussian distribution are derived. Advantages and disadvantages of these stochastic representations are discussed. The non-Euclidean geometric measure representation of the axis-aligned two-dimensional Gaussian distribution in Richter (2011) is taken to motivate a new geometric parametrization of the regular Gaussian law. Estimators of the new parameters and corresponding distributions are derived.

Keywords: Stochastic representations - random coordinates - maximum likelihood estimation - exact distributions.

Mathematics Subject Classification: Primary 60D05 - Secondary 62E15 - 62F10 - 62H10.

1. INTRODUCTION

Gaussian random vectors and their distributions are among the most often used ones in probability theory and mathematical statistics, see, e.g., Anderson (2003), Cambanis et al. (1981), Fang et al. (1990), Muirhead (1982) or Tong (1990). It may be surprising therefore that even the two-dimensional case is not yet completely studied with respect to all its basic properties. Similarly, the correlation coefficient is one of the original notions expressing dependence properties not only for the components of Gaussian random vectors and plays even these days an important role in applications like finance and insurance, see, e.g., Embrechts et al. (2002). But even in the case of two correlated random variables following a joint normal distribution it is not yet completely revealed which geometric properties of the random vector and its distribution this coefficient reflects. The non-Euclidean geometric measure representation of the two-dimensional heteroscedastic axis-aligned Gaussian law recently derived in Richter (2011) stimulates some new considerations.

The focus of the present paper is first on stochastic representations of two-dimensional Gaussian random vectors and second on a suitable parametrization of their distributions. It can be a fruitful way to analyze continuous random vectors by making use of coordinates other than Cartesian ones which reflect certain basic geometric properties of the density level sets. For example, studying spherical distributions the usual polar coordinates lead to a geometric measure representation in Richter (1991) which enabled the authors in Kalke et al. (2012) to derive the exact distribution of the component-by-component product of a continuous two-dimensional spherical distribution and to contribute this way to studies on statistics of an elliptically contoured sample like the one in Nadarajah and Gupta (2005). Moreover, suitable generalizations of polar coordinates were introduced for studying the multivariate p -generalized homoscedastic normal (or power exponential) distribution and its $I_{n,p}$ -symmetric generalizations in Richter (2007, 2009), for studying the heteroscedastic uncorrelated Gaussian case and its elliptically contoured generalizations in Richter (2011, 2012), and simplex coordinates were introduced in Henschel and Richter (2002) for studying the multivariate exponential distribution and its simplicially contoured generalizations. In case of the $I_{n,p}$ -symmetric distributions, the generalized polar coordinates lead to stochastic representations which were used to extend the class of skewed distributions in Arellano-Valle and Richter (2012) and which also were used to generalize the Box-Muller method in context of a simulation of the p -generalized normal distribution in Kalke and Richter (2011). Again, it may be surprising that a standard mathematical method, which was developed in earlier centuries, may even nowadays essentially contribute to a real scientific

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