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On some properties of the regular multinomial model and algebraic multinomial model associated with biochemical reaction networks

Yapage N.

Department of Mathematics, University of Ruhuna, Matara, Sri Lanka

It is well known that the multinomial model is a generalization of the binomial model in probability theory and some classes of biochemical reaction networks (BCRNs) have multinomial stationary distributions. We use the additional term "regular" to differentiate the classical statistical models with the algebraic statistical models. Algebraic statistics is a fairly new but rapidly developing field of research related to algebraic geometry and plays a central role in systems biology particularly in the study of BCRNs. In this work, we first discuss some statistical and geometrical properties such as entropy, relative entropy and Fisher information of the regular multinomial model of classical statistics elucidating its exponential family structure. This multinomial model turns out to be a differentiable manifold and has rich properties due to its exponential family structure. Next, we describe the (stoichiometric) algebraic multinomial model of data associated with a particular family of BCRNs from the view point of algebraic statistics and discuss its manifold structure. Motivation for this investigation comes from the previous discussion on regular multinomial model. Theory of BCRNs can be described and defined using vector spaces and related algebraic concepts and such networks can be represented by graphs with nodes (species) and edges (reactions). The stochastic analysis of such networks are widely used to understand the dynamical and information processing aspects. According to the statistical model introduced here, the differentiability becomes a key factor for this model to be considered as a differentiable manifold but it can be solved using the algebraic methods and nonparametric information geometry effectively. This would allow one to elaborate on the algebraic exponential family structure of this kind of models and to discuss its information geometry.

Key words: *Mathematical statistics, information theory/geometry, exponential family, biochemical reaction networks, algebraic statistics*

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*Corresponding author: nihal@maths.ruh.ac.lk