THE INFORMATION GEOMETRY OF SPACE AND TIME

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Abstract

The introduction of geometrical methods has turned out to be extremely natural and useful in statistical inference. This suggests a possible reason why the laws of physics involve geometrical notions in a very fundamental way. The reason is that the laws of physics are nothing but convenient models to process information about the world. If this turns out to be true then it should be possible to derive the laws of physics directly from the rules of probability theory and entropic arguments. In particular, it should be possible to derive the general theory of relativity from an underlying "statistical geometrodynamics" in much the same way that thermodynamics can be explained in terms of an underlying statistical mechanics.

My objective here is to report progress towards the formulation of such a theory [1,2]. I use the information metric of Fisher and Rao to assign a geometry to space in the presence of the simplest form of matter – a dust of identical particles. The information geometry thus introduced is the conformal geometry of space and is of purely statistical origin. The dynamics follows from a principle of inference, the Method of Maximum Entropy, and the basic assumption that there exists a trajectory, that in moving from one state to another the system will pass through a continuous set of intermediate states. No additional "physical" postulates such as an equation of motion or an action principle are needed. The resulting "entropic" dynamics shows remarkable similarities with the general theory of relativity. For example, the dynamical degrees of freedom are those that specify the conformal geometry of space; there is a gauge symmetry under 3d diffeomorphisms; there is no reference to an external time; there is a natural intrinsic time defined by the change of the system itself which, just as in general relativity, can only be obtained after the equations of motion are solved; the theory is time reversible. There is an additional gauge symmetry under scale transformations; I conjecture that under a suitable choice of gauge one can recover the usual notion of a relativistic space-time.

References:

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[2] A. Caticha: "Towards a Statistical Geometrodynamics" in *Decoherence and Entropy in Complex Systems* ed. by H.-T. Elze (Springer Verlag, 2004). (arXiv.org/abs/gr-qc/0301061).