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Application of Fisher Information to Complex Dynamic Systems

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ABSTRACT

Fisher information was developed by the statistician Ronald Fisher as a measure of the information obtainable from data being used to fit a related parameter. Starting from the work of Ronald Fisher¹ and B. Roy Frieden², we have developed Fisher information as a measure of order in dynamic systems^{3,4}. This is important because order is a very fundamental property of dynamic systems. For example, according to the 2nd Law of Thermodynamics, entropy must be an increasing function of time for the whole universe, system plus surroundings. This gives rise to conjectures regarding the lost of work with entropy generation in a general processes. It can be shown that under conditions under which entropy increases with time, the Fisher information becomes a decreasing function of time. This gives rise to a Fisher information analog to the traditional 2nd Law of Thermodynamics. The Fisher information, however, is a purely observational quantity that can be estimated for systems that are not well-defined and for which only partial data exists. This opens to analysis a category of systems which would be difficult to treat by other methods. This is also important because the kinds of systems, e.g. geographical regions, supply chains, and complex technological assemblages, required to understand sustainability are often not well defined and rarely have complete data sets. We have, therefore, been exploring the use of Fisher information for analyzing dynamic systems for sustainability. This includes the formulation of an expanded Sustainable Regimes Hypothesis, and the application of Fisher information to geographical areas, ecosystems, and combined social-ecological-industrial model systems. Salient results from all of these research efforts will be presented and discussed including model and real systems.

¹ Fisher, R.A. *Monthly Notices Royal Astronomical Soc.*, 1920, 80, 758.

² Frieden, B.R. *Science from Fisher Information: A Unification*; Cambridge University Press: Cambridge, 2004.

³ Mayer, A.L.; Pawlowski, C.W.; Fath, B.D.; Cabezas, H. In *Exploratory Data Analysis using Fisher Information*; Frieden and Gatenby, Eds.; Springer-Verlag: London, 2007; pp. 217-244.

⁴ Karunanithi, A.T.; Cabezas, H.; Frieden, B.R.; Pawlowski, C.W. *Ecol. Soc.* 2008, 13 (1), 22.