Rényi Cross-Entropy Measures for Common Distributions and Processes with Memory

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Abstract: Two Rényi-type generalizations of the Shannon cross-entropy, the Rényi cross-entropy and the Natural Rényi cross-entropy, were recently used as loss functions for the improved design of deep learning generative adversarial networks. In this work, we derive the Rényi and Natural Rényi differential cross-entropy measures in closed form for a wide class of common continuous distributions belonging to the exponential family, and we tabulate the results for ease of reference. We also summarise the Rényi-type cross-entropy rates between stationary Gaussian processes and between finite-alphabet time-invariant Markov sources.

1. Introduction

The Rényi entropy [1] of order a of a probability mass function p with finite support S is defined as

$$H_a(p) = \frac{1}{1-a} \ln \sum_{x \in S} p(x)^a \tag{1}$$

for $a > 0$, $a \neq 1$. The Rényi entropy generalizes the Shannon entropy,

$$H(p) = - \sum_{x \in S} p(x) \ln p(x), \tag{2}$$

in the sense that as $a \to 1$, $H_a(p) \to H(p)$. Several other Rényi-type information measures have been put forward, each obeying the condition that their limit as a goes to one reduces to a Shannon-type information measure. This includes the Rényi divergence (of order a) between two discrete distributions p and q with common finite support S, given by

$$D_a(p\|q) = \frac{1}{a-1} \ln \sum_{x \in S} p(x)^a q(x)^{1-a} \tag{3}$$

which reduces to the familiar Kullback–Leibler divergence,

$$D_{KL}(p\|q) = \sum_{x \in S} p(x) \ln \frac{p(x)}{q(x)}, \tag{4}$$

as $a \to 1$. Note that in some cases [2], there may exist multiple Rényi-type generalisations for the same information measure (particularly for mutual information).

Many of these definitions admit natural counterparts in the case when the involved distributions have a probability density function (pdf). This gives rise to information measures such as the Rényi differential entropy for pdf p with support S,

$$h_a(p) = \frac{1}{1-a} \ln \int_S p(x)^a \, dx, \tag{5}$$

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diffusion processes Suitable for use as a graduate text and or a reference work this volume contains many examples exercises and an extensive bibliography It brings together many results that have not appeared previously in book form

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