DIFFUSION PROCESSES AND THEIR PATHS

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Recent confusion concerning extremal paths occurring in the functional integral approach to simple continuous Markov processes will be clarified by considering continuous and differentiable functions.

The functional integral representation of the propagator for a continuous Markov process $\{x(t), t \geq 0\}$ may be written formally as:

$$P(x_f, t_f | x_i, t_i)\, \mathrm{d}x_f = \int\!\!\int \mathcal{D}\{x(t)\} \exp[-S]\,. \qquad (1)$$

where we follow Feynman's notation [1], and where $\mathcal{D}\{x(t)\}$ is a functional measure which need not be discussed explicitly here (see e.g. refs. [2–5]).

1. The discrete action. The lattice expression for the action S may be given as [3] [#1,#2]:

$$S = \tau \sum_{k=1}^{N} L_k\,, \qquad (2)$$

$$L_k = \frac{1}{2c_2}\left[\frac{x_k - x_{k-1}}{\tau} - \alpha c_1(x_k) - \beta c_1(x_{k-1})\right]^2 + \alpha c_1'(x_{k-1})\,. \qquad (3)$$

where the prime indicates differentiation with respect to x, where α and β are arbitrary fractions such that $\alpha + \beta = 1$, and where ultimately the short time lapse τ tends to zero ($N\tau = t_f - t_i$). It is noted that there are in eq. (3) in fact three coefficients, which however are interrelated due to the requirement that the propagator obeys the Fokker–Planck equation with drift function $c_1(x)$ and constant diffusion coefficient c_2. In other words, the lagrangian L_k essentially belongs to a *stochastic* problem.

We now distinguish between two fundamentally different classes of paths associated with the above formulation.

(i) *The most-probable-transition-path.* This is the path (chain) of most probable successive small time (τ) transitions. Thus, this path has one fixed end point and one free end point. To derive its equation of motion we consider eqs. (1)–(3) with fixed x_{k-1} and determine the likeliest value of x_k. It is to be noted that here we only need *one* term from the sum over k in eq. (2). That is:

$$0 = \tau\, \partial L_k / \partial x_k = \frac{1}{c_2}\left[\frac{x_k - x_{k-1}}{\tau} - \alpha c_1(x_k) - \beta c_1(x_{k-1})\right] \times [1 - \alpha\tau c_1'(x_k)]\,. \qquad (4)$$

We next let $\tau \downarrow 0$ and consider those paths for which $(x_k - x_{k-1})/\tau$ tends to a definite limit $\dot{x}$, that means we consider the subclass of *once differentiable functions* $[x(t)]$. Disregarding terms of order τ one obtains:

$$(x_k - x_{k-1})/\tau = \alpha c_1(x_k) + \beta c_1(x_{k-1}) + O(\tau), \qquad (5)$$

which, since $\alpha + \beta = 1$, thus leads to the *first order* differential equation:

[#1] We have corrected for a few misprints in form. (2.18) of ref. [3].
[#2] The last term in L_k may be partially specified at the post-point x_k, but — the corresponding term in S being of order τ — this does not introduce anything new.

Diffusion Processes And Their Sample Paths

M Tight

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