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Approximation of epidemic models by diffusion processes and their statistical inference

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Among various mathematical frameworks, multidimensional continuous-time Markov jump processes (Z_t) on $\N^d$ form a natural set-up for modeling SIR-like epidemics. In this study we extend the results of Ethier & Kurtz (05) on the approximation of density-dependent population processes by Gaussian and diffusion processes with small diffusion coefficient ($\frac{1}{\sqrt{N}}$, where N is the population size) and use the later to provide good estimators of epidemic model parameters built on our previous study. The results of Guy et al. (12) on discretely observed diffusion processes with small diffusion coefficient are extended to time-dependent diffusions. Consistent and asymptotically Gaussian estimates are obtained for a fixed number n of observations (which corresponds to the epidemic context) and for $N\rightarrow \infty$. We then propose a correction term, which yields better estimates non asymptotically. Finally, we use simulations of epidemics (SIR and $SIRS$ models, corresponding to single and recurrent outbreaks, respectively) with different characteristics (variation of R_0, the basic reproduction number, N and n) to assess the performances of the estimators. We obtain that they have good asymptotic properties and behave noticeably well for realistic numbers of observations and population sizes. These findings lay the foundations of an inference method for partially observed epidemic data. Indeed, contrary to the majority of current inference techniques for partially observed processes, which necessitates computer intensive simulations, our method being mostly an analytical approach requires only the classical

optimization steps.

Comments: 25 pages, 10 figures