Using stochastic differential equations to model fishing vessels displacement

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Abstract : Understanding the dynamics of fishing vessels is essential to characterize spatial distribution of fishing effort on a fine spatial scale and to estimate the impact of fishing pressure on the marine ecosystem. Models that works from the coupling of discrete-time Markov chains for the sequence of hidden behaviours (fishing, steaming ...) and piecewise linear movement of fishing boats conditioned by these behavioural states have proved their usefulness to describe fishing vessels dynamics. But three major weaknesses of this class of models have been pointed out I) they can hardly cope with irregular data acquisition ; II) switches in the hidden behavioural process are supposed synchronous to the observed positions ; III) they are not spatially explicit.

To fill these gaps we propose a new model for fishing vessel's displacement by coupling a continuous time Hidden Markov process to the observed process derived from a stochastic differential equation which possibly depends on covariates.

The hidden behaviour is supposed to be a Markov process Z_s taking values in $\{1 \dots K\}$ (1 standing for steaming, 2 for fishing, for instance). The observed process X_s is supposed to satisfy a stochastic differential equation which parameters depend on Z_x :

$$dX_s = b_{Z_s}(X_s) + \sigma_{Z_s}(X_s)dW_s$$

where $b_k(\cdot)$ and $\sigma_k(\cdot)$ are respectively the drift and the diffusion functions satisfying regular conditions, and W is the standard Wiener process. In addition to this, an observation process describe the actual position in function of the observed process $Y_s = X_s + \epsilon_s$.

Statistical techniques based on MCMC algorithms or EM algorithms (and their stochastics variations MCEM, SAEM, ...) are presented to estimate parameters of this model. An application to a set of trajectories of French fishing vessels performing in the Eastern Channel is shown to highlight the potentiality of the method and how it may outperform more classical models.

References

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