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Functional marked point processes – A natural structure to unify spatio-temporal frameworks and to analyse dependent functional data

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This paper treats functional marked point processes (FMPPs), which are defined as marked point processes where the marks are random elements in some (Polish) function space. Such marks may represent e.g. spatial paths or functions of time. To be able to consider e.g. multivariate FMPPs, we also attach an additional, Euclidean, mark to each point. We indicate how the FMPP framework quite naturally connects the point process framework with both the functional data analysis framework and the geostatistical framework; in particular, we define spatio-temporal geostatistical marking for point processes. We further show that various existing stochastic models fit well into the FMPP framework, in particular marked point processes with real valued marks. To be able to carry out non-parametric statistical analyses for functional marked point patterns, we study characteristics such as product densities and Palm distributions, which are the building blocks for summary statistics. We proceed to define a new family of summary statistics, so-called weighted marked reduced moment measures, in order to study features of the functional marks. We derive non-parametric estimators for these summary statistics and, in addition, we show how other existing (marked and/or inhomogeneous) summary statistics may be obtained as special cases of these summary statistics. We finally apply these statistical tools to analyse the population structure such as demographic evolution and sex ratio over time in Spain provinces.