



## **Multivariate Frailty Models for the Multi-type Recurrent Event Data using Monte Carlo EM Algorithm**

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Multi-type recurrent event data arise in many situations when two or more different event types may occur repeatedly over an observation period. For example, in a randomized controlled clinical trial to study the efficacy of nutritional supplements for skin cancer prevention, there can be two types of skin cancer event occur repeatedly over time. The research objectives of analyzing such data often include characterizing the event rate of different event types, estimating the effect of covariates on each event process, and understanding the correlation structure among different event types. In this paper, we propose to use a multivariate frailty proportional intensity model with multivariate random effects. The model can take into account the dependencies among event types as well as the effect of covariates. Maximum likelihood estimates of the regression coefficients, variance-covariance components, and the nonparametric baseline intensity function are obtained using a Monte Carlo expectation maximization (EM) algorithm. The E-step of the algorithm involves the calculation of the conditional expectations of the random effects by using the Metropolis-Hastings sampling. The proposed method is general and it can easily handle recurrent event data with more than two types of events. Simulation studies are used to validate the performance of the proposed method. The proposed method is then applied to the skin cancer data.

**Key Words:** Correlated frailty; Cox model; Proportional hazards model; Random effects; Survival analysis; Skin cancer.