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# BART-FH: FLEXIBLE NONLINEAR MODELING FOR SMALL AREA ESTIMATION


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**Abstract**

The Fay-Herriot model has been the workhorse of area-level small area estimation. This model links direct survey estimates to area-level covariates through a linear mixed-effects framework. While effective, this model assumes a linear relationship between covariates and the true area-level quantities, limiting its flexibility in capturing complex patterns inherent in real-world data. In this work, we introduce an extension of the Fay-Herriot model that integrates Bayesian Additive Regression Trees (BART) to model the true area-level quantities as nonlinear functions of the covariates, complemented by an additive random effect to account for unexplained heterogeneity. The proposed BART Fay-Herriot (BART-FH) model leverages the nonparametric capabilities of BART to capture intricate nonlinear relationships and interactions among covariates, offering a more flexible alternative to traditional linear models. To evaluate the performance of the BART-FH model, we conduct an empirical simulation study comparing its estimation accuracy and predictive capabilities against the standard Fay-Herriot model. Furthermore, we apply the BART-FH model to data from the American Community Survey (ACS).


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