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Energy norm regularized sparse simultaneous reconstruction of solutions to parameterized PDEs

We present and analyze a novel sparse polynomial approximation method for the solution of PDEs with stochastic and parametric inputs. Our approach treats the parameterized problem as a problem of sparse signal reconstruction through a reformulation of the standard basis pursuit denoising problem. To achieve global reconstruction of solutions to the parameterized elliptic PDE, we employ a novel mixed ℓ_1 and energy norm-based method of regularization. Combined with the standard measurement scheme developed for compressed sensing-based sparse polynomial recovery, this approach allows for simultaneous global approximations of the solution over both physical and parametric domains. In addition, we are able to show that, with minimal sample complexity, error estimates comparable to the best s-term approximation are achievable, while requiring only *a priori* bounds on polynomial truncation error in energy norms. While the current work focuses on sparse approximation of solutions to parameterized elliptic PDE models, we note that the developments herein may be readily applied to any parameterized systems satisfying a sparsity assumption. Finally, we perform extensive numerical experiments on several high-dimensional parameterized elliptic PDE models to demonstrate the superior recovery properties of the proposed approach.