We investigate theoretical properties and numerical algorithms for A-optimal and D-optimal regression designs based on the second-order least squares estimator. Several theoretical results are derived for the optimal designs on design spaces consisting of finite many points, including an innovative expression to characterize the A-optimal design criterion, transformation invariance properties of the optimal designs and multiplicative algorithms, an equivalence result to connect the A-optimal design problem with a semidefinite programming problem, and a property of local optimal designs. In addition, an effective and efficient numerical algorithm is developed using a semidefinite programming method in convex optimization. Convex optimization algorithms are also compared with the multiplicative algorithms through several examples. The results can be applied to both linear and nonlinear regression models. Our results indicate that the SLSE with the optimal design based on the SLSE is much more efficient than the ordinary least squares estimator (OLSE) with the optimal design based on the OLSE.