

principle, this approach could fail due to optimization difficulties, but for many problems optimization does not seem to be a significant barrier, provided that the model is chosen appropriately.

### 11.4.2 Automatic Hyperparameter Optimization Algorithms

The ideal learning algorithm just takes a dataset and outputs a function, without requiring hand-tuning of hyperparameters. The popularity of several learning algorithms such as logistic regression and SVMs stems in part from their ability to perform well with only one or two tuned hyperparameters. Neural networks can sometimes perform well with only a small number of tuned hyperparameters, but often benefit significantly from tuning of forty or more hyperparameters. Manual hyperparameter tuning can work very well when the user has a good starting point, such as one determined by others having worked on the same type of application and architecture, or when the user has months or years of experience in exploring hyperparameter values for neural networks applied to similar tasks. However, for many applications, these starting points are not available. In these cases, automated algorithms can find useful values of the hyperparameters.

If we think about the way in which the user of a learning algorithm searches for good values of the hyperparameters, we realize that an optimization is taking place: we are trying to find a value of the hyperparameters that optimizes an objective function, such as validation error, sometimes under constraints (such as a budget for training time, memory or recognition time). It is therefore possible, in principle, to develop **hyperparameter optimization** algorithms that wrap a learning algorithm and choose its hyperparameters, thus hiding the hyperparameters of the learning algorithm from the user. Unfortunately, hyperparameter optimization algorithms often have their own hyperparameters, such as the range of values that should be explored for each of the learning algorithm's hyperparameters. However, these secondary hyperparameters are usually easier to choose, in the sense that acceptable performance may be achieved on a wide range of tasks using the same secondary hyperparameters for all tasks.

### 11.4.3 Grid Search

When there are three or fewer hyperparameters, the common practice is to perform **grid search**. For each hyperparameter, the user selects a small finite set of values to explore. The grid search algorithm then trains a model for every joint specification of hyperparameter values in the Cartesian product of the set of values for each individual hyperparameter. The experiment that yields the best validation