

2006. Geoffrey Hinton showed that a kind of neural network called a deep belief network could be efficiently trained using a strategy called greedy layer-wise pre-training (Hinton *et al.*, 2006), which will be described in more detail in section 15.1. The other CIFAR-affiliated research groups quickly showed that the same strategy could be used to train many other kinds of deep networks (Bengio *et al.*, 2007; Ranzato *et al.*, 2007a) and systematically helped to improve generalization on test examples. This wave of neural networks research popularized the use of the term “deep learning” to emphasize that researchers were now able to train deeper neural networks than had been possible before, and to focus attention on the theoretical importance of depth (Bengio and LeCun, 2007; Delalleau and Bengio, 2011; Pascanu *et al.*, 2014a; Montufar *et al.*, 2014). At this time, deep neural networks outperformed competing AI systems based on other machine learning technologies as well as hand-designed functionality. This third wave of popularity of neural networks continues to the time of this writing, though the focus of deep learning research has changed dramatically within the time of this wave. The third wave began with a focus on new unsupervised learning techniques and the ability of deep models to generalize well from small datasets, but today there is more interest in much older supervised learning algorithms and the ability of deep models to leverage large labeled datasets.

1.2.2 Increasing Dataset Sizes

One may wonder why deep learning has only recently become recognized as a crucial technology though the first experiments with artificial neural networks were conducted in the 1950s. Deep learning has been successfully used in commercial applications since the 1990s, but was often regarded as being more of an art than a technology and something that only an expert could use, until recently. It is true that some skill is required to get good performance from a deep learning algorithm. Fortunately, the amount of skill required reduces as the amount of training data increases. The learning algorithms reaching human performance on complex tasks today are nearly identical to the learning algorithms that struggled to solve toy problems in the 1980s, though the models we train with these algorithms have undergone changes that simplify the training of very deep architectures. The most important new development is that today we can provide these algorithms with the resources they need to succeed. Figure 1.8 shows how the size of benchmark datasets has increased remarkably over time. This trend is driven by the increasing digitization of society. As more and more of our activities take place on computers, more and more of what we do is recorded. As our computers are increasingly networked together, it becomes easier to centralize these records and curate them