robotic manipulation tasks. Google has demonstrated that reinforcement learning can be deployed to learn robotic object control, using a factory of robotic arms to enable large-scale training on real robots (see Figure 10-1). It's likely that such enhanced learning techniques for robots will begin filtering into the larger robotics industry over the next few years.

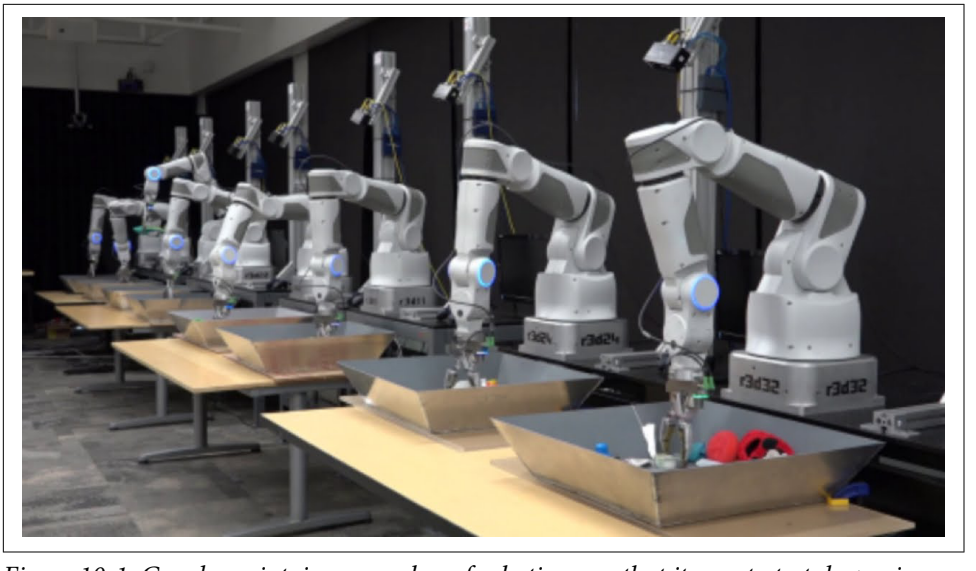

Figure 10-1. Google maintains a number of robotic arms that it uses to test deep reinforcement learning methods for robotic control. This fundamental research will likely find its way to the factory floor in the next few years.

Deep Learning in Agriculture

Industrial farming is already heavily mechanized, with sophisticated tractors deployed to plant and even pick crops. Advances in robotics and in computer vision are accelerating this trend toward automation. Convolutional networks have already been employed to identify weeds for removal with less pesticide. Other companies have experimented with self-driving tractors, automated fruit picking, and algorithmic crop yield optimization. These are mainly research projects for the time being, but these efforts will likely blossom into major deployments over the next decade.

Using Deep Learning Ethically

Most of this book has focused on the effective use of deep learning. We've covered many techniques for building deep models that generalize well on different data types. However, it's also worth spending spending some time thinking about the societal effects of the systems we build as engineers. Deep learning systems unleash a host of potentially unsettling applications.

For one, convolutional networks will enable the widespread deployment of face detection technologies. China has taken a lead in real-world deployment of such systems (Figure 10-2).

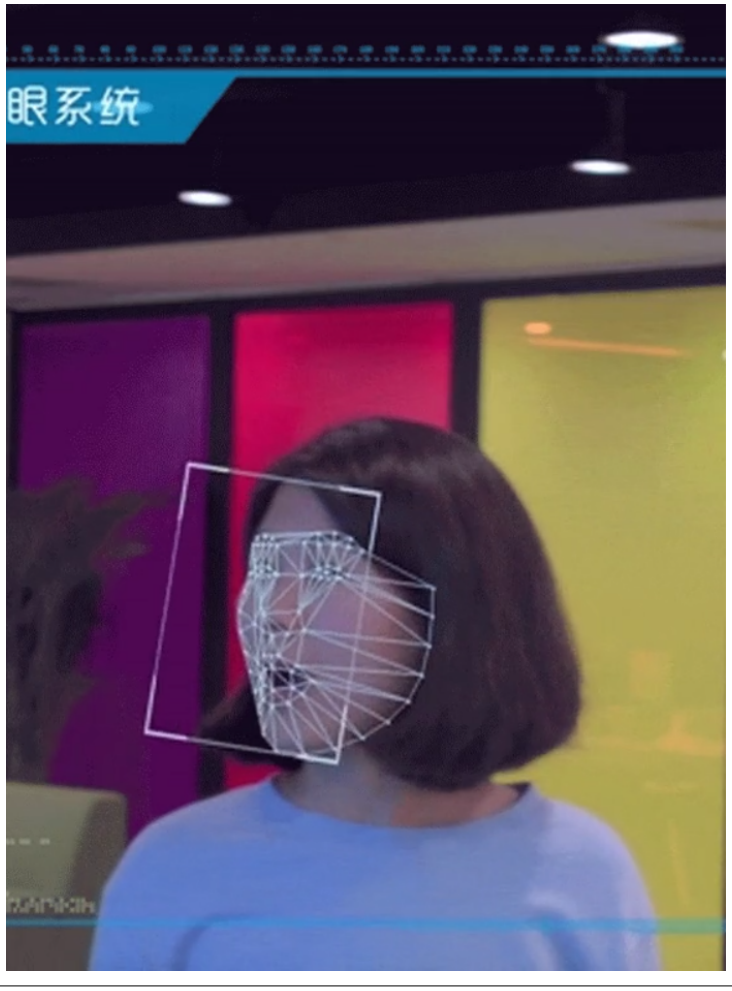

Figure 10-2. The Chinese government has broadly deployed face detection algorithms based on convolutional networks. The ability of these systems to track individuals will likely mean that anonymity in public settings will be a thing of the past in China.

Note that omnipresent facial detection will mean that public anonymity will belong to the past. Any actions taken in the public sphere will be logged and tracked by corporations and governments. This vision of the future should sound unsettling to anyone concerned with the ethical implications of deep learning.

The broader lesson here is that when algorithms can understand visual and perceptual information, nearly all aspects of human life will fall under algorithmic sway. This is a macroscopic trend, and it's not clear that any one engineer will have the power to prevent this future from coming into existence. Nonetheless, engineers retain the ability to vote with their feet. Your skills are valuable and in demand; don't work for companies following unethical practices and building potentially dangerous systems.

Bias in AI

Machine learning and deep learning provide the capabilities to learn interesting models from data without too much effort. This solidly mathematical process can provide the mirage of objectivity. However, it is strongly worth noting that all sorts of bias can creep into such analyses. Biases in the underlying data, drawn from historical, prejudiced records, can induce models to learn fundamentally unfair models. Google infamously once learned that a flawed visual prediction model had labeled black consumers as gorillas, likely due to biased training data that lacked adequate representation of people of color. While this system was rapidly corrected once brought to Google's notice, such failures are deeply troubling and are emblematic of more fundamental problems of exclusion in the technology industry.

As AI is increasingly used in applications such as prisoner parole granting and loan approval processes, it becomes increasingly important for us to ensure that our models aren't making racist assumptions or learning biases already present in historical data. If you are working on sensitive data, making predictions that may alter the course of human lives, check twice and check thrice to make sure that your systems aren't falling prey to biases.

Is Artificial General Intelligence Imminent?

There are widespread discussions about whether artificial general intelligence (AGI) will soon come into existence. Experts disagree strongly over whether AGI is worth seriously planning for. Our view is that while there's no harm in doing research on "AI value alignment" and "safe reward function" design, the artificial intelligence systems of today and the foreseeable future are unlikely to rapidly achieve sentience. As you will have learned first hand, most deep learning systems are simply sophisticated numerical engines, prone to many finicky numerical stability issues. It will likely take decades of fundamental advances before general intelligence becomes an issue. At the same time, as we've discussed in the previous section, artificial intelligence is already having dramatic impact on human societies and industries. It is absolutely worth