13

The Future

What is covered in this chapter:

- Current attitude of the general public toward robots and how this may change in the coming years.
- Possible shifts and developments in the nature of human–robot relationships, specifically companion bots.
- Further development of the technology of human–robot interactions, specifically artificial intelligence.
- The inherent issues with predicting the future ("crystal ball problems").

As with other technologies that have become common in our daily lives, such as personal computers, smartphones, or the internet, sooner or later, we expect robots to become assimilated into society. They may even be accepted into our personal and even intimate spaces. Robots are currently being designed to be coworkers, tutors, and assistants in the medical field and to provide services in care settings, in education, in people's homes and even in space stations (see Figure 13.1). Research into human–robot interaction (HRI) continues unabated, and companies keep a keen eye on social robots, releasing products that either are fully fledged social robots, such as the Sony Aibo (Figure 2.10), or that take inspiration from HRI and interaction design research, such as digital home assistants.

Technological advances make this vision increasingly real but alone are not sufficient to move us closer to a future with robots. Recent polls in the United States and Europe show that overall, robots are considered desirable for jobs that people find too hard or undesirable. But the public takes a more reserved attitude when it comes to social robots that provide companionship, care, and other socially assistive and interactive applications (Smith, 2014; European Commission, 2017). In general, people tend to have a welcoming and positive attitude toward robots, although some HRI studies have shown that on occasion, some people experience fairly high levels of robot anxiety and other negative attitudes toward robots, resulting in a low willingness to interact with robots in their personal space or workplace settings (Reich-Stiebert and Eyssel, 2013, 2015). Any technical and societal revolution evokes strong responses, both positive and negative, and social robots are not going to be any different.

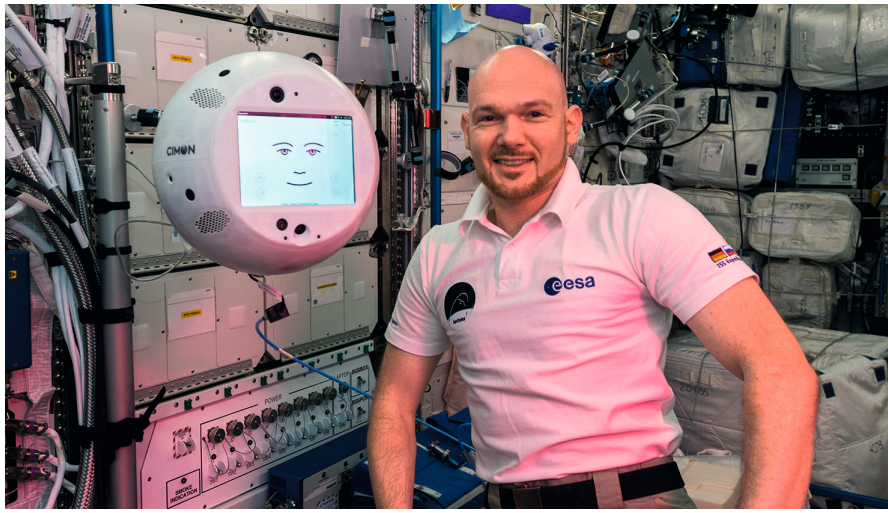

Figure 13.1 The Cimon robot (2018–present), built by the German Aerospace Center, Airbus, and IBM, assists astronauts on the International Space Station. (Source: National Aeronautics and Space Administration)

As technology advances and social robots become more common, people will have more opportunities to experience the potential and limitations of the technology and may become more accepting of them through mere exposure. As we mentioned in our discussion of nonverbal cues, direct interaction with members of another social group—in this case, robots—changes attitudes and decreases anxiety related to that group (Crisp and Turner, 2013; Pettigrew et al., 2011). Wullenkord (2017) showed that just imagining collaborative interaction with a Nao robot prior to actually interacting with it improved attitudes and reactions toward the robot and increased the perceived quality of the interaction. We can therefore expect that as people have increased contact with robots, be it directly or through the media, attitudes will become more positive, and the willingness to use robots will increase over time.

As we have seen in the rest of this book, however, advances in HRI research can significantly speed up this process. By better understanding people's concerns, mapping societal needs, and identifying opportunities for automation, we can create interactions that will be positive and beneficial to people and society as a whole. As with any technological revolution, the introduction of social robots will be slow at first, with daring companies releasing new products and early adopters buying and using these, thereby providing valuable real-life lessons on what interactive devices and robots could mean to us (Hoffman, 2019). End users have high expectations for social robots, and such commercial products tend to overpromise and underdeliver. But recent years have witnessed a positive feedback loop between new revolutions in artificial intelligence (AI), academic research, industry efforts, and the tech market, with products integrated into social robots becoming commercially successful. Speech recognition, natural-language processing, and visual understanding of social and physical context are now found in thousands of products, and their success is likely to be the origin of the success of social robots.

We also need to consider that the media frequently portray robots negatively or unrealistically. For example, there has been much talk of robots, instead of people, looking after those in need of assistance in our aging societies. This is not a pleasant thought, if only because it confronts us with a reality in which human contact has become increasingly rare and where we need robotic technology to substitute for human warmth. The way this future scenario is portrayed by the media, however, is unrealistic. This manner of framing robots in society may sell newspapers, but it creates undue anxiety and distracts us from what robots could really contribute. In eldercare, cuddly animal-like robots are already used, much to the satisfaction of the elderly residents, families, and staff.

We are often quick to judge, and robots evoke strong emotions. Facilitating an open mind about novel developments in technology and science might be a step toward achieving a more positive view and a stronger sense of acceptance by the general public. These changes can only be observed through longitudinal studies, and HRI scholars must work together with the communities they seek to serve to consider how technological developments can come together with societal structures to produce positive change. There is no quick "technological fix" for societal problems, such as demographic change. Besides developing much-needed technologies, it is also crucial to take a human-centered approach that focuses on the actual psychological, social, and emotional needs of the people using and being affected by robots. A more human-centered view coupled with technological advancement will together create robust and socially appropriate robots that can benefit us all.

13.1 The nature of human–robot relationships

When waiting to check in at the airport, a machine handles the check-in process. In Japan, Pepper robots greet us when we enter a bank or a shop. When care is provided mainly by machines rather than humans, this has strong implications for the development and maintenance of human relationships. Even currently, many technologies, such as mobile phones, social networks, and online games, have resulted in less face time between people and vast changes in interpersonal communication. Instead of writing letters or meeting in person, people communicate via messages on Snapchat or WhatsApp. Our patterns of when we talk to whom about what are changing (see Figure 13.2), as are the ways we begin and end our romantic relationships—by smartphone. Robots may contribute to further estrangement among people, as argued by Turkle (2017), or robots could be designed to support and even increase interaction among people. This effect has been seen with the seal-like robot Paro in a day home, in which older adults ended up meeting and talking more to others when the robot was put in a public space (Wada and Shibata, 2007).

Clearly, as social robots and AI are developed further, they will likely play an increasingly larger role in our everyday lives and society. Because the nature of human–robot relationships is a product of the robots' capabilities and

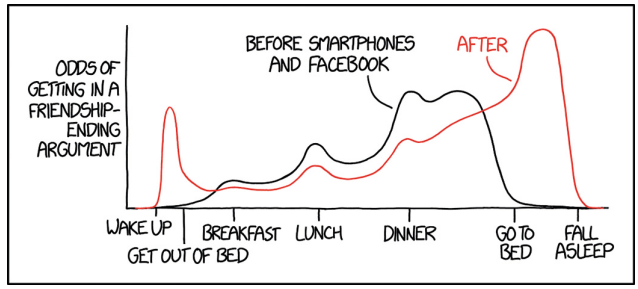

Figure 13.2 Odds of getting into a friendship-ending argument before and after the introduction of smartphones. (Source: XKCD)

the users' preferences, these developments are inevitably tied to the question of what issues we consider ethical and desirable to address with robots and AI.

For example, one major societal issue at the moment is loneliness. Feeling socially connected to others has an almost incredible list of benefits for individual mental and physical health (Vaillan, 2015). This will become increasingly relevant as the populations of developed countries continue to age in the upcoming decades. An increasing part of the population is in need of care, not just for attending to their physical needs of feeding, bathing, and clothing but for emotional care as well. It might be that the younger generations are neither willing nor competently able to serve these dual needs on their own. Particularly, the emotional needs of seniors or people with cognitive or physical impairments have to be taken into account, but all people are in danger of growing more and more lonely and disconnected (American Osteopathic Association, 2016).

The lack of social connection can have a serious impact on our psychological well-being and health. The "need to belong," a key motivation of human nature (Baumeister and Leary, 1995), can easily become disrupted. To illustrate, research by Eisenberger et al. (2003) shed light on the neuroanatomical underpinnings of reactions to social exclusion, whereas Williams (2007) has documented the negative social consequences of exclusionary status. That is, when the need to belong is violated, people not only feel a lower sense of belonging but also experience lower self-esteem, feel less in control, and even regard their existence as less meaningful than when their inclusionary status is not under threat. In addition, the risk of developing Alzheimer's disease is double in lonely people compared to socially connected individuals, and loneliness is a predictor of a decline in cognitive abilities (Shankar et al., 2013). In light of the detrimental effects of loneliness on quality of life and psychological and cognitive functioning, robots could play an important role in mediating these effects.

A few commercial start-ups have been offering artificially intelligent "companions," although so far with only modest success, such as Gatebox's "Living With" project. If AI and robots are developed to the point where they can reliably imitate human interaction patterns, they could be extremely helpful in relieving feelings of boredom and loneliness.

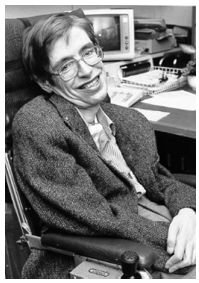

Figure 13.3 Not everyone is charmed by the idea of strong AI. The late theoretical physicist Stephen William Hawking and the entrepreneur and engineer Elon Musk have both been vocal critics against the development of strong AI.

What remains to be seen is how comfortable people are with the different potential roles that AI may take on. As the quest for strong or general AI continues, the question of whether such AI is desirable is heard ever louder. Whereas the most spectacular version of this question considers how we can ensure that such an AI would remain benevolent to the human race, it is at least as interesting to consider the issue of whether people would be comfortable with handing over power in the first place. Assume that strong AI is developed, the sole purpose of which is to enhance the well-being of society while adhering to a set of rules that keep it from harming humans (e.g., Asimov's Laws of Robotics; see Section 12.2). Can we throw out all the concerns about self-interest, bias, and hidden political agendas that are inherent to human leadership and, instead, fully trust that the AI would take proper care (see Figure 13.3)? Would we agree with such a setup?

13.2 The technology of HRI

HRI is lifted on the tides of technological progress. New sensors and actuators and continuous developments in AI are quickly adopted into HRI applications. Given the steady progress in AI and its applications, there is every reason to believe that a number of technical problems that currently still require the smoke and mirrors of Wizard-of-Oz (WoZ) control will soon be delivered autonomously by the robot.

Progress in HRI is not so much held back by a lack of development in robotic hardware but, rather, by a lack of progress in autonomous control and AI. Testament to this is the ability of human operators to hold a meaningful interaction through a robot. It is clearly not the limited view through the sensors and the limited expressivity of the actuators that hinder the interaction. Rather, it is the artificial cognition—substituted by real cognition in the case of WoZ control—that is lacking. There is, of course, room for improvement in robot hardware: the speed and power of actuators need work, and the energy autonomy of robots needs to improve drastically. Furthermore, robotics and social robotics in particular have always taken a "Frankenstein approach" to hardware, building robots from whatever technology is readily available rather than developing radically new hardware solutions. But at this point, breakthroughs in HRI are most likely to come from progress in robot control and AI. Machine learning holds considerable promise here. However, there are fundamental barriers to the use of machine learning in HRI. Because machine learning requires vast amounts of annotated data and computational time, it comes to its own in domains that allow offline learning and for which huge amounts of training data are available or, when not available, can be generated. Although there is plenty of human interaction going on in the world, these interactions run in real-time. As opposed to machine learning of how to play the game of chess or Go, where the learning can run as fast as computers will allow, machine learning of HRI strategies inherently runs online. No

matter how fast the computer is, the interaction pace is dictated by the human interaction partner, and the evaluation and updates of the machine learning will run in "human time" rather than in computer time. One solution for facilitating machine learning for HRI might be to use more robots and data from more interactions: pooling interaction events could be a solution to the dearth of HRI data and could speed up the evaluation of learned interaction strategies. It is unclear what the next technological breakthroughs will be in AI and robotics, but one thing is clear: HRI will readily absorb them.

13.3 Crystal ball problems

Predicting the future is hard to do, and especially in the field of HRI, it seems as if every stance imaginable is defended with passion by a small army of experts (and a large group of those wishing to be experts), ranging from doomsday predictions to nirvana forecasts. The Tesla company, for example, made grandiose promises in 2022 for its Optimus humanoid robot, not only about its unrealistically affordable price but also about its unprecedented abilities. Promises that are yet to be delivered.

It proves to be nearly impossible to gain consensus on the far future of HRI and even on small and concrete predictions of how long it will take to develop a specific capability or what we actually want from a robot. Just as with AI, all bets are off. Still, it is clear that robot butlers—such as the Able Mabel housemaid robot envisioned by the BBC in 1966—remain elusive.

First, we can perhaps take some lessons from developments in AI, which have been rapid yet unable to match early expectations. When the initial ideas around AI were first introduced in the 1950s, it was expected that strong AI would be available within a few decades (McCorduck, 1979; Russell and Norvig, 2022). Half a century later, AI still struggles with understanding the real world. And although progress has been impressive on some fronts—think about recent developments in natural-language interaction—advances have been uneven. It seems that when data are available in abundance and learning is cheap to evaluate, then AI can learn fast and even achieve superhuman performance. This was famously shown by the Deep Blue computer program beating the world champion Gary Kasparov at chess in the late 1990s (Campbell et al., 2002), as well as recent victories in ever more complex games such as Go (Murphy, 2016) and Stratego. Because the fortunes of robotics are often tied to those of AI, we can expect to see similar trends in social robotics, with robots getting superhuman abilities on some fronts while lagging on others.

In recent years, there have been numerous start-ups and large corporations venturing into the social robotics market. Buoyed by technological breakthroughs, they build novel products looking for equally novel use cases. But building and especially selling social robots remains challenging. Most commercial social robots are available for a few years, and after lower-than-expected sales, the companies then pull the products from the market. We cannot help but notice that many of the robots we discuss and show in this

book are no longer available. We should not forget that it is still the early days for commercial social robots. Just as for countless other technologies—the mobile phone, the smartphone, the personal computer, and the MP3 player, to name but a few—early and therefore brave ventures at introducing social robots on the market will know winners and losers, but victory belongs to those who believe in it the most and believe in it the longest.

This raises the question of whether we are really capable of knowing what we want from a robot. What we think we want robots to do today is likely not going to be what robots will be doing in the future. The interplay between our needs and technological abilities will more likely result in applications we can currently barely imagine. As demonstrated in this book, it is good to widen the range of perspectives involved in our discussions when building a future with robots.

There are lessons we can learn from the history and recent successes in AI. Although deep learning has achieved remarkable progress, it is important to acknowledge that past expectations often led to excessive optimism followed by disappointment. Two previous AI booms serve as examples of this pattern. The first occurred in the 1950s when predictions about the emergence of strong AI were made. The second boom took place in the 1970s, with the belief that we could capture all existing knowledge in formal representations. Although these periods ultimately led to two of several AI winters, AI research persisted and contributed to the development of fundamental knowledge in pattern recognition, such as notable advancements in neural networks. This paved the way for the eventual success of the latest breakthroughs in pattern recognition, fueled by increased computational power and access to vast amounts of data. Similarly, although some start-ups focusing on robotics might fail, boom-and-bust cycles in social robots are likely to occur. Predicting which ventures will succeed and when remains a challenging task. Nevertheless, we firmly believe that our understanding of HRI will be central to future commercial successes.

Questions for you to think about:

- Which technological developments and related social developments have surprised you the most in your lifetime?
- What kind of future would you want to see with robots? What kind of future would you be afraid of or concerned about?
- How much time do you spend interacting with people face to face versus in mediated environments (e.g., Facebook, conference call)? What about nonhuman agents—do you interact with them at all? In what circumstances and how much?
- Who is caring for your grandparents or parents? What kind of community do they live in? Do you live close to them? Who do you think will take care of you in the future? What kind of community might you find yourself living in?

13.4 Exercises

The answers to these questions are available in the Appendix.

**** Exercise 13.1 Loneliness** What consequences are typically associated with loneliness? Select one or more options from the following list:

1. Reduced self-esteem
2. Increased risk of developing Alzheimer's disease
3. Decline in cognitive abilities
4. Reduced physiological abilities
5. Reduced financial income
6. Lack of perceived control
7. Increased risk of developing cancer

**** Exercise 13.2 Technology** What technology is mainly holding back HRI? Select one option from the following list:

1. The development of sensors
2. The development of actuators
3. The development of power storage and delivery
4. The development in AI
5. The development of smart materials

*** Exercise 13.3 Face time** How do you predominantly communicate with your friends? Select one option from the following list:

1. Through mediated communication environments (e.g., Facebook, Instagram, Zoom, Skype, etc.)
2. Through face-to-face communication

*** Exercise 13.4 Contact** With whom do you have more physical contact on a daily basis? Select one option from the following list:

1. Your partner (or friends)
2. Your mobile phone

*** Exercise 13.5 Parents** Do you want a robot to take care of your parents when they can no longer care for themselves? Select one option from the following list:

1. Yes
2. No

******* Exercise 13.6 HRI movie analysis** Watch a movie (or one or two episodes of a TV series) of your choice in which robots play a major role. Pay close attention to HRI and how it is depicted in the film; you'll probably want to take notes as you watch. Then write up a short analysis of the HRI components of the movie. Do not just give a summary or review of the movie itself; address the ways in which humans and robots interact and communicate

with each other. You can include visuals from the film in your analysis, if you like. You should also explicitly refer to any connections to the HRI themes that you read about in this book.

Some examples of relevant films and TV shows are as follows: *Ex Machina*; *Wall-E*; *Westworld*; *Moon*; *The Iron Giant*; *Star Wars*; *Silent Running*; *Short Circuit*; *2001: A Space Odyssey*; *The Hitchhiker's Guide to the Galaxy*; *A.I.*; *I, Robot*; *Metropolis*; *Ghost in the Shell*; *Astro Boy*; *Frank and the Robot*; and *Human*.

Your review should address the following questions:

1. What roles do the robots have in society? What kinds of tasks do they perform? Where do they interact with people?
2. What are the channels or modalities that people use to communicate with the robots? How does their communication evolve?
3. What modes of expression do the robots use to communicate with people? What about with each other?
4. What are the consequences of robots in society? How do people react to the robots—positively or negatively—and do their reactions change over time? What could be done to make negative consequences or reactions more positive?
5. What do you think are the hard and easy social and technical problems involved with developing HRI of the sort shown in the movie? Also include potential ethical issues resulting from using robots in society.

Future reading:

- Future of Life Institute. An open letter—Research priorities for robust and beneficial artificial intelligence, January 2015. URL https://futureoflife.org/ai-open-letter/
- Nourbakhsh, Illah Reza. *Robot Futures*. MIT Press, Cambridge, MA, 2013. ISBN 9780262018623. URL http://worldcat.org/oclc/945438245
- Wilson, Daniel H. *How to Survive a Robot Uprising: Tips on Defending Yourself against the Coming Rebellion*. Bloomsbury, London, New York, 2005. ISBN 9781582345925. URL http://worldcat.org/oclc/1029483559
- Cribb, Jo, and Glover, David. *Don't Worry about the Robots*. Allen & Unwin, Auckland, New Zealand, 2018. ISBN 9781760633509. URL http://worldcat.org/oclc/1042120802