1 The Vision of Sociable Robots

What is a sociable robot? It is a difficult concept to define, but science fiction offers many examples. There are the mechanical droids R2-D2 and C-3PO from the movie *Star Wars* and the android Lt. Commander Data from the television series *Star Trek: The Next Generation*. Many wonderful examples exist in the short stories of Isaac Asimov and Brian Aldiss, such as the robots Robbie (Asimov, 1986) and David (Aldiss, 2001). For me, a sociable robot is able to communicate and interact with us, understand and even relate to us, in a personal way. It should be able to understand us and itself in social terms. We, in turn, should be able to understand it in the same social terms—to be able to relate to it and to empathize with it. Such a robot must be able to adapt and learn throughout its lifetime, incorporating shared experiences with other individuals into its understanding of self, of others, and of the relationships they share. In short, a sociable robot is socially intelligent in a human-like way, and interacting with it is like interacting with another person. At the pinnacle of achievement, they could befriend us, as we could them. Science fiction illustrates how these technologies could enhance our lives and benefit society, but it also warns us that this dream must be approached responsibly and ethically, as portrayed in Philip K. Dick's *Do Androids Dream of Electric Sheep* (Dick, 1990) (made into the movie *Blade Runner*).

1.1 Why Sociable Robots?

Socially intelligent robots are not only interesting for science fiction. There are scientific and practical reasons for building robots that can interact with people in a human-centered manner. From a scientific perspective, we could learn a lot about ourselves from the process of building socially intelligent robots. Our evolution, our development from infancy to adulthood, our culture from generation to generation, and our day-to-day existence in society are all profoundly shaped by social factors (Vygotsky et al., 1980; Forgas, 2000; Brothers, 1997; Mead, 1934). Understanding our sociality is critical to understanding our humanity.

Toward this goal, robots could be used as experimental testbeds for scientific inquiry (Adams et al., 2000). Computational models of our social abilities could be implemented, tested, and analyzed on robots as they participate in controlled social scenarios. In this way, robots could potentially be used in the same studies and experiments that scientists use to understand human social behavior. Robot data could be compared with human performance under similar conditions. Differences between the two could be used to refine the models and inspire new experiments. Furthermore, given a thorough understanding of the implementation, parameters of the model could be systematically varied to understand their effects on social behavior. By doing so, social behavior disorders could be better understood, which in turn could aid in the development of effective treatments. For instance, autism is regarded as an impairment in the ability to interact with and understand others in social terms. A few efforts are under way to use robots in treatment of autistic children (Dautenhahn, 2000) and to try to understand this impairment by modeling it on robots (Scassellati, 2000b).

As humans, we not only strive to understand ourselves, but we also turn to technology to enhance the quality of our lives. From an engineering perspective, we try to make these technologies natural and intuitive to use and to interact with. As our technologies become more intelligent and more complex, we still want to interact with them in a familiar way. We tend to anthropomorphize our computers, our cars, and other gadgets for this reason, and their interfaces resemble how we interact with each other more and more (Mithen, 1996). Perhaps this is not surprising given that our brains have evolved for us to be experts in social interaction (Barton & Dunbar, 1997).

Traditionally, autonomous robots have been targeted for applications requiring very little (if any) interaction with humans, such as sweeping minefields, inspecting oil wells, or exploring other planets. Other applications such as delivering hospital meals, mowing lawns, or vacuuming floors bring autonomous robots into environments shared with people, but human-robot interaction in these tasks is still minimal. Examples of these robots are shown in figure 1.1.

New commercial applications are emerging where the ability to interact with people in a compelling and enjoyable manner is an important part of the robot's functionality. A couple of examples are shown in figure 1.2. A new generation of robotic toys have emerged, such as Furby, a small fanciful creature whose behavior changes the more children play with it. Dolls and "cyber-pets" are beginning to incorporate robotic technologies as well. For

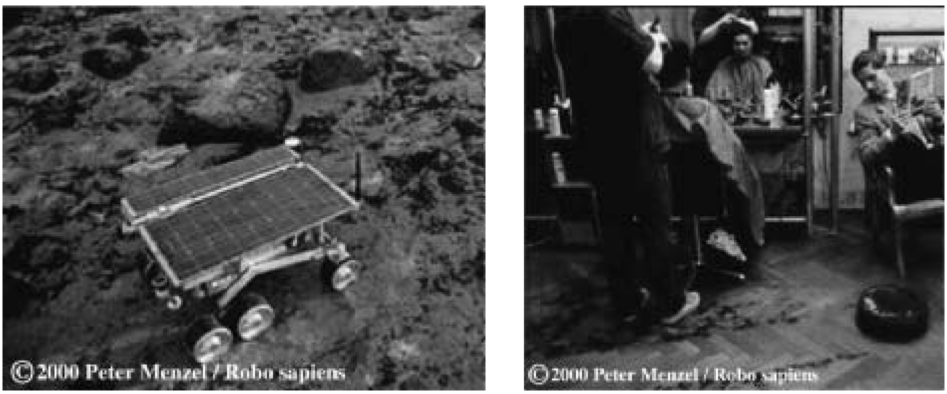

Figure 1.1
Some examples of applications motivating autonomous robots. To the left is NASA's *Sojourner,* a planetary micro-rover that gathered scientific data on Mars. To the right is a commercial autonomous vacuum-cleaning robot.

Figure 1.2
Some examples of robots entering the toy and entertainment markets. To the left is iRobot's Bit, a prototype robotic doll that can display a number of facial expressions. To the right is Tiger Electronic's Furby.

Figure 1.3
Some examples of research exploring robots that cooperate with and assist humans. On the left is Sweet Lips, a museum tour guide robot. The right shows NEC's domestic robot prototype.

instance, Hasboro's My Real Baby changes facial expressions according to its "mood," which is influenced by how it is played with. Although the ability of these products to interact with people is limited, they are motivating the development of increasingly life-like and socially sophisticated robots. Someday, these toys might be sophisticated enough to appreciate and foster the social needs and cognitive development of a child.

Companies and universities are exploring new applications areas for robots that assist people in a number of ways (see figure 1.3). For instance, robotic tour guides have appeared in a few museums and are very popular with children (Burgard et al., 1998; Thrun et al., 1999). Honda has developed an adult-sized humanoid robot called P3 and a child-sized version called Asimo. The company is exploring entertainment applications, such as robotic soccer players.[1] Eventually, however, it will be plausible for companies to pursue domestic uses for robots, humanoid or otherwise. For example, NEC is developing a household robot resembling R2-D2 that can help people interact with electronic devices around the house (e.g., TV, computer, answering service, etc.). Health-related applications are also being explored, such as the use of robots as nursemaids to help the elderly (Dario & Susani, 1996; see also `www.cs.cmu.edu/~nursebot`). The commercial success of these robots hinges on their ability to be part of a person's daily life. As a result, the robots must be responsive to and interact with people in a natural and intuitive manner.

It is difficult to predict what other applications the future holds for socially intelligent robots. Science fiction has certainly been a source of inspiration for many of the applications being explored today. As a different twist, what if you could "project" yourself into a physical avatar? Unlike telerobotics or telepresence of today, the robotic "host" would have to be socially savvy enough to understand the intention of the human "symbiont." Then, acting in concert with the human, the robot would faithfully carry out the person's wishes while portraying his/her personality. This would enable people to physically interact with faraway people, an exciting prospect for people who are physically isolated, perhaps bedridden for health reasons.

Another possibility is an artifact that you wear or carry with you. An example from science fiction would be the Primer described in Neal Stephenson's *The Diamond Age* (2000). The Primer is an interactive book equipped with sophisticated artificial intelligence. It is socially aware of the little girl who owns it, can identify her specifically, knows her personally, is aware of her education and abilities, and shapes its lessons to foster her continued growth and development into adulthood. As another possibility, the technology could take the form of a small creature, like a gargoyle, that sits on your shoulder and acts as an information assistant for you.[2] Over time, the gargoyle could adapt to you, learn your preferences, retrieve information for you—similar to the tasks that software agents might carry out while sharing your world and supporting natural human-style interaction. These gargoyles could interact with each other as well, serving as social facilitators to bring people with common interests into contact with each other.

1. Robocup is an organized event where researchers build soccer-playing robots to investigate research questions into cooperative behavior, team strategy, and learning (Kitano et al., 1997; Veloso et al., 1997).

2. Rhodes (1997) talks of a rememberance agent, a continuously running proactive memory aid that uses the physical context of a wearable computer to provide notes that might be relevant in that context. This is a similar idea, but now it is a wearable robot instead of a wearable computer.

1.2 The Robot, Kismet

The goal of this book is to pioneer a path toward the creation of sociable robots. Along the way, I've tried to provide a map of this relatively uncharted area so that others might follow. Toward this goal, the remainder of this chapter offers several key components of social intelligence and discusses what these abilities consist of for these machines. Many of these attributes are derived from several distinguishing characteristics of human social intelligence. From this, I construct a framework and define a set of design issues for building socially intelligent robots in the following chapters. Our journey should be a responsible one, well-conceived and well-intentioned. For this reason, this book also raises some of the philosophical and ethical questions regarding how building such technologies shapes our self-understanding, and how these technologies might impact society. This book does not provide answers but instead hopes to foster discussion that will help us to develop these sorts of technologies in responsible ways.

Aspects of this potentially could be applied to the design of socially intelligent software agents. There are significant differences between the physical world of humans and the virtual world of computer agents, however. These differences impact how people perceive and interact with these two different types of technology, and vice versa. Perhaps the most striking difference is the physical and immediately proximate interactions that transpire between humans and robots that share the same social world. Some issues and constraints remain distinct for these different technologies. For this reason, I acknowledge relevant research in the software agents community, but focus my presentation on the efforts in the robotics domain.

Humans are the most socially advanced of all species. As one might imagine, an autonomous humanoid robot that could interpret, respond, and deliver human-style social cues even at the level of a human infant is quite a sophisticated machine. Hence, this book explores the simplest kind of human-style social interaction and learning, that which occurs between a human infant with its caregiver. My primary interest in building this kind of sociable, infant-like robot is to explore the challenges of building a socially intelligent machine that can communicate with and learn from people.

This is a scientific endeavor, an engineering challenge, and an artistic pursuit. Starting in 1997, my colleagues and I at the MIT Artificial Intelligence Lab began to construct such a robot (see figure 1.4). It is called Kismet, and we have implemented a wide variety of infant-level social competencies into it by adapting models and theories from the fields of psychology, cognitive development, and ethology. This book, a revised version of my doctoral dissertation (Breazeal, 2000c), uses the implementation of Kismet as a case study to illustrate how this framework is applied, how these design issues are met, how scientific and artistic insights are incorporated into the design, and how the work is evaluated. It is a very

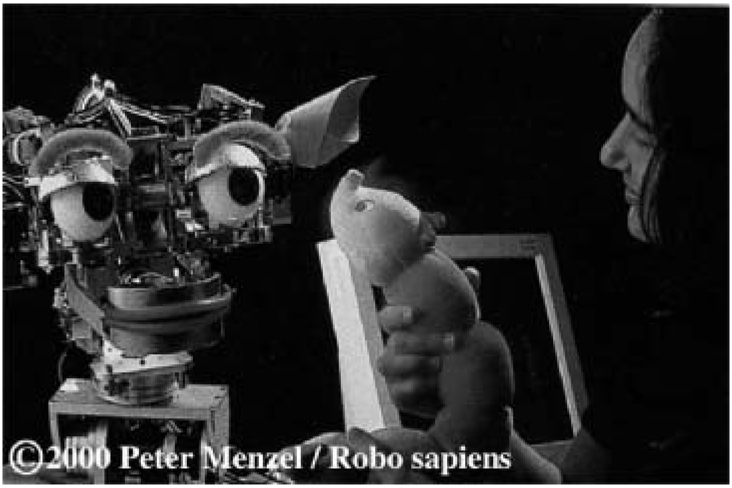

Figure 1.4
Kismet, a sociable "infant" robot being developed at MIT.

ambitious and highly integrated system, running on fifteen networked computers. (If you have not viewed the enclosed CD-ROM, I recommend you do so. I will reference its demos at relevant points as well.) This book reveals the ideas, insights, and inspiration, and technical details underlying Kismet's compelling, life-like behavior. Significant progress has been made, yet much work remains to be done to fully realize the vision of a sociable robot.

1.3 Ingredients of Sociable Robots

As stated in the preface, one goal of building a sociable robot is to gain a scientific understanding of social intelligence and human sociality. Another goal is to design robots that can interact with people on "human terms." Accordingly, it is important to consider the specific ways in which we understand and interact with the social world. If done well, humans will be able to engage the robot by utilizing their natural social machinery instead of having to overly and artificially adapt their way of interaction. Dautenhahn (1998) identifies a number of characteristics of human social intelligence that should be considered when designing socially intelligent technologies. Much of the discussion in this section (and in the final chapter in section 13.3) is based on the broader issues of human-style social intelligence as presented by Dautenhahn. These key characteristics of human social intelligence have guided my work with Kismet, and the body work presented in this book both instantiates and elaborates upon them.

Being There

Humans are embodied and situated in the social world. We ground our experiences through our body as we interact with the environment and with others. As such, our bodies provide us with a means for relating to the world and for giving our experiences meaning (Lakoff, 1990). Brooks has extensively argued for the importance of embodiment and being situated in the world for understanding and generating intelligent behavior in animals and robots (Brooks, 1990). Socially intelligent robots can better support these human characteristics if they are *embodied* and *socially situated* with people. For this reason, Kismet is a physical robot that interacts with people face-to-face.

Having a body and existing within a shared environment is advantageous for both the robot as well as for those people who interact with it. From the perspective of the robot, its body provides it with a vehicle for experiencing and for interacting with the social world. Further, the robot can interpret these experiences within a social context. From the perspective of a human who interacts with the robot, it is also beneficial for the robot to have a body. Given that humans have evolved to socially interact with embodied creatures, many of our social skills and communication modalities rely on both parties having a body. For instance, people frequently exchange facial expressions, gestures, and shift their gaze direction when communicating with others. Even at a more basic level, people rely on having a point of reference for directing their communication efforts toward the desired individual, and for knowing where to look for communicative feedback from that individual.

The embodiment and situatedness of a robot can take several forms. For instance, the robot could share the same physical space as a person, such as a humanoid robot that communicates using familiar social cues (Brooks et al., 1999). Alternatively, the technology could be a computer-animated agent within a virtual space that interacts with a human in the physical world. Embodied conversational agents (Cassell, 1999a) are a prime example. It is also possible to employ virtual-reality (VR) techniques to immerse the human within the virtual world of the animated agent (Rickel & Johnson, 2000). These robots or animated agents are often humanoid in form to support gestures, facial expressions, and other embodied social cues that are familiar to humans. The nature of the experience for the human varies in each of these different scenarios depending upon the sensing limits of the technologies (such as keyboards, cameras, microphones, etc.); whether the human must be instrumented (e.g., wearing data gloves, VR helmets, etc.); the amount of freedom the person has to move within the space; and the type of display technology employed, be it mechanical, projected on a large screen, or displayed on a computer monitor.

Life-Like Quality

People are attracted to life-like behavior and seem quite willing to anthropomorphize nature and even technological artifacts. We appear biased to perceive and recognize other living beings and are able to do so quite early in our development (Trevarthen, 1979). We tend to interpret behavior (such as self-propelled movement) as being intentional, whether it is demonstrated by a living creature or not (Premack & Premack, 1995). When engaging a non-living agent in a social manner, people show the same tendencies (Reeves & Nass, 1996). Ideally, humans would interact with robots as naturally as they interact with other people. To facilitate this kind of social interaction, robot behavior should reflect life-like qualities. Much attention has been directed to giving Kismet's behavior this quality so that people will engage the robot naturally as a social being.

Living agents such as animals and humans are *autonomous*. They are capable of promoting their survival and performing tasks while negotiating the complexities of daily life. This involves maintaining their desired relationship with the environment, yet they continually change this balance as resources are competed for and consumed. Robots that share a social environment with others must also able to foster their continued existence while performing their tasks as they interact with others in an ever-changing environment.

Autonomy alone is not sufficiently life-like for human-style sociability, however. Interacting with a sociable robot should not be like interacting with an ant or a fish, for instance. Although ants and fish are social species, they do not support the human desire to treat others as distinct personalities and to be treated the same in turn. For this reason, it is important that sociable robots be *believable*.

The concept of believability originated in the arts for classically animated characters (Thomas & Johnston, 1981) and was later introduced to interactive software agents (Bates, 1994). Believable agents project the "illusion of life" and convey personality to the human who interacts with it. To be believable, an observer must be able and willing to apply sophisticated social-cognitive abilities to predict, understand, and explain the character's observable behavior and inferred mental states in familiar social terms. Displaying behaviors such as giving attention, emotional expression, and playful antics enable the human observer to understand and relate to these characters in human terms. Pixar and Walt Disney are masters at creating believable characters, animating and anthropomorphizing nature and inanimate objects from trees to Luxo lamps. An excellent discussion of believability in robots can be found in Dautenhahn (1997, 1998).

Human-Aware

To interact with people in a human-like manner, sociable robots must *perceive* and *understand* the richness and complexity of natural human social behavior. Humans communicate with one another through gaze direction, facial expression, body movement, speech, and language, to name a few. The recipient of these observable signals combines them with knowledge of the sender's personality, culture, past history, the present situational context, etc., to infer a set of complex mental states. *Theory of mind* refers to those social skills that allow humans to correctly attribute beliefs, goals, perceptions, feelings, and desires to the self and to others (Baron-Cohen, 1995; Leslie, 1994). Other sophisticated mechanisms such as *empathy* are used to understand the emotional and subjective states of others. These capabilities allow people to understand, explain, and predict the social behavior of others, and to respond appropriately.

To emulate human social perception, a robot must be able to identify who the person is (identification), what the person is doing (recognition), and how the person is doing it (emotive expression). Such information could be used by the robot to treat the person as an individual, to understand the person's surface behavior, and to potentially infer something about the person's internal states (e.g., the intent or the emotive state). Currently, there are vision-based systems capable of identifying faces, measuring head pose and gaze direction, recognizing gestures, and reading facial expressions. In the auditory domain, speech recognition and speaker identification are well-researched topics, and there is a growing interest in perceiving emotion in speech. New techniques and sensing technologies continue to be developed, becoming increasingly transparent to the user and perceiving a broader repertoire of human communication behavior. Not surprisingly, much of Kismet's perceptual system is specialized for perceiving and responding to people.

For robots to be human-aware, technologies for sensing and perceiving human behavior must be complemented with social cognition capabilities for understanding this behavior in social terms. As mentioned previously, humans employ theory-of-mind and empathy to infer and to reflect upon the intents, beliefs, desires, and feelings of others. In the field of narrative psychology, Bruner (1991) argues that stories are the most efficient and natural human way to communicate about personal and social matters. Schank & Abelson (1977) hypothesize that stories about one's own experiences and those of others (in addition to how these stories are constructed, interpreted, and interrelated) form the basic constituents of human memory, knowledge, social communication, self understanding, and the understanding of others. If robots shared comparable abilities with people to represent, infer, and reason about social behavior in familiar terms, then the communication and understanding of social behavior between humans and robots could be facilitated.

There are a variety of approaches to computationally understanding social behavior. Scassellati (2000a) takes a developmental psychology approach, combining two popular theories on the development of theory of mind in children (that of Baron-Cohen [1995] and Leslie [1994]), and implementing the synthesized model on a humanoid robot. In the tradition of AI reasoning systems, the BDI approach of Kinny et al. (1996) explicitly and symbolically models social expertise where agents attribute beliefs, desires, intents, abilities, and other mental states to others. In contrast, Schank & Abelson (1977) argue in favor of a story-based approach for representing and understanding social knowledge, communication, memory, and experience. Dautenhahn (1997) proposes a more embodied and interactive approach to understanding persons where storytelling (to tell autobiographic stories about oneself and to reconstruct biographic stories about others) is linked to the empathic, experiential way to relate other persons to oneself.

Being Understood

For a sociable robot to establish and maintain relationships with humans on an individual basis, the robot must understand people, and people should be able to intuitively understand the robot as they would others. It is also important for the robot to *understand its own self,* so that it can socially reason about itself in relation to others. Hence, in a similar spirit to the previous section, the same social skills and representations that might be used to understand others potentially also could be used by a robot understand its own internal states in social terms. This might correspond to possessing a theory-of-mind competence so that the robot can reflect upon its own intents, desires, beliefs, and emotions (Baron-Cohen, 1995). Such a capacity could be complemented by a story-based ability to construct, maintain, communicate about, and reflect upon itself and past experiences. As argued by Nelson (1993), autobiographical memory encodes a person's life history and plays an important role in defining the self.

Earlier, the importance of believability in robot design was discussed. Another important and related aspect is *readability*. Specifically, the robot's behavior and manner of expression (facial expressions, shifts of gaze and posture, gestures, actions, etc.) must be well matched to how the human observer intuitively interprets the robot's cues and movements to understand and predict its behavior (e.g., their theory-of-mind and empathy competencies). The human engaging the robot will tend to anthropomorphize it to make its behavior familiar and understandable. For this to be an effective strategy for inferring the robot's "mental states," the robot's outwardly observable behavior must serve as an accurate window to its underlying computational processes, and these in turn must be well matched to the person's social interpretations and expectations. If this match is close enough, the human can intuitively understand how to interact with the robot appropriately. Thus, readability supports the human's social abilities for understanding others. For this reason, Kismet has been designed to be a readable robot.

More demands are placed on the readability of robots as the social scenarios become more complex, unconstrained, and/or interactive. For instance, readability is reduced to believability in the case of passively viewed, non-interactive media such as classical animation. Here, observable behaviors and expressions must be familiar and understandable to a human observer, but there is no need for them to have any relation to the character's internal states. In this particular case, the behaviors are pre-scripted by animation artists, so there are no internal states that govern their behavior. In contrast, interactive digital pets (such as PF Magic's Petz or Bandai's Tamagotchi) present a more demanding scenario. People can interact with these digital pets within their virtual world via keyboard, mouse, buttons, etc. Although still quite limited, the behavior and expression of these digital pets is produced by a combination of pre-animated segments and internal states that determine which of these segments should be displayed. Generally speaking, the observed behavior is familiar and appealing to people if an intuitive relationship is maintained for how these states change with time, how the human can influence them, and how they are subsequently expressed through animation. If done well, people find these artifacts to be interesting and engaging and tend to form simple relationships with them.

Socially Situated Learning

For a robot, many social pressures demand that it continuously learn about itself, those it interacts with, and its environment. For instance, new experiences would continually shape the robot's personal history and influence its relationship with others. New skills and competencies could be acquired from others, either humans or other agents (robotic or otherwise). Hence, as with humans, robots must also be able to learn throughout their lifetime. Much of the inspiration behind Kismet's design comes from the socially situated learning and social development of human infants.

Many different learning strategies are observed in other social species, such as learning by imitation, goal emulation, mimicry, or observational conditioning (Galef, 1988). Some of these forms of social learning have been explored in robotic and software agents. For instance, learning by imitation or mimicry is a popular strategy being explored in humanoid robotics to transfer new skills to a robot through human demonstration (Schaal, 1997) or to acquire a simple proto-language (Billard & Dautenhahn, 2000). Others have explored social-learning scenarios where a robot learns about its environment by following around another robot (the model) that is already familiar with the environment. Billard and Dautenhahn (1998) show how robots can be used in this scenario to acquire a proto-language to describe significant terrain features.

In a more human-style manner, a robot could learn through tutelage from a human instructor. In general, it would be advantageous for a robot to learn from people in a manner that is natural for people to instruct. People use many different social cues and skills to help others learn. Ideally, a robot could leverage these same cues to foster its learning. In the next chapter, I explore in depth the question of learning from people as applied to humanoid robots.

1.4 Book Overview

This section offers a road map to the rest of the book, wherein I present the inspiration, the design issues, the framework, and the implementation of Kismet. In keeping with the infant-caregiver metaphor, Kismet's interaction with humans is dynamic, physical, expressive, and social. Much of this book is concerned with supplying the infrastructure to support socially situated learning between a robot infant and its human caregiver. Hence, I take care in each chapter to emphasize the constraints that interacting with a human imposes on the design of each system, and tie these issues back to supporting socially situated learning.

The chapters are written to be self-contained, each describing a different aspect of Kismet's design. It should be noted, however, that there is no central control. Instead, Kismet's coherent behavior and its personality emerge from all these systems acting in concert. The interaction between these systems is as important as the design of each individual system.

Evaluation studies with naive subjects are presented in many of the chapters to socially ground Kismet's behavior in interacting with people. Using the data from these studies, I evaluate the work with respect to the performance of the human-robot system as a whole.

- *Chapter 2* I motivate the realization of sociable robots and situate this work with Kismet with respect to other research efforts. I provide an in-depth discussion of socially situated learning for humanoid robots to motivate Kismet's design.
- *Chapter 3* I highlight some key insights from developmental psychology. These concepts have had a profound impact on the types of capabilities and interactions I have tried to achieve with Kismet.
- *Chapter 4* I present an overview of the key design issues for sociable robots, an overview of Kismet's system architecture, and a set of evaluation criteria.
- *Chapter 5* I describe the system hardware including the physical robot, its sensory configuration, and the computational platform. I also give an overview of Kismet's low-level visual and auditory perceptions. A detailed presentation of the visual and auditory systems follows in later chapters.
- *Chapter 6* I offer a detailed presentation of Kismet's visual attention system.
- *Chapter 7* I present an in-depth description of Kismet's ability to recognize affective intent from the human caregiver's voice.
- *Chapter 8* I give a detailed presentation of Kismet's motivation system, consisting of both homeostatic regulatory mechanisms as well as models of emotive responses. This system serves to motivate Kismet's behavior to maintain Kismet's internal state of "well-being."
- *Chapter 9* Kismet has several time-varying motivations and a broad repertoire of behavioral strategies to satiate them. This chapter presents Kismet's behavior system that arbitrates among these competing behaviors to establish the current goal of the robot. Given the goal of the robot, the motor systems are responsible for controlling Kismet's output modalities (body, face, and voice) to carry out the task. This chapter also presents an overview of

Kismet's diverse motor systems and the different levels of control that produce Kismet's observable behavior.

• *Chapter 10* I present an in-depth look at the motor system that controls Kismet's face. It must accommodate various functions such as emotive facial expression, communicative facial displays, and facial animation to accommodate speech.

• *Chapter 11* I describe Kismet's expressive vocalization system and lip synchronization abilities.

• *Chapter 12* I offer a multi-level view of Kismet's visual behavior, from low-level oculomotor control to using gaze direction as a powerful social cue.

• *Chapter 13* I summarize our results, highlight key contributions, and present future work for Kismet. I then look beyond Kismet and offer a set of grand challenge problems for building sociable robots of the future.

1.5 Summary

In this chapter, I outlined the vision of sociable robots. I presented a number of well-known examples from science fiction that epitomize the vision of a sociable robot. I argued in favor of constructing such machines from the scientific pursuit of modeling and understanding social intelligence through the construction of a socially intelligent robot. From a practical perspective, socially intelligent technologies allow untrained human users to interact with robots in a way that is natural and intuitive. I offered a few applications (in the present, the near future, and the more distant future) that motivate the development of robots that can interact with people in a rich and enjoyable manner. A few key aspects of human social intelligence were characterized to derive a list of core ingredients for sociable robots. Finally, I offered Kismet as a detailed case study of a sociable robot for the remainder of the book. Kismet explores several (certainly not all) of the core ingredients, although many other researchers are exploring others.