Chapter 13
Conversational Interfaces: Devices, Wearables, Virtual Agents, and Robots

Abstract We are surrounded by a plethora of smart objects such as devices, wearables, virtual agents, and social robots that should help to make our life easier in many different ways by fulfilling various needs and requirements. A conversational interface is the best way to communicate with this wide range of smart objects. In this chapter, we cover the special requirements of conversational interaction with smart objects, describing the main development platforms, the possibilities offered by different types of device, and the relevant issues that need to be considered in interaction design.

13.1 Introduction

So far we have discussed conversational interfaces on smartphones. In this chapter, we turn to other smart objects that also require a conversational interface, such as various types of wearable device, virtual agents, and social robots.

Smartphones and wearable devices have built-in sensors and actuators that gather data about the user and the environment, including location, motion, orientation, and biosignals such as heart rate. The interpretation of the data from the sensors is sometimes performed in a small built-in processor, but it is usually performed outside the wearable in another device with higher computational power such as a smartphone, usually through Bluetooth or Wi-fi communication. As discussed in Sect. 13.2, this is one of the reasons why wearables are not as widespread as other technologies, as in many cases they are used just as another interface to the smartphone.

Currently, wearables can obtain data from users that until recently was not accessible on regular consumer gadgets at affordable prices. This opens a new world of possibilities for developers wishing to exploit this data and to create exciting applications. For example, the "quantified self" movement[1] aims to exploit

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[1] http://quantifiedself.com. Accessed February 22, 2016.

M. McTear et al., *The Conversational Interface*,
DOI 10.1007/978-3-319-32967-3_13

this technology by allowing users to quantify their daily activities, mainly in terms of physical and physiological data (e.g., heart rate, sleeping hours, etc.), so that they can monitor their activity and gain a better understanding of themselves (Chan et al. 2012). Many applications are being developed to foster health, self-knowledge, motivation, and active and healthy living. Calvo and Peters (2014) have called applications such as these "positive computing".

Designing conversational interfaces is even more critical in the case of robots. As robots move from industrial applications to other domains in which a relationship with the user is crucial, e.g., companionship, health care, education, and entertainment, there has been an increasing focus on making robots more human-like in their appearance and, more importantly, in their communicative capabilities.

In the following sections, we describe the issues involved in designing and implementing conversational interfaces for these wearables, virtual agents, and social robots.

13.2 Wearables

Wearable computing devices (wearables) have expanded rapidly in recent years as a result of factors such as the availability of wireless access and acceptance by the public of wearable designs (Baker et al. 2015). Initially, wearables were seen as the next stage in a movement in personal computing from fixed desktop PCs to portable devices such as laptops, then to smaller devices such as smartphones and tablets, and finally to wearables. Wearables are small computing systems that the user can carry comfortably, just like an item of clothing or jewelry. However, it soon became apparent that, in addition to being portable, having the devices near to the user's body could also provide additional sources of valuable information.

13.2.1 Smartwatches and Wristbands

Smartwatches and wristbands are the most common wearable technologies. They can be used as an interface to a smartphone so that the user can receive notifications and messages without having to take the phone out of a bag or pocket. Users can specify that only urgent notifications should appear on their smartwatches so that they are only interrupted when something important happens (e.g., calls from certain contacts, or messages with a certain content). However, some users like to stay constantly connected and do not want to miss a single thing, so that the wearable provides a stimulus that is nearer to them, such as a vibration on the wrist as opposed to the vibration of the mobile phone inside a purse, or a stimulus that might otherwise be missed, for example, when exercising.

However, some wearables such as smartwatches can also run apps that are developed specifically for the device. Many apps for mobile phones also have smartwatch versions that have been developed using special APIs. Some smartwatches can be used with different wearable vendors, such as Android Wear,[2] and others are vendor specific, such as Pebble Developer,[3] or WatchKit for Apple Watch.[4] Chapter 16 presents a laboratory on how to develop multimodal applications with Android Wear.

Smartphones and wristbands can also make use of sensors to measure pulse, body temperature, galvanic skin response (GSR), heart rate, and skin temperature. In some cases, the devices have displays that provide feedback to the user, while in other cases the information gathered by the sensors is sent to a smartphone where different apps can display the interpreted data. For example, heart rate data is typically shown on the screen of the device, while sleep-tracking data acquired during the night is usually shown as a graphic on a smartphone.

Usually, smartphone apps that allow users to monitor their data are vendor specific; that is, the company that sells the wearable device provides the app. Apps may contain historical data, for example, by establishing and tracking goals, such as the number of steps to walk during the week or the number of hours of sleep, and by linking with a community of users and providing challenges, for example, to see who exercises more during a weekend. This is the case with apps provided by companies such as Adidas, Fitbit, Garmin, Jawbone, MisFit, Nike, and Polar. Many of these companies also provide developer APIs and SDKs, for example, Fitbit, Garmin, and Polar. There are also solutions for developers who want to integrate training data into their applications, for example, Google Fit[5] and Apple HealthKit.[6] With these APIs, health and fitness data is stored in secure locations and can be easily discovered and tracked.

13.2.2 *Armbands and Gloves*

Armbands and gloves are used mainly for gesture control. Their positioning allows muscle sensors to detect changes in movements of the arm and gestures of the hands (see Fig. 13.1).[7] This allows them to capture movements to control devices remotely, for example, by defining a gesture to play music, or making a robot reproduce hand movements.

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[2] http://developer.android.com/wear/index.html. Accessed February 22, 2016.

[3] http://developer.getpebble.com/. Accessed February 22, 2016.

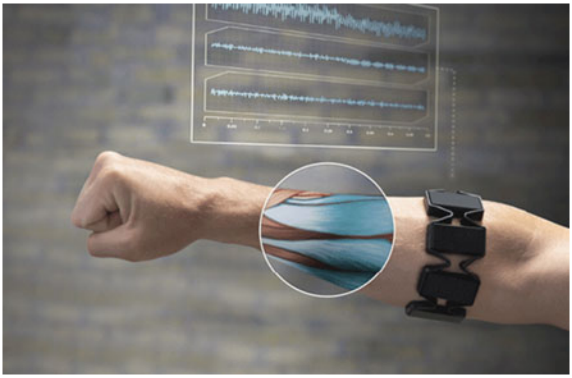
[4] https://developer.apple.com/watchkit/. Accessed February 22, 2016.

[5] https://developers.google.com/fit/. Accessed February 22, 2016.

[6] https://developer.apple.com/healthkit/. Accessed February 22, 2016.

[7] https://www.myo.com/. Accessed February 22, 2016.

Fig. 13.1 The Myo gesture control armband, made by Thalmic Labs (reproduced with permission from Thalmic Labs)



13.2.3 Smart Glasses

Glasses with mountable microphones or video cameras can function as augmented reality glasses for navigation. Using a wireless connection, they can provide virtual information to the user that is superposed on what they are looking at (Fig. 13.2).

Despite the huge enthusiasm that greeted the appearance of Google glasses, their development is still in its infancy. In fact, Google stopped their glasses beta program in January 2015, although the project has not been officially canceled. There are several glasses in the market, but most of them are beta versions, for example, the Sony SmartEyeglass, for which there is a developer version.[8]

Glasses can also incorporate holographic technology, as in Microsoft's HoloLens.[9] A Developer Edition was made available in 2016. Interestingly, Microsoft has paid special attention to ways of interacting with the glasses, focusing primarily on spoken communication, as this enhances the feeling of immersion created by the combination of augmented and virtual reality.

Glasses should be light to wear, and the superposed information should not be disruptive for the user. Currently, smart glasses are still quite large and heavy compared with normal glasses, and they may result in some discomfort for users. Sony recommend in their terms and conditions that the use of their glasses should be limited to 2 hours a day to reduce discomfort, eye strain, fatigue, and dizziness. Smart glasses can also help users who regularly use normal glasses by monitoring their sight problems. For example, Shima glasses[10] offer developers and beta testers the possibility to have their prescription embedded within the device.

There are some issues with smart glasses that still need to be resolved. One of these is privacy, since users can record video and audio with the glasses and this could infringe on the privacy of other people. Another issue is safety, as a user may

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[8] http://developer.sonymobile.com/products/smarteyeglass/. Accessed February 22, 2016.

[9] https://www.microsoft.com/microsoft-hololens/en-us/development-edition. Accessed 17 April 2016.

[10] http://www.laforgeoptical.com/. Accessed February 22, 2016.

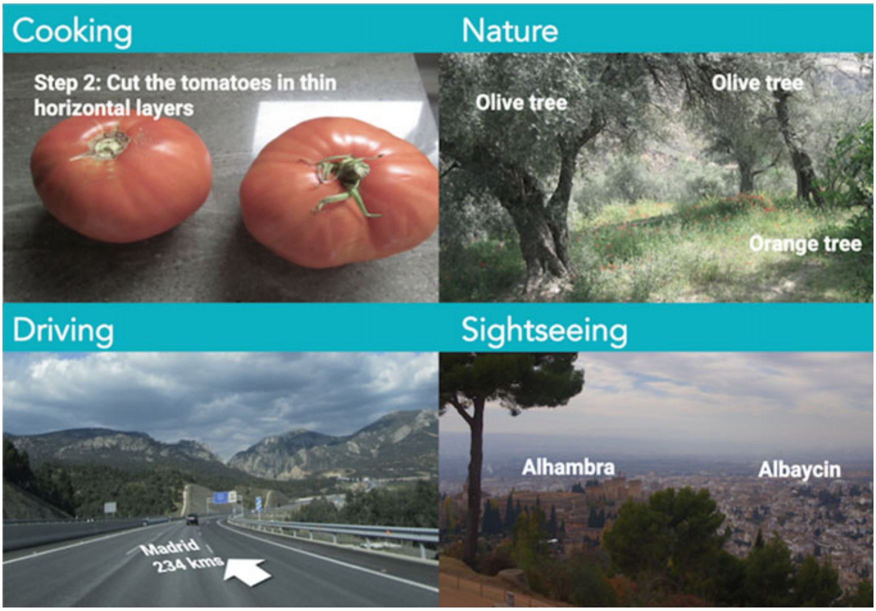

Fig. 13.2 Scenarios for smart glasses

be reading the information displayed in the glasses while driving or doing other critical and potentially harmful activities.

13.2.4 Smart Jewelry

Smart jewelry is a more fashionable alternative to smartwatches and fitness trackers. Different start-ups are creating smart jewelry. For example, Vinaya presents Bluetooth-connected smart pendants that connect to the iPhone and vibrate to provide notifications of important events. Indeed, their Web page,[11] in which they show their ring sketched like a *pret-a-porter* dress design, looks more like the Web page of a fashion magazine than a technology company. Ringly[12] displays rings with different colors and materials that notify text messages, e-mail, WhatsApp messages, phone calls, social networks, etc., and MEMI[13] presents bracelets with similar functionalities.

However, though these examples of smart jewelry look similar to a normal piece of jewelry, their capacity is limited to notifications and they do not have sensing

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[11] http://www.vinaya.com/. Accessed February 22, 2016.

[12] https://ringly.com/. Accessed February 22, 2016.

[13] http://www.memijewellery.com/. Accessed February 22, 2016.

Fig. 13.3 The Misfit pendant (reproduced with permission from Misfit)

capabilities. Integrating sensors would require a larger piece of jewelry, as is the case with the Bellabeat LEAF.[14] LEAF can be used as a pendant or clip, making it less like the jewelry of Vinaya, although it still has a very aesthetic design. The functionalities of LEAF are similar to those of fitness trackers, for example, activity tracking and sleep monitoring. This is the same for the Misfit pendant[15] (Fig. 13.3). Other companies plan to offer sensing functionalities on devices that look like real jewelry, for example, EarO-Smart.[16] These devices are usually targeted at female customers and sometimes include applications designed for women, for example, to track sleep patterns during menstrual cycles.

13.2.5 Smart Clothing

Clothes with embedded sensors are a relatively new technology that has been emerging recently. This technology is being embraced mainly in the health and fitness domains, as many of the available products monitor vital signs and biomechanics. Athletes can wear smart clothing that allows coaches to monitor them and to spot who is under pressure, how to avoid and control injuries, as well as enabling them to compare players and to compare the same player in different positions.[17]

Some items of smart clothing such as shirts or body suits can collect data such as heart rate, breathing rate, or the intensity of a workout and can provide feedback on

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[14] https://www.bellabeat.com/. Accessed February 22, 2016.

[15] https://store.misfit.com/. Accessed February 22, 2016.

[16] http://earosmart.com/. Accessed February 22, 2016.

[17] http://www.catapultsports.com/uk/. Accessed February 22, 2016.

which parts of the body are under too much pressure.[18,19,20] There are also socks that analyze and improve running form by tracking the position of the feet and the foot-landing technique, helping to prevent injuries while also tracking data such as the number of steps taken, the distance covered, calories, and cadence.[21] There are also belts that adjust automatically when you eat too much. Generally, these items of smart clothing are connected to specific apps that can be used on a mobile phone to monitor the information coming from the shirt sensors.

In addition to applications for athletes, smart clothing can help with health monitoring by keeping track of cardiac, respiratory, and activity data for people suffering from diverse conditions. Another application is monitoring the sleep of babies.

13.3 Multimodal Conversational Interfaces for Smart Devices and Wearables

Smart devices and wearables have introduced new interaction scenarios that have different implications for interface development. With smaller and simpler wearables such as fitness bands, communication between the system and the user can be restricted to small buttons for user–system interaction and light-emitting diodes (LEDs) and vibration for system–user interaction. With more sophisticated devices such as smartwatches, spoken interaction is augmented with visual responses based on cards.

The principles of conversation described in Chap. 3 apply also to wearables and smartphones with respect to prompt and menu design, relevant dialog act selection, the design of confirmations, turn taking, and grounding strategies. However, there are some additional aspects that must be considered. For example, developers must take into account that users have preconceived ideas about how to operate a particular device. Currently, the spoken interaction paradigm for wearables and smartphones is more command-like than conversational; thus, designers who intend to build a conversational interface for these devices must be aware that users may not address the device in a conversational way unless they are instructed on how to do so by the system.

Another relevant aspect is an Internet connection. Many systems still perform speech recognition online and thus require an active Internet connection while the user is speaking to the device. Thus, developers must consider whether voice is the best alternative depending on whether the device is likely to be connected to the Internet, and even when the device is always likely to be connected, they must

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[18] http://www.hexoskin.com/. Accessed February 22, 2016.

[19] http://omsignal.com/pages/omsignal-bra. Accessed February 22, 2016.

[20] http://www.heddoko.com/. Accessed February 22, 2016.

[21] http://www.sensoriafitness.com/. Accessed February 22, 2016.

predict mechanisms to maintain communication with users if the connection is temporarily lost. In this situation, the solution is usually to balance the different modalities that are available on the device to obtain the best combination of oral, visual, and gestural communication. Unfortunately, guidelines for developers using Android[22] and iOS[23] focus mainly on how to program the interfaces rather than on design issues, though Microsoft provides some speech design guidelines for Windows Phones.[24]

With respect to visual interfaces, cards are becoming a useful design pattern since they can be placed beneath or beside one another and stacked on top of each other so that they can be swiped and easily navigated. The content of Web pages and apps is increasingly becoming an aggregation of many individual pieces of content from heterogeneous services on to cards, and interaction with our smartphones and devices is more and more a flow of notifications from a wide range of different apps.[25] Many companies now use cards, from social networks such as Twitter (Twitter Cards for multimedia) and Facebook (each input in the wall is shown as a card in the history of the user), blogs (e.g., Pinterest was one of the first to move the blog concept from posts to visual cards), all sorts of apps (e.g., Apple Passbook), and even operating systems (e.g., cards on Windows 8) and Web applications (e.g., Google Now uses a wide range of cards[26]).

Chris Tse, from cardstack.io, discusses patterns of card UI design and good design practice.[27] He places the types of card in a continuum from long-lived to short-lived cards. At the long-lived end of the spectrum, cards function as records, for example, Apple Passbook, while at the medium end they function as teasers and at the short-lived end they function as alerts.

The anatomy of a card is usually context, lens, and triggers (Fig. 13.4). For example, in the figure, we can see that cards present small pieces of information in a highly browsable way that some people might even find addictive.[28]

Hierarchy is not relevant with cards. Card collections display cards that are at the same level of importance, even if they have varied layouts (see Fig. 13.5) or are related to different issues. The focus is on the ability of the user to scan through them. Card collections usually scroll vertically, though there are many different

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[22] http://developer.android.com/intl/es/training/wearables/apps/voice.html. Accessed February 22, 2016.

[23] https://developer.apple.com/library/ios/documentation/AVFoundation/Reference/AVSpeechSynthesizer_Ref. Accessed February 22, 2016.

[24] https://msdn.microsoft.com/en-us/library/windows/apps/jj720572%28v=vs.105%29.aspx. Accessed February 22, 2016.

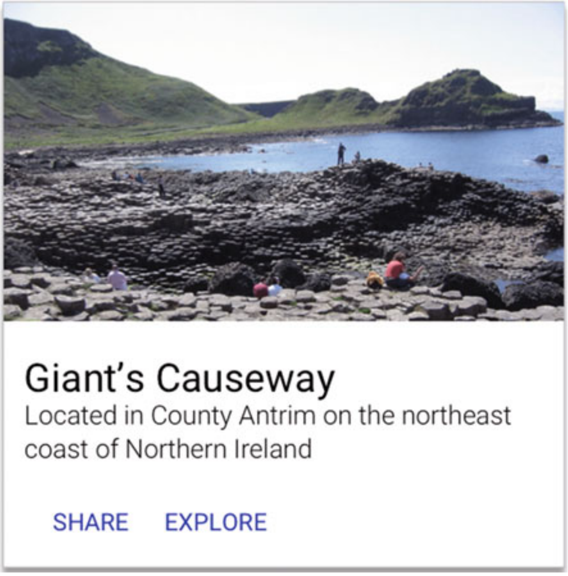
[25] https://blog.intercom.io/why-cards-are-the-future-of-the-web/. Accessed February 22, 2016.

[26] https://www.google.com/landing/now/#cards. Accessed February 22, 2016.

[27] https://speakerdeck.com/christse/patterns-of-card-ui-design. Accessed February 22, 2016.

[28] More in: https://www.google.com/design/spec/components/cards.html#cards-actions. Accessed February 22, 2016.

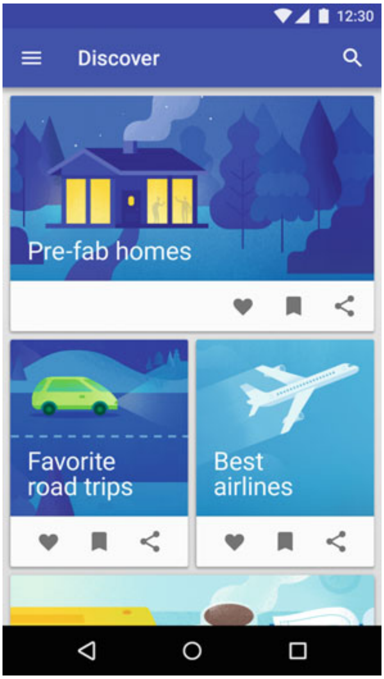
Fig. 13.4 A sample card



Giant's Causeway

Located in County Antrim on the northeast coast of Northern Ireland

Fig. 13.5 Sample card collection showing cards with different layouts (https://www.google.com/design/spec/components/cards.html#cards-content. Accessed February 24, 2016). Google and the Google logo are registered trademarks of Google Inc., used with permission



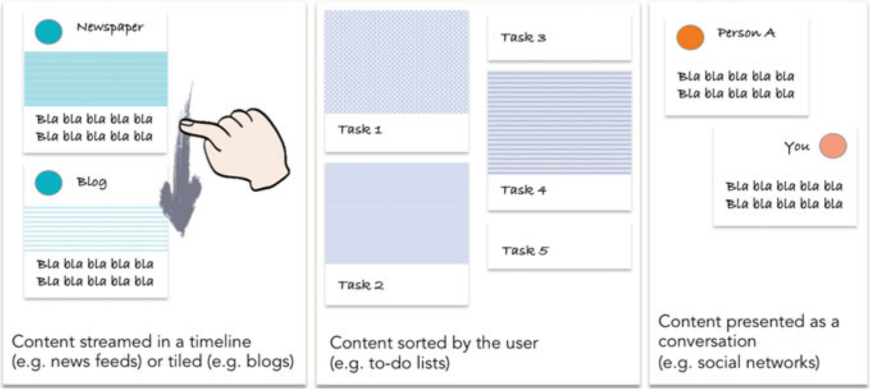


Fig. 13.6 Different types of card container

containers that can be used[29] that allow a seamless experience with many different screen sizes and devices (see Fig. 13.6). However, card-centric user interfaces may not be suitable for all contexts.[30]

Speech and card interfaces may be complemented by augmented reality applications. Molineux and Cheverst (2012) outline very interesting case studies of museum guidance supported by on-device object recognition, phone–cam interactions for large public displays, way finding for individuals with cognitive impairments, and hand-gesture manipulation of projected content.

Smartphones and wearables allow gestural interaction. This can be done in general-purpose devices such as smartphones thanks to sensors like the accelerometer and in specific wearables such as the armbands shown in Fig. 13.1. Dunne et al. (2014) present a study of the effect of gestural interaction on wearability. The authors distinguish two types of gestural interactions: passive and active. In passive interactions, the device listens for movements that trigger certain actions. In active interactions, the user consciously performs movements to provide instructions to the device.

For active input, designers must find a trade-off between clarity and visual distinction of the input. That is, if a gesture is remarkably different from everyday movements, it will be easily recognizable by the device, but also by other people (it has a “social weight”). On the other hand, if the gesture is more natural, it is less noticed as it is more likely that everyday movements are interpreted as an input gesture by the device.

Currently, there is no standard vocabulary for gestures, which makes it difficult to generate interfaces that are usable. In fact, we have learnt from visual languages

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[29] http://thenextweb.com/dd/2015/06/16/how-cards-are-taking-over-web-design/. Accessed February 22, 2016.

[30] http://ux.stackexchange.com/questions/60495/what-are-the-advantages-of-a-card-centric-user-interface. Accessed February 22, 2016.

(like sign language) that visual expressions are inherently ambiguous and that general-purpose visual languages often fail. Instead, experts recommend focusing design on specific domains and contexts (Ardito et al. 2014).

Other authors are working on silent speech interfaces (Bedri et al. 2015), where the user "talks silently," moving the mouth and/or tongue as if to pronounce a phrase that is not vocalized. These interfaces are usually meant for people who have lost their capacity to produce intelligible speech because of neurological or motor injuries but who are still able to articulate mouth and tongue. To build these interfaces, different sensors can be placed in the mouth and in earplugs to recognize tongue and jaw movements. However, it is difficult to distinguish silent speech from other actions such as eating. Similarly, Jeon and Lee (2013) have studied the use of non-speech sounds on mobile devices.

As can be observed, wearable devices and smartphones have opened many new possibilities for multimodal interfaces that must be addressed from a multidisciplinary perspective, bringing together interaction designers, usability researchers, and general human–computer interaction (HCI) practitioners to analyze the opportunities and directions to take in designing more natural interactions based on spoken language. This has been a topic for recent technical and scientific workshops, some of which have the aim of gaining more widespread acceptance of speech and natural language interaction (Munteanu et al. 2014).

13.4 Virtual Agents

Virtual characters that are able to display multimodal behaviors are being used nowadays for a variety of purposes, from unidirectional communication in which they take the role of a presenter and the user simply listens as if they are watching a TV show, to conversational partners from a wide spectrum of more directed information-providing tasks, to open tasks such as artificial companions.

These characters have been endowed with different visual appearances. Some early characters were cartoon like. For example, Smartakus, an animated character with the shape of an "i," was used in the SmartKom Project to present information (Wahlster et al. 2001). Then, more anthropomorphic agents appeared. For example, the August talking head had lip-synchronized speech synthesis, nonverbal behavior, and approach and gaze behavior to show awareness of the user's actions (Gustafson et al. 1999), while the REA agent used eye gaze, body posture, hand gestures, and facial displays to contribute to the conversation and organize her own interventions (Cassell et al. 2000).

The focus in current systems is on developing agents with a full body. Humans depend to a great extent on embodied behaviors to make sense and engage in face-to-face conversations. The same happens with machines: embodied agents help to leverage naturalness and users judge the system's understanding to be worse when it does not have a body (Cassell 2001). According to Cassell et al. (2000), the body is the best way to alternate multiple representations in order to convey multimodal information and to regulate conversation. Embodied conversational agents (ECAs) exhibit multimodal communicative capabilities comprising voice, gestures, facial expressions, gaze, and body posture and may play different roles of varying complexity, for example, as companions for the elderly, as toys, virtual trainers, intelligent tutors, or as Web/sales agents.

However, embodiment plays a central role for the system's output, enabling the agent to produce gestures and behaviors that enhance the image its projects, and also for its perceptual functions. Advances in the understanding of human cognition have demonstrated that our minds are not reasoning devices that can be isolated from our bodies. Rather, they are tied to the physical world to the extent that we understand concepts as relations between our bodies and the world. Early agents had limited perceptual abilities and the knowledge they had about the environment and the user was limited. According to André and Pelachaud (2010), for an ECA to be believable, it must be equipped with a sensory mechanism that makes it possible to render sophisticated attending behaviors.

13.5 Multimodal Conversations with Virtual Agents

ECAs should be endowed with refined communicative, emotional, and social capabilities. This means that apart from task-oriented functions, they should also integrate interpersonal goals. Many studies have demonstrated that there is a significant improvement in engagement and likeability when interacting with agents that display believable nonverbal behaviors. For example, Bickmore and Cassell (2005) show the importance of small talk to build rapport and trust with the REA agent, an ECA that acted as a real estate agent. Interactional functions helped create and maintain an open channel of communication between the user and the agent.

André and Pelachaud (2010) provide a concise but comprehensive overview of the design of ECAs. According to their description, many ECAs rely on Information State dialog managers like TRINDI (Traum and Larsson 2003) (see Chaps. 4 and 10). Also, their multimodal behavior is learnt from human–human conversations from which models are extracted and refined. Data-driven approaches are still not fully adopted, and so a vast amount of data must be gathered and annotated to observe the wide range of gestures and expressions that occur in face-to-face communication. In addition, not only the gestures themselves must be simulated, but also special attention must be paid to their temporal dynamics, co-occurrence, and the different meanings that may be conveyed when merging several gestures.

The design and development of the multimodal behaviors of ECAs has focused on issues such as the reusability of the components and the separation of behavior planning from behavior generation and realization. Different standards are being defined to establish common architectures and languages, such as the Situation, Agent, Intention, Behavior, Animation (SAIBA) framework, the Behavior Markup Language (BML), and the Functional Markup Language (FML) (described in

Chap. 15). These elements are able to encode affect, coping strategies, emphasis, turn management strategies, as well as head, face, gaze, body movements, gestures, lip movements, and speech. Other languages, e.g., Multimodal Utterance Representation Markup Language (MURML), focus on coupling verbal utterances with gestures that are associated with linguistic elements (Kopp and Wachsmuth 2004).

A lot of effort has also been put on building emotional models for ECAs, as will be described in Chaps. 14 and 15. For example, ECAs may be built to be artificial companions, and in that case, the objective of the system may be more related to emotion (e.g., making someone happy or confident) than accomplishing a certain task. As stated by Cowie, "companionship is an emotional business," and this encompasses several social, psychological, and ethical issues that are described in detail in Wilks (2010).

13.6 Examples of Tools for Creating Virtual Agents

Greta.[31] Greta is a real-time three-dimensional ECA developed by the Greta Team at Telecom ParisTech. Greta is based on a 3D model of a woman compliant with the Moving Picture Experts Group (MPEG-4) animation standard and is able to communicate using a rich palette of verbal and nonverbal behaviors in standard languages. Greta can talk and simultaneously show facial expressions, gestures, gaze, and head movements.

The Virtual Human Toolkit.[32] The Institute for Creative Technologies (ICT) Virtual Human Toolkit is a collection of modules, tools, and libraries designed to aid and support researchers and developers with the creation of ECAs. It provides modules for multimodal sensing, character editing and animation, and nonverbal behavior generation.

SmartBody.[33] SmartBody is a character animation platform developed originally at the University of Southern California that is included in the Virtual Human Toolkit but can also be used separately. It provides locomotion, steering, object manipulation, lip-syncing, gazing, and other nonverbal behaviors. The software is provided free and open source under the GNU Lesser General Public License (LGPL) and is multiplatform (it works on Windows, Linux, OSx, Android, and iOS).

MAX and the Articulated Communicator Engine (ACE).[34] ACE is a toolkit for building ECAs with a kinematic body model and multimodal utterance generation based on MURML. MAX is an ECA developed for cooperative construction tasks that has been under development at the University of Bielefeld for more than a decade.

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[31] http://perso.telecom-paristech.fr/~pelachau/Greta/. Accessed February 24, 2016.

[32] https://vhtoolkit.ict.usc.edu/. Accessed February 24, 2016.

[33] http://smartbody.ict.usc.edu. Accessed February 24, 2016.

[34] http://www.techfak.uni-bielefeld.de/~skopp/max.html. Accessed February 24, 2016.

13.7 Social Robots

Robots are moving out of factories and increasingly entering our homes. This has provoked a paradigm shift: in this new scenario, users are not trained to operate the robots; instead, the users are naïve and untrained and so the robots must be able to communicate with them in an intuitive and natural fashion (Mathur and Reichling 2016). This can be achieved by endowing robots with the ability to hold conversations with their users. The complexity of these interactions may vary depending on the type and function of the robot.

On the one hand, robots may be understood as tools that can be used to access functionality and request information using a command-like interface. On the other hand, robots may be conceptualized as "hedonic" systems with which humans can engage in more complex relationships using a conversational interface. Robots such as these are known as *social robots*. With social robots, humans apply the social interaction models that they would employ with other humans, since they perceive the robots as social agents with which humans can engage in stronger and more lasting relationships. Social robots can also provide entertainment, sociability, credibility, trust, and engagement (de Graaf et al. 2015).

In the literature, there are many examples demonstrating that human beings attribute social identity to robots, even when the robots are seen as tools. Sung et al. (2007) show how some users attribute personalities to their cleaning robots. Hoenen et al. (2016) discuss how robots (in particular, the non-anthropomorphic ones) can be considered as social entities and how the social identity of a robot can be established through social interaction. Peca et al. (2015) show that interactivity between humans and objects can be a key factor in whether infants perceive a robot as a social agent. In this study, infants aged 9–17 months witnessed an interaction between an adult and a robot and they made inferences regarding its social agency based on the responsiveness of the robot.

Children often address robots as social agents. For example, Kahn et al. (2012) show how children believed that the robot used in experiments had feelings and was a social being that they considered as a friend with whom they could entrust secrets. Given findings such as these, one of the most promising application domains for social robots is to build robots for children, for entertainment and pedagogic purposes, and also to provide help for children suffering from conditions such as autism. However, currently, social interactions with most commercial robots are usually very predictable, so the robot loses its magic with continued use and children eventually lose interest.

Robots are also considered as an aid for aging populations by improving their quality of life and helping them to stay fit and healthy, supporting autonomy, and mitigating loneliness. To obtain these benefits, adults must accept robots as part of their home environment, find them easy to operate, and perceive them as social counterparts. Different studies have shown that people's acceptance of robots depends on a variety of social factors including safety, fun, social presence, and perceived sociability (Heerink et al. 2010). Also it is important that the robots adhere to human social rules including friendliness, speech styles, and ways of addressing the user. Other studies highlight barriers to the acceptance of robots by older adults, including older adults' uneasiness with technology, a feeling of stigmatization, and ethical/societal issues associated with robot use (Wu et al. 2014).

Some authors have warned about particular undesired effects of social robots. For example, Turkle (2012) discusses the negative impact that robots may have on our ability to build human relationships and deal with complexities and problems when we have robots as companions that can cater for every need:

> Our population is aging; there will be robots to take care of us. Our children are neglected; robots will tend to them. We are too exhausted to deal with each other in adversity; robots will have the energy. Robots won't be judgmental.

However, other authors even find it plausible that robots may be used in the future to influence their users to become more ethical (Borenstein and Arkin 2016).

13.8 Conversational Interfaces for Robots

Interacting with social robots puts several unique requirements on the conversational interface (Cuayáhuitl et al. 2015). As far as spoken language interaction is concerned, a robot has to be able to predict the direction of the arrival of speech within a wide area and be able to distinguish voice from noise, whereas with other devices, speech is directed toward a microphone that is usually held close to the user's mouth. This is known as *speech localization*. Other aspects of speech localization include exhibiting social interaction cues such as approaching the speaker or looking at them and also managing turn taking in single and multiparty conversations. As far as language understanding is concerned, robots need to be able to understand and use language beyond a restricted set of commands. Given that they operate in a situated environment, robots have the advantage that they can learn language by extracting representations of the meanings of natural language expressions that are tied to perception and actuation in the physical world (Matuszek et al. 2012). Flexible and optimized dialog management is also crucial. Robots should be able to engage in mixed initiative dialog and perform affective interaction (Mavridis 2015). They should also be able to recognize and produce multimodal behaviors that accompany speech (Lourens et al. 2010). See Chap. 15 for a more detailed discussion of expressive behaviors.

All these challenges must be addressed in order to develop social robots. According to Looije et al. (2010), social behaviors such as turn taking and emotional expressions are essential for a robot to be perceived as trustworthy. Social robots must also be compliant with social norms. Awaad et al. (2015) maintain that this involves a mixture of knowledge about procedures (knowing how to accomplish tasks) and functional affordances of objects (knowing what objects are used for). For example, they argue that robots should know that if no glasses are available when serving water, then a mug is a valid substitution, and that such a substitution is socially acceptable. Also, there may be aspects of human-human interactions that users may not wish to see in robots, such as social control or criticism (Baron 2015). Breazeal (2003, 2004) argues for taking the robot's perspective when tackling the relevant design issues, including naturalness, user expectation, user–robot relationship, and teamwork.

There are various requirements that need to be considered in the design of a social robot if it is to act as a companion. Luh et al. (2015) developed a scale of "companionship" for virtual pets based on the companionship features of real pets. The most important factors were enjoyment, psychological satisfaction, autonomy, responsibility, and interactive feedback. Benyon and Mival (2007) describe personification technologies in term of utility, form, emotion, personality, trust, and social attitudes, all of which should be considered during design. Pearson and Borenstein (2014) emphasize ethical aspects of creating companions for children, while Leite et al. (2013) present a detailed survey of studies of long-term human–robot interactions and provide directions for future research, including the need for continuity and incremental novel behaviors, affective interactions, empathy, and adaptation.

Looking at negative attitudes toward robots, the Negative Attitudes toward Robots Scale (NARS) and Robot Anxiety Scale (RAS) study negative attitudes and anxiety toward robots that may lead to users adopting a strategy of avoiding communication with robots (Nomura et al. 2006; Kanda and Ishiguro 2012). Other authors have related these factors to their perceived ease of use, which is directly related to the interface and how it influences social presence and perceived enjoyment (Heerink et al. 2010).

In summary, the integration of social robots into everyday life depends to a great extent on their ability to communicate with users in a satisfying way, for which multimodal conversation is of paramount importance (Fortunati et al. 2015). The effects of expressive multimodal behaviors and the display of emotions and personality are discussed in Chap. 15.

13.9 Examples of Social Robots and Tools for Creating Robots

13.9.1 Aldebaran Robots

The Aldebaran robots are the most widespread robots within the scientific community. Their family of robots includes NAO,[35] Pepper, and Romeo (Fig. 13.7). NAO is a small robot that has been used extensively for research and educational purposes. Pepper and Romeo are more recent. The former was created for SoftBank

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[35] https://www.aldebaran.com/en/humanoid-robot/nao-robot. Accessed February 22, 2016.

Fig. 13.7 Aldebaran's NAO, Romeo, and Pepper robots (reproduced with permission from Aldebaran)

Mobile (an important mobile phone operator in Japan)[36] and has been endowed with emotion recognition capabilities, and the latter is a robot intended for research purposes.[37] All of the robots include sensors and actuators and incorporate a microphone and speakers to allow conversational interaction.[38]

13.9.2 *Jibo*

Jibo[39] is a social robot that was not designed with humanoid characteristics but more like a Disney or Pixar character with a single eye and a moving head and body that are used to give him a personality and promote social engagement (Fig. 13.8). Jibo can track faces and capture photographs, process speech, and respond using natural social and emotive cues. Developers can add skills and content to Jibo by using the Jibo SDK that provides animation tools for movements and displays, timeline tools for sequencing, behavior tools for engagement, and a visual simulator. You can see a video of Jibo here.[40]

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[36] https://www.aldebaran.com/en/a-robots/who-is-pepper. Accessed February 22, 2016.

[37] http://projetromeo.com/en/. Accessed February 22, 2016.

[38] http://www.theverge.com/2016/1/6/10726082/softbank-pepper-ibm-watson-collaboration. Accessed February 22, 2016.

[39] https://www.jibo.com/. Accessed February 22, 2016.

[40] https://www.youtube.com/watch?v=3N1Q8oFpX1Y. Accessed February 22, 2016.

Fig. 13.8 Jibo, the social robot (reproduced with permission from Jibo)

13.9.3 FurHat

The FurHat platform was developed by human–computer interaction experts at Furhat Robotics with a strong background in dialog systems.[41] FurHat (Fig. 13.9) is a robotic head based on a projection system that renders facial expressions, with motors to move the neck and head. Developers can use an open-source SDK, and there are libraries for speech recognition and synthesis as well as face recognition and tracking (Al Moubayed et al. 2012). You can see a video of FurHat here.[42]

13.9.4 Aisoy

Aisoy[43] is a programmable robot to encourage creative thinking in children and improve their ability to solve challenging problems. Aisoy can be programmed by children (with Scratch or Blocky), but it also has an SDK for programming in higher-order languages. It is based on the Raspberry Pi and can be used for conversational applications as it incorporates a microphone and speakers (Fig. 13.10).

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[41] http://www.furhatrobotics.com/. Accessed February 22, 2016.

[42] https://www.youtube.com/watch?v=v84e6HMFbyc. Accessed February 22, 2016.

[43] http://www.aisoy.com/.

Fig. 13.9 Furhat (reproduced with permission from Furhat Robotics)

Fig. 13.10 The Aisoy robot (reproduced with permission from Aisoy Robotics)

13.9.5 Amazon Echo

Amazon Echo[44] is similar to social robots such as Jibo and Pepper except that it does not provide an anthropomorphic physical embodiment. Instead, it has the form of a cylinder about 9 inches tall containing a microphone array and speakers. Echo is connected to Alexa, a cloud-based voice service that provides a range of capabilities known as *skills*, including information, creating shopping lists, providing news and traffic information, streaming music, and also some home control functions such as controlling lights. The use of far-field speech recognition and beam-forming technology means that Echo can hear from any direction and cope with ambient noise such as music playing in the background.

13.9.6 Hello Robo

The idea behind Hello Robo is that personal robotics should be more accessible and affordable to everyone.[45] Open-source robots have been developed that can be replicated using a desktop 3D printer. Examples are maki and poly.[46]

13.9.7 The Open Robot Hardware Initiative

Open robot hardware was created to provide resources and open-source hardware for developers of robotics applications. The Web site has information about different projects and provides tutorials on topics including robotic arms and hands, humanoid robots, vehicles and drones, legged robots, swarm robots, actuators and sensors, and modules for specific application domains such as social, health, and educational robotics.[47]

13.9.8 iCub.org: Open-Source Cognitive Humanoid Robotic Platform

The EU project RobotCub generated the iCub humanoid robot (Fig. 13.11) that is currently used worldwide and can be obtained from the Italian Institute of Technology for a fee. It has 53 motors that move the head, arms and hands, waist,

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[44] http://www.amazon.com/echo. Accessed February 22, 2016.

[45] http://www.hello-robo.com/. Accessed March 1, 2016.

[46] http://inmoov.fr. Accessed March 1, 2016.

[47] http://www.openrobothardware.org/linkedprojects. Accessed February 22, 2016.

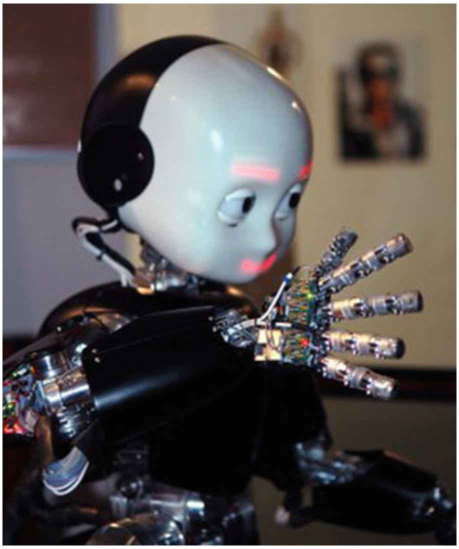

Fig. 13.11 The iCub robot (reproduced with permission)

and legs. It can see and hear, and it has a sense of proprioception (body configuration) and movement (using accelerometers and gyroscopes). It is open source, and its code and even the production drawing describing its mechanical and electronic parts are available on the web page.[48]

13.9.9 SPEAKY for Robots

SPEAKY for Robots[49] (Bastianelli et al. 2015) aims to foster the definition and deployment of voice user interfaces (VUIs) in robotic applications where human–robot interaction is required. The goal is to develop a Robotic Voice Development Kit (RVDK).

13.9.10 The Robot Operating System (ROS)

ROS is an open-source project that aims to develop a platform for writing robot software and sharing code solutions and algorithms.[50] It is particularly interesting for students as it breaks the expert-only barrier.

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[48] http://www.icub.org/. Accessed February 22, 2016.

[49] http://www.dis.uniroma1.it/~labrococo/?q=node/373. Accessed February 22, 2016.

[50] http://www.ros.org/. Accessed February 22, 2016.

13.10 Summary

A variety of smart devices, wearables, virtual agents, and social robots are being developed that provide new ways to interact with Web services and with our environment. However, the potential for these devices still has to be realized as often their interface does not go beyond the command-and-control metaphor. In this chapter, we have addressed the possibilities and challenges for designers and developers of multimodal conversational interfaces to smart devices, wearables, virtual agents, and robots.

Further Reading

Trappl (2013) is a book of readings about agents and robots as butlers and companions. The chapters cover psychological and social considerations, experiences with and prerequisites for virtual or robotic companions, acceptability, trustworthiness, social impact, and usage scenarios involving spoken communication. Nishida et al. (2014) cover various aspects of conversational artifacts with a special emphasis on conversational agents. Markowitz (2014) is a comprehensive examination of conversational robots from technical, functional, and social perspectives, including aspects such as how to endow robots with conversational capabilities and how they can autonomously learn language. Also covered are the social aspects of spoken interaction with robots and how they will shape the future. There is also a special issue of the Information Society Journal about social robots and how robots are moving from the industrial to the domestic sphere.[51] Roberto Pieraccini, Director of Advanced Conversational Technologies at Jibo, Inc., reviews the challenges that social robots bring to voice interaction and how the technologies for interacting with social robots differ from those for telephone applications and personal assistants.[52]

The Mobile Voice Conference is a forum for industrial perspectives and new advances in speech interfaces for mobile devices.[53] The Conversational Interaction Technology Web site is an excellent source of information about recent innovations in speech technology, including wearables, devices, and robots.[54] Trends in wearables can be found here.[55,56]

Hexoskin has created a community of researchers that use their smart clothes for remote monitoring and provide software for data analysis and a list of scientific projects and papers.[57] Alpha2 is a programmable robot with a built-in speech

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[51] http://www.tandfonline.com/toc/utis20/31/3. Accessed February 22, 2016.

[52] http://robohub.org/the-next-era-of-conversational-technology/. Accessed February 22, 2016.

[53] http://mobilevoiceconference.com/. Accessed February 22, 2016.

[54] http://citia.lt-innovate.eu/. Accessed February 22, 2016.

[55] https://www.wearable-technologies.com. Accessed February 22, 2016.

[56] http://urbanwearables.technology/. Accessed February 22, 2016.

[57] http://www.hexoskin.com/pages/health-research. Accessed February 22, 2016.

system that incorporates voice search as well as giving verbal reminders and receiving speech commands.[58]

There are numerous conferences on the challenges of social robots, for example, the International Conference on Social Robotics (ICSR).[59] There is also an International Journal on Social Robotics that covers the latest developments in all aspects of social robotics.[60] Royakkers and vanEst (2015) present a literature review of some relevant questions raised by the new robotics, including ethical issues.

RoboHelper is a human–human dialog corpus between an elderly person and a human helper that is being used as a baseline for training robotic companions (Chen et al. 2015). The corpus contains the transcribed dialogs that have been annotated using the Anvil tool.[61]

Exercises

1. Visit the Web pages of companies specializing in smart jewelry or smart clothes and examine what sorts of conversational interface are provided in the products.
2. Consider some new forms of conversational interface. There is a series of demos from the Interaction and Communication Design Lab at Toyohashi University of Technology in Japan of interactions with objects in the environment such as a Sociable Trash Box and a Sociable Dining Table.[62] Look at these demos and consider the usefulness of conversational interfaces for these sorts of objects.

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[58] http://www.ubtrobot.com/en/html/archive/2015092816.html. Accessed February 22, 2016.

[59] http://www.icsoro.org/. Accessed February 22, 2016.

[60] http://link.springer.com/journal/12369. Accessed February 22, 2016.

[61] http://www.anvil-software.org/.

[62] http://www.icd.cs.tut.ac.jp/en/project.html. Accessed 12 April 2016.

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