

# Human-Robot Interaction

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As in human–human interaction, several modalities can be used at once in human-robot interaction in social contexts. Vision, eye gaze, verbal dialogue, touch, and gestures are examples of modalities that can be used herein. In a social context, the intelligence that a robot display depends on the modalities it uses and each modality can have specific importance and effect on the human side of the interaction which translates into the degree of trust that the robot has. Moreover, the acceptance of robots in social interaction depends on their ability to express emotions and they require a proper design of emotional expressions to improve their likability and believability as multimodal interaction can enhance the engagement

social robotics

artificial intelligence

human-robot interaction

## 1. Modalities of Human-Robot Interaction

### 1.1. Vision Systems in Robots

Visual perception provides what was suggested to be the most important information to robots, allowing them to achieve successful interaction with human partners <sup>[1]</sup>. This information can be used in a variety of tasks, such as navigation, obstacle avoidance, detection, understanding, and manipulation of objects, and assigning meanings to a visual configuration of a scene <sup>[2][3]</sup>. More specifically, the vision has been used for the estimation of the 3D position and orientation of a user in an environment <sup>[4]</sup>, the estimation of distances between a robot and users <sup>[5]</sup>, tracking human targets and obtaining their poses <sup>[6]</sup>, understanding human behavior aiming to contribute to the cohabitation between assistive robots and humans <sup>[7]</sup>. Similarly, the vision has been used in a variety of other applications, such as recognizing patterns and figures in exercises in a teaching assistance context in a high school <sup>[8]</sup>, detecting and classifying waste material as a child would do <sup>[9]</sup>, and detecting people entering a building for a possible interaction <sup>[10]</sup>. Moreover, the vision has been used in <sup>[11]</sup> for medication sorting, taking into account pill types and numbers, in <sup>[12]</sup> for sign recognition in a sign tutoring task with deaf or hard of hearing children, and in <sup>[13]</sup> as part of a platform used for cognitive stimulation in elderly users with mild cognitive impairments.

### 1.2. Conversational Systems in Robots

Although some applications of social robotics involve robots taking vocal commands without generating a vocal reply <sup>[14]</sup>, interactions can be made richer when the robot can engage in conversations. A typical social robot with autonomous conversation ability must have the capacity to acquire sound signals, process them to recognize the speech, recognize the whole sequence of words pronounced by the human interlocutor, formulate an appropriate

reply, and synthesize the sound signal corresponding to the reply, then emit this signal using a loudspeaker. The core component of this ability is the recognition of word sequences and the generation of reply sequences [15]. This can rely on a learning stage where the system acquires the experience of answering word sequences by observing a certain number of conversations that are mainly between humans. Techniques used in this area involve word and character embeddings, and learning through recurrent neural network (RNN) architectures, long short-term memory networks (LSTM), and gated recurrent units (GRU) [15][16]. It is to note that not all social robotic systems with conversational capacities have the same levels of complexity as some use limited vocabularies in their verbal dialogues. Herein, Conversation scenarios were seen in [17], verbal dialogue in [18], dialogues between children and a robot in [19], and some word utterances in [9]. A review of conversational systems usages in psychiatry was made in [20]. It covered different aspects such as therapy bots, avatars, and intelligent animal-like robots. Additionally, an algorithm for dialogue management has been proposed in [21] for social robots and conversational agents. It is aimed at ensuring a rich and interesting conversation with users. Furthermore, robot rejection of human commands has been addressed in [22] with aspects such as how rejections can be phrased by the robot. GPT-3 [23] has emerged as a language model with potential applications in conversational systems and social robotics [24]. However, in several conversational systems, problems have been reported, such as hallucinations [25][26], response blandness, and incoherence [15]. The research work presented in [27] aimed at improving the conversational capabilities of a social robot by reducing the possibility of problems as described above, and improving the human-robot interaction with an expressive face. It intended to have a 3-D printed animatronic robotics head with an eye mechanism, a jaw mechanism, and a head mechanism. The three mechanisms are designed to be driven by servo motors to actuate the head synchronously with the audio output. The robotics head design is optimized to fit microphones, cameras, and speakers. The robotics head is envisioned to meet students and visitors in a university. To ensure the appropriateness of the interactions, several stages will be included in the control framework of the robot and a database of human–human conversations will be built upon for the machine learning of the system. This database will be built in the aim of training the conversational system in contexts similar to its contexts of usage. This will increase the adequacy of the conversational system's parameters with respect to the tasks it is required to do, and increase the coherence and consistency of the utterances it produces. For that, the recorded data will comply with the following specifications:

- Context of the interactions: Visitors approach the receptionist and engage in conversations in English. Both questions and answers will be included in the database.
- Audio recordings of the conversations: a text by speech recognition modules is used to transcript the conversation.
- Video recordings of the interaction, showing the face and upper body of the receptionist, with a quality of images usable by body posture recognition systems.
- The collected data will be used to progressively train the system. Each conversation will be labeled with the corresponding date, time and interaction parties.

- Participants will be asked to be free to ask questions they may have to inquire about the center in English, without having any other constraint or any specific text to pronounce.

### 1.3. Expressions and Gestures

Aside from the ability to process and generate sequences of words, a social robot requires more capacities to increase engagement and realism in the interaction with a human. This can be done through speech-accompanying gestures and facial expressions. Indeed, facial expression has an important role in communication between humans because it is rich in information, together with gestures and sound [28][29][30]. This issue has been studied in psychology, and research indicates that there are six main emotions associated with distinctive facial expressions [31]. At Columbia University [32], scientists and engineers developed a robot that can raise eyebrows, smile, and have forehead wrinkles similar to humans. This robot can express the face more accurately compared to the rest of the robots. This robot, called Eva, can mimic head movements and facial expressions. In this robot, 25 muscles are used, and 12 of them are dedicated specifically to the face. These muscles can produce facial skin excitations of up to 15 mm. In other works, different examples can be found for applications of gestures and expressions in social robotics. For instance, gestures have been combined with verbal dialogue and screen display in [18] for health data acquisition in hospitals with Pepper. In [33], a robot with the ability to display facial expressions was used in studies related to storytelling robots. These studies focused on the roles of the emotional facial display, contextual head movements, and voice acting. In [29], a framework for generating robot behaviors using speech, gestures, and facial expressions was proposed, to improve the expressiveness of a robot in interaction with humans. of interaction with human users.

## 2. Metrics of Human Perception and Acceptability

The usage of social robots in the different environments and contexts presented above is subjected to their acceptability by humans as partners in the interaction. Indeed, to be accepted in social contexts, robots need to show degrees of intelligence, morphology, or usefulness that can be judged positively by users, not to mention cultural influences on expectations towards and responses to social robots [34]. The study published in 2021 in [35] focused on the perception that humans have of the cognitive and affective abilities of robots and began with the hypothesis that this perception varied in accordance with the degree of human-likeness that robots have. However, the results obtained with students on four robots used in the study did not prove this hypothesis. A study made in 2005 in [36] showed the acceptability of persons for robots as companions in the home, more as assistants, machines, or servants than as a friend. More recently, the literature review and study made in [37] mentions anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety as five key concepts in human-robot interaction. The study also emphasized the importance of being aware of human perception and cognition measures developed by psychologists for engineers developing robots. Additionally, according to the tasks expected from the robots, different measures of performance can be made, such as true recognition measures in speech recognition tasks. But a robot can have a high performance in a specific task, without having a positive impact on its social context. Therefore, the performances of robots in social usage are in many cases measured through evaluations made by humans using questionnaires and metrics calculated based on them. The

outcomes of such evaluations are affected by the subjectivity of the persons participating in them and their numbers. Herein, certain metrics/measures can be mentioned as follows:

- in [38], a robotic platform was equipped with the capacity to perform the two tasks of group interaction, where it had to maintain an appropriate position and orientation in a group, and the person following. The human evaluation began with a briefing of 15 subjects about the purpose of each task, followed by a calibration step where the subjects were shown human-level performance in each task, followed by interaction with the robotic platform for each task. Then, the subjects were asked to rate the social performance of the platform with a number from 1 to 10 where 10 was human-level performance. The authors suggested increasing the number of subjects and a more detailed questionnaire to be necessary for reaching definitive conclusions.
- the “Godspeed” series of questionnaires has been proposed in [37] to help creators of robots in the robot development process. Five questionnaires using 5-point scales address the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. For example, in the anthropomorphism questionnaire (Godspeed I), participants are asked to rate their impressions of the robot with an integer from fake (1) to natural (5), and from machine-like (1) to human-like (5), and from artificial (1) to lifelike (5). Also in the animacy questionnaire (Godspeed II), participants can rate the robot for example from dead (1) to alive (5), from stagnant (1) to lively (5), and from inert (1) to interactive (5). The authors in [37] report cultural backgrounds, prior experiences with robots, and personality to be among the factors affecting the measurements made in such questionnaires. Furthermore, the perceptions of humans are unstable as their expectations and knowledge change with the increase of their experiences with robots. This means, for the authors in [37], that repeating the same experiment after a long duration of time would yield different results.
- in the context of elderly care and assistance, the Almere model was proposed in [39] as an adaptation and theoretical extension of the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire [40]. Questionnaire items in the Almere model were adapted from the UTAUT questionnaire to fit the context of assistive robot technology and address elderly users in a care home. Different constructs are adopted and defined and questionnaires related to them, respectively. This resulted in constructs such as the users’ attitude towards the technology their intention to use it, their perceived enjoyment, perceived ease of use, perceived sociability and usefulness, social influence and presence, and trust. Experiments made on the model consisted of a data collection instrument with different questionnaire items on a 5-point Likert-type scale ranging from 1 to 5, corresponding to statements ranging from “totally disagree” to “totally agree”, respectively.

Other metrics and approaches for the evaluation of the engagement in the interaction between humans and robots have been proposed. The work presented in [41] proposes metrics that can be easily retrieved from off-the-shelf sensors, by static and dynamic analysis of body posture, head movements and gaze of the human interaction partner.

The work made in [37] revealed two important points related to the assessment of human-robot interaction: the need for a standardized measurement tool and the effects of user background and time on the measurements. The

authors also invited psychologists to contribute to the development of the questionnaires. These issues can have implications for social robotics studies that should be addressed to improve assessment quality and results and advance robotic system designs and tasks accurately. More recently, the work shown in [42] proposed a standardized process for choosing and using scales and questionnaires used in human-robot interaction. For instance, the authors in [42] specified that a scale cannot be trusted in a certain study if not already validated in a similar study and that scales can be unfit or have limitations concerning a specific study. In such a case, they should be modified and re-validated.

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