Computational Human-Robot Interaction

Andrea Thomaz
The University of Texas at Austin USA
athomaz@ece.utexas.edu

Guy Hoffman
Cornell University, Ithaca USA
hoffman@cornell.edu

Maya Cakmak
University of Washington, Seattle USA
mcakmak@uw.edu

now
the essence of knowledge
Boston — Delft

Foundations and Trends® in Robotics

Published, sold and distributed by:
now Publishers Inc.
PO Box 1024
Hanover, MA 02339
United States
Tel. +1-781-985-4510
www.nowpublishers.com
sales@nowpublishers.com

Outside North America:
now Publishers Inc.
PO Box 179
2600 AD Delft
The Netherlands
Tel. +31-6-51115274

The preferred citation for this publication is

A. Thomaz, G. Hoffman and M. Cakmak. *Computational Human-Robot Interaction*. Foundations and Trends® in Robotics, vol. 4, no. 2-3, pp. 105–223, 2013.

This Foundations and Trends® issue was typeset in LaTeX using a class file designed by Neal Parikh. Printed on acid-free paper.

ISBN: 978-1-68083-209-9

Foundations and Trends® in Robotics
Volume 4, Issue 2-3, 2013

Editorial Scope

Topics

Foundations and Trends® in Robotics publishes survey and tutorial articles in the following topics:

- Mathematical modelling
- Kinematics
- Dynamics
- Estimation methods
- Artificial intelligence in robotics
- Software systems and architectures
- Sensors and estimation
- Planning and control
- Human-robot interaction
- Industrial robotics
- Service robotics

Information for Librarians

Foundations and Trends® in Robotics, 2013, Volume 4, 4 issues. ISSN paper version 1935-8253. ISSN online version 1935-8261. Also available as a combined paper and online subscription.

Foundations and Trends® in Robotics
Vol. 4, No. 2-3 (2013) 105–223

DOI: 10.1561/2300000049

Computational Human-Robot Interaction

Andrea Thomaz
The University of Texas at Austin USA
athomaz@ece.utexas.edu

Guy Hoffman
Cornell University, Ithaca USA
hoffman@cornell.edu

Maya Cakmak
University of Washington, Seattle USA
mcakmak@uw.edu

Contents

Abstract

We present a systematic survey of computational research in human-robot interaction (HRI) over the past decade. Computational HRI is the subset of the field that is specifically concerned with the algorithms, techniques, models, and frameworks necessary to build robotic systems that engage in social interactions with humans. Within the field of robotics, HRI poses distinct computational challenges in each of the traditional core research areas: perception, manipulation, planning, task execution, navigation, and learning. These challenges are addressed by the research literature surveyed here. We surveyed twelve publication venues and include work that tackles computational HRI challenges, categorized into eight topics: (a) perceiving humans and their activities; (b) generating and understanding verbal expression; (c) generating and understanding non-verbal behaviors; (d) modeling, expressing, and understanding emotional states; (e) recognizing and conveying intentional action; (f) collaborating with humans; (g) navigating with and around humans; and (h) learning from humans in a social manner. For each topic, we suggest promising future research areas.

A. Thomaz, G. Hoffman and M. Cakmak. *Computational Human-Robot Interaction*. Foundations and Trends® in Robotics, vol. 4, no. 2-3, pp. 105–223, 2013.

DOI: 10.1561/2300000049.

1

Introduction

The field of human-robot interaction (HRI) is expanding and maturing. At the time of writing, dedicated publications on HRI and social robotics research include two special-interest journals and three conferences, in contrast to a single conference and no dedicated journals in 2005. In addition, HRI is a research topic which is increasingly solicited and included in the broader robotics community.

The goal of this survey paper is to provide a systematic overview of the field of HRI over the past decade (from 2005 to 2015), with a focus on the computational frameworks and algorithms currently used to enable robots to interact with humans. Two influential surveys of the field were published in 2003 and 2007 [Fong et al., 2003, Goodrich and Schultz, 2007], and a book chapter surveyed part of the HRI literature in 2008 [Breazeal et al., 2008]. This survey starts roughly where Goodrich and Schultz [2007] left off, covering what has proven to be the most active period of HRI research thus far.

This paper's focus, however, is different from the previous surveys. As the research area has developed, we have identified a lack of a systematic survey focusing specifically on computational HRI research. This subfield of HRI, which includes algorithmic and systems-oriented work is distinct from the large body of research dealing with the empirical, psychological, cultural, and user-interface aspects of the field. So far, there has not been a comprehensive survey article covering computational HRI. In addition, to the best of our knowledge, there has never been a systematic review of the literature in an attempt to represent the bibliometric trends, balance, and distribution of work in HRI. This paper aims to fill these gaps.

1.1 Methodology

While no survey paper can argue for exhaustiveness, we employed a systematic methodology when selecting for inclusion. Our search covered the entire archive of the top-rated journals and refereed conference proceedings which publish work on HRI and social robotics. This included traditional robotics journals and conferences, one human-computer interaction conference, and specialized HRI and social robotics venues. In total, we surveyed twelve venues:

- IEEE Transactions on Robotics (T-RO)
- International Journal of Robotics Research (IJRR)
- Autonomous Robots (AuRo)
- Journal of Human-Robot Interaction (JHRI)
- International Journal of Social Robotics (IJSR)
- Robotics: Science and Systems (RSS)
- International Conference on Robotics and Automation (ICRA)
- International Conference on Intelligent Robots and Systems (IROS)
- International Conference on Human-Robot Interaction (HRI)
- International Symposium on Robot and Human Interactive Communication (RO-MAN)

- International Conference on Social Robotics (ICSR)
- ACM Conference on Human Factors in Computing Systems (CHI)

For these twelve venues, we considered the entire archive published since January 2005 and selected papers based on pre-defined inclusion criteria, described in the following section.

1.1.1 Inclusion Criteria

Delineating the research which contributes to the technologies underlying socially interactive robots is a non-trivial question of field boundary and demarcation. With an eye on the grand challenge of building autonomous socially intelligent robots, our goal was to specifically cover computational, i.e., algorithmic and robotics-oriented (as opposed to psychology-oriented), and synthetic (as opposed to descriptive or inferential) research. This excludes all user studies only measuring human responses to robot behavior or designs. Of the computational papers considered, we further limited the survey by including only work that has a clear element of robotics and a clear element of social interaction.

In other words, our rule-of-thumb for inclusion requires that both the social and the computational should be present in the research, and that the intended application of the work is in robotics. To formalize this, we defined several inclusion and exclusion criteria, organized by type and topic of the research papers we considered:

- **Perception of Humans** — There is a large body of work in the robotics and HRI literature concerned with the perception of humans. Out of those we include only the subset of papers in which the perception was geared towards, or focused on, social interaction. We either exclude or only briefly mention work that is aimed at detecting and tracking people in the environment generally, without specific application to HRI, such as perception for situational awareness or context understanding.

  There are a number of venues concerned with computational perception, such as the Conference on Computer Vision and Pattern Recognition (CVPR) and the International Conference on

Computer Vision (ICCV), to name two. The fact that we did not survey these venues inherently narrows our scope to research aimed at robotics applications and at HRI in particular. This means that we do not survey some of the core computational perception work, even though it has undoubtedly affected the field of HRI significantly.

- **Learning** — Machine learning also constitutes a large part of robotics research. We focus on the subset of papers in which learning happens either with an eye on social interaction or directly through social interaction. We do not include work merely treating human data as a learning database for inference, even if it is geared toward robotics.

  A similar point can be made for foundational work in machine learning as we made earlier with respect to computational perception. Research in venues such as the International Conference on Machine Learning (ICML) or Neural Information Processing Systems (NIPS) is not represented in this survey, even though much of it has clear relation to the work discussed herein.

- **Collaboration, Navigation, and Manipulation** — In human-robot collaboration, navigation, and manipulation papers, we focus on those that include a distinctly social aspect. This means that we exclude a large body of efficiency-centric collaborative robotics work found in industrial robotics research. We do include a few selected works on collaborative manipulation, in particular those that relate to intentionality.

- **Autonomy** — As a rule, we include only research in which the robot has at least some autonomy, or that is concerned with developing methods that serve robot autonomy. This excludes most, if not all, work with the Wizard-of-Oz (WoZ) methodology, with a few exceptions, described below.

We cannot claim that the boundaries of this survey are crisply delineated. In fact, it would be fair to say that more papers were borderline for inclusion than clear-cut. For example, we include some purely empirical studies which are designed with computational questions in mind, or have clear implications for autonomously interactive robotic systems. We include such work in particular when it helps frame the discussion of subsequent computational research.

Overall, we identified, read, and considered 926 papers out of the original several thousands of papers published in the above-mentioned venues in the survey time frame. Our criteria narrow this list even further, resulting in a total of 375 papers representing the state of the art in computational HRI.

1.2 Overview

HRI is an interdisciplinary field with roots and connections in several more established disciplines of robotics and computer science. This is reflected in the categorization of the work surveyed here. Each section can be viewed as the application and extension of robotics research to the socially interactive context.

For example, techniques from the field of robot perception have been adapted and extended to specifically perceive information used for social interaction, and in particular to reason about human intention. Similarly, whereas the broader field of robotics studies kinematics and motion planning, a socially interactive robot needs to view these issues in the context of nonverbal communicative behavior. Motion planning is made socially aware in order to communicate intents and create bonds. The broader topic of machine learning for robotics gives rise to research in socially-guided robot learning, building on human models of tutelage and instruction. Similarly, the long tradition of robot navigation is seen through a new lens of social navigation, both accounting for human social needs and expressing social signals during navigation.

Inspired by this perspective, Figure 1.1 shows an overview of this paper. The paper flows from fundamental robot capabilities, such as perception of human activities, expression of verbal and nonverbal behavior, and the role of emotion models in HRI, to higher-level social robot skills, including reasoning about intentions, collaboration, navigation, and learning.

Full text available at: http://dx.doi.org/10.1561/2300000035

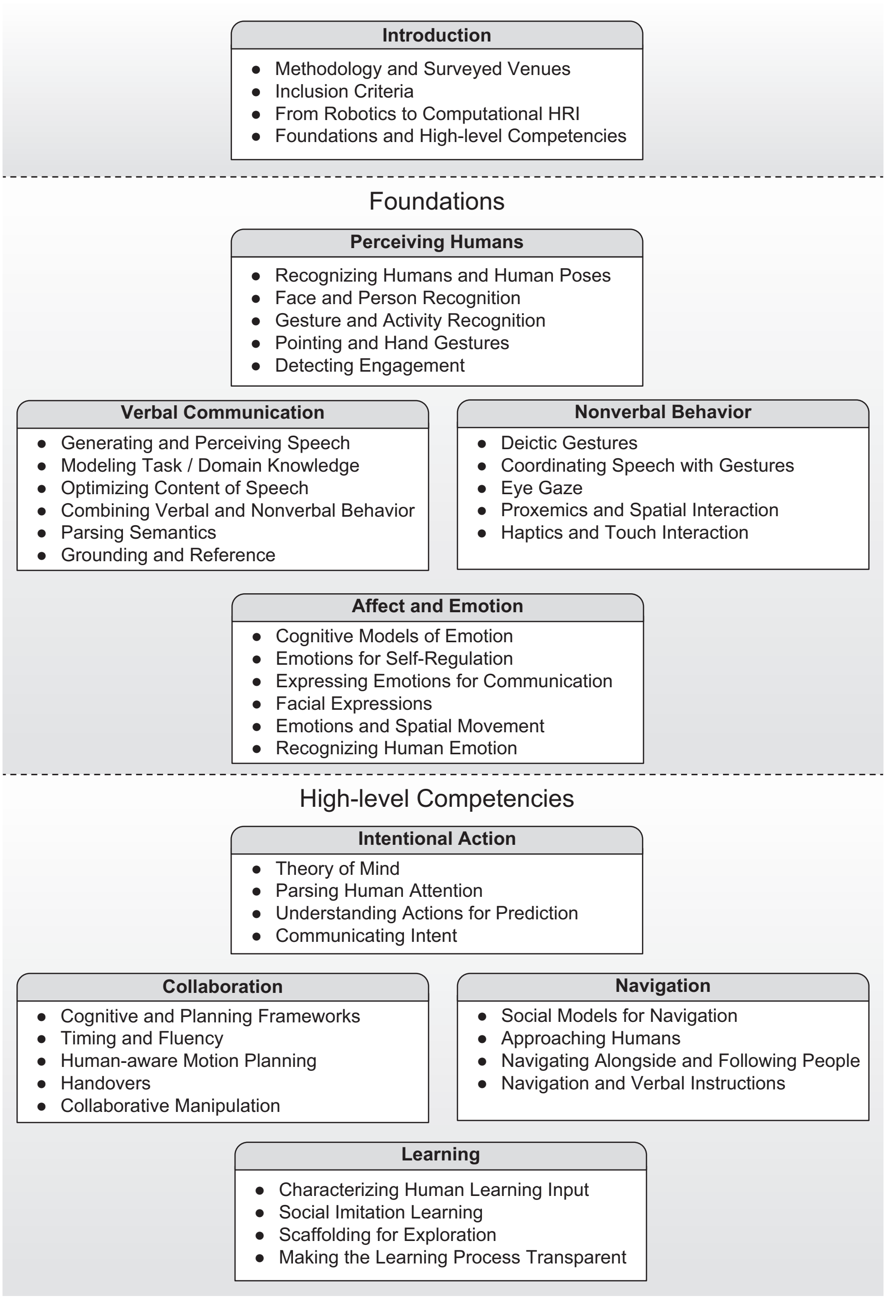

Figure 1.1: Overview of the Paper Structure

1.2.1 Foundations

Sections 2–5 cover basic capabilities and modalities of interaction. These core behaviors are precursors to successful interaction with humans.

The first of these skills, covered in Section 2, is the ability to perceive humans in a social context. The computational issues arising from this goal include a number of challenges: First, a robot might need to recognize a human social partner, find their face, and possibly recognize their identity. Then, a robot could recognize gestures, track the focus of the human's attention, identify activities, and detect the human's engagement or disengagement with the robot.

Next, Section 3 covers systems and methods aimed at generating and understanding verbal expression, geared toward human dialog with social robots. This includes a variety of technical challenges, including optimizing speech content, expressing task and domain knowledge, understanding context, and grounding verbal content in the physical world. We also cover work that looks at paralinguistics, such as the tone of voice (vocalics) and the timing of speech acts.

Section 4 considers nonverbal behavior. To support social interaction, robots need the ability to generate and understand the variety of nonverbal behavior exhibited in human communication. This includes the detection and generation of body movements (kinesics), pointing gestures, speech-accompanying gestures, and gaze, as well as space and territory management (proxemics), and touch interactions (haptics).

A central aspect of human nonverbal behavior is the perception and generation of emotional behaviors and signals. Work on this topic, covered in Section 5, skirts the boundary between Affective Comput-ing and HRI, including computational models representing emotional states and the use of emotion for robot self-regulation. We also cover frameworks and methods for generating emotion expression and techniques for detecting human emotional states in the context of human-robot social interaction.

1.2.2 High-level Competencies

In the second portion of this survey we discuss social behaviors that build on the skills covered in the first portion. This begins with the expression and recognition of intentional behavior. Humans have natural tendency to parse the world on intentional boundaries. Therefore, understanding, predicting and reasoning about intentions is fundamental to interaction. Section 6 surveys work concerned with the automatic detection, classification, and recognition of human intention. This includes work on Theory of Mind capabilities for robots, on the prediction of human activities as intentional agents, and on mechanisms to achieve joint attention. This section concludes by looking at how robots can generate actions that communicate intent in an appropriate way, based on animation principles and legibility optimization. The capacity to understand and communicate intentional action then serves as the basis for the last three sections covering the social behaviors of collaboration, navigation, and learning.

Section 7 includes research focused on human-robot collaborative activities, a highly active subfield of computational HRI. In order to collaborate successfully with a human, a robot needs to adjust its motion planning algorithms, optimizing for social aspects of the movement. A large body of work deals with computational challenges in embodied shared activities, including collaborative planning and scheduling, while others consider timing, anticipation, and team fluency. Finally we look at two highly-studied instances of human-robot collaboration: object handovers and collaborative manipulation of a shared object.

All of the above sections are equally applicable to stationary and mobile robots. However, mobile robots have unique challenges associated with the social aspects of their use of space. Section 8 surveys research on socially-aware robot navigation and mobility. In many ways this is a particular case of collaborative behavior. First, mobile robots need to recognize and generate intentional behavior. Then, there are social aspects of the navigation itself, including approaching people, moving around people, and accompanying humans along their walking path.

Finally, Section 9 looks at machine learning in the context of HRI, including robot learning guided by humans. This capacity also builds on the robots' ability to represent and reproduce intentional behavior in order to help human teachers give better instruction. The section covers the particular features of human-generated machine learning input as well as human-inspired learning techniques, such as scaffolding. In this section, we stress the importance of social signals in robot learning, enabling a more transparent learning process by the robot.

References

H. Admoni, B. Hayes, D. Feil-Seifer, D. Ullman, and B. Scassellati. Are you looking at me?: perception of robot attention is mediated by gaze type and group size. In *Proceedings of the 8th ACM/IEEE international conference on human-robot interaction*, pages 389–396. IEEE Press, 2013.

H. Admoni, A. Dragan, S. S. Srinivasa, and B. Scassellati. Deliberate delays during robot-to-human handovers improve compliance with gaze communication. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, pages 49–56. ACM, 2014.

H. S. Ahn and J. Y. Choi. Emotional behavior decision model based on linear dynamic systems for intelligent service robots. In *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on*, pages 786–791. IEEE, 2007.

H. S. Ahn, D.-W. Lee, D. Choi, D.-Y. Lee, M. Hur, and H. Lee. Appropriate emotions for facial expressions of 33-dofs android head ever-4 h33. In *RO-MAN, 2012 IEEE*, pages 1115–1120. IEEE, 2012.

B. Akgun, M. Cakmak, J. W. Yoo, and A. L. Thomaz. Trajectories and keyframes for kinesthetic teaching: A human-robot interaction perspective. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, pages 391–398. ACM, 2012.

S. Al Moubayed, M. Baklouti, M. Chetouani, T. Dutoit, A. Mahdhaoui, J-C. Martin, S. Ondas, C. Pelachaud, J. Urbain, and M. Yilmaz. Generating robot/agent backchannels during a storytelling experiment. In *Robotics and Automation, 2009. ICRA'09. IEEE International Conference on*, pages 3749–3754. IEEE, 2009.

R. Alazrai and C. S. G. Lee. Real-time emotion identification for socially intelligent robots. In *Robotics and Automation (ICRA), 2012 IEEE International Conference on*, pages 4106–4111. IEEE, 2012.

J. Aleotti, V. Micelli, and S. Caselli. An affordance sensitive system for robot to human object handover. *International Journal of Social Robotics*, 6(4): 653–666, 2014.

S. Alexandrova, M. Cakmak, K. Hsiao, and L. Takayama. Robot programming by demonstration with interactive action visualizations. *Proceedings of Robotics: Science and Systems, Berkeley, USA*, 2014.

A. Aly and A. Tapus. A model for synthesizing a combined verbal and nonverbal behavior based on personality traits in human-robot interaction. In *Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction*, pages 325–332. IEEE Press, 2013.

M. Ammi, V. Demulier, S. Caillou, Y. Gaffary, Y. Tsalamlal, J.-C. Martin, and A. Tapus. Haptic human-robot affective interaction in a handshaking social protocol. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 263–270. ACM, 2015.

S. Andrist, E. Spannan, and B. Mutlu. Rhetorical robots: making robots more effective speakers using linguistic cues of expertise. In *Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction*, pages 341–348. IEEE Press, 2013.

S. Andrist, X. Z. Tan, M. Gleicher, and B. Mutlu. Conversational gaze aversion for humanlike robots. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, pages 25–32. ACM, 2014.

M. L. Anjum, O. Ahmad, S. Rosa, J. Yin, and B. Bona. Skeleton tracking based complex human activity recognition using kinect camera. In *Social Robotics*, pages 23–33. Springer, 2014.

B. Argall, B. Browning, and M. Veloso. Learning by demonstration with critique from a human teacher. In *Proceedings of the ACM/IEEE international conference on Human-robot interaction*, pages 57–64. ACM, 2007.

M. Argyle and J. Dean. Eye-contact, distance and affiliation. *Sociometry*, pages 289–304, 1965.

M. Argyle, R. Ingham, F. Alkema, and M. McCallin. The different functions of gaze. *Semiotica*, 7(1):19–32, 1973.

L. Aryananda. Learning to recognize familiar faces in the real world. In *Robotics and Automation, 2009. ICRA'09. IEEE International Conference on*, pages 1991–1996. IEEE, 2009.

E. Avrunin and R. Simmons. Socially-appropriate approach paths using human data. In *Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on*, pages 1037–1042, Aug 2014.

E. Avrunin, J. Hart, A. Douglas, and B. Scassellati. Effects related to synchrony and repertoire in perceptions of robot dance. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 93–100. ACM, 2011.

D. A. Baldwin, J. A. Baird, M. M. Saylor, and M. A. Clark. Infants parse dynamic action. *Child Development*, 72(3):708–717, 2001. ISSN 1467-8624. URL `http://dx.doi.org/10.1111/1467-8624.00310`.

L. Bascetta, G. Ferretti, P. Rocco, H. Ardö, H. Bruyninckx, E. Demeester, and E. D. Lello. Towards safe human-robot interaction in robotic cells: an approach based on visual tracking and intention estimation. In *Intelligent Robots and Systems (IROS), 2011 IEEE/RSJ International Conference on*, pages 2971–2978. IEEE, 2011.

A. Bauer, K. Klasing, G. Lidoris, Q. Mühlbauer, F. Rohrmüller, S. Sosnowski, T. Xu, K. Kühnlenz, D. Wollherr, and M. Buss. The autonomous city explorer: Towards natural human-robot interaction in urban environments. *International Journal of Social Robotics*, 1(2):127–140, 2009a.

A. Bauer, D. Wollherr, and M. Buss. Information retrieval system for human-robot communication - asking for directions. In *Robotics and Automation, 2009. ICRA '09. IEEE International Conference on*, pages 4150–4155, May 2009b.

M. Beetz, F. Stulp, P. Esden-Tempski, A. Fedrizzi, U. Klank, I. Kresse, A. Maldonado, and F. Ruiz. Generality and legibility in mobile manipulation. *Autonomous Robots*, 28(1):21–44, 2010.

N. Bellotto and H. Hu. A bank of unscented kalman filters for multimodal human perception with mobile service robots. *International Journal of Social Robotics*, 2(2):121–136, 2010.

N. Bellotto, M. Hanheide, and N. Van de Weghe. Qualitative design and implementation of human-robot spatial interactions. In *Social Robotics*, pages 331–340. Springer, 2013.

H. Ben Amor, G. Neumann, S. Kamthe, O. Kroemer, and J. Peters. Interaction primitives for human-robot cooperation tasks. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 2831–2837. IEEE, 2014.

C. C. Bennett and S. Šabanović. Deriving minimal features for human-like facial expressions in robotic faces. *International Journal of Social Robotics*, 6(3):367–381, 2014.

M. Berlin, J. Gray, A. L. Thomaz, and C. Breazeal. Perspective taking: An organizing principle for learning in human-robot interaction. In *Proceedings of the National Conference on Artificial Intelligence*, volume 21(2), page 1444. Menlo Park, CA; Cambridge, MA; London; AAAI Press; MIT Press; 1999, 2006.

C. Bevan and D. Stanton Fraser. Shaking hands and cooperation in tele-present human-robot negotiation. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 247–254. ACM, 2015.

A. Billard, S. Callinon, R. Dillmann, and S. Schaal. Robot programming by demonstration. In B. Siciliano and O. Khatib, editors, *Handbook of Robotics*, chapter 59. Springer, New York, NY, USA, 2008.

S. N. Blisard and M. Skubic. Modeling spatial referencing language for human-robot interaction. In *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pages 698–703. IEEE, 2005.

S. Boucenna, P. Gaussier, P. Andry, and L. Hafemeister. A robot learns the facial expressions recognition and face/non-face discrimination through an imitation game. *International Journal of Social Robotics*, 6(4):633–652, 2014.

M. E. Bratman. Shared cooperative activity. *The philosophical review*, 101 (2):327–341, 1992.

C. Breazeal and B. Scassellati. How to build robots that make friends and influence people. In *Intelligent Robots and Systems, 1999. IROS'99. Proceedings. 1999 IEEE/RSJ International Conference on*, volume 2, pages 858–863. IEEE, 1999.

C. Breazeal and A. L. Thomaz. Learning from human teachers with socially guided exploration. In *Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on*, pages 3539–3544. IEEE, 2008.

C. Breazeal, A. Wang, and R. Picard. Experiments with a robotic computer: body, affect and cognition interactions. In *Human-Robot Interaction (HRI), 2007 2nd ACM/IEEE International Conference on*, pages 153–160. IEEE, 2007.

C. Breazeal, A. Takanishi, and T. Kobayashi. Social robots that interact with people. In *Springer handbook of robotics*, pages 1349–1369. Springer, 2008.

C. Breazeal, J. Gray, and M. Berlin. An embodied cognition approach to mindreading skills for socially intelligent robots. *The International Journal of Robotics Research*, 28(5):656–680, 2009.

C. L. Breazeal. *Designing sociable robots.* MIT press, 2004.

P. Bremner and U. Leonards. Speech and gesture emphasis effects for robotic and human communicators: A direct comparison. In *HRI*, pages 255–262, 2015.

D. A. Brenna, C. Sonia, V. Manuela, and B. Brett. A survey of robot learning from demonstration. *Robotics and Autonomous Systems*, 57(5), 2009.

M. Bretan, G. Hoffman, and G. Weinberg. Emotionally expressive dynamic physical behaviors in robots. *International Journal of Human-Computer Studies*, 78:1–16, 2015.

A. G. Brooks and R. C. Arkin. Behavioral overlays for non-verbal communication expression on a humanoid robot. *Autonomous Robots*, 22(1):55–74, 2007.

A. G. Brooks and C. Breazeal. Working with robots and objects: Revisiting deictic reference for achieving spatial common ground. In *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*, pages 297–304. ACM, 2006.

J. Brookshire. Person following using histograms of oriented gradients. *International journal of social robotics*, 2(2):137–146, 2010.

X. Broquère, A. Finzi, J. Mainprice, S. Rossi, D. Sidobre, and M. Staffa. An attentional approach to human–robot interactive manipulation. *International Journal of Social Robotics*, 6(4):533–553, 2014.

B. Burger, I. Ferrané, F. Lerasle, and G. Infantes. Two-handed gesture recognition and fusion with speech to command a robot. *Autonomous Robots*, 32(2):129–147, 2012.

J. Butterfield, O. C. Jenkins, D. M. Sobel, and J. Schwertfeger. Modeling aspects of theory of mind with markov random fields. *International Journal of Social Robotics*, 1(1):41–51, 2009.

M. Cakmak and A. L. Thomaz. Designing robot learners that ask good questions. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, pages 17–24. ACM, 2012.

M. Cakmak, N. DePalma, A. L. Thomaz, and R. Arriaga. Effects of social exploration mechanisms on robot learning. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 128–134. IEEE, 2009.

M. Cakmak, N. DePalma, R. I. Arriaga, and A. L. Thomaz. Exploiting social partners in robot learning. *Autonomous Robots*, 29(3-4):309–329, 2010.

M. Cakmak, S. S. Srinivasa, M. K. Lee, S. Kiesler, and J. Forlizzi. Using spatial and temporal contrast for fluent robot-human hand-overs. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 489–496. ACM, 2011.

R. Cantrell, M. Scheutz, P. Schermerhorn, and X. Wu. Robust spoken instruction understanding for hri. In *Human-Robot Interaction (HRI), 2010 5th ACM/IEEE International Conference on*, pages 275–282. IEEE, 2010.

R. Cantrell, P. Schermerhorn, and M. Scheutz. Learning actions from human-robot dialogues. In *RO-MAN, 2011 IEEE*, pages 125–130. IEEE, 2011.

P. Carcagnì, D. Cazzato, M. Del Coco, M. Leo, G. Pioggia, and C. Distante. Real-time gender based behavior system for human-robot interaction. In *Social Robotics*, pages 74–83. Springer, 2014.

M. Carpenter, K. Nagell, Tomasello, G. M. Butterworth, and C. Moore. Social cognition, joint attention, and communcative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, 63(4):1–174, 1998.

J. Cassell. *Embodied conversational agents*. MIT press, 2000.

W. P. Chan, C. A. C. Parker, H. M. Van Der Loos, and E. A. Croft. A human-inspired object handover controller. *The International Journal of Robotics Research*, 32(8):971–983, 2013.

C. Chao and A. L. Thomaz. Timing in multimodal turn-taking interactions: Control and analysis using timed petri nets. *Journal of Human-Robot Interaction*, 1(1), 2012.

C. Chao and A. L. Thomaz. Controlling social dynamics with a parametrized model of floor regulation. *Journal of Human-Robot Interaction*, 2(1):4–19, 2013.

C. Chao, M. Cakmak, and A. L. Thomaz. Transparent active learning for robots. In *Human-Robot Interaction (HRI), 2010 5th ACM/IEEE International Conference on*, pages 317–324. IEEE, 2010.

C. Chao, J. Lee, M. Begum, and A. L. Thomaz. Simon plays simon says: The timing of turn-taking in an imitation game. In *RO-MAN, 2011 IEEE*, pages 235–240. IEEE, 2011.

S. Chao, S. Masahiro, S. Christian, K. Takayuki, and I. Hiroshi. A model of distributional handing interaction for a mobile robot. In *Proceedings of Robotics: Science and Systems*, Berlin, Germany, June 2013.

T. L. Chen and C. C. Kemp. Lead me by the hand: Evaluation of a direct physical interface for nursing assistant robots. In *Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction*, pages 367–374. IEEE Press, 2010.

S. Chernova and A. L. Thomaz. Robot learning from human teachers. *Synthesis Lectures on Artificial Intelligence and Machine Learning*, 8(3):1–121, 2014. URL `http://dx.doi.org/10.2200/S00568ED1V01Y201402AIM028`.

S. Chernova and M. Veloso. Confidence-based multi-robot learning from demonstration. *International Journal of Social Robotics*, 2(2):195–215, 2010.

L. Chi-Pang, C. Chen-Tun, C. Kuo-Hung, and F. Li-Chen. Human-centered robot navigation: Towards a harmoniously human-robot coexisting environment. *Robotics, IEEE Transactions on*, 27(1):99–112, Feb 2011. ISSN 1552-3098.

V. Chidambaram, Y.-H. Chiang, and B. Mutlu. Designing persuasive robots: how robots might persuade people using vocal and nonverbal cues. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, pages 293–300. ACM, 2012.

A. Chrungoo, S. S. Manimaran, and B. Ravindran. Activity recognition for natural human robot interaction. In *Social Robotics*, pages 84–94. Springer, 2014.

V. Chu, K. Bullard, and A. L. Thomaz. Multimodal real-time contingency detection for hri. In *Intelligent Robots and Systems (IROS 2014), 2014 IEEE/RSJ International Conference on*, pages 3327–3332. IEEE, 2014.

Y. Chuang, L. Chen, G. Zhao, and G. Chen. Hand posture recognition and tracking based on bag-of-words for human robot interaction. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 538–543. IEEE, 2011.

F. Cid, J. A. Prado, P. Bustos, and P. Nunez. A real time and robust facial expression recognition and imitation approach for affective human-robot interaction using gabor filtering. In *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*, pages 2188–2193. IEEE, 2013.

H. H. Clark. *Using language*. Cambridge university press, 1996.

P. R. Cohen and H. J. Levesque. Teamwork. *Nous*, 25(4):487–512, 1991.

S. Costa, F. Soares, and C. Santos. Facial expressions and gestures to convey emotions with a humanoid robot. In *Social Robotics*, pages 542–551. Springer, 2013.

C. Darwin. *The expression of the emotions in man and animals*. John Murray, 1873.

K. Dautenhahn, M. Walters, S. Woods, K. L. Koay, C. L. Nehaniv, A. Sisbot, R. Alami, and T. Siméon. How may i serve you?: A robot companion approaching a seated person in a helping context. In *Proceedings of the 1st ACM SIGCHI/SIGART Conference on Human-robot Interaction*, HRI '06, pages 172–179, New York, NY, USA, 2006. ACM. ISBN 1-59593-294-1. URL http://doi.acm.org.ezprimo1.idc.ac.il/10.1145/1121241.1121272.

D. De Tommaso, S. Calinon, and D. G. Caldwell. A tangible interface for transferring skills. *International Journal of Social Robotics*, 4(4):397–408, 2012.

R. Deits, S. Tellex, P. Thaker, D. Simeonov, T. Kollar, and N. Roy. Clarifying commands with information-theoretic human-robot dialog. *Journal of Human-Robot Interaction*, 2(2):58–79, 2013.

D. C. Dennett. *The Intentional Stance*. MIT Press, 1989.

G. Diego and K. O. Arras. Please do not disturb! minimum interference coverage for social robots. In *Intelligent Robots and Systems (IROS), 2011 IEEE/RSJ International Conference on*, pages 1968–1973, Sept 2011.

H. Ding, G. Reißig, K. Wijaya, D. Bortot, K. Bengler, and O. Stursberg. Human arm motion modeling and long-term prediction for safe and efficient human-robot-interaction. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 5875–5880. IEEE, 2011.

A. Dragan, R. Holladay, and S. Srinivasa. Deceptive robot motion: synthesis, analysis and experiments. *Autonomous Robots*, 39(3):331–345, 2015.

A. D. Dragan, K. C. T. Lee, and S. S. Srinivasa. Legibility and predictability of robot motion. In *Human-Robot Interaction (HRI), 2013 8th ACM/IEEE International Conference on*, pages 301–308. IEEE, 2013.

D. Droeschel, J. Stückler, and S. Behnke. Learning to interpret pointing gestures with a time-of-flight camera. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 481–488. ACM, 2011a.

D. Droeschel, J. Stückler, D. Holz, and S. Behnke. Towards joint attention for a domestic service robot-person awareness and gesture recognition using time-of-flight cameras. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 1205–1210. IEEE, 2011b.

B. A. Duncan and R. R. Murphy. Comfortable approach distance with small unmanned aerial vehicles. In *RO-MAN, 2013 IEEE*, pages 786–792, Aug 2013.

F. Duvallet, T. Kollar, and A. Stentz. Imitation learning for natural language direction following through unknown environments. In *Robotics and Automation (ICRA), 2013 IEEE International Conference on*, pages 1047–1053. IEEE, 2013.

A. Edsinger and C. C Kemp. Human-robot interaction for cooperative manipulation: Handing objects to one another. In *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on*, pages 1167–1172. IEEE, 2007.

P. Ekman and W. V. Friesen. The repertoire of nonverbal behavior: Categories, origins, usage, and coding. *Semiotica*, 1(1):49–98, 1969.

P. Evrard and A. Kheddar. Homotopy-based controller for physical human-robot interaction. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 1–6. IEEE, 2009.

R. Fang, M. Doering, and J. Y. Chai. Embodied collaborative referring expression generation in situated human-robot interaction. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 271–278. ACM, 2015.

J. Fasola and M. J. Mataric. Modeling dynamic spatial relations with global properties for natural language-based human-robot interaction. In *RO-MAN, 2013 IEEE*, pages 453–460, Aug 2013.

J. Fasola and M. J. Mataric. Interpreting instruction sequences in spatial language discourse with pragmatics towards natural human-robot interaction. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 2720–2727. IEEE, 2014.

D. Feil-Seifer and M. Mataric. Automated detection and classification of positive vs. negative robot interactions with children with autism using distance-based features. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 323–330. ACM, 2011.

D. Feil-Seifer and M. J. Matarić. A multi-modal approach to selective interaction in assistive domains. In *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pages 416–421. IEEE, 2005.

F. Ferland, A. Aumont, D. Létourneau, and F. Michaud. Taking your robot for a walk: Force-guiding a mobile robot using compliant arms. In *Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction*, pages 309–316. IEEE Press, 2013.

G. Ferrer, A. Garrell, and A. Sanfeliu. Robot companion: A social-force based approach with human awareness-navigation in crowded environments. In *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*, pages 1688–1694, Nov 2013.

M. Finke, K. L. Koay, K. Dautenhahn, C. L. Nehaniv, M. L. Walters, and J. Saunders. Hey, i'm over here-how can a robot attract people's attention? In *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pages 7–12. IEEE, 2005.

K. Fischer, L. C. Jensen, and L. Bodenhagen. To beep or not to beep is not the whole question. In *Social Robotics*, pages 156–165. Springer, 2014.

A. Flagg and K. MacLean. Affective touch gesture recognition for a furry zoomorphic machine. In *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction*, pages 25–32. ACM, 2013.

A. F. Foka and P. E. Trahanias. Probabilistic autonomous robot navigation in dynamic environments with human motion prediction. *International Journal of Social Robotics*, 2(1):79–94, 2010.

T. Fong, I. Nourbakhsh, and K. Dautenhahn. A survey of socially interactive robots. *Robotics and Autonomous Systems*, 42(3-4):143–166, March 2003. ISSN 09218890. URL `http://linkinghub.elsevier.com/retrieve/pii/S092188900200372X`.

M. E. Foster, E. G. Bard, M. Guhe, R. L. Hill, J. Oberlander, and A. Knoll. The roles of haptic-ostensive referring expressions in cooperative, task-based human-robot dialogue. In *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction*, pages 295–302. ACM, 2008.

B. Fransen, V. Morariu, E. Martinson, S. Blisard, M. Marge, S. Thomas, A. Schultz, and D. Perzanowski. Using vision, acoustics, and natural language for disambiguation. In *Proceedings of the ACM/IEEE international conference on Human-robot interaction*, pages 73–80. ACM, 2007.

S. Frintrop, A. Königs, F. Hoeller, and D. Schulz. A component-based approach to visual person tracking from a mobile platform. *International Journal of Social Robotics*, 2(1):53–62, 2010.

M. J. Gielniak and A. L. Thomaz. Generating anticipation in robot motion. In *RO-MAN, 2011 IEEE*, pages 449–454. IEEE, 2011a.

M. J. Gielniak and A. L. Thomaz. Spatiotemporal correspondence as a metric for human-like robot motion. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 77–84. ACM, 2011b.

M. J. Gielniak and A. L. Thomaz. Enhancing interaction through exaggerated motion synthesis. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, pages 375–382. ACM, 2012.

M. J. Gielniak, C. K. Liu, and A. L. Thomaz. Generating human-like motion for robots. *The International Journal of Robotics Research*, 32(11):1275–1301, 2013.

R. Gockley, R. Simmons, and J. Forlizzi. Modeling affect in socially interactive robots. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 558–563. IEEE, 2006.

R. Gockley, J. Forlizzi, and R. Simmons. Natural person-following behavior for social robots. In *Proceedings of the ACM/IEEE International Conference on Human-robot Interaction*, HRI '07, pages 17–24, New York, NY, USA, 2007. ACM. ISBN 978-1-59593-617-2. URL `http://doi.acm.org.ezprimo1.idc.ac.il/10.1145/1228716.1228720`.

R. Gomez, T. Kawahara, K. Nakamura, and K. Nakadai. Multi-party human-robot interaction with distant-talking speech recognition. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, pages 439–446. ACM, 2012.

M. A. Goodrich and A. C. Schultz. Human-Robot Interaction: A Survey. *Foundations and Trends® in Human-Computer Interaction*, 1(3):203–275, February 2007. ISSN 1551-3955.

A. Gopnik, D. Sobel, L. Schulz, and C. Glymour. Causal learning mechanisms in very young children: Two, three, and four-year-olds infer causal relations from patterns of variation and covariation. *Developmental Psychology*, 37 (5):620–629, 2001.

J. Gray and C. Breazeal. Manipulating mental states through physical action. *International Journal of Social Robotics*, 6(3):315–327, 2014.

P. M. Greenfield. I of the teacher in learning activities of everyday life. In B. Rogoff and J. Lave, editors, *Everyday cognition: its development in social context*. Harvard University Press, Cambridge, MA, 1984.

E. C. Grigore, K. Eder, A. G. Pipe, C. Melhuish, and U. Leonards. Joint action understanding improves robot-to-human object handover. In *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*, pages 4622–4629. IEEE, 2013.

S. Guadarrama, L. Riano, D. Golland, D. Gouhring, Y. Jia, D. Klein, P. Abbeel, and T. Darrell. Grounding spatial relations for human-robot interaction. In *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*, pages 1640–1647. IEEE, 2013.

G. György, N. Zoltan, C. Gergely, and B. Szilvia. Taking the intentional stance at 12 months of age. *Cognition*, 56(2):165 – 193, 1995.

J. Ham, R. H. Cuijpers, and J.-J. Cabibihan. Combining robotic persuasive strategies: The persuasive power of a storytelling robot that uses gazing and gestures. *International Journal of Social Robotics*, 7(4):479–487, 2015.

N. Hanajima, T. Goto, Y. Ohta, H. Hikita, and M. Yamashita. A motion rule for human-friendly robots based on electrodermal activity investigations and its application to mobile robot. In *Intelligent Robots and Systems, 2005. (IROS 2005). 2005 IEEE/RSJ International Conference on*, pages 3791–3797, Aug 2005.

S. Handri, S. Nomura, and K. Nakamura. Determination of age and gender based on features of human motion using adaboost algorithms. *International Journal of Social Robotics*, 3(3):233–241, 2011.

M. Hanheide, S. Wrede, C. Lang, and G. Sagerer. Who am i talking with? a face memory for social robots. In *Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on*, pages 3660–3665. IEEE, 2008.

M. Häring, J. Eichberg, and E. André. Studies on grounding with gaze and pointing gestures in human-robot-interaction. In *Social Robotics*, pages 378–387. Springer, 2012.

T. Hashimoto, S. Hiramatsu, T. Tsuji, and H. Kobayashi. Realization and evaluation of realistic nod with receptionist robot SAYA. In *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on*, pages 326–331. IEEE, 2007.

K. P. Hawkins, N. Vo, S. Bansal, and A. F. Bobick. Probabilistic human action prediction and wait-sensitive planning for responsive human-robot collaboration. In *Humanoid Robots (Humanoids), 2013 13th IEEE-RAS International Conference on*, pages 499–506. IEEE, 2013.

K. P. Hawkins, S. Bansal, N. N. Vo, and A. F. Bobick. Anticipating human actions for collaboration in the presence of task and sensor uncertainty. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 2215–2222. IEEE, 2014.

D. Helbing and P. Molnar. Social force model for pedestrian dynamics. *Physical review E*, 51(5):4282, 1995.

S. Hemachandra, T. Kollar, N. Roy, and S. Teller. Following and interpreting narrated guided tours. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 2574–2579, May 2011.

S. Hemachandra, M. R. Walter, S. Tellex, and S. Teller. Learning spatial-semantic representations from natural language descriptions and scene classifications. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 2623–2630. IEEE, 2014.

J. Hirth, N. Schmitz, and K. Berns. Towards social robots: Designing an emotion-based architecture. *International Journal of Social Robotics*, 3(3): 273–290, 2011.

M. A. T. Ho, Y. Yamada, and Y. Umetani. An adaptive visual attentive tracker for human communicational behaviors using hmm-based td learning with new state distinction capability. *Robotics, IEEE Transactions on*, 21 (3):497–504, 2005.

J. R. Hoare and L. E. Parker. Using on-line conditional random fields to determine human intent for peer-to-peer human robot teaming. In *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on*, pages 4914–4921. IEEE, 2010.

G. Hoffman. Dumb robots, smart phones: A case study of music listening companionship. In *RO-MAN, 2012 IEEE*, pages 358–363. IEEE, 2012.

G. Hoffman. Evaluating fluency in human-robot collaboration. In *Robotics: Science and Systems (RSS'13) Workshop on Human-Robot Collaboration*, 2013.

G. Hoffman and C. Breazeal. Collaboration in human-robot teams. In *Proc. of the AIAA 1st Intelligent Systems Technical Conference, Chicago, IL, USA*, 2004.

G. Hoffman and C. Breazeal. Cost-based anticipatory action selection for human–robot fluency. *Robotics, IEEE Transactions on*, 23(5):952–961, 2007.

G. Hoffman and C. Breazeal. Effects of anticipatory perceptual simulation on practiced human-robot tasks. *Autonomous Robots*, 28(4):403–423, 2010.

G. Hoffman and K. Vanunu. Effects of robotic companionship on music enjoyment and agent perception. In *Human-Robot Interaction (HRI), 2013 8th ACM/IEEE International Conference on*, pages 317–324. IEEE, 2013.

G. Hoffman and G. Weinberg. Interactive improvisation with a robotic marimba player. *Autonomous Robots*, 31(2-3):133–153, 2011.

R. M. Holladay, A. D. Dragan, and S. S. Srinivasa. Legible robot pointing. In *Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on*, pages 217–223. IEEE, 2014.

T. M. Howard, S. Tellex, and N. Roy. A natural language planner interface for mobile manipulators. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 6652–6659. IEEE, 2014.

C.-M. Huang and A. L. Thomaz. Effects of responding to, initiating and ensuring joint attention in human-robot interaction. In *RO-MAN, 2011 IEEE*, pages 65–71. IEEE, 2011.

C.-M. Huang, M. Cakmak, and B. Mutlu. Adaptive coordination strategies for human-robot handovers. In *Proceedings of Robotics: Science and Systems*, 2015.

Chien-Ming Huang and Bilge Mutlu. Modeling and evaluating narrative gestures for humanlike robots. In *Proceedings of Robotics: Science and Systems*, Berlin, Germany, June 2013.

M. Huber, H. Radrich, C. Wendt, M. Rickert, A. Knoll, T. Brandt, and S. Glasauer. Evaluation of a novel biologically inspired trajectory generator in human-robot interaction. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 639–644. IEEE, 2009.

S. Iengo, S. Rossi, M. Staffa, and A. Finzi. Continuous gesture recognition for flexible human-robot interaction. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 4863–4868. IEEE, 2014.

T. Iio, M. Shiomi, K. Shinozawa, T. Miyashita, T. Akimoto, and N. Hagita. Lexical entrainment in human-robot interaction: can robots entrain human vocabulary? In *Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on*, pages 3727–3734. IEEE, 2009.

T. Iio, M. Shiomi, K. Shinozawa, T. Akimoto, K. Shimohara, and N. Hagita. Entrainment of pointing gestures by robot motion. In *Social Robotics*, pages 372–381. Springer, 2010.

C. T. Ishi, C. Liu, H. Ishiguro, and N. Hagita. Head motions during dialogue speech and nod timing control in humanoid robots. In *Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction*, pages 293–300. IEEE Press, 2010.

O. C. Jenkins, G. González, and M. M. Loper. Tracking human motion and actions for interactive robots. In *Proceedings of the ACM/IEEE international conference on Human-robot interaction*, pages 365–372. ACM, 2007.

D. O. Johnson, R. H. Cuijpers, and D. van der Pol. Imitating human emotions with artificial facial expressions. *International Journal of Social Robotics*, 5(4):503–513, 2013.

B. Jung and G. S Sukhatme. Real-time motion tracking from a mobile robot. *International Journal of Social Robotics*, 2(1):63–78, 2010.

T. Kanda, D. F. Glas, M. Shiomi, and N. Hagita. Abstracting people's trajectories for social robots to proactively approach customers. *Robotics, IEEE Transactions on*, 25(6):1382–1396, Dec 2009. ISSN 1552-3098.

M. Karg, M. Schwimmbeck, K. Kuhnlenz, and M. Buss. Towards mapping emotive gait patterns from human to robot. In *RO-MAN, 2010 IEEE*, pages 258–263. IEEE, 2010.

Y. Kato, T. Kanda, and H. Ishiguro. May i help you?: design of human-like polite approaching behavior. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 35–42. ACM, 2015.

J. Kedzierski, R. Muszyński, C. Zoll, A. Oleksy, and M. Frontkiewicz. Emys—emotive head of a social robot. *International Journal of Social Robotics*, 5 (2):237–249, 2013.

R. Kelley, A. Tavakkoli, C. King, M. Nicolescu, M. Nicolescu, and G. Bebis. Understanding human intentions via hidden markov models in autonomous mobile robots. In *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction*, pages 367–374. ACM, 2008.

W. G. Kennedy, M. D. Bugajska, A. M. Harrison, and J. G. Trafton. "like-me" simulation as an effective and cognitively plausible basis for social robotics. *International Journal of Social Robotics*, 1(2):181–194, 2009.

H.-R. Kim, K. W. Lee, and D.-S. Kwon. Emotional interaction model for a service robot. In *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pages 672–678. IEEE, 2005.

R. Kirby, R. Simmons, and J. Forlizzi. Companion: A constraint-optimizing method for person-acceptable navigation. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 607–612, Sept 2009.

N. Kirchner, A. Alempijevic, and G. Dissanayake. Nonverbal robot-group interaction using an imitated gaze cue. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 497–504. ACM, 2011.

N. H. Kirk, D. Nyga, and M. Beetz. Controlled natural languages for language generation in artificial cognition. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 6667–6672. IEEE, 2014.

T. Kishi, T. Kojima, N. Endo, M. Destephe, T. Otani, L. Jamone, P. Kryczka, G. Trovato, K. Hashimoto, S. Cosentino, et al. Impression survey of the emotion expression humanoid robot with mental model based dynamic emotions. In *Robotics and Automation (ICRA), 2013 IEEE International Conference on*, pages 1663–1668. IEEE, 2013.

T. Kitade, S. Satake, T. Kanda, and M. Imai. Understanding suitable locations for waiting. In *Proceedings of the 8th ACM/IEEE International Conference on Human-robot Interaction*, HRI '13, pages 57–64, Piscataway, NJ, USA, 2013. IEEE Press. ISBN 978-1-4673-3055-8. URL `http://dl.acm.org.ezprimo1.idc.ac.il/citation.cfm?id=2447556.2447566`.

M. Knapp, J. Hall, and T. Horgan. *Nonverbal communication in human interaction*. Cengage Learning, 2013.

R. A. Knepper and D. Rus. Pedestrian-inspired sampling-based multi-robot collision avoidance. In *RO-MAN, 2012 IEEE*, pages 94–100, Sept 2012.

R. A. Knepper, S. Tellex, A. Li, N. Roy, and D. Rus. Recovering from failure by asking for help. *Autonomous Robots*, 39(3):347–362, 2015.

H. Knight and R. Simmons. Expressive motion with x, y and theta: Laban effort features for mobile robots. In *Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on*, pages 267–273. IEEE, 2014.

H. Knight, R. Toscano, W. D. Stiehl, A. Chang, Y. Wang, and C. Breazeal. Real-time social touch gesture recognition for sensate robots. In *Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on*, pages 3715–3720. IEEE, 2009.

W. B. Knox, P. Stone, and C. Breazeal. Training a robot via human feedback: A case study. In *Social Robotics*, pages 460–470. Springer, 2013.

T. Kollar, S. Tellex, D. Roy, and N. Roy. Toward understanding natural language directions. In *Human-Robot Interaction (HRI), 2010 5th ACM/IEEE International Conference on*, pages 259–266. IEEE, 2010.

T. Kollar, V. Perera, D. Nardi, and M. Veloso. Learning environmental knowledge from task-based human-robot dialog. In *Robotics and Automation (ICRA), 2013 IEEE International Conference on*, pages 4304–4309, May 2013.

Y. Kondo, K. Takemura, J. Takamatsu, and T. Ogasawara. A gesture-centric android system for multi-party human-robot interaction. *Journal of Human-Robot Interaction*, 2(1):133–151, 2013.

S. Koo and D.-S. Kwon. Recognizing human intentional actions from the relative movements between human and robot. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 939–944, Sept 2009.

H. S. Koppula and A. Saxena. Anticipating human activities using object affordances for reactive robotic response. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 38(1):14–29, 2016.

H. S. Koppula, R. Gupta, and A. Saxena. Learning human activities and object affordances from rgb-d videos. *The International Journal of Robotics Research*, 32(8):951–970, 2013.

T. Kruse, A. Kirsch, H. Khambhaita, and R. Alami. Evaluating directional cost models in navigation. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction*, HRI '14, pages 350–357, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2658-2. URL `http://doi.acm.org.ezprimo1.idc.ac.il/10.1145/2559636.2559662`.

M. Kuderer and W. Burgard. An approach to socially compliant leader following for mobile robots. In *Social Robotics*, pages 239–248. Springer, 2014.

D. Kulic and E. A. Croft. Affective state estimation for human–robot interaction. *Robotics, IEEE Transactions on*, 23(5):991–1000, 2007.

Y. Kuno, H. Sekiguchi, T. Tsubota, S. Moriyama, K. Yamazaki, and A. Yamazaki. Museum guide robot with communicative head motion. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 33–38. IEEE, 2006.

W. Y. Kwon and I. H. Suh. A temporal bayesian network with application to design of a proactive robotic assistant. In *Robotics and Automation (ICRA), 2012 IEEE International Conference on*, pages 3685–3690. IEEE, 2012.

R. Laban and L. Ullmann. *The mastery of movement.* ERIC, 1971.

C. Lang, S. Wachsmuth, M. Hanheide, and H. Wersing. Facial communicative signal interpretation in human-robot interaction by discriminative video subsequence selection. In *Robotics and Automation (ICRA), 2013 IEEE International Conference on*, pages 170–177. IEEE, 2013.

J. Lasseter. Principles of traditional animation applied to 3d computer animation. In *SIGGRAPH '87: Proceedings of the 14th annual conference on Computer graphics and interactive techniques*, pages 35–44, New York, NY, USA, 1987. ACM.

B. Lau, K. O. Arras, and W. Burgard. Multi-model hypothesis group tracking and group size estimation. *International Journal of Social Robotics*, 2(1): 19–30, 2010.

J. Lee, J. F. Kiser, A. F. Bobick, and A. L. Thomaz. Vision-based contingency detection. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 297–304. ACM, 2011.

J. Lee, C. Chao, A. F. Bobick, and A. L. Thomaz. Multi-cue contingency detection. *International Journal of Social Robotics*, 4(2):147–161, 2012.

M. K. Lee, S. Kiesler, J. Forlizzi, S. Srinivasa, and P. Rybski. Gracefully mitigating breakdowns in robotic services. In *Human-Robot Interaction (HRI), 2010 5th ACM/IEEE International Conference on*, pages 203–210. IEEE, 2010.

I. Leite, R. Henriques, C. Martinho, and A. Paiva. Sensors in the wild: Exploring electrodermal activity in child-robot interaction. In *Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction*, pages 41–48. IEEE Press, 2013.

S. Lemaignan, R. Ros, E. A. Sisbot, R. Alami, and M. Beetz. Grounding the interaction: Anchoring situated discourse in everyday human-robot interaction. *International Journal of Social Robotics*, 4(2):181–199, 2012.

C. Lenz, S. Nair, M. Rickert, A. Knoll, W. Rosel, J. Gast, A. Bannat, and F. Wallhoff. Joint-action for humans and industrial robots for assembly tasks. In *Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on*, pages 130–135. IEEE, 2008.

Y. Li, K. P. Tee, W. L. Chan, R. Yan, Y. Chua, and D. K. Limbu. Continuous role adaptation for human–robot shared control. *Robotics, IEEE Transactions on*, 31(3):672–681, 2015.

C. Lichtenthäler, A. Peters, S. Griffiths, and A. Kirsch. Social navigation-identifying robot navigation patterns in a path crossing scenario. In *Social Robotics*, pages 84–93. Springer, 2013.

C. Liu, K. Conn, N. Sarkar, and W. Stone. Online affect detection and robot behavior adaptation for intervention of children with autism. *Robotics, IEEE Transactions on*, 24(4):883–896, 2008.

P. Liu, D. F. Glas, T. Kanda, H. Ishiguro, and N. Hagita. It's not polite to point: generating socially-appropriate deictic behaviors towards people. In *Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction*, pages 267–274. IEEE Press, 2013.

A. Lockerd and C. Breazeal. Tutelage and socially guided robot learning. In *Intelligent Robots and Systems, 2004.(IROS 2004). Proceedings. 2004 IEEE/RSJ International Conference on*, volume 4, pages 3475–3480. IEEE, 2004.

M. Lohse, K. J. Rohlfing, B. Wrede, and G. Sagerer. Try something else! when users change their discursive behavior in human-robot interaction. In *Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on*, pages 3481–3486. IEEE, 2008.

M. Lohse, R. Rothuis, J. Gallego-Pérez, D. E. Karreman, and V. Evers. Robot gestures make difficult tasks easier: the impact of gestures on perceived workload and task performance. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1459–1466. ACM, 2014.

M. Luber and K. O. Arras. Multi-hypothesis social grouping and tracking for mobile robots. In *Robotics: Science and Systems*, 2013.

M. Luber, L. Spinello, J. Silva, and K. O. Arras. Socially-aware robot navigation: A learning approach. In *Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on*, pages 902–907, Oct 2012.

I. Lütkebohle, F. Hegel, S. Schulz, M. Hackel, B. Wrede, S. Wachsmuth, and G. Sagerer. The bielefeld anthropomorphic robot head "flobi". In *Robotics and Automation, 2010. ICRA 2010. Proceedings IEEE International Conference on*, volume 3(7), pages 3384–3391, 2010.

J. MacGlashan, M. Babes-Vroman, M. desJardins, M. Littman, S. Muresan, S. Squire, S. Tellex, D. Arumugam, and L. Yang. Grounding english commands to reward functions. In *Robotics: Science and Systems*, 2015.

J. Mainprice and D. Berenson. Human-robot collaborative manipulation planning using early prediction of human motion. In *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*, pages 299–306. IEEE, 2013.

J. Mainprice, E. A. Sisbot, L. Jaillet, J. Cortés, R. Alami, and T. Siméon. Planning human-aware motions using a sampling-based costmap planner. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 5012–5017. IEEE, 2011.

J. Mainprice, M. Gharbi, T. Siméon, and R. Alami. Sharing effort in planning human-robot handover tasks. In *RO-MAN, 2012 IEEE*, pages 764–770. IEEE, 2012.

M. Mason and M. Lopes. Robot self-initiative and personalization by learning through repeated interactions. In *Human-Robot Interaction (HRI), 2011 6th ACM/IEEE International Conference on*, pages 433–440. IEEE, 2011.

M. Masuda and S. Kato. Motion rendering system for emotion expression of human form robots based on laban movement analysis. In *RO-MAN, 2010 IEEE*, pages 324–329. IEEE, 2010.

T. Matsumaru, K. Iwase, K. Akiyama, T. Kusada, and T. Ito. Mobile robot with eyeball expression as the preliminary-announcement and display of the robot's following motion. *Autonomous Robots*, 18(2):231–246, 2005.

C. Matuszek, D. Fox, and K. Koscher. Following directions using statistical machine translation. In *Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction*, pages 251–258. IEEE Press, 2010.

B. A. Maxwell. Building robot systems to interact with people in real environments. *Autonomous Robots*, 22(4):353–367, 2007.

D. McColl and G. Nejat. Affect detection from body language during social hri. In *RO-MAN, 2012 IEEE*, pages 1013–1018. IEEE, 2012.

D. McColl, Z. Zhang, and G. Nejat. Human body pose interpretation and classification for social human-robot interaction. *International Journal of Social Robotics*, 3(3):313–332, 2011.

S. McKeague, J. Liu, and G.-Z. Yang. An asynchronous rgb-d sensor fusion framework using monte-carlo methods for hand tracking on a mobile robot in crowded environments. In *Social Robotics*, pages 491–500. Springer, 2013.

R. Mead, A. Atrash, and M. J. Matarić. Proxemic feature recognition for interactive robots: automating metrics from the social sciences. In *Social Robotics*, pages 52–61. Springer, 2011.

R. Mead, A. Atrash, and M. J. Matarić. Automated proxemic feature extraction and behavior recognition: Applications in human-robot interaction. *International Journal of Social Robotics*, 5(3):367–378, 2013.

J. R. Medina, T. Lorenz, and S. Hirche. Synthesizing anticipatory haptic assistance considering human behavior uncertainty. *Robotics, IEEE Transactions on*, 31(1):180–190, 2015.

E. Meisner, V. Isler, and J. Trinkle. Controller design for human-robot interaction. *Autonomous Robots*, 24(2):123–134, 2008.

A. N. Meltzoff. The human infant as imitative generalist: A 20-year progress report on infant imitation with implications for comparative psychology. In B. G. Galef C. M. Heyes, editor, *Social Learning in Animals: The Roots of Culture*. Academic Press, San Diego, CA, 1996.

Ç. Meriçli, M. Veloso, and H. L. Akın. Multi-resolution corrective demonstration for efficient task execution and refinement. *International Journal of Social Robotics*, 4(4):423–435, 2012.

M. P. Michalowski and R. Simmons. Multimodal person tracking and attention classification. In *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*, pages 347–348. ACM, 2006.

M. P. Michalowski, S. Sabanovic, and H. Kozima. A dancing robot for rhythmic social interaction. In *Human-Robot Interaction (HRI), 2007 2nd ACM/IEEE International Conference on*, pages 89–96. IEEE, 2007.

F. Michaud, C. Côté, D. Létourneau, Y. Brosseau, J-M. Valin, É. Beaudry, C. Raïevsky, A. Ponchon, P. Moisan, P. Lepage, et al. Spartacus attending the 2005 AAAI conference. *Autonomous Robots*, 22(4):369–383, 2007.

T. Miller, A. Exley, and W. Schuler. Elements of a spoken language programming interface for robots. In *Proceedings of the ACM/IEEE international conference on Human-robot interaction*, pages 231–237. ACM, 2007.

G. Milliez, M. Warnier, A. Clodic, and R. Alami. A framework for endowing an interactive robot with reasoning capabilities about perspective-taking and belief management. In *Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on*, pages 1103–1109. IEEE, 2014.

T. Minato and H. Ishiguro. Construction and evaluation of a model of natural human motion based on motion diversity. In *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction*, pages 65–72. ACM, 2008.

M. Minsky. Music, mind, and meaning. In *Music, mind, and brain*, pages 1–19. Springer, 1982.

Y. Mohammad and T. Nishida. Fluid imitation. *International Journal of Social Robotics*, 4(4):369–382, 2012.

A. Moon, D. M. Troniak, B. Gleeson, M. K. X. J. Pan, M. Zheng, B. A. Blumer, K. MacLean, and E. A. Croft. Meet me where i'm gazing: how shared attention gaze affects human-robot handover timing. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, pages 334–341. ACM, 2014.

N.-J. Moore, M. Hickson, and D. W. Stacks. *Nonverbal communication: Studies and applications*. Oxford University Press, 6th ed edition, 2013.

S. Morales, Y. Luis, S. Satake, R. Huq, D. Glas, T. Kanda, and N. Hagita. How do people walk side-by-side?: Using a computational model of human behavior for a social robot. In *Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction*, HRI '12, pages 301–308, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1063-5. URL `http://doi.acm.org.ezprimo1.idc.ac.il/10.1145/2157689.2157799`.

A. Mörtl, M. Lawitzky, A. Kucukyilmaz, M. Sezgin, C. Basdogan, and S. Hirche. The role of roles: Physical cooperation between humans and robots. *The International Journal of Robotics Research*, 31(13):1656–1674, 2012.

L. Moshkina and R. C. Arkin. Human perspective on affective robotic behavior: A longitudinal study. In *Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on*, pages 1444–1451. IEEE, 2005.

Q. Muhlbauer, S. Sosnowski, X. Tingting, Z. Tianguang, K. Kuhnlenz, and M. Buss. Navigation through urban environments by visual perception and interaction. In *Robotics and Automation, 2009. ICRA '09. IEEE International Conference on*, pages 3558–3564, May 2009.

M. Mühlig, M. Gienger, and J. J Steil. Interactive imitation learning of object movement skills. *Autonomous Robots*, 32(2):97–114, 2012.

R. Murakami, L. Y. Morales Saiki, S. Satake, T. Kanda, and H. Ishiguro. Destination unknown: Walking side-by-side without knowing the goal. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction*, HRI '14, pages 471–478, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2658-2. URL `http://doi.acm.org.ezprimo1.idc.ac.il/10.1145/2559636.2559665`.

B. Mutlu, T. Shiwa, T. Kanda, H. Ishiguro, and N. Hagita. Footing in human-robot conversations: how robots might shape participant roles using gaze cues. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pages 61–68. ACM, 2009a.

B. Mutlu, F. Yamaoka, T. Kanda, H. Ishiguro, and N. Hagita. Nonverbal leakage in robots: communication of intentions through seemingly unintentional behavior. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pages 69–76. ACM, 2009b.

Y. Nagai. The role of motion information in learning human-robot joint attention. In *Robotics and Automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE International Conference on*, pages 2069–2074. IEEE, 2005.

Y. Nagai, C. Muhl, and K. J. Rohlfing. Toward designing a robot that learns actions from parental demonstrations. In *Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on*, pages 3545–3550. IEEE, 2008.

N. Najmaei and M. R. Kermani. Prediction-based reactive control strategy for human-robot interactions. In *Robotics and Automation (ICRA), 2010 IEEE International Conference on*, pages 3434–3439. IEEE, 2010.

K. Nakagawa, M. Shiomi, K. Shinozawa, R. Matsumura, H. Ishiguro, and N. Hagita. Effect of robot's active touch on people's motivation. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 465–472. ACM, 2011.

K. Nakagawa, M. Shiomi, K. Shinozawa, R. Matsumura, H. Ishiguro, and N. Hagita. Effect of robotââĆň™s whispering behavior on peopleââĆň™s motivation. *International Journal of Social Robotics*, 5(1):5–16, 2013.

K. Namera, S. Takasugi, K. Takano, T. Yamamoto, and Y. Miyake. Timing control of utterance and body motion in human-robot interaction. In *Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on*, pages 119–123. IEEE, 2008.

L. Nardi and L. Iocchi. Representation and execution of social plans through human-robot collaboration. In *Social Robotics*, pages 266–275. Springer, 2014.

A. Niculescu, B. van Dijk, A. Nijholt, H. Li, and S. L. See. Making social robots more attractive: the effects of voice pitch, humor and empathy. *International journal of social robotics*, 5(2):171–191, 2013.

S. Nikolaidis and J. Shah. Human-robot cross-training: computational formulation, modeling and evaluation of a human team training strategy. In *Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction*, pages 33–40. IEEE Press, 2013.

S. Nikolaidis, R. Ramakrishnan, K. Gu, and J. Shah. Efficient model learning from joint-action demonstrations for human-robot collaborative tasks. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 189–196. ACM, 2015.

D. Norman. *Emotional Design: Why We Love (or Hate) Everyday Things*. Basic Books, New York, 2004.

D. Nyga, M. Tenorth, and M. Beetz. How-models of human reaching movements in the context of everyday manipulation activities. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 6221–6226. IEEE, 2011.

Y. Okuno, T. Kanda, M. Imai, H. Ishiguro, and N. Hagita. Providing route directions: design of robot's utterance, gesture, and timing. In *Human-Robot Interaction (HRI), 2009 4th ACM/IEEE International Conference on*, pages 53–60. IEEE, 2009.

S. Ou and R. Grupen. From manipulation to communicative gesture. In *Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction*, pages 325–332. IEEE Press, 2010.

E. Pacchierotti, H. I. Christensen, and P. Jensfelt. Evaluation of passing distance for social robots. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 315–320, Sept 2006.

A. Panangadan, M. Matarić, and G. S. Sukhatme. Tracking and modeling of human activity using laser rangefinders. *International Journal of Social Robotics*, 2(1):95–107, 2010.

A. K. Pandey and R. Alami. A framework towards a socially aware mobile robot motion in human-centered dynamic environment. In *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on*, pages 5855–5860, Oct 2010a.

A. K. Pandey and R. Alami. Mightability maps: A perceptual level decisional framework for co-operative and competitive human-robot interaction. In *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on*, pages 5842–5848. IEEE, 2010b.

P. Papadakis, P. Rives, and A. Spalanzani. Adaptive spacing in human-robot interactions. In *Intelligent Robots and Systems (IROS 2014), 2014 IEEE/RSJ International Conference on*, pages 2627–2632, Sept 2014.

J.-C. Park, H.-R. Kim, Y.-M. Kim, and D.-S. Kwon. Robot's individual emotion generation model and action coloring according to the robot's personality. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 257–262. IEEE, 2009.

M. Pateraki, H. Baltzakis, P. Kondaxakis, and P. Trahanias. Tracking of facial features to support human-robot interaction. In *Robotics and Automation, 2009. ICRA'09. IEEE International Conference on*, pages 3755–3760. IEEE, 2009.

C. Perez Quintero, R. T. Fomena, A. Shademan, N. Wolleb, T. Dick, and M. Jagersand. Sepo: Selecting by pointing as an intuitive human-robot command interface. In *Robotics and Automation (ICRA), 2013 IEEE International Conference on*, pages 1166–1171. IEEE, 2013.

L. Peternel, T. Petrič, E. Oztop, and J. Babič. Teaching robots to cooperate with humans in dynamic manipulation tasks based on multi-modal human-in-the-loop approach. *Autonomous robots*, 36(1-2):123–136, 2014.

R. W. Picard. *Affective computing*, volume 252. MIT press Cambridge, 1997.

B. Raducanu and F. Dornaika. Dynamic facial expression recognition using laplacian eigenmaps-based manifold learning. In *Robotics and Automation (ICRA), 2010 IEEE International Conference on*, pages 156–161. IEEE, 2010.

M. Ralph and M. A. Moussa. Toward a natural language interface for transferring grasping skills to robots. *Robotics, IEEE Transactions on*, 24(2): 468–475, 2008.

V. Raman, C. Lignos, C. Finucane, K. C. T. Lee, M. P. Marcus, and H. Kress-Gazit. Sorry dave, i'm afraid i can't do that: Explaining unachievable robot tasks using natural language. In *Robotics: Science and Systems*, volume 2. Citeseer, 2013.

P. Ratsamee, Y. Mae, K. Ohara, M. Kojima, and T. Arai. Social navigation model based on human intention analysis using face orientation. In *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*, pages 1682–1687, Nov 2013.

R. Read and T. Belpaeme. Situational context directs how people affectively interpret robotic non-linguistic utterances. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, pages 41–48. ACM, 2014.

T. Ribeiro and A. Paiva. The illusion of robotic life: principles and practices of animation for robots. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, pages 383–390. ACM, 2012.

C. Rich, B. Ponsler, A. Holroyd, and C. L. Sidner. Recognizing engagement in human-robot interaction. In *Human-Robot Interaction (HRI), 2010 5th ACM/IEEE International Conference on*, pages 375–382. IEEE, 2010.

L. D. Riek, T.-C. Rabinowitch, P. Bremner, A. G. Pipe, M. Fraser, and P. Robinson. Cooperative gestures: Effective signaling for humanoid robots. In *Human-Robot Interaction (HRI), 2010 5th ACM/IEEE International Conference on*, pages 61–68. IEEE, 2010.

J. Rios-Martinez, A. Spalanzani, and C. Laugier. From proxemics theory to socially-aware navigation: A survey. *International Journal of Social Robotics*, 7(2):137–153, 2015.

R. Ros, S. Lemaignan, E. A. Sisbot, R. Alami, J. Steinwender, K. Hamann, and F. Warneken. Which one? grounding the referent based on efficient human-robot interaction. In *RO-MAN, 2010 IEEE*, pages 570–575. IEEE, 2010.

J. A. Russell. Core affect and the psychological construction of emotion. *Psychological review*, 110(1):145, 2003.

P. E. Rybski, K. Yoon, J. Stolarz, and M. M. Veloso. Interactive robot task training through dialog and demonstration. In *Human-Robot Interaction (HRI), 2007 2nd ACM/IEEE International Conference on*, pages 49–56. IEEE, 2007.

M. S. Ryoo, T. J. Fuchs, L. Xia, J. K. Aggarwal, and L. Matthies. Robot-centric activity prediction from first-person videos: What will they do to me'. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 295–302. ACM, 2015.

J. Saldien, K. Goris, B. Vanderborght, J. Vanderfaeillie, and D. Lefeber. Expressing emotions with the social robot probo. *International Journal of Social Robotics*, 2(4):377–389, 2010.

M. Salem, S. Kopp, I. Wachsmuth, K. Rohlfing, and F. Joublin. Generation and evaluation of communicative robot gesture. *International Journal of Social Robotics*, 4(2):201–217, 2012.

M. Salem, S. Kopp, and F. Joublin. Closing the loop: Towards tightly synchronized robot gesture and speech. In *Social Robotics*, pages 381–391. Springer, 2013a.

M. Salem, M. Ziadee, and M. Sakr. Effects of politeness and interaction context on perception and experience of hri. In *Social Robotics*, pages 531–541. Springer, 2013b.

M. Salem, M. Ziadee, and M. Sakr. Marhaba, how may i help you?: Effects of politeness and culture on robot acceptance and anthropomorphization. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, pages 74–81. ACM, 2014.

J. Sanghvi, G. Castellano, I. Leite, A. Pereira, P. W. McOwan, and A. Paiva. Automatic analysis of affective postures and body motion to detect engagement with a game companion. In *Human-Robot Interaction (HRI), 2011 6th ACM/IEEE International Conference on*, pages 305–311. IEEE, 2011.

S. Satake, T. Kanda, D. F. Glas, M. Imai, H. Ishiguro, and N. Hagita. A robot that approaches pedestrians. *Robotics, IEEE Transactions on*, 29(2): 508–524, April 2013. ISSN 1552-3098.

S. Satake, H. Iba, T. Kanda, M. Imai, and Y. M. Saiki. May i talk about other shops here?: Modeling territory and invasion in front of shops. In *Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction*, HRI '14, pages 487–494, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2658-2. URL http://doi.acm.org.ezprimo1.idc.ac.il/10.1145/2559636.2559669.

J. Sattar and G. Dudek. Towards quantitative modeling of task confirmations in human-robot dialog. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 1957–1963. IEEE, 2011.

J. Sattar and J. J. Little. Ensuring safety in human-robot dialog—a cost-directed approach. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 6660–6666. IEEE, 2014.

A. Sauppé and B. Mutlu. Robot deictics: How gesture and context shape referential communication. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, pages 342–349. ACM, 2014.

B. Scassellati. Foundations for a theory of mind for a humanoid robot. *Massachusetts Institute of Technology, Department of Electrical Engineering and Computer Science, PhD Thesis*, 2001.

K. R. Scherer. What are emotions? and how can they be measured? *Social science information*, 44(4):695–729, 2005.

A. J. Schmid, O. Weede, and H. Wörn. Proactive robot task selection given a human intention estimate. In *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on*, pages 726–731. IEEE, 2007.

O. C. Schrempf, U. D. Hanebeck, A. J. Schmid, and H. Worn. A novel approach to proactive human-robot cooperation. In *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pages 555–560. IEEE, 2005.

N. Sebanz, H. Bekkering, and G. Knoblicha. Joint action: Bodies and minds moving together. *Trends in Cognitive Science*, 2006.

J. Shah, J. Wiken, B. Williams, and C. Breazeal. Improved human-robot team performance using chaski, a human-inspired plan execution system. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 29–36. ACM, 2011.

M. Sharma, D. Hildebrandt, G. Newman, J. E. Young, and R. Eskicioglu. Communicating affect via flight path exploring use of the laban effort system for designing affective locomotion paths. In *Human-Robot Interaction (HRI), 2013 8th ACM/IEEE International Conference on*, pages 293–300. IEEE, 2013.

C. Shi, T. Kanda, M. Shimada, F. Yamaoka, H. Ishiguro, and N. Hagita. Easy development of communicative behaviors in social robots. In *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on*, pages 5302–5309. IEEE, 2010.

H. Shibata, M. Kano, S. Kato, and H. Itoh. A system for converting robot'emotion'into facial expressions. In *Robotics and Automation, 2006. ICRA 2006. Proceedings 2006 IEEE International Conference on*, pages 3660–3665. IEEE, 2006.

M. Shiomi, T. Kanda, H. Ishiguro, and N. Hagita. A larger audience, please!: encouraging people to listen to a guide robot. In *Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction*, pages 31–38. IEEE Press, 2010.

M. Shiomi, F. Zanlungo, K. Hayashi, and T. Kanda. Towards a socially acceptable collision avoidance for a mobile robot navigating among pedestrians using a pedestrian model. *International Journal of Social Robotics*, 6(3): 443–455, 2014.

C. L. Sidner, C. Lee, L.-P. Morency, and C. Forlines. The effect of head-nod recognition in human-robot conversation. In *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*, pages 290–296. ACM, 2006.

D. Silvera-Tawil, D. Rye, and M. Velonaki. Interpretation of social touch on an artificial arm covered with an eit-based sensitive skin. *International Journal of Social Robotics*, 6(4):489–505, 2014.

E. A. Sisbot and R. Alami. A human-aware manipulation planner. *Robotics, IEEE Transactions on*, 28(5):1045–1057, 2012.

E. A. Sisbot, L. F. Marin-Urias, R. Alami, and T. Simeon. A human aware mobile robot motion planner. *Robotics, IEEE Transactions on*, 23(5):874–883, Oct 2007. ISSN 1552-3098.

E. A. Sisbot, L. F. Marin-Urias, X. Broquere, D. Sidobre, and R. Alami. Synthesizing robot motions adapted to human presence. *International Journal of Social Robotics*, 2(3):329–343, 2010.

M. Sorostinean, F. Ferland, A. Tapus, et al. Motion-oriented attention for a social gaze robot behavior. In *Social Robotics*, pages 310–319. Springer, 2014.

A. St Clair and M. J. Mataric. How robot verbal feedback can improve team performance in human-robot task collaborations. In *HRI*, pages 213–220, 2015.

C. Stanton and C. J. Stevens. Robot pressure: the impact of robot eye gaze and lifelike bodily movements upon decision-making and trust. In *Social Robotics*, pages 330–339. Springer, 2014.

M. Staudte and M. W. Crocker. Visual attention in spoken human-robot interaction. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pages 77–84. ACM, 2009.

W. D. Stiehl, J. Lieberman, C. Breazeal, L. Basel, L. Lalla, and M. Wolf. Design of a therapeutic robotic companion for relational, affective touch. In *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pages 408–415. IEEE, 2005.

K. W. Strabala, M. K. Lee, A. D. Dragan, J. L. Forlizzi, S. Srinivasa, M. Cakmak, and V. Micelli. Towards seamless human-robot handovers. *Journal of Human-Robot Interaction*, 2(1):112–132, 2013.

H. B. Suay and S. Chernova. Effect of human guidance and state space size on interactive reinforcement learning. In *RO-MAN, 2011 IEEE*, pages 1–6. IEEE, 2011.

H. B. Suay, R. Toris, and S. Chernova. A practical comparison of three robot learning from demonstration algorithm. *International Journal of Social Robotics*, 4(4):319–330, 2012.

K. Sugiura, Y. Shiga, H. Kawai, T. Misu, and C. Hori. Non-monologue hmm-based speech synthesis for service robots: A cloud robotics approach. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 2237–2242. IEEE, 2014.

M. Svenstrup, S. Tranberg, H. J. Andersen, and T. Bak. Pose estimation and adaptive robot behaviour for human-robot interaction. In *Robotics and Automation, 2009. ICRA'09. IEEE International Conference on*, pages 3571–3576. IEEE, 2009.

E. Sviestins, N. Mitsunaga, T. Kanda, H. Ishiguro, and N. Hagita. Speed adaptation for a robot walking with a human. In *Human-Robot Interaction (HRI), 2007 2nd ACM/IEEE International Conference on*, pages 349–356, March 2007.

D. Szafir, B. Mutlu, and T. Fong. Communication of intent in assistive free flyers. In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, pages 358–365. ACM, 2014.

D. Szafir, B. Mutlu, and T. Fong. Communicating directionality in flying robots. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 19–26. ACM, 2015.

L. Takayama, D. Dooley, and W. Ju. Expressing thought: improving robot readability with animation principles. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 69–76. ACM, 2011.

K. Talamadupula, G. Briggs, T. Chakraborti, M. Scheutz, and S. Kambhampati. Coordination in human-robot teams using mental modeling and plan recognition. In *Intelligent Robots and Systems (IROS 2014), 2014 IEEE/RSJ International Conference on*, pages 2957–2962. IEEE, 2014.

B. Tanya, C. Malinda, C. Josep, and T. Michael. Unwilling Versus Unable: Infants' Understanding of Intentional Action. *Developmental Psychology*, 41:328–337, 2005.

T. Tasaki, K. Komatani, T. Ogata, and H. G. Okuno. Spatially mapping of friendliness for human-robot interaction. In *Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on*, pages 1277–1282. IEEE, 2005.

S. Tellex, T. Kollar, S. Dickerson, M. R. Walter, A. G. Banerjee, S. Teller, and N. Roy. Approaching the symbol grounding problem with probabilistic graphical models. *AI magazine*, 32(4):64–76, 2011.

S. Tellex, P. Thaker, R. Deitsl, D. Simeonovl, T. Kollar, and N. Royl. Toward information theoretic human-robot dialog. *Robotics*, page 409, 2013.

S. Tellex, R. Knepper, A. Li, D. Rus, and N. Roy. Asking for help using inverse semantics. In *Robotics: Science and systems*, volume 2, page 3, 2014.

C. L. Teo, Y. Yang, H. Daumé III, C. Fermüller, and Y. Aloimonos. Towards a watson that sees: Language-guided action recognition for robots. In *Robotics and Automation (ICRA), 2012 IEEE International Conference on*, pages 374–381. IEEE, 2012.

F. Thomas and O. Johnston. *Disney Animation: The Illusion of Life.* Abbeville Press, New York, 1981.

A. L. Thomaz. *Socially Guided Machine Learning.* PhD thesis, Massachusetts Institute of Technology, 2006.

A. L. Thomaz and M. Cakmak. Learning about objects with human teachers. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pages 15–22. ACM, 2009.

A. L. Thomaz, G. Hoffman, and C. Breazeal. Experiments in socially guided machine learning: understanding how humans teach. In *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*, pages 359–360. ACM, 2006a.

A. L. Thomaz, G. Hoffman, and C. Breazeal. Reinforcement learning with human teachers: Understanding how people want to teach robots. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 352–357. IEEE, 2006b.

M. Tomasello. *The Cultural Origins of Human Cognition*. Harvard University Press, March 2001. ISBN 0674005821.

M. Tomasello, M. Carptenter, J. Call, T. Behne, and H. Moll. Understanding and sharing intentions: the origins of cultural cognition. *Behavioral and Brain Sciences (in press)*, 2004.

E. A. Topp and H. I. Christensen. Detecting region transitions for human-augmented mapping. *Robotics, IEEE Transactions on*, 26(4):715–720, Aug 2010. ISSN 1552-3098.

C. Torrey, A. Powers, S. R. Fussell, and S. Kiesler. Exploring adaptive dialogue based on a robot's awareness of human gaze and task progress. In *Proceedings of the ACM/IEEE international conference on Human-robot interaction*, pages 247–254. ACM, 2007.

C. Torrey, S. Fussell, and S. Kiesler. How a robot should give advice. In *Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction*, pages 275–282. IEEE Press, 2013.

E. Torta, R. H. Cuijpers, J. F. Juola, and D. van der Pol. Design of robust robotic proxemic behaviour. In *Social robotics*, pages 21–30. Springer, 2011.

E. Torta, J. van Heumen, R. H. Cuijpers, and J. F. Juola. How can a robot attract the attention of its human partner? a comparative study over different modalities for attracting attention. In *Social robotics*, pages 288–297. Springer, 2012.

E. Torta, J. van Heumen, F. Piunti, L. Romeo, and R. Cuijpers. Evaluation of unimodal and multimodal communication cues for attracting attention in human–robot interaction. *International Journal of Social Robotics*, 7(1): 89–96, 2015.

G. Trafton, L. Hiatt, A. Harrison, F. Tamborello, S. Khemlani, and A. Schultz. ACT-R/E: An embodied cognitive architecture for human-robot interaction. *Journal of Human-Robot Interaction*, 2(1):30–55, 2013.

J. G. Trafton, M. D. Bugajska, B. R. Fransen, and R. M. Ratwani. Integrating vision and audition within a cognitive architecture to track conversations. In *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction*, pages 201–208. ACM, 2008.

H. S. Tranberg, M. Svenstrup, H. J. Andersen, and T. Bak. Adaptive human aware navigation based on motion pattern analysis. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 927–932, Sept 2009.

P. Trautman, J. Ma, R. M. Murray, and A. Krause. Robot navigation in dense human crowds: Statistical models and experimental studies of human–robot cooperation. *The International Journal of Robotics Research*, 34(3):335–356, 2015. URL `http://ijr.sagepub.com/content/34/3/335.abstract`.

J.-M. Valin, S. Yamamoto, J. Rouat, F. Michaud, K. Nakadai, and H. G. Okuno. Robust recognition of simultaneous speech by a mobile robot. *Robotics, IEEE Transactions on*, 23(4):742–752, 2007.

M. Van den Bergh, D. Carton, R. De Nijs, N. Mitsou, C. Landsiedel, K. Kuehnlenz, D. Wollherr, L. Van Gool, and M. Buss. Real-time 3d hand gesture interaction with a robot for understanding directions from humans. In *RO-MAN, 2011 IEEE*, pages 357–362. IEEE, 2011.

E. T. Van Dijk, E. Torta, and R. H. Cuijpers. Effects of eye contact and iconic gestures on message retention in human-robot interaction. *International Journal of Social Robotics*, 5(4):491–501, 2013.

G. Venture, H. Kadone, T. Zhang, J. Grèzes, A. Berthoz, and H. Hicheur. Recognizing emotions conveyed by human gait. *International Journal of Social Robotics*, 6(4):621–632, 2014.

L. S. Vygotsky and Ed. M. Cole. *Mind in society: the development of higher psychological processes.* Harvard University Press, Cambridge, MA, 1978.

Z. Wang, K. Mülling, M. P. Deisenroth, H. B. Amor, D. Vogt, B. Schölkopf, and J. Peters. Probabilistic movement modeling for intention inference in human–robot interaction. *The International Journal of Robotics Research*, 32(7):841–858, 2013.

A. Weiss, J. Igelsböck, M. Tscheligi, A. Bauer, K. Kühnlenz, D. Wollherr, and M. Buss. Robots asking for directions: the willingness of passers-by to support robots. In *Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction*, pages 23–30. IEEE Press, 2010.

K. Williams and C. Breazeal. A reasoning architecture for human-robot joint tasks using physics-, social-, and capability-based logic. In *Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on*, pages 664–671. IEEE, 2012.

M.-A. Williams, S. Abidi, P. Gärdenfors, X. Wang, B. Kuipers, and B. Johnston. Interpreting robot pointing behavior. In *Proceedings of the 5th International Conference on Social Robotics-Volume 8239*, pages 148–159, 2013.

A. Xu and G. Dudek. Trust-driven interactive visual navigation for autonomous robots. In *Robotics and Automation (ICRA), 2012 IEEE International Conference on*, pages 3922–3929. IEEE, 2012.

T. Yamaguchi and S. Hashimoto. Attractiveeye: Augmented gaze representation for "what is the robot looking at?". In *Robotics and Automation, 2009. ICRA'09. IEEE International Conference on*, pages 3389–3394. IEEE, 2009.

K. Yamane, M. Revfi, and T. Asfour. Synthesizing object receiving motions of humanoid robots with human motion database. In *Robotics and Automation (ICRA), 2013 IEEE International Conference on*, pages 1629–1636. IEEE, 2013.

F. Yamaoka, T. Kanda, H. Ishiguro, and N. Hagita. Developing a model of robot behavior to identify and appropriately respond to implicit attention-shifting. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pages 133–140. ACM, 2009.

A. Yamazaki, K. Yamazaki, Y. Kuno, M. Burdelski, M. Kawashima, and H. Kuzuoka. Precision timing in human-robot interaction: coordination of head movement and utterance. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 131–140. ACM, 2008.

H. Yan, M. H. Ang Jr, and A. N. Poo. A survey on perception methods for human–robot interaction in social robots. *International Journal of Social Robotics*, 6(1):85–119, 2014.

H.-D. Yang, A.-Y. Park, S.-W. Lee, et al. Gesture spotting and recognition for human–robot interaction. *Robotics, IEEE Transactions on*, 23(2):256–270, 2007.

W. Yuan, E. Brunskill, T. Kollar, and N. Roy. Where to go: Interpreting natural directions using global inference. In *Robotics and Automation, 2009. ICRA '09. IEEE International Conference on*, pages 3761–3767, May 2009.

Y. Zeng, Y. Li, P. Xu, and S. S. Ge. Human-robot handshaking: A hybrid deliberate/reactive model. In *Social Robotics*, pages 258–267. Springer, 2012.

J. Zhang and A. J. C. Sharkey. Listening to sad music while seeing a happy robot face. In *Social Robotics*, pages 173–182. Springer, 2011.