Certificate I: Understanding AI and Machine Learning in Africa

Course AIML01: Artificial Intelligence – Past, Present, and Future

Module 4: Future Challenges

Lecture 1: Collaborating with Machines and Robots

Carnegie Mellon University
Africa

Learning Objectives

1. Identify the challenges poses by designing robots that can interact and collaborate with people in natural, realistic, everyday settings.

2. Explain the need for these robots to exhibit variable degrees of autonomy.

3. Identify the challenge of establishing trustworthy interactions between robots and people

Lecture Contents

1. Complexity and uncertainty of real-world interaction
2. Challenges posed by collaboration between people and robots
3. Reading intentions and Theory of Mind
4. Variable autonomy
5. Trustworthy Interaction in Human-Robot Collaboration
6. Lecture summary
7. Recommended reading & references

Dealing with the Uncertainty and Complexity of the Real World

- AI has contributed significantly to the design of intelligent control systems and cognitive architectures for robots
  - Sensorimotor behaviors, e.g., perception, navigation, and manipulation
  - Cognitive capabilities, e..g., planning, language understanding

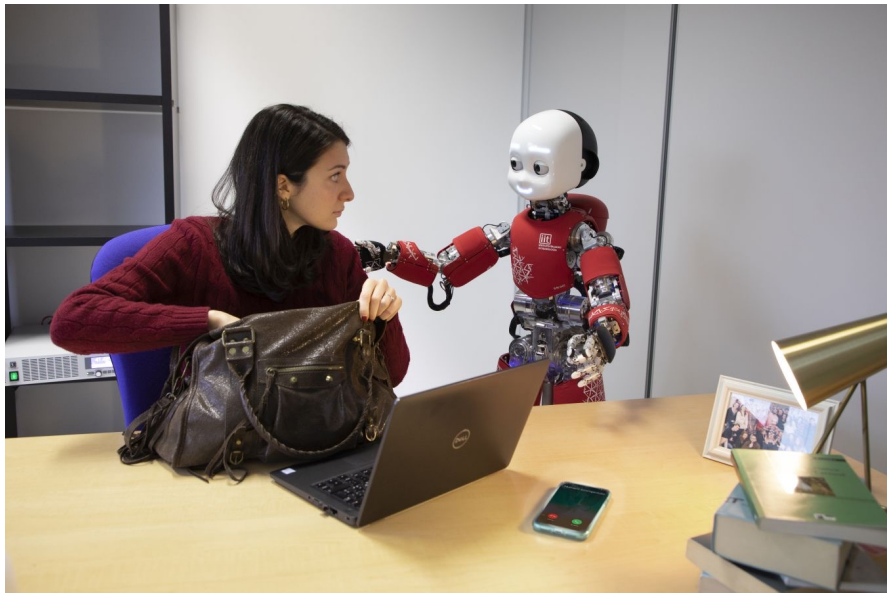
We touched on some of these topics in Lecture AIML01-03-02. You might like to revisit it before proceeding.

- Major challenges still remain for reliable, robust realization of above skills
  - Handling cluttered, dynamic, unpredictable environments
  - Objects to be grasped or obstacles to be avoided can be
    - Difficult to see and possibly hidden
    - Appear in different, unforeseen places

HRI and Collaborative Human-Machine Interaction

A significant challenge for robots
– and intelligent machines in general –
is that of handling interaction with people for collaborative tasks

- Human-robot interaction (HRI)
- Social robotics



(Sandini et al., 2021)

HRI and Collaborative Human-Machine Interaction

Variety of scenarios

- Joint action in flexible manufacturing setup between a worker and a cobot (collaborative robot)

Image courtesy of Fraunhofer IPA

HRI and Collaborative Human-Machine Interaction

Variety of scenarios

- Joint action in flexible manufacturing setup between a worker and a cobot (collaborative robot)
- Assistive robot companions for older and disabled people in hospital and care homes

Source: https://robots.ieee.org/robots/paro/

HRI and Collaborative Human-Machine Interaction

Variety of scenarios

- Joint action in flexible manufacturing setup between a worker and a cobot (collaborative robot)
- Assistive robot companions for older and disabled people In hospital and care homes
- Robot tutors for education or entertainment

Source: https://robots.ieee.org/robots/kiwi

HRI and Collaborative Human-Machine Interaction

Some of the challenges for future research on the combination of AI and collaborative robots are

- Developing the skills required for effective interaction
- Designing machines that can interact with a variable degree of autonomy
- Designing machines that can engage in long-term, trustworthy interaction that fosters well-being

Reading Intentions and Theory of Mind

The research challenge of using AI to achieve the social and cognitive skills for interaction includes

- The ability of to read a person's intentions
- The implementation of an artificial Theory of Mind (Vinanzi et al. 2019)

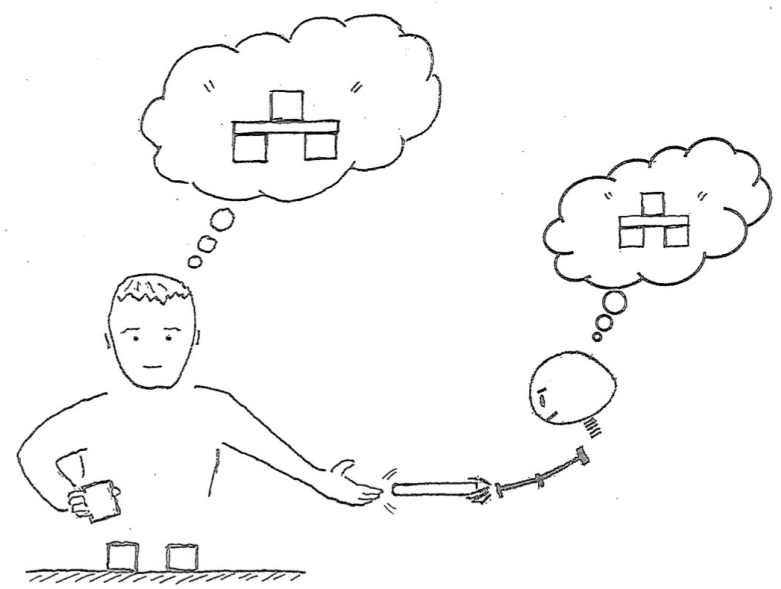
Reading Intentions and Theory of Mind

- Intention reading is the ability of the robot to infer the person's intended goal when working together on some joint interaction

- For example, when a cobot is working with a person to assemble the parts of some object

  - It must anticipate the goal

  - It must anticipate the next action that the person expects the robot to perform

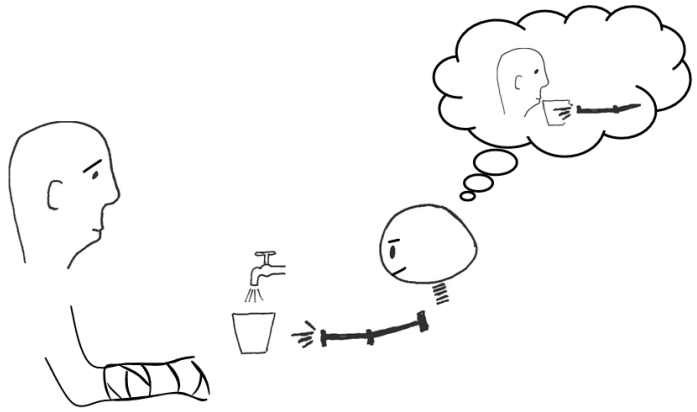


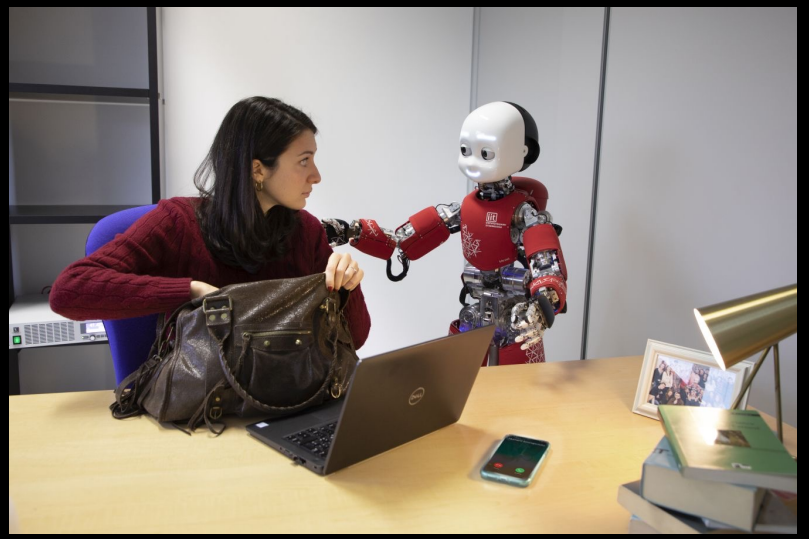
Reading Intentions and Theory of Mind

Theory of Mind describes a more general view of intention reading

It concerns the robot's ability to understand and infer

- The person's goals
- The person's beliefs and desires





"This sequence of pictures depicts a situation in which the iCub humanoid robot (www.icub.org) is interacting with a human, reading her intention to get her phone from her bag."

Sandini, G., A. Sciutti, and D. Vernon, Cognitive Robotics. In M. Ang, O. Khatib, and B. Siciliano (Eds.), Encyclopedia of Robotics. Springer, 2021.
Images courtesy of Istituto Italiano di Tecnologia

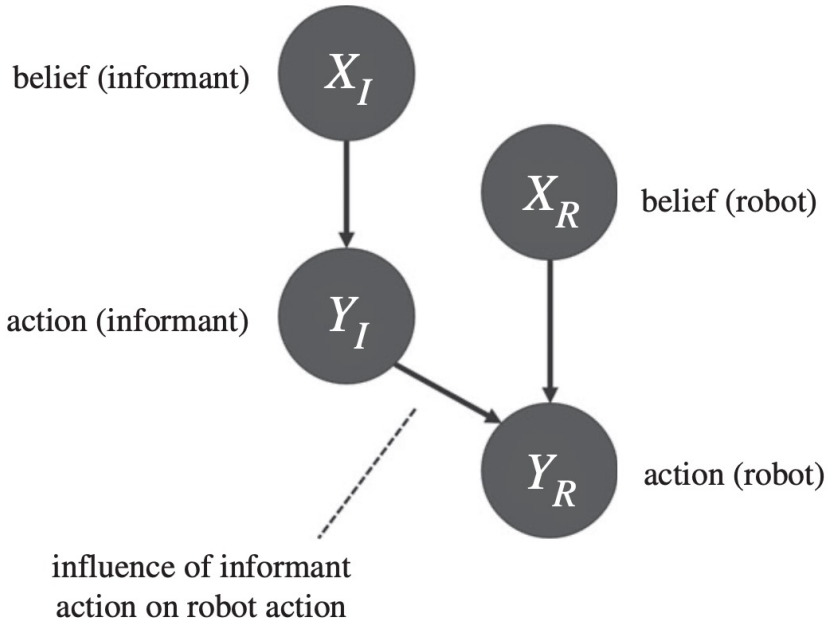
Reading Intentions and Theory of Mind

AI methods, such as

Bayesian networks and

deep learning

can be used to build artificial theory of mind skills in robots (Vinanzi et al. 2019)



(Vinanzi et al., 2019)

The Bayesian network that models the relation between the robot and an informant. The agent generates a separate network for each user, with the same structure but different probability distribution. A Bayesian network is a probabilistic graphical model: refer back to Lecture AIML01-02-03.

Variable Autonomy

Whether or not a robot is self-governing and determines its own goals

Autonomy is not black and white issue:
there are degrees of autonomy
While there are two extremes:

1. Full autonomy
   - e.g., an autonomous car without a driver

2. No autonomy
   - e.g., a bomb disposal mobile robot tele-operated by a human

https://robots.ieee.org/robots/boss


https://robots.ieee.org/robots/packbot

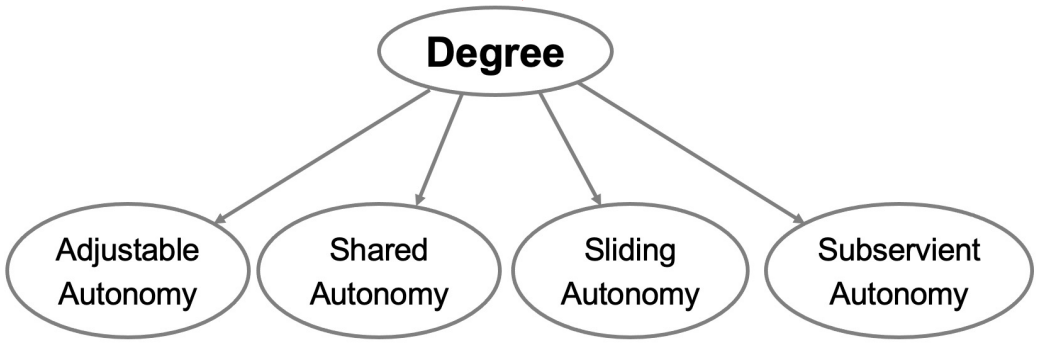
Variable Autonomy

Most of tasks in which intelligent robots will interact with people involve a variable degree of collaboration

This requires a robot with a variable degree of autonomy

- to adapt to the user needs
- to adapt to the environmental circumstances

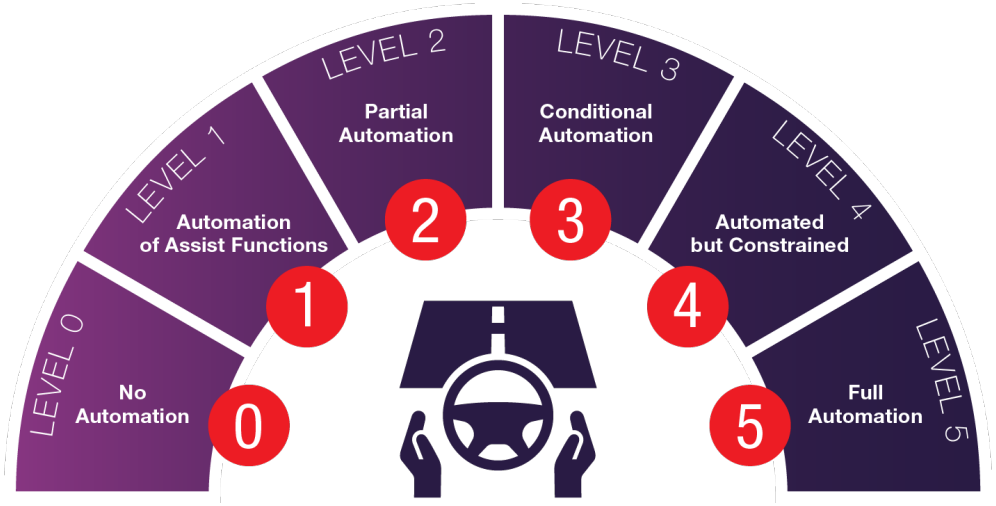
Typically, the system controls its own behavior to a greater or lesser extent , but the goals are determined by the human with which it is interacting



Also referred to as conditional automation

Variable Autonomy

Take, for example, the case of intelligent assisted driving and the six levels of driving automation identified by the car industry

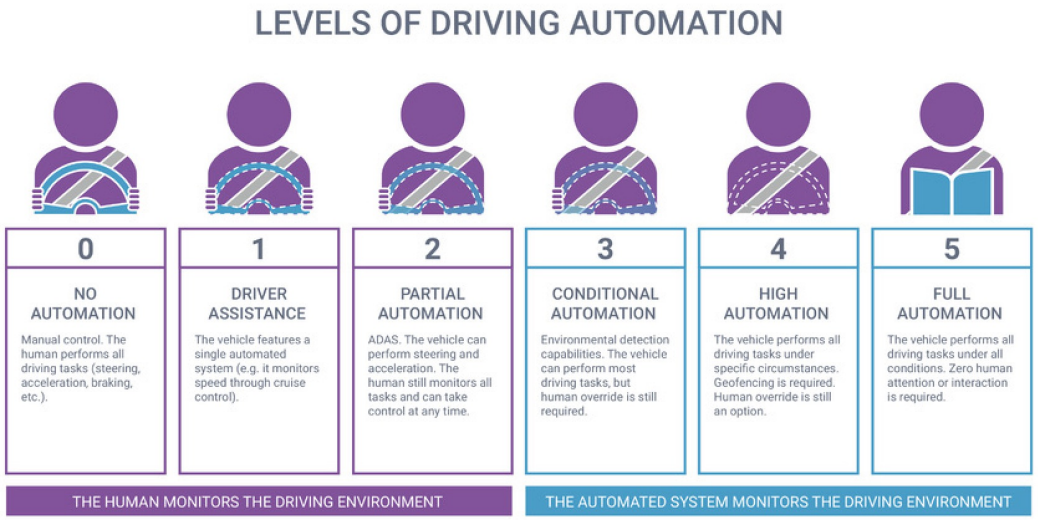


https://www.eeworldonline.com/breaking-the-psychological-barrier-to-autonomous-vehicle-adoption/

Variable Autonomy

Future intelligent vehicles will switch from situations of conditional autonomy

- In which the car performs some lane-following, steering and acceleration tasks autonomously,
- When it can easily cope with the road and traffic conditions



https://www.3cems.com/the-6-levels-of-vehicle-autonomy_n69

To no automation for situations in which the driver must take control when the car is unable to perform the driving task

Trustworthy Interaction in Human-Robot Collaboration

- The robot must be able to engage in continuous, meaningful, and contextualised interaction
- Over a series of interactions lasting for days, weeks, or longer
- This will require robots to have the ability to
  - Recognize a person and their personality and preferences
  - Remember recent interactions
  - Engage in empathic behaviour with the person needs (Leite et al. 2013)

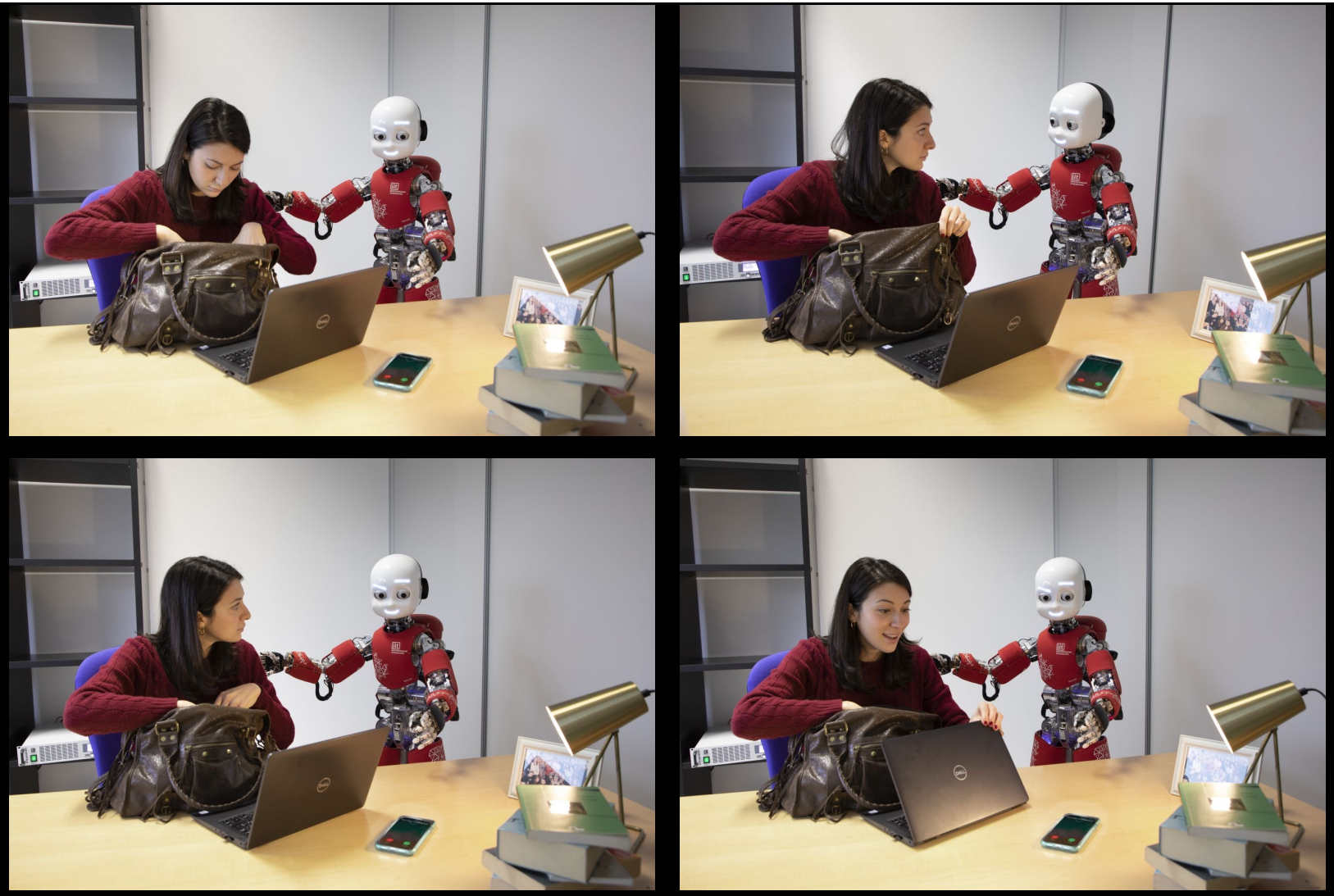
Trustworthy Interaction in Human-Robot Collaboration

- This is a significant challenge in robotics, as the great majority of current intelligent robots are only capable of short-term interaction

- Trustworthy interaction, a growing field of research, requires people's acceptance and trust of the robot's behavior and decision-making process

- This is also linked to ethical issue explainable AI
  (which we will cover in Lecture AIML01-04-04)

  and to the achievement of peoples' and robot's reciprocal theory of mind
  (Mou et al. 2020; Vinanzi et al. 2021)



"This sequence of pictures depicts a situation in which the iCub humanoid robot (www.icub.org) is interacting with a human, reading her intention to get her phone from her bag, and alerting her to the fact that it is on the desk, hidden from her by the laptop.
Note that this sequence has been staged to illustrate the desired capabilities of a cognitive robot and has not yet been implemented."

Sandini, G., A. Sciutti, and D. Vernon, Cognitive Robotics. In M. Ang, O. Khatib, and B. Siciliano (Eds.), Encyclopedia of Robotics. Springer, 2021.
Images courtesy of Istituto Italiano di Tecnologia

Lecture Summary

Collaborative interaction poses many challenges

1. Robust perception and action
2. Reading intentions
3. Theory of mind
4. Variable degrees of autonomy
5. Trustworthy behavior

Recommended Reading

Bartneck, C., Belpaeme, T., Eyssel, F., Kanda, T., Keijsers, M., & Šabanović, S. (2020). Human-robot interaction: An Introduction. Cambridge University Press.

Chapter 2 – What is Human-Robot Interaction? pp. 6-17.

https://www.human-robot-interaction.org

Sandini, G., A. Sciutti, and D. Vernon, Cognitive Robotics. In M. Ang, O. Khatib, and B. Siciliano (Eds.), Encyclopedia of Robotics. Springer, 2021.

http://vernon.eu/publications/2021_Sandini_et_al.pdf

References

Leite, I., Martinho, C., & Paiva, A. (2013). Social robots for long-term interaction: a survey.
https://doi.org/10.1098/rstb.2018.0032

Mou W., Ruocco M., Zanatto D., Cangelosi A. (2020). When would you trust a robot? A study on trust and theory of mind in human-robot interactions. Proceedings of RO-MAN 2020, 29th IEEE International Conference on Robot and Human Interactive Communication, Naples, August 2020.
https://arxiv.org/abs/2101.10819

Vinanzi S., Patacchiola M., Chella A., Cangelosi A. (2019). Would a robot trust you? Developmental robotics model of trust and theory of mind. Philosophical Transactions of the Royal Society B., 374.
https://doi.org/10.1098/rstb.2018.0032

Vinanzi S., Cangelosi A., Goerick C. (2021). The collaborative mind: Intention reading and trust in human-robot interaction. iScience, 24(2).
https://www.cell.com/iscience/fulltext/S2589-0042(21)00098-5