Humanoid robots - Human-robot interaction

Doc. Mgr. Matěj Hoffmann, Ph.D.

Great efficiency in human absence...

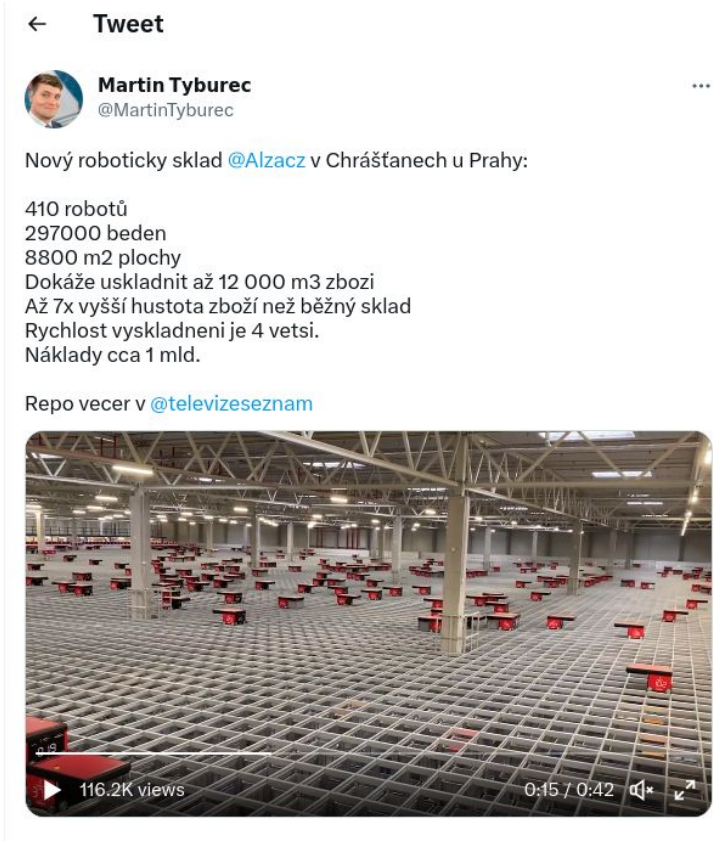
Kia, Žilina
https://youtu.be/i7SuPSBg130?t=332

Ocado, London, grocery warehouse.
https://youtu.be/ssZ_8cqfBIE

Same thing in local context

New robotic warehouse @Alzacz in Chrášťany near Prague:

- 410 robots
- 297000 boxes
- 8800 m^2 of space
- can store up to 12 000 m of goods
- Up to 7 times higher density of goods than a conventional warehouse.
- Pick speed is 4 times faster.
- Cost approx. 1 billion CZK (46.5 mil. $)



Dec 12, 2022:
https://twitter.com/MartinTyburec/status/1602289811448107009?s=20&t=dDtEDwMDwGJknMDWxSIUSA

But there are limits to it....

- Robot clumsiness
- Robot intelligence
- Humans explicitly part of the task
  - Assisting humans
  - Entertaining humans

ABB Elektro-Praha, collaborative making of power plugs

Paro, therapeutic seal robot,
https://youtu.be/2ZUn9qtG8ow

trend vision!?

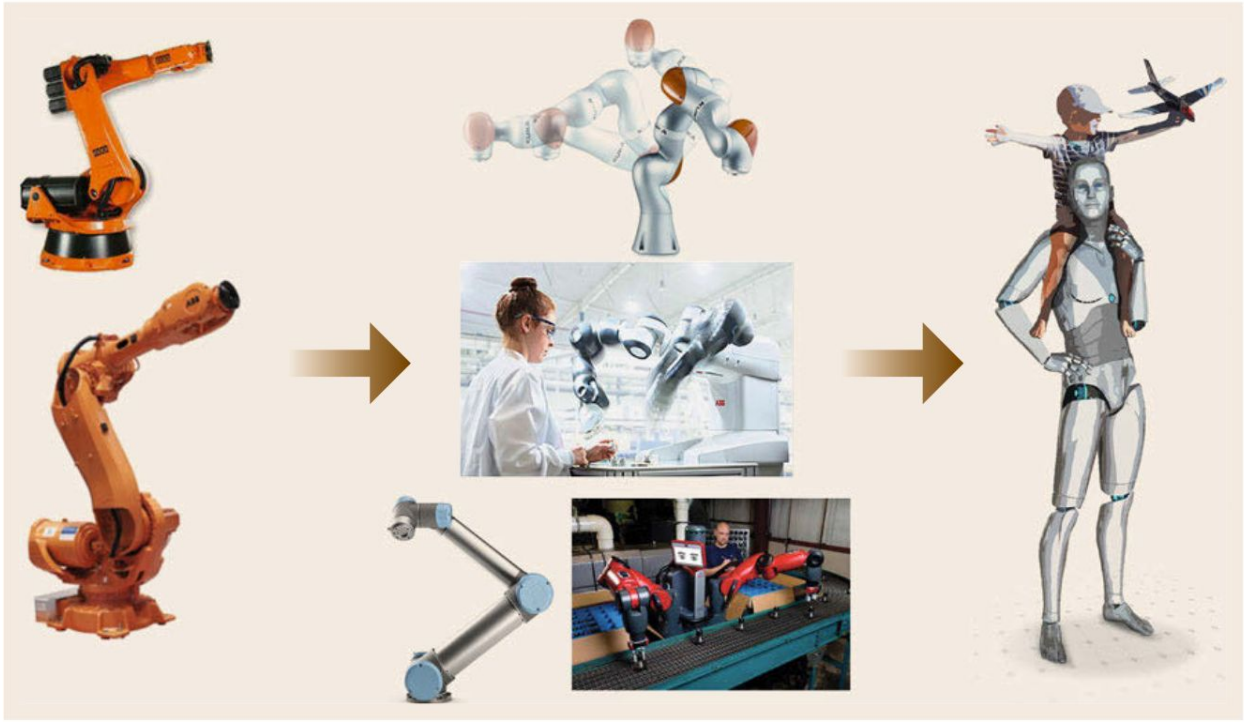


Fig. 69.1 The current paradigm shift in robotics induced by new target domains and robots toward the vision of close human–robot coexistence (courtesy of Keller und Knappich Augsburg (KUKA), Deutsches Zentrum für Luft- und Raumfahrt (DLR), ABB, Rethink Robotics)

Haddadin, S., & Croft, E. (2016). Physical human–robot interaction. In *Springer handbook of robotics* (pp. 1835-1874). Springer, Cham.

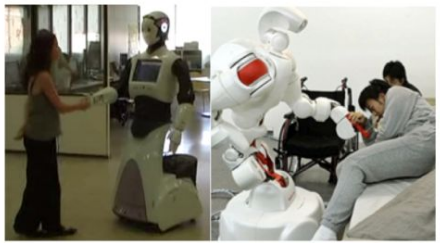
Human-robot collaboration

traditional robotics

replacing humans

human-friendly robotics

collaborating with humans



co-workers on factory floor

personal robots in service

Physical HRI - Lecture slides by Alessandro de Luca
http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf

10 years from now?

sci-fi?

reality?

20 years from now?

- Close, safe, and dependable physical interaction between human and robot in a shared workspace.
- Robots need to be carefully designed for human friendliness. That is, they have to be able to safely sense, reason, learn, and act in a partially unknown world inhabited by humans.

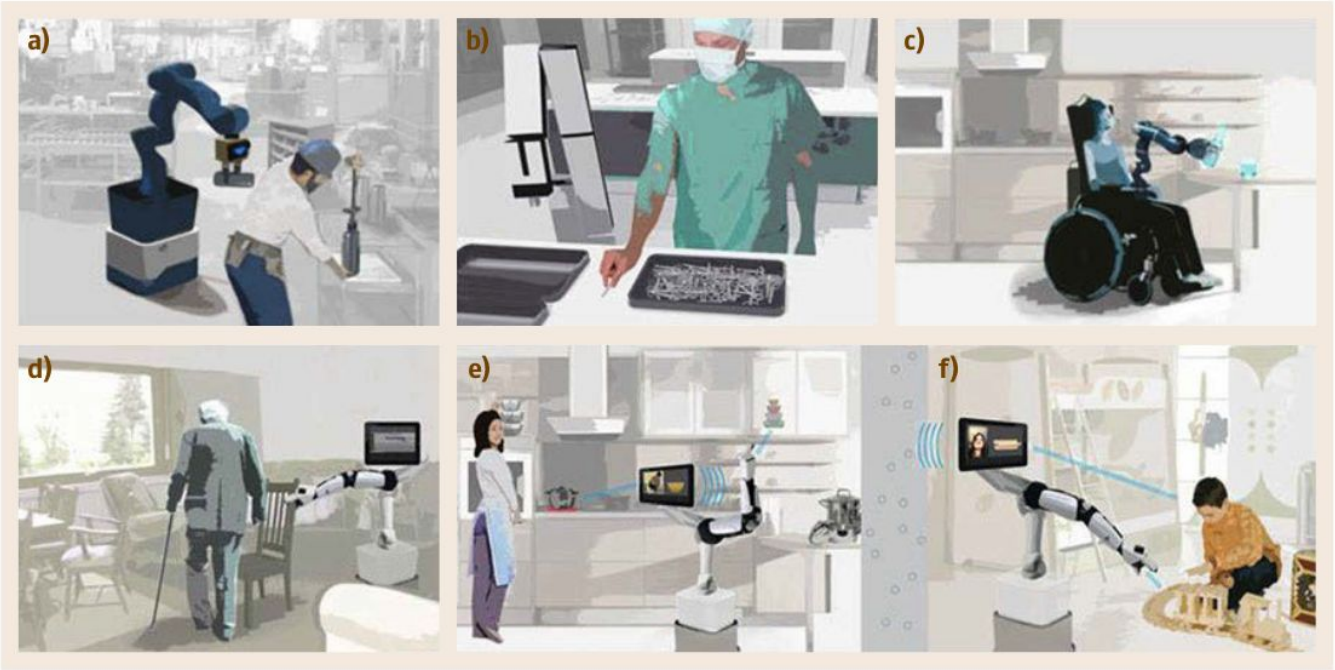


Fig.69.2a–f Application examples for pHRI, ranging from shop floor logistics and manipulation **(a,b)**, over professional service robots and assisitve devices for the disabled **(c,d)**, to service robots in domestic applications **(e,f)**

Haddadin, S., & Croft, E. (2016). Physical human–robot interaction. In *Springer handbook of robotics* (pp. 1835-1874). Springer, Cham.

Classification of interaction

- supportive - **robot** not integral to the central performance of a task, but instead **provides the human with the tools, materials, and information**...
  - museum tour guide robots, shopping assistant robots for aiding seniors, homecare robots
- collaborative - human and robot both work on the task, with the **labor divided** between the robot and human, each separately completing the parts of the task best suited to their abilities, but more frequently interacting through turn taking and part/tool passing
- cooperative - extension of cooperative manipulation to include force interactions with humans. **Human and robot work in direct physical contact**, or indirect contact through a common object, with continuous and cooperative shared control of the task.
  - cooperative lifting and carrying, kinesthetic teaching, coordinated material han, rehabilitation therapy

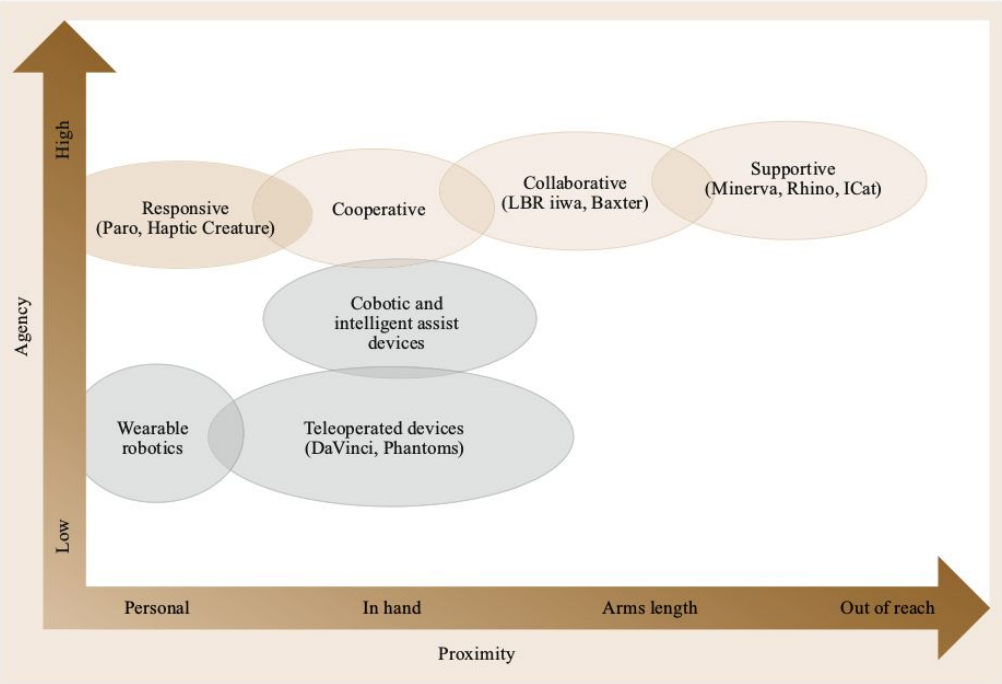
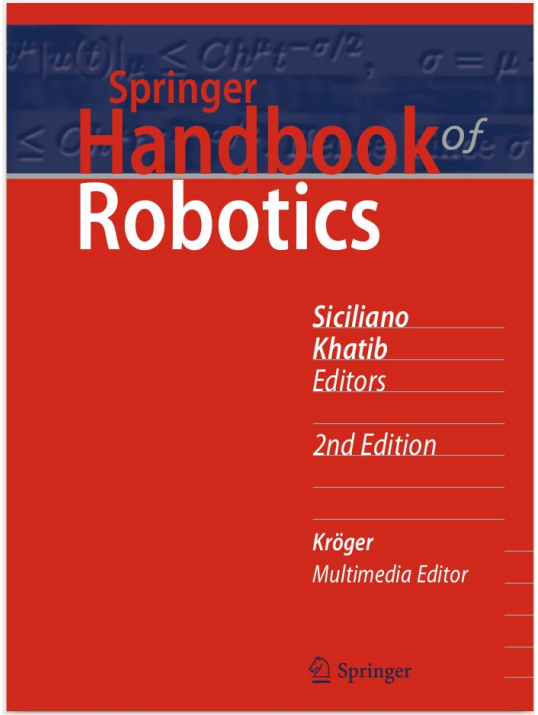


Fig. 69.3 Classification scheme for pHRI, by proximity of the interaction and agency (available autonomy) of the robot

Haddadin, S., & Croft, E. (2016). Physical human–robot interaction. In *Springer handbook of robotics* (pp. 1835-1874). Springer, Cham.



Multimedia Contents

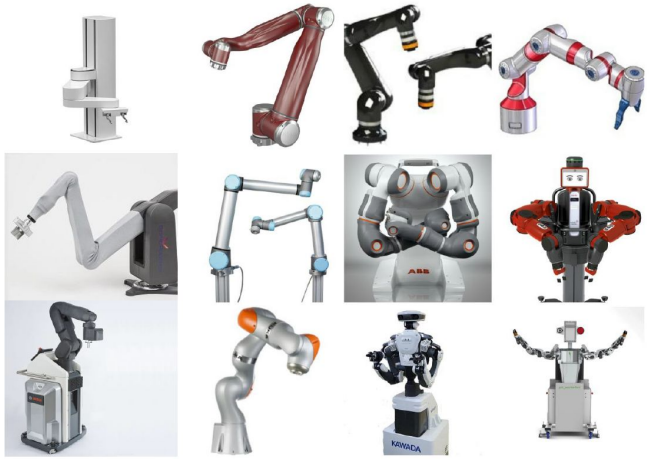
Part G Robots

Part G Robots and Humans

Ed. by Daniela Rus

HRI - physical or social (cognitive)?

- Physical HRI is a lot about **safety**, through
  - Mechanics: lightweight design, compliant components…
  - Electronics: low-latency, high reliability…
  - Software/Control:
    - Reactive - quick response after collision
    - Predictive
      - keeping safe separation distance
      - anticipating human movements…
- Social HRI is a very different story
  - Engineering is only ⅓ of the picture…



A selection of collaborative robots. Image credit: Robotiq.

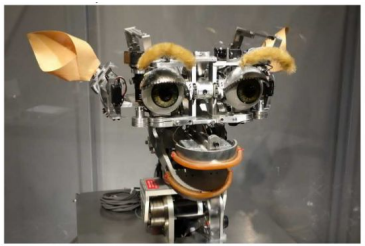


Figure 2.3 Kismet (1997–2004), an early example of social human–robot interaction research from the Massachusetts Institute of Technology. (Source: Daderot)

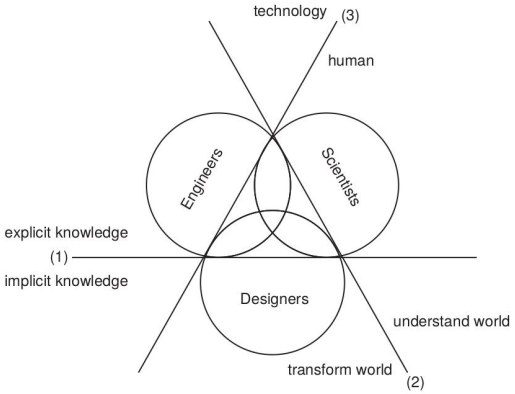
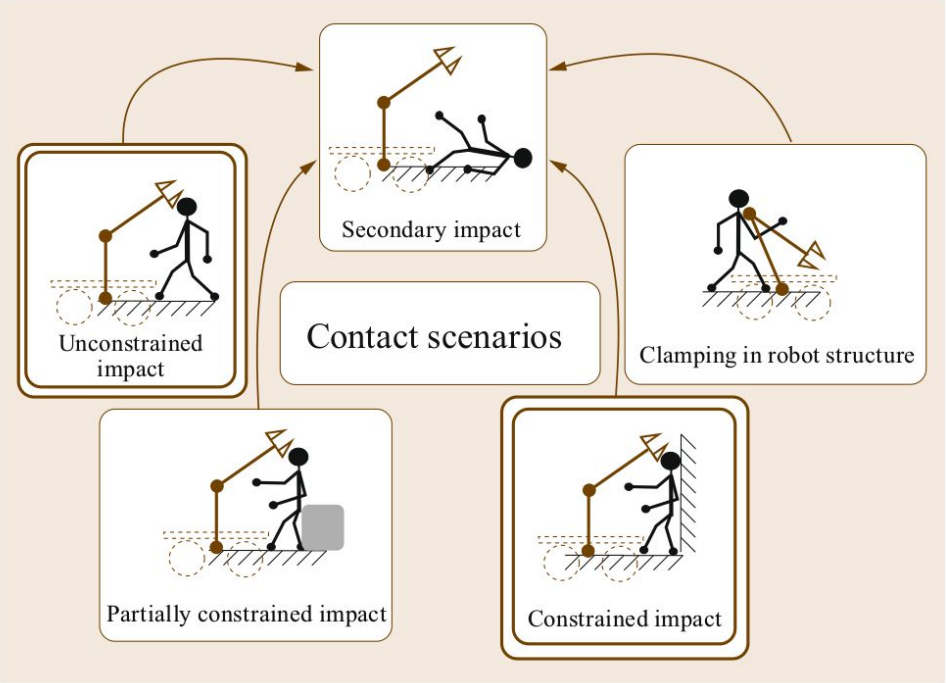


Fig 2.2 in Bartneck, C., Belpaeme, T., Eyssel, F., Kanda, T., Keijsers, M., & Šabanović, S. (2020). *Human-robot interaction: An introduction*. Cambridge University Press.

Human safety



http://handbookofrobotics.org/view-chapter/69/videodetails/608

S. Haddadin, A. Albu-Schäffer, M. Strohmayr, M. Frommberger, G. Hirzinger: Injury evaluation of human-robot impacts, Proc. IEEE Int. Conf. Robot. Autom. (ICRA), Pasadena (2008), pp. 2203 – 2204;

Fig. 69.4 Robot–human impact scenario classes. Unconstrained and constrained impacts are considered the two main scenarios

Haddadin, S., & Croft, E. (2016). Physical human–robot interaction. In *Springer handbook of robotics* (pp. 1835-1874). Springer, Cham.

Safe design

- Lightweight
  - high-strength metals, or composite materials for the robot links
- Tendon-based robots
  - Remote direct drives - actuators in robot base.
  - Low reduction ratios -> back-driveability.
- Elastic actuation
  - Series Elastic Actuation (SEA)
  - Variable Stiffness Actuation (VSA)
  - Variable Impedance Actuations (VIA) - stiffness & damping

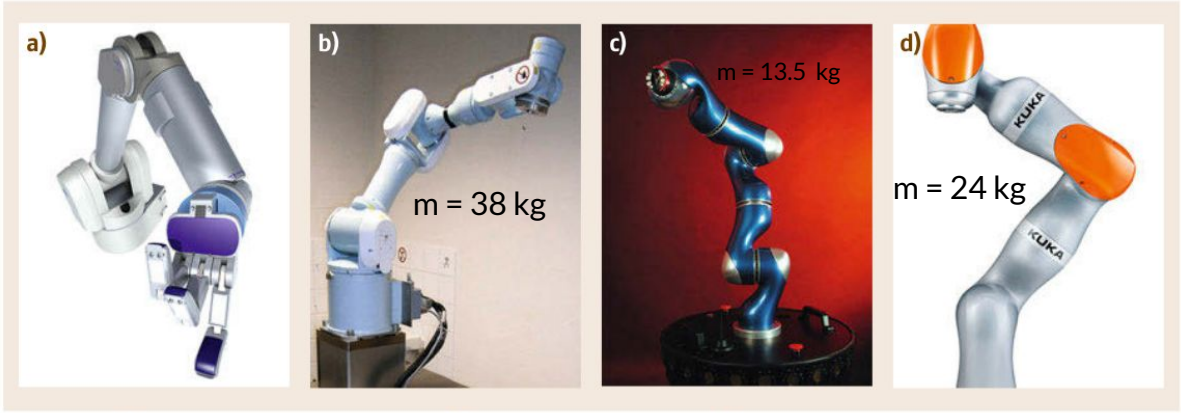


Fig. 69.10 (a) Barrett arm (after [69.58]), (b) Mitsubishi PA10 arm, (c) DLR lightweight robot III (after [69.59]), (d) KUKA LBR iiwa (after [69.60]) (courtesy of Barret Technology Inc., DLR, KUKA)

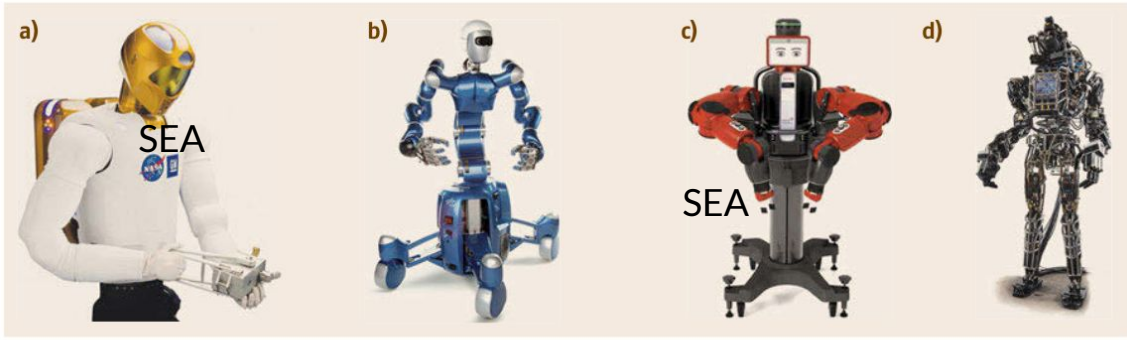


Fig. 69.11 (a) NASA *Robonaut 2*, (b) DLR *Rollin' Justin*, (c) Rethink Robotics *Baxter* and (d) Boston Dynamics *Atlas* (courtesy of NASA, DLR, Rethink Robotics Inc., Boston Dynamics)

Haddadin, S., & Croft, E. (2016). Physical human–robot interaction. In *Springer handbook of robotics* (pp. 1835-1874). Springer, Cham.

Safe design for social HRI

Be so small and weak that you cannot possibly harm anyone…

\+ soft…

Note: for iCub and Pepper, this is already not entirely true…

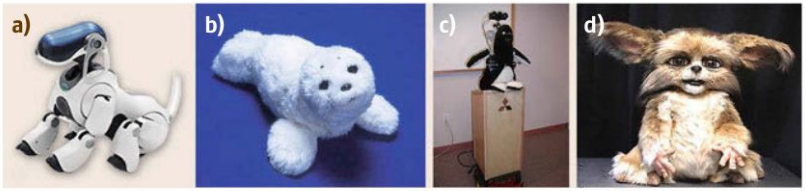


Fig.72.3a–d Examples of social robots inspired by animals with anthropomorphic qualities: **(a)** AIBO, the robotic dog developed by Sony (after [72.30]), **(b)** Paro, the therapeutic seal robot developed at AIST (after [72.31]), **(c)** Mel, the conversational robotic penguin developed at MERL (after [72.32]), and **(d)** Leonardo developed at the MIT Media Lab (after [72.33])

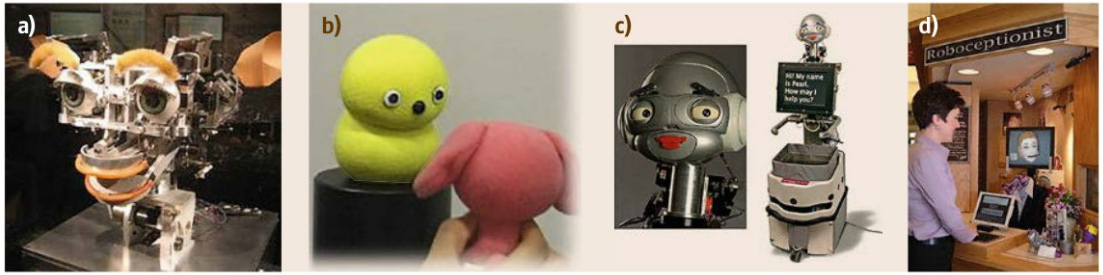
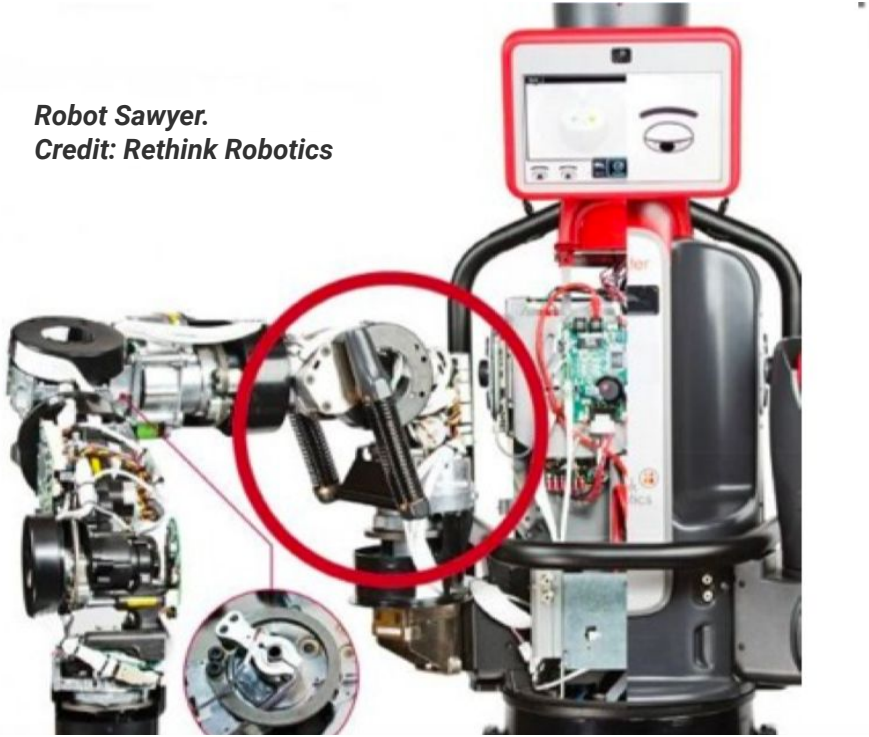


Fig.72.4a–d Examples of social robots that are neither humanoid nor zoomorphic but capture key social attributes: **(a)**: Kismet (after [72.3]); **(b)** Keepon (after [72.34]); **(c)** Pearl (after [72.35]); **(d)** Valerie (after [72.36])

Breazeal, C., Dautenhahn, K., & Kanda, T. (2016). Social robotics. *Springer handbook of robotics*, 1935-1972.

Compliant collision



Robot Sawyer.
Credit: Rethink Robotics

passive compliance ~ spring.

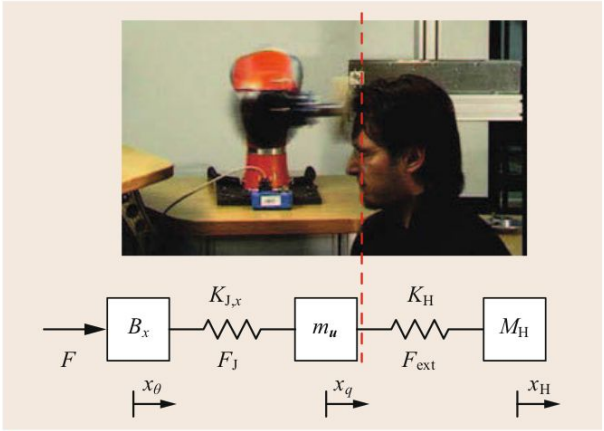


Fig. 69.12 Human–robot collision in operational space, which is defined by the reflected flexible dynamics of the robot and the local contact stiffness/mass properties of the human head

active compliance ~ fast control emulating a spring (or something else)

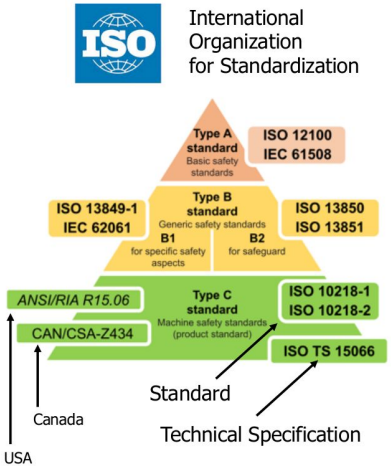
Trade-off between safety and performance

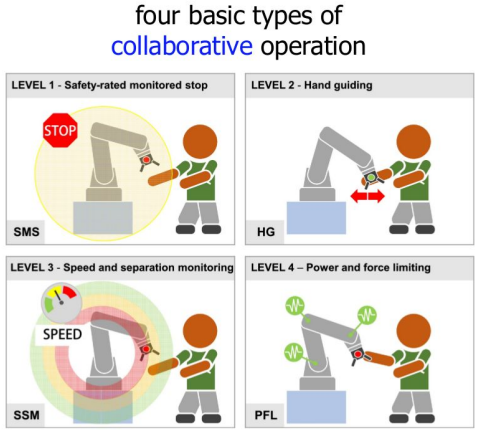
There’s no free lunch…

Perception for interaction

- What would we like to sense and how?
  - forces in interaction
  - human proximity
  - special requirement: 200% reliability

Safety standards in industrial robotics





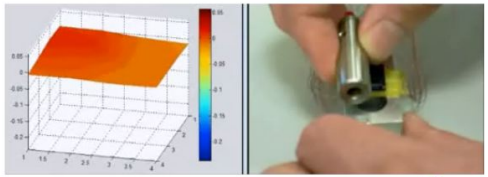
Villani et al.: Mechatronics, 2018

pHRI *36*

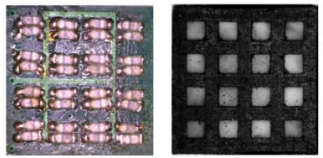
Physical HRI - Lecture slides by Alessandro de Luca
http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf

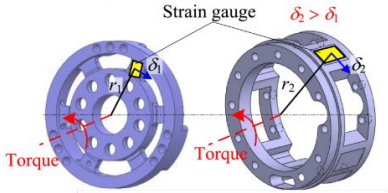
Perception for interaction

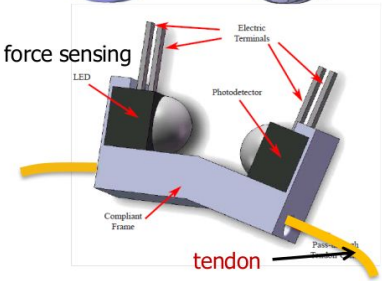
- proprioceptive and contact sensing
  - joint torque and tendon force sensing, stiffness sensing (indirect or by estimation), Force/Torque (F/T) sensors (in fingers and at the tip)
  - tactile sensing for distributed contact measurement



video



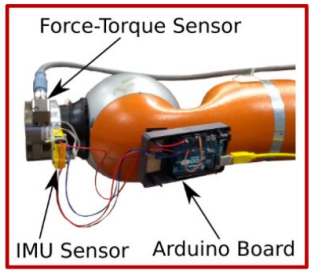


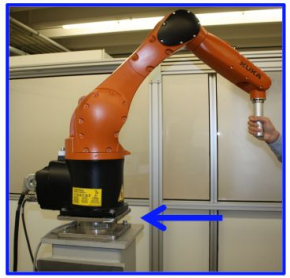


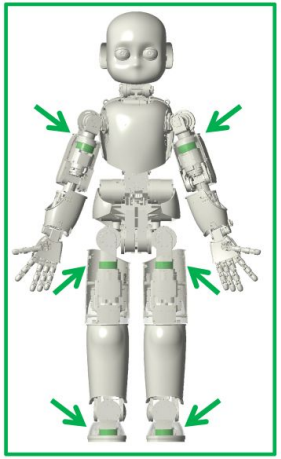
Physical HRI - Lecture slides by Alessandro de Luca
http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf

Perception for interaction

- F/T sensors at the end-effector, link, and/or base levels







pHRI *52*

Physical HRI - Lecture slides by Alessandro de Luca
http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf

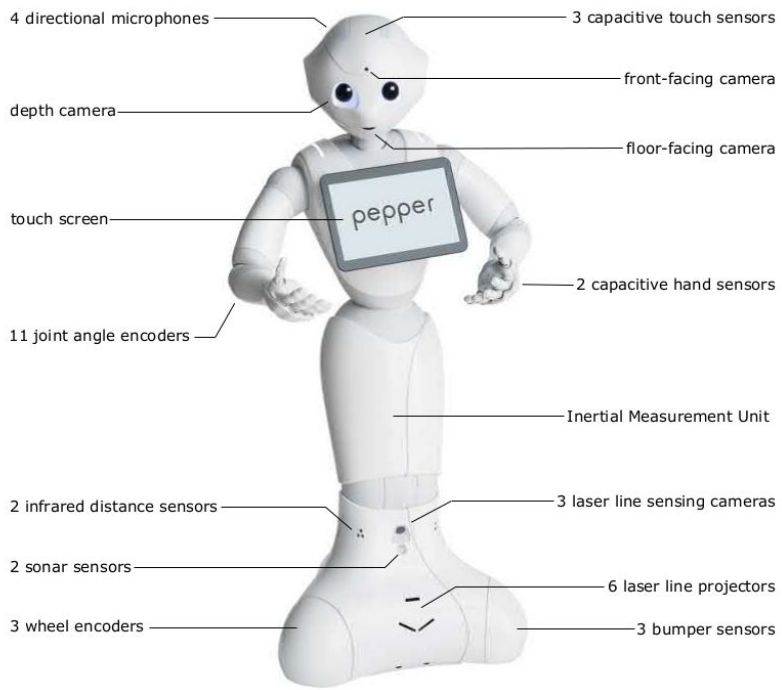
Perception for interaction

- exteroceptive sensing
  - laser scanners, proximity sensors (magnetic, ultrasound, …)
  - cameras (single, stereo, catadioptric, event-based, …), Vicon system



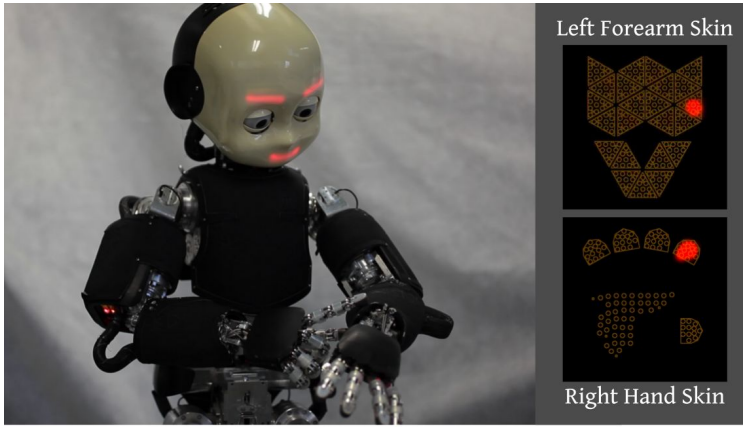



Physical HRI - Lecture slides by Alessandro de Luca
http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf



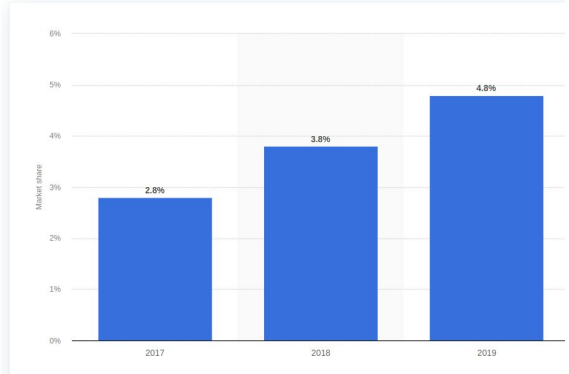
Perception for interaction

Electronic skin

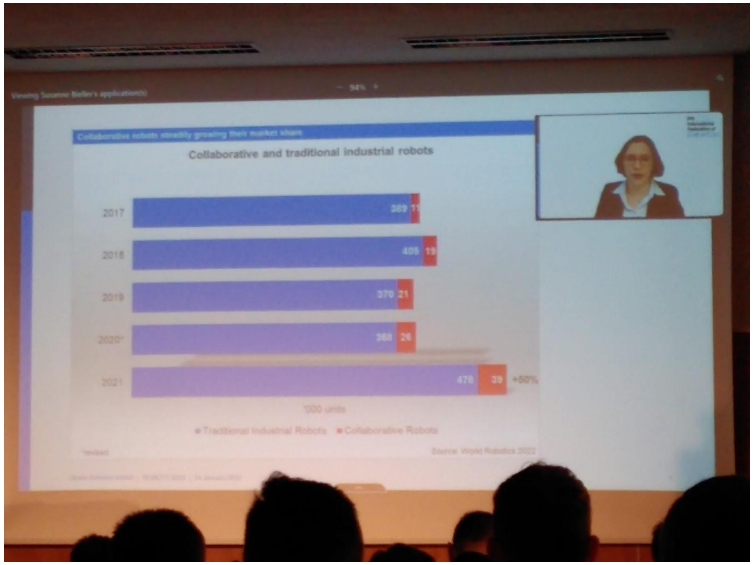


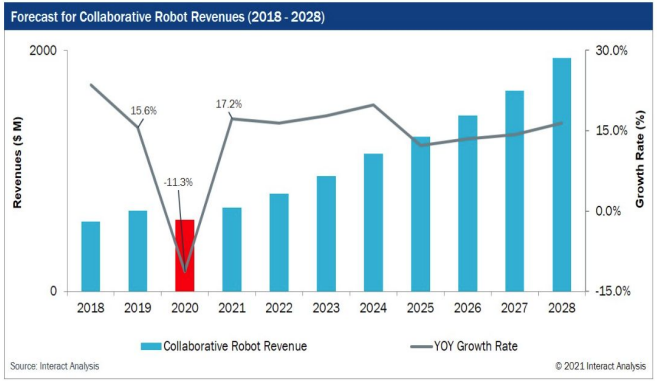
Collaborative robots market

Collaborative robots' share of the global industrial robot market between 2017 and 2019



https://www.statista.com/statistics/897655/cobot-industrial-robot-market-share





Susanne Bieler, International Federation of Robotics: Global robotics market – Status, trends and outlook

Cobots: growing, faster than industrial robots.
Currently 7.5% of all robots.
Technological trends: human-robot collaboration steadily developing.

@ Roboty, Brno, 24.1.2023

Social HRI

- It’s safe. So what is the challenge?
- Design
  - robot
  - interaction
- Useful or fun applications.

Thriving research community

ICSR 2022 – 14th International Conference on Social Robotics

December 13th-16th 2022, Florence, Italy

https://www.icsr2022.it/

HRI 2023 STOCKHOLM, SE

Authors Submission Attending Program About Press

ACM/IEEE International Conference on Human-Robot Interaction

March 13-16, 2023 Stockholm, SE

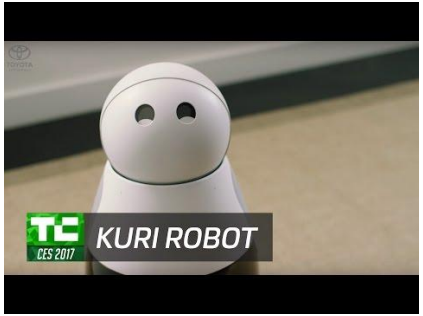
We are excited to announce the 18th Annual ACM/IEEE International Conference on Human Robot Interaction (HRI). HRI 2023 is the 18th annual conference for basic and applied HRI research. Researchers from across the world present their best work to HRI to exchange ideas about the theory, technology, data, and science furthering the state-of-the-art in the field.

https://humanrobotinteraction.org/2023/

Problems with commercial social robots

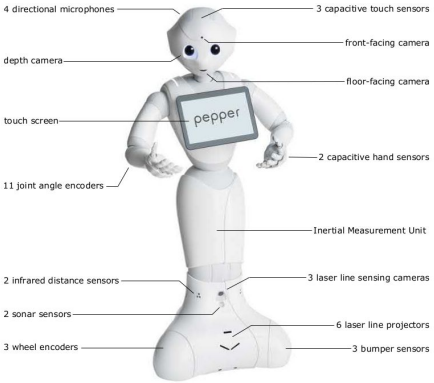
- Sony AIBO
  - 1999-2006 - then discontinued - not commercially successful
  - 2018 new generation relaunched
- Softbank Pepper (20 000 $)
  - Alive, but expectations were probably greater…
- Kuri (700 $)
- Jibo (900 $)
- Anki - Cozmo & Vector

Kuri



https://youtu.be/Gvle_O4vD18

Pepper



Jibo

https://youtu.be/H0h20jRA5M0

Cozmo & Vector

https://youtu.be/gW2fCFSzuIQ

Problems with commercial social robots

Lessons learned (Guy Hoffman)

1. Long-term engagement is the holy grail.
2. We need artists.
3. Embodiment does create emotional bonds.
4. Design matters.

GUEST ARTICLE | ROBOTICS

Anki, Jibo, and Kuri: What We Can Learn from Social Robots That Didn't Make It ›It's been a tough few years for social home robots: Where do we go from here?

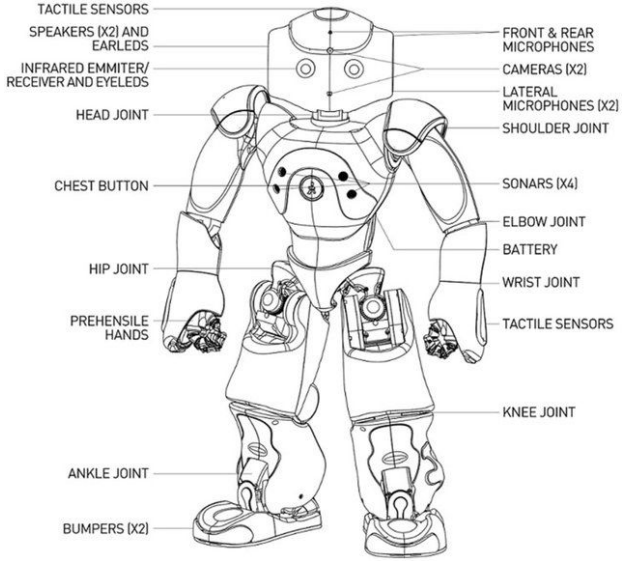
BY GUY HOFFMAN | 01 MAY 2019 | 7 MIN READ |

https://spectrum.ieee.org/anki-jibo-and-kuri-what-we-can-learn-from-social-robotics-failures

vs.

Some success stories - Nao (2008-now)

- 2008, Aldebaran/Softbank
- Price: ~ 10 000 $
- More than 10 000 exemplars sold.
- Currently in V6
- Used as a unified platform for **research**, social HR in particular.
- Used also for robot football - Robocup.
- Allows easy control via Choregraphe.



Some success stories - Kaspar

- Not a commercial success story.
- Social robot for children with autism.

https://youtu.be/D6gTHPoO9VI

Resources

- Books / book sections
  - Bartneck, C., Belpaeme, T., Eyssel, F., Kanda, T., Keijsers, M., & Šabanović, S. (2020). *Human-Robot Interaction: An Introduction*. Cambridge University Press.
  - Haddadin, S., & Croft, E. (2016). Physical human–robot interaction. In *Springer Handbook of Robotics* (pp. 1835-1874). Springer, Cham.
  - Breazeal, C., Dautenhahn, K., & Kanda, T. (2016). Social robotics. *Springer Handbook of Robotics*, 1935-1972.
  - Matarić, M. J., & Scassellati, B. (2016). Socially assistive robotics. *Springer Handbook of Robotics*, 1973-1994.
- Online resources
  - Alessandro de Luca
    - Physical HRI - Lecture slides by Alessandro de Luca: http://www.diag.uniroma1.it/deluca/pHRI.php.
    - Talks on youtube. E.g., https://youtu.be/L_Ql9P2-ybY