

Humanoid robots - Human-robot interaction

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

But there are limits to it....

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

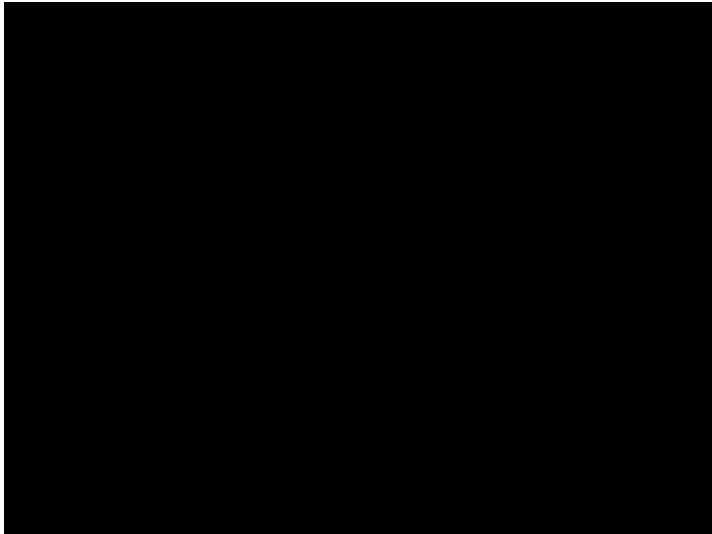


ABB Elektro-Praha, collaborative making of power plugs



<https://youtu.be/nMiE4Xh2CNY>



Paro, therapeutic seal robot,

<https://youtu.be/2ZUn9qtG8ow>

trend

vision!?

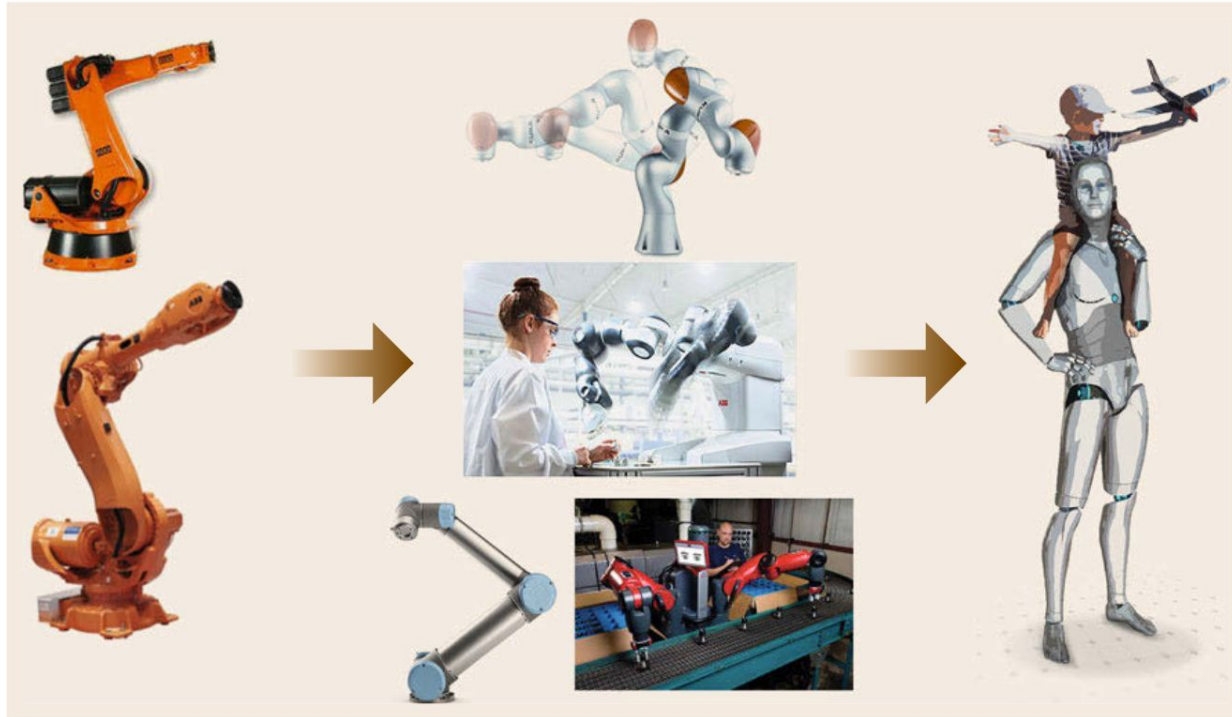


Fig. 69.1 The current paradigm shift in robotics induced by new target domains and robots toward the vision of close human–robot coexistence (courtesy of Keller und Knappich Augsburg (KUKA), Deutsches Zentrum für Luft- und Raumfahrt (DLR), ABB, Rethink Robotics)

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

pHRI



personal robots in service

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Physical HRI - Lecture slides by Alessandro de Luca

http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf

10 years from now?

reality?

20 years from now?

sci-fi?

- 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.

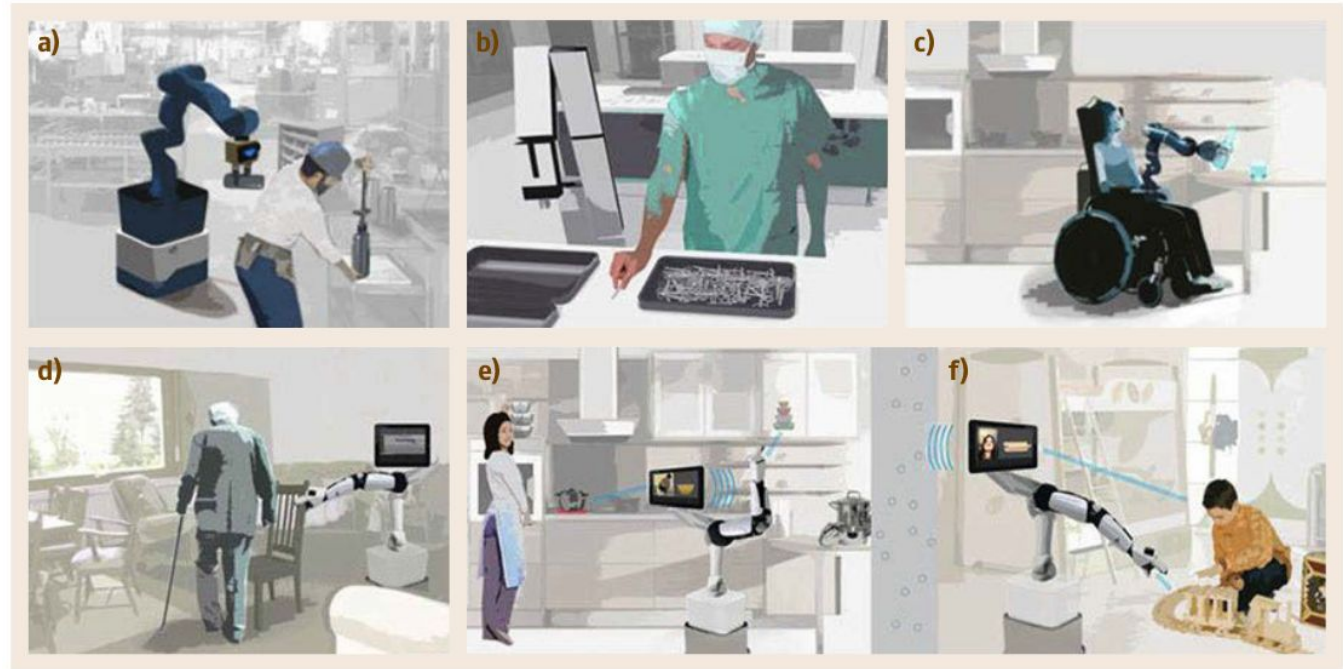


Fig.69.2a–f Application examples for **pHRI**, ranging from shop floor logistics and manipulation (**a,b**), over professional service robots and assistive devices for the disabled (**c,d**), to service robots in domestic applications (**e,f**)

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

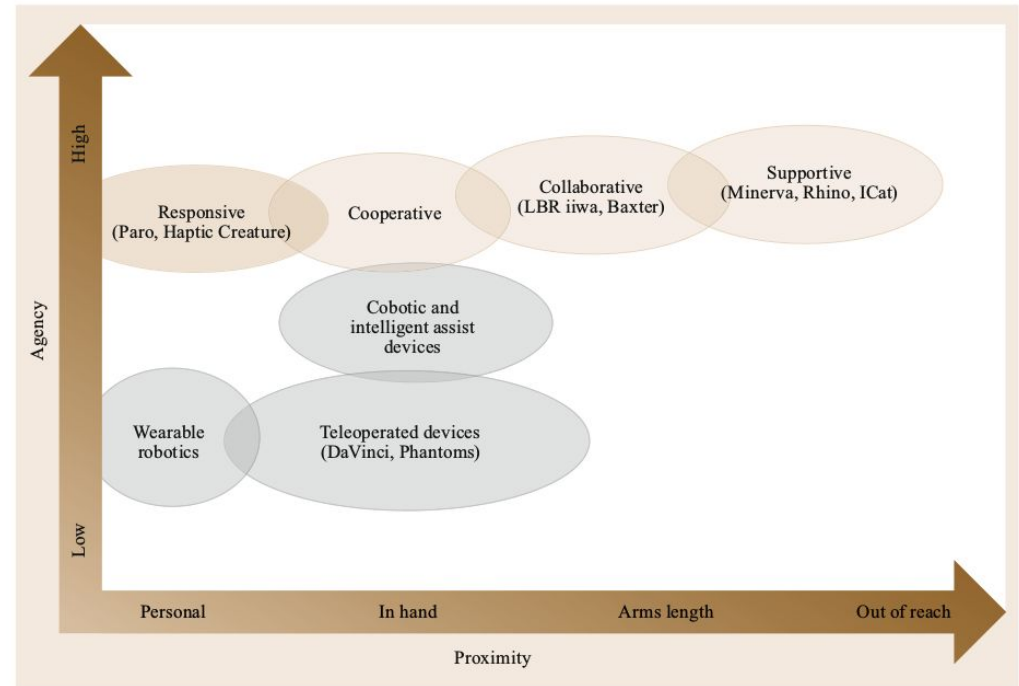


Fig. 69.3 Classification scheme for pHRI, by proximity of the interaction and agency (available autonomy) of the robot

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

Springer Handbook of Robotics

Siciliano
Khatib
Editors

2nd Edition

Kröger
Multimedia Editor

 Springer

Multimedia Contents



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Ed. by Daniela Rus

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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 $\frac{1}{3}$ of the picture...

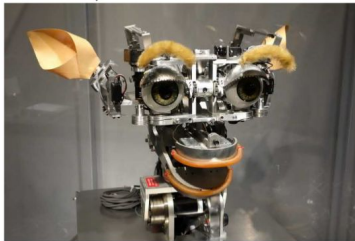
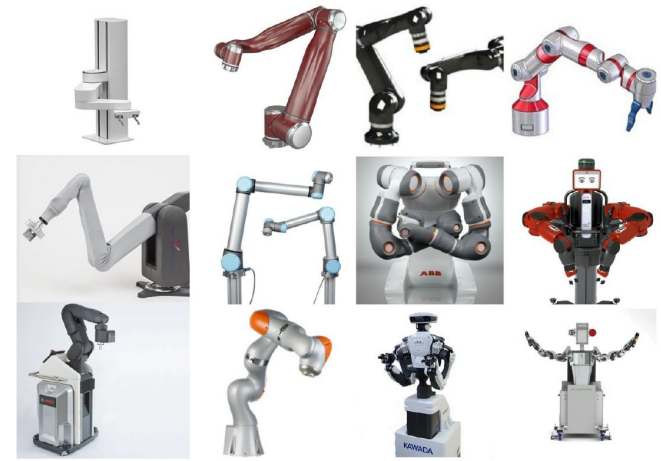


Figure 2.3
Kismet
(1997-2004), an
early example of
social
human-robot
interaction
research from the
Massachusetts
Institute of
Technology.
(Source: Dalerot)



A selection of collaborative robots. Image credit: Robotiq.

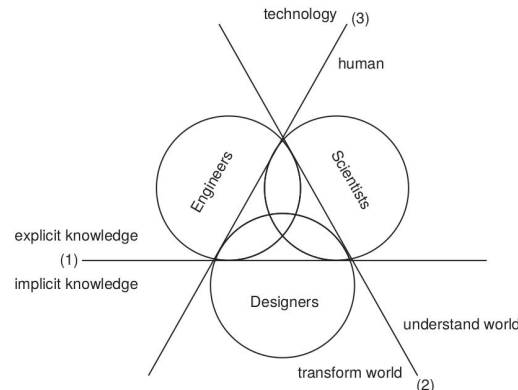
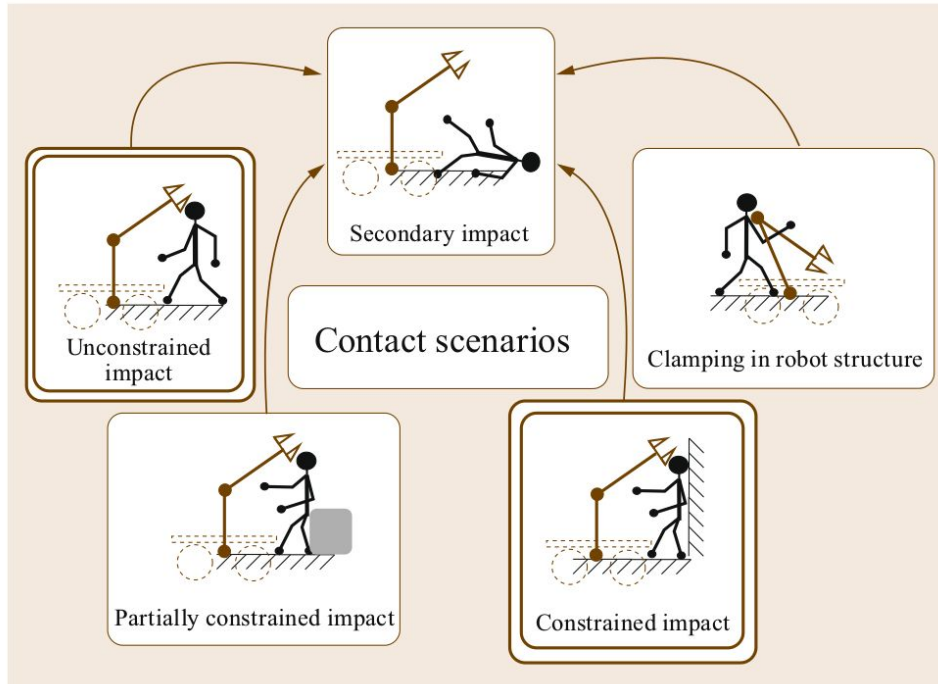


Fig 2.2 in Bartneck, C., Belpaeme, T., Eyssele, F., Kanda, T., Keijsers, M., & Šabanović, S. (2020). *Human-robot interaction: An introduction*. Cambridge University Press.

Human safety



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

S. Haddadin, A. Albu-Schäffer, M. Strohmayer, M. Frommberger, G. Hirzinger: Injury evaluation of human-robot impacts, Proc. IEEE Int. Conf. Robot. Autom. (ICRA), Pasadena (2008), pp. 2203 – 2204; doi: 10.1109/ROBOT.2008.4543534.

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 Actuators (VIA) - stiffness & damping

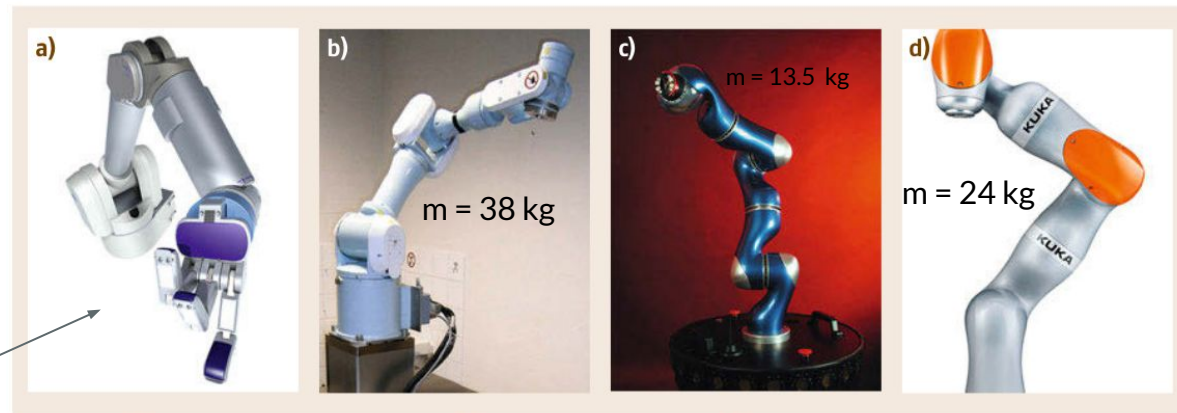


Fig. 69.10 (a) Barrett arm (after [69.58]), (b) Mitsubishi PA10 arm, (c) DLR lightweight robot III (after [69.59]), (d) KUKA LBR iiwa (after [69.60]) (courtesy of Barret Technology Inc., DLR, KUKA)

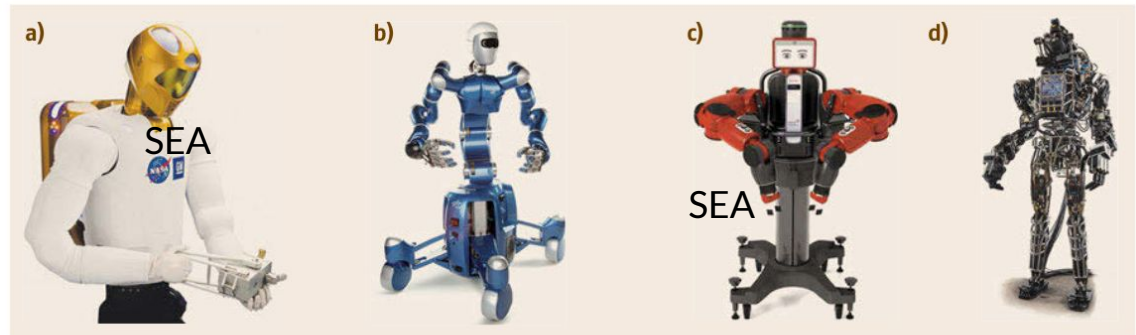


Fig. 69.11 (a) NASA Robonaut 2, (b) DLR Rollin' Justin, (c) Rethink Robotics Baxter and (d) Boston Dynamics Atlas (courtesy of NASA, DLR, Rethink Robotics Inc., Boston Dynamics)

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...

Note: for iCub and Pepper, this is already not fully true...

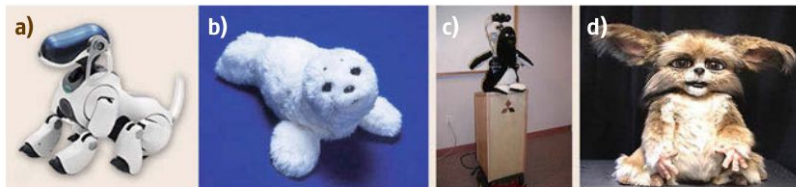


Fig.72.3a-d Examples of social robots inspired by animals with anthropomorphic qualities: (a) AIBO, the robotic dog developed by Sony (after [72.30]), (b) Paro, the therapeutic seal robot developed at AIST (after [72.31]), (c) Mel, the conversational robotic penguin developed at MERL (after [72.32]),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

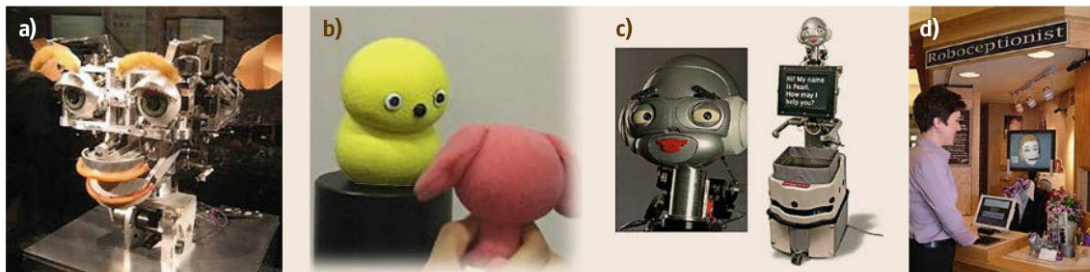
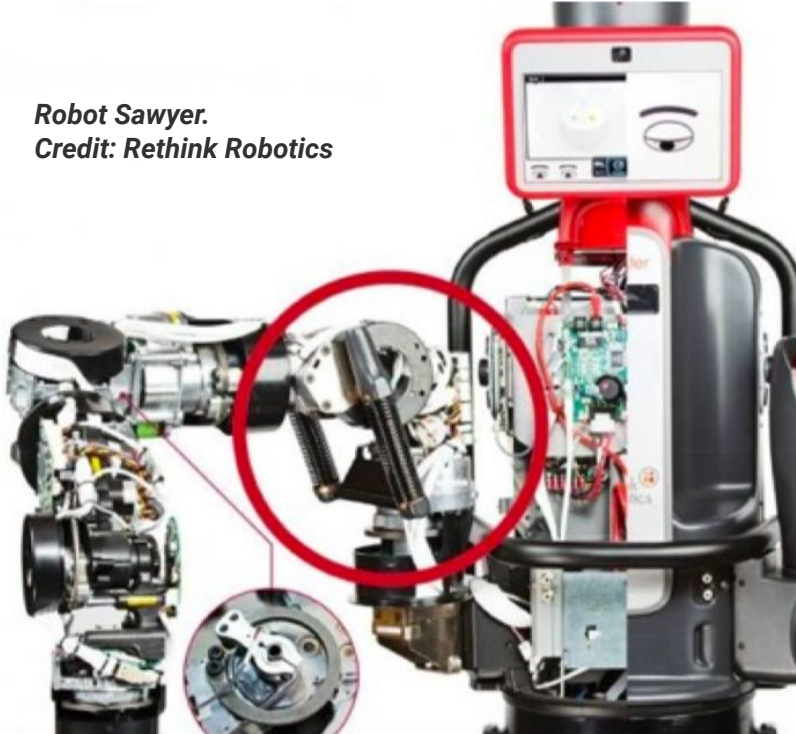


Fig.72.4a-d Examples of social robots that are neither humanoid nor zoomorphic but capture key social attributes: (a) Kismet (after [72.3]); (b) Keepon (after [72.34]); (c) Pearl (after [72.35]); (d) Valerie (after [72.36])

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.

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

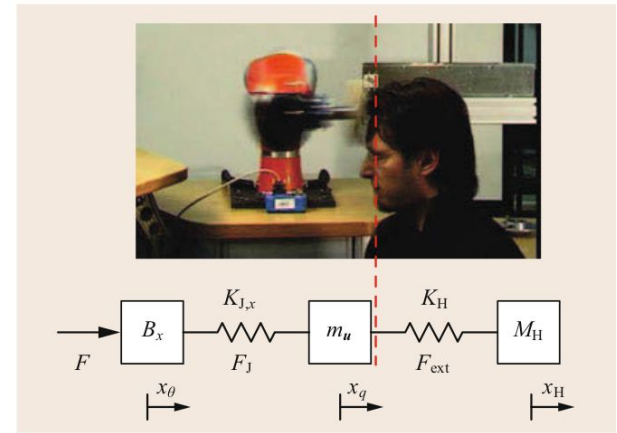
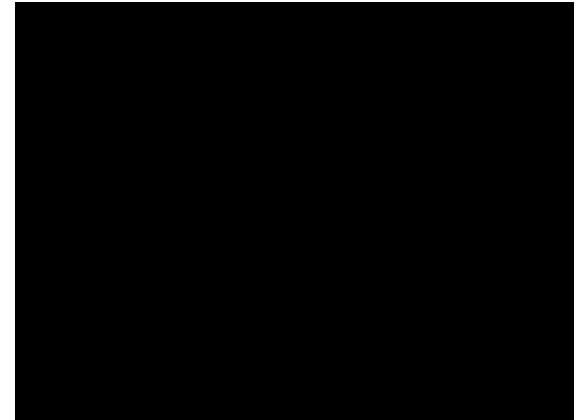


Fig. 69.12 Human–robot collision in operational space, which is defined by the reflected flexible dynamics of the robot and the local contact stiffness/mass properties of the human head



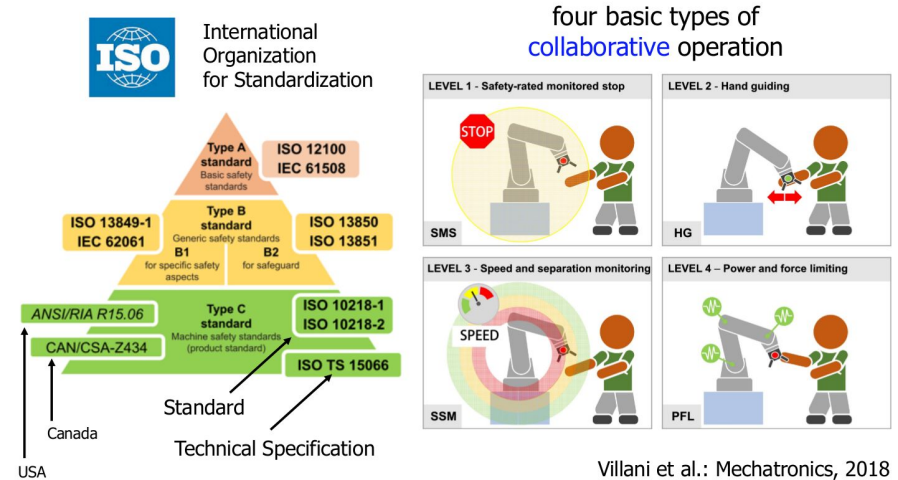
Trade-off between safety and performance

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



pHRI

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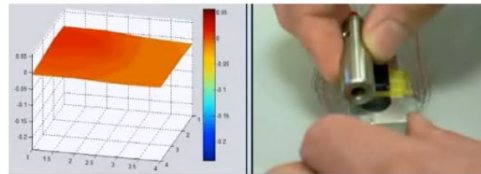
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http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf

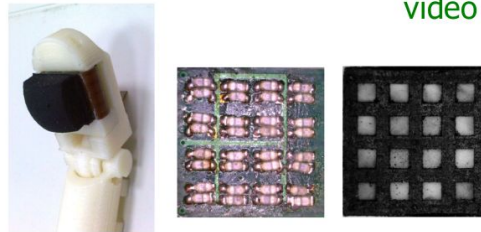


Perception for interaction

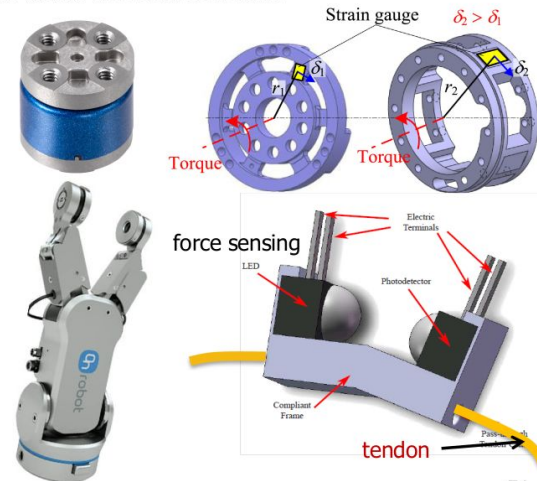
- proprioceptive and contact sensing
 - joint torque and tendon force sensing, stiffness sensing (indirect or by estimation), Force/Torque (F/T) sensors (in fingers and at the tip)
 - tactile sensing for distributed contact measurement



video



pHRI



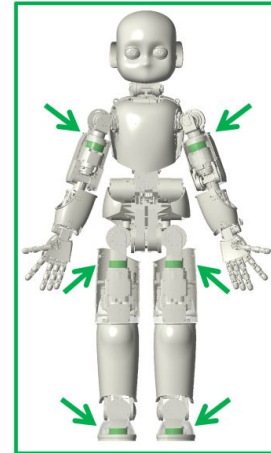
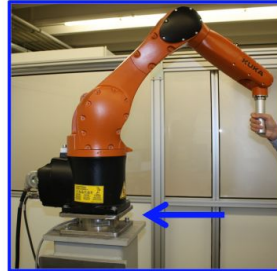
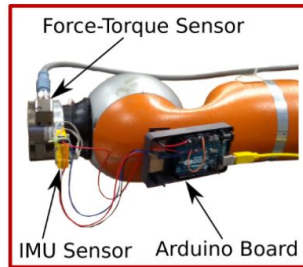
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http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf



Perception for interaction

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



pHRI

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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

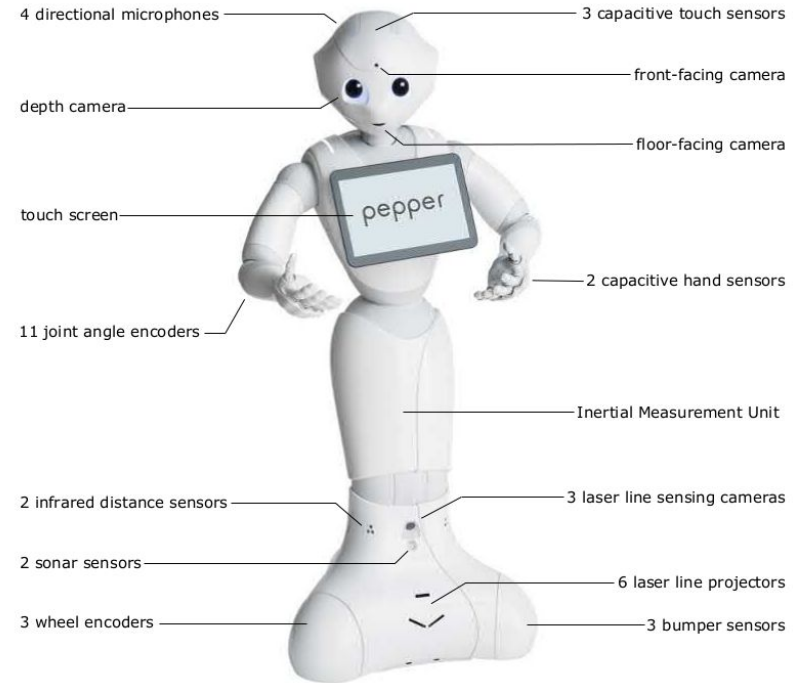


pHRI

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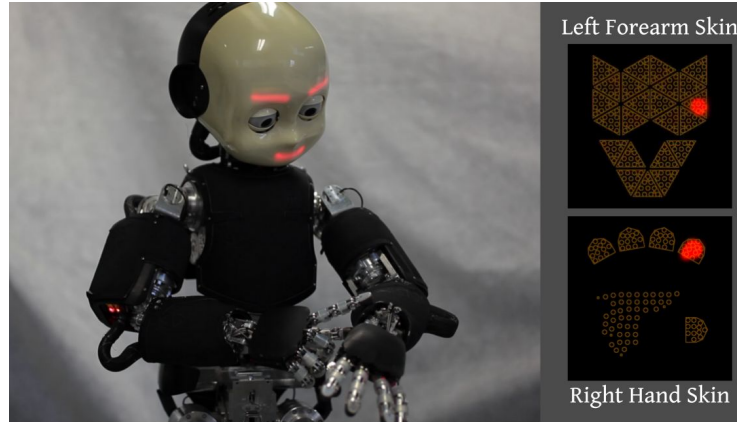
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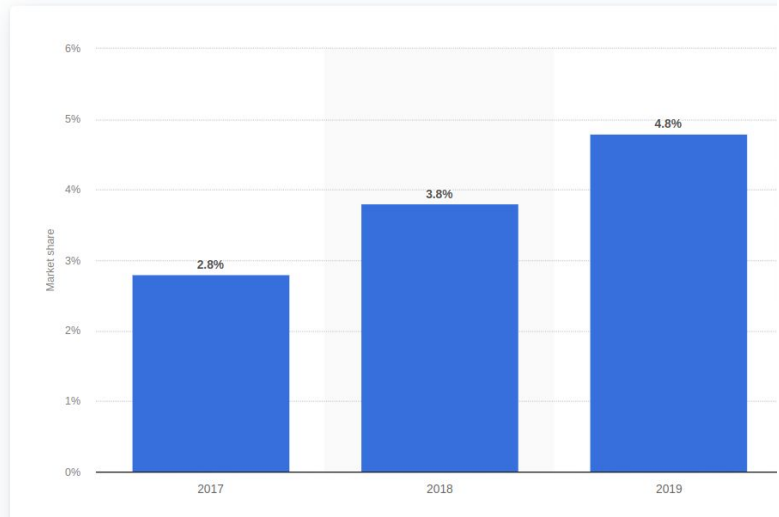
Perception for interaction

Electronic skin

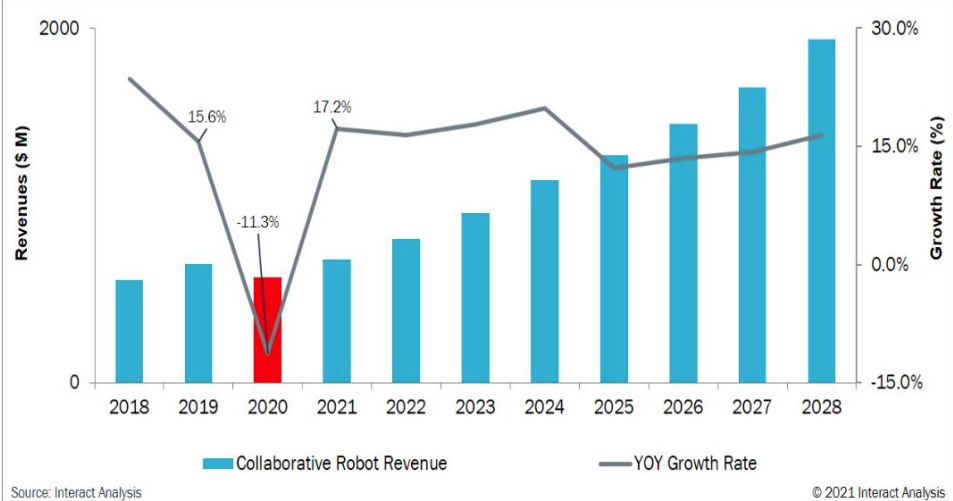


Collaborative robots market

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



Forecast for Collaborative Robot Revenues (2018 - 2028)

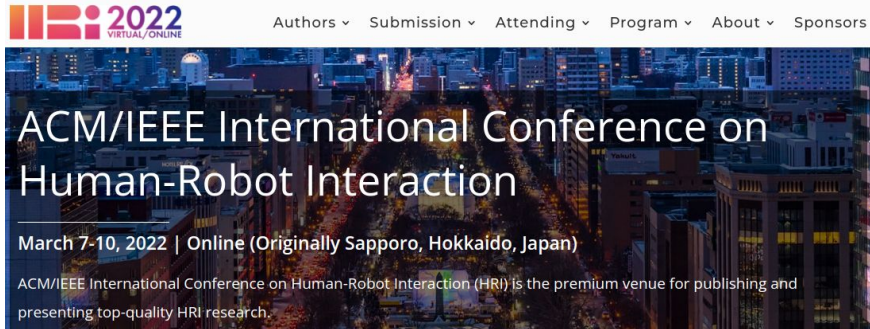


<https://www.statista.com/statistics/897655/cobot-industrial-robot-market-share>

Social HRI

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

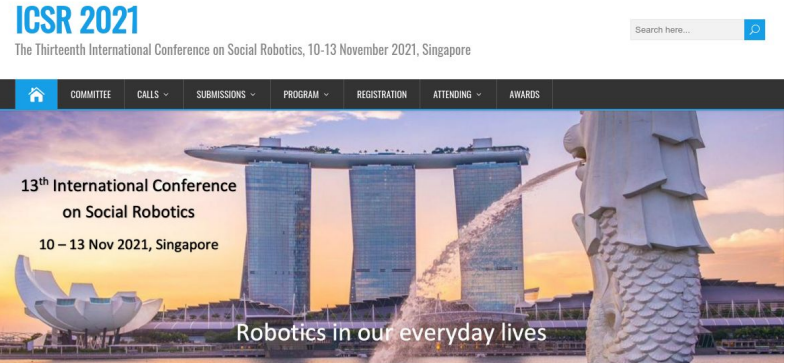
Thriving research community



ACM/IEEE International Conference on Human-Robot Interaction
March 7-10, 2022 | Online (Originally Sapporo, Hokkaido, Japan)

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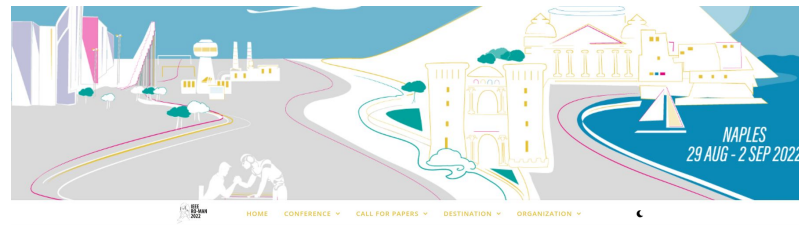
ICSR 2021
The Thirteenth International Conference on Social Robotics, 10-13 November 2021, Singapore

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13th International Conference on Social Robotics
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Robotics in our everyday lives



NAPLES
29 AUG - 2 SEP 2022

HOME CONFERENCE ▾ CALL FOR PAPERS ▾ DESTINATION ▾ ORGANIZATION ▾



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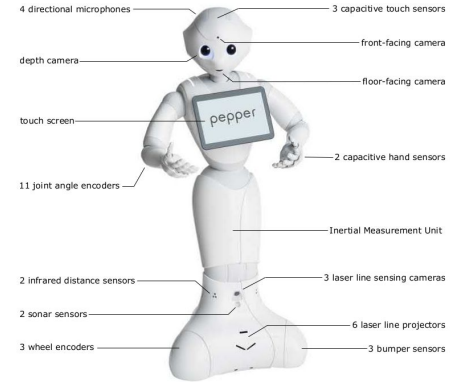
31st IEEE International Conference on Robot & Human Interactive Communication

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...
- Jibo (900 \$)
- Kuri (700 \$)
- Anki - Cozmo & Vector



https://youtu.be/Gvle_O4vD18



<https://youtu.be/H0h20jRA5M0>



<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

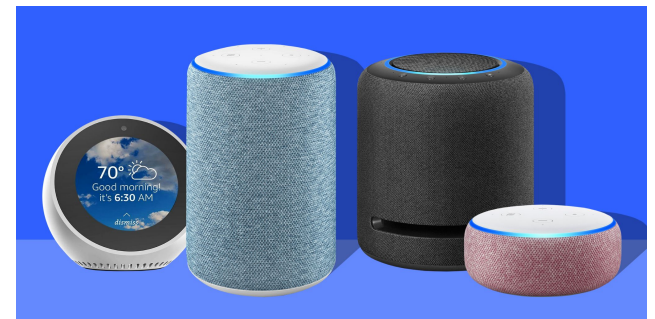
Anki, Jibo, and Kuri: What We Can Learn from Social Robots That Didn't Make It

> 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 | □

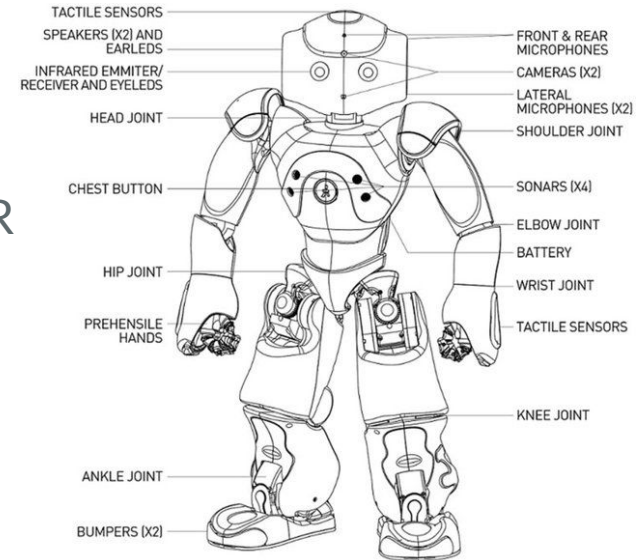
<https://spectrum.ieee.org/anki-jibo-and-kuri-what-we-can-learn-from-social-robotics-failures>

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_QI9P2-ybY