

# 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](https://youtu.be/ssZ_8cqfBIE)

# Same thing in local context

New robotic warehouse @Alzacz in Chrášťany near Prague:

- 410 robots
- 297000 boxes
- 8800 m<sup>2</sup> 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. \$)

← Tweet



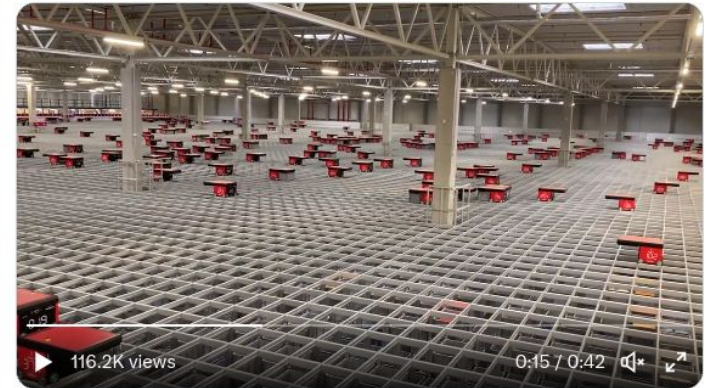
**Martin Tyburec**  
@MartinTyburec

...

Nový robotický sklad @Alzacz v Chrášťanech u Prahy:

410 robotů  
297000 beden  
8800 m<sup>2</sup> plochy  
Dokáže uskladnit až 12 000 m<sup>3</sup> zboží  
Až 7x vyšší hustota zboží než běžný sklad  
Rychlost vyskladnění je 4x větší.  
Náklady cca 1 mld.

Repo večer v @televizeznam



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

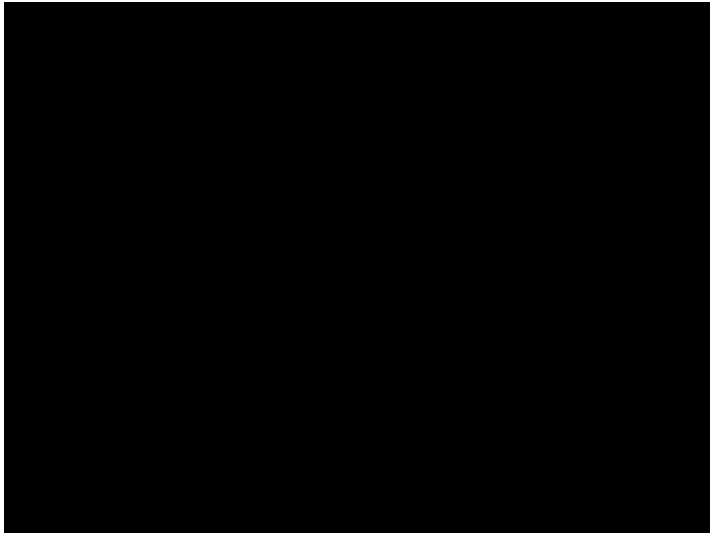


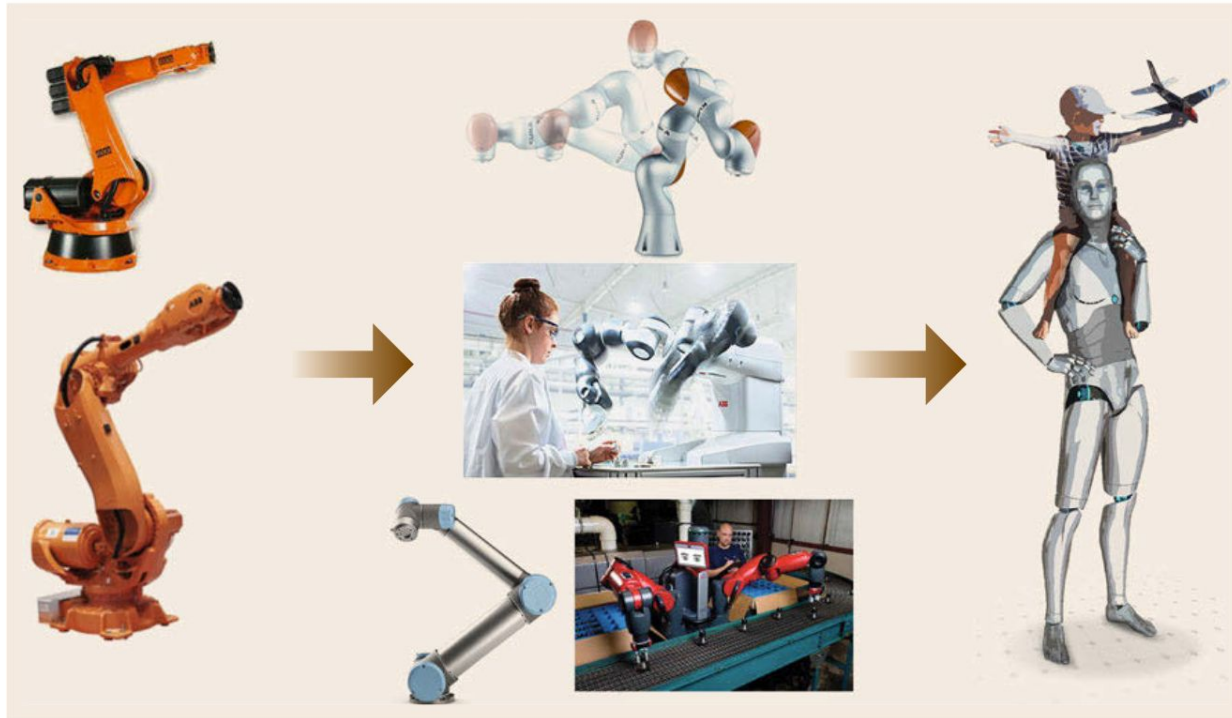
ABB Elektro-Praha, collaborative making of power plugs



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

*pHRI*



personal robots in service

*11*

Physical HRI - Lecture slides by Alessandro de Luca

[http://www.diag.uniroma1.it/deluca/pHRI\\_elective/pHRI\\_Introduction.pdf](http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf)

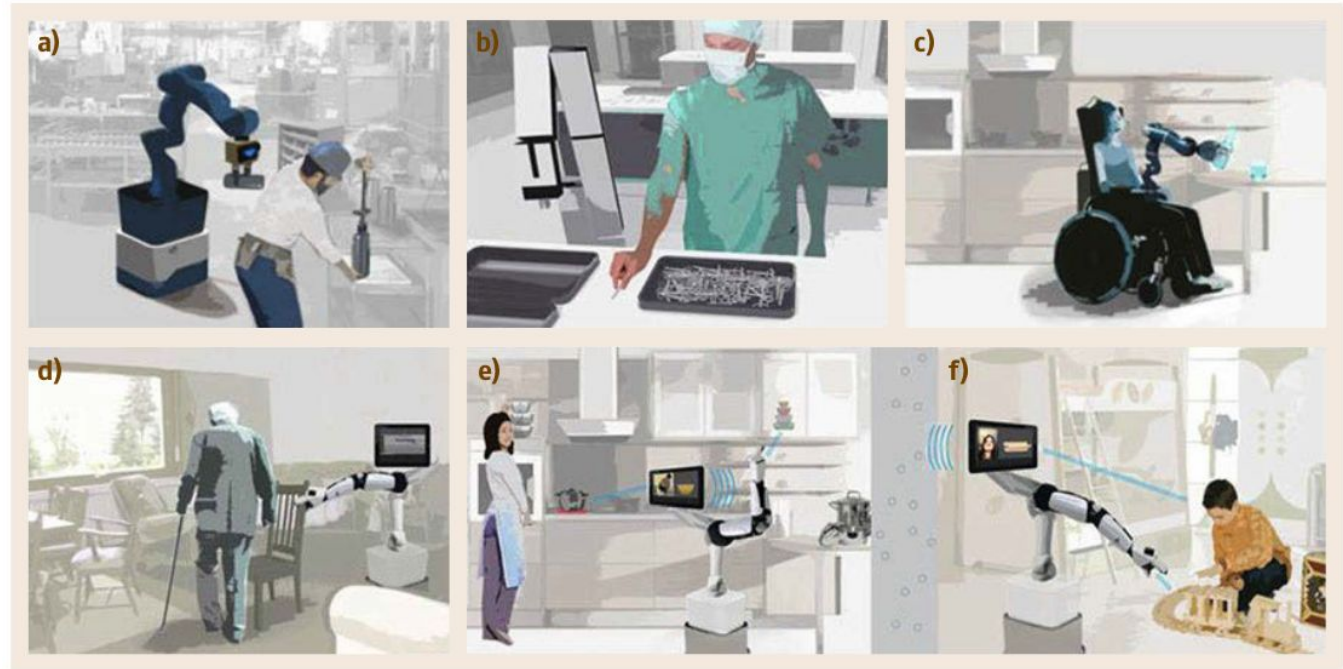
10 years from now?

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

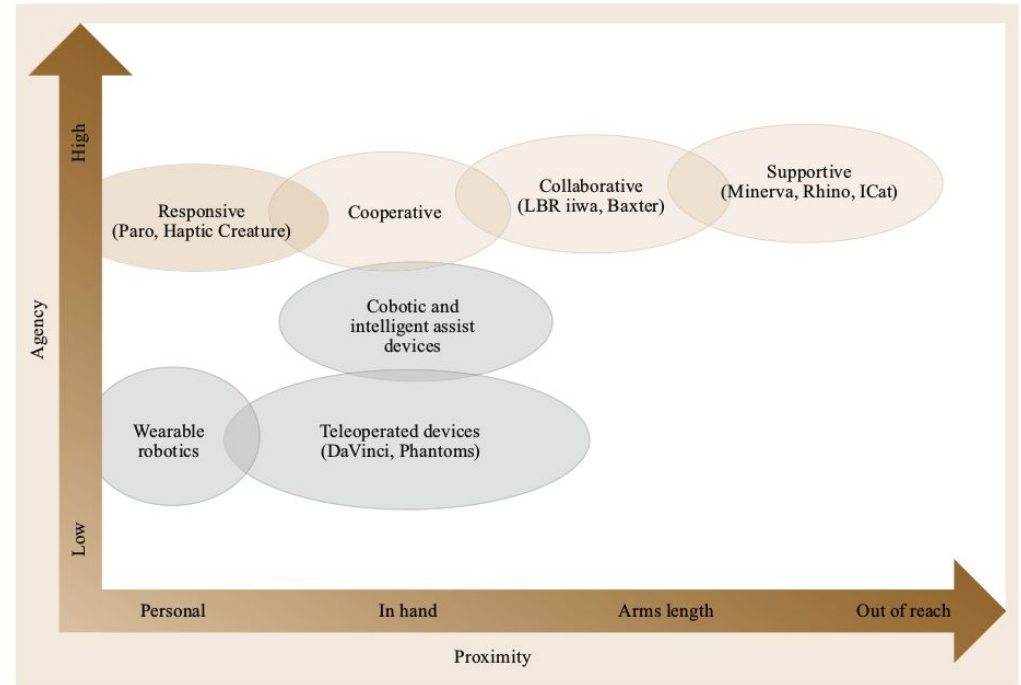


Fig. 69.3 Classification scheme for pHRI, by proximity of the interaction and agency (available autonomy) of the robot

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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George Bekey, Arroyo Grande, USA

# 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...

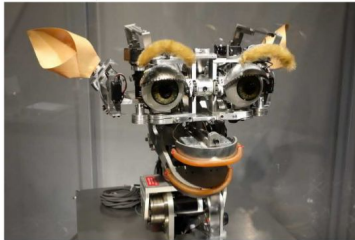
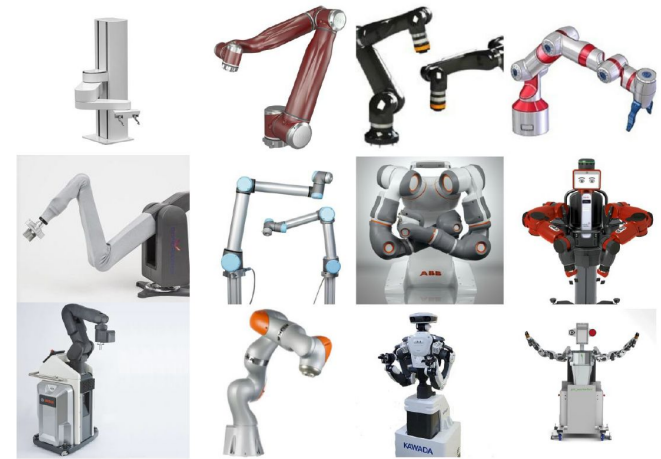


Figure 2.3  
Kismet  
(1997-2004), an  
early example of  
social  
human-robot  
interaction  
research from the  
Massachusetts  
Institute of  
Technology.  
(Source: Dalerot)



A selection of collaborative robots. Image credit: Robotiq.

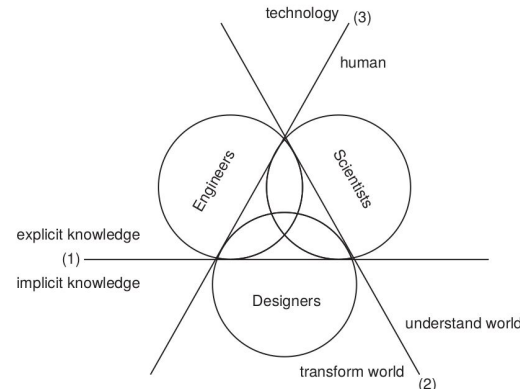
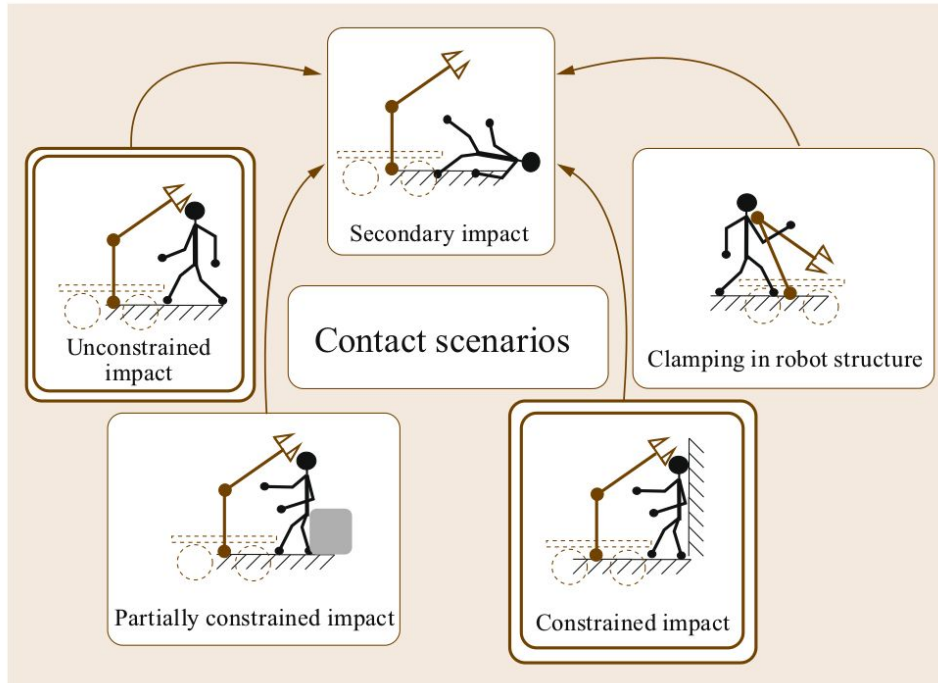


Fig 2.2 in Bartneck, C., Belpaeme, T., Eyssele, F., Kanda, T., Keijsers, M., & Šabanović, S. (2020). *Human-robot interaction: An introduction*. Cambridge University Press.

# Human safety



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

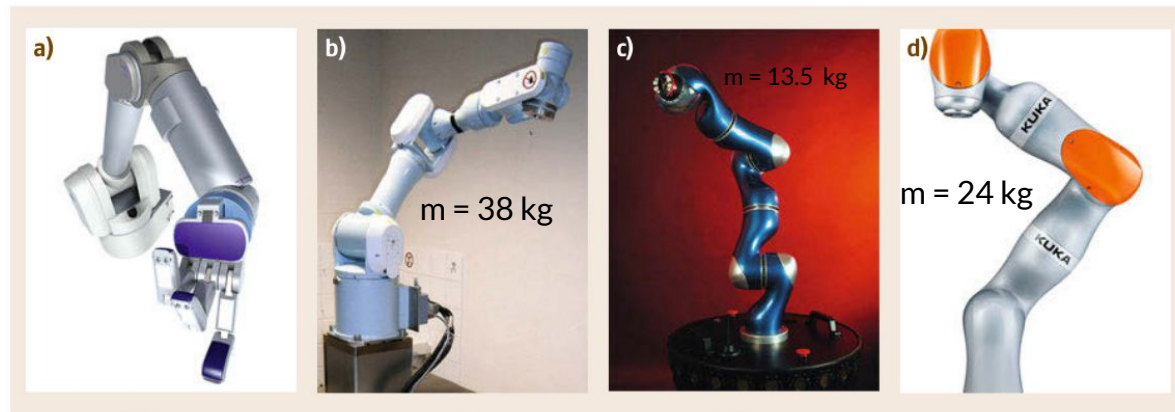
S. Haddadin, A. Albu-Schäffer, M. Strohmayer, M. Frommberger, G. Hirzinger: Injury evaluation of human-robot impacts, Proc. IEEE Int. Conf. Robot. Autom. (ICRA), Pasadena (2008), pp. 2203 – 2204; doi: 10.1109/ROBOT.2008.4543534.

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

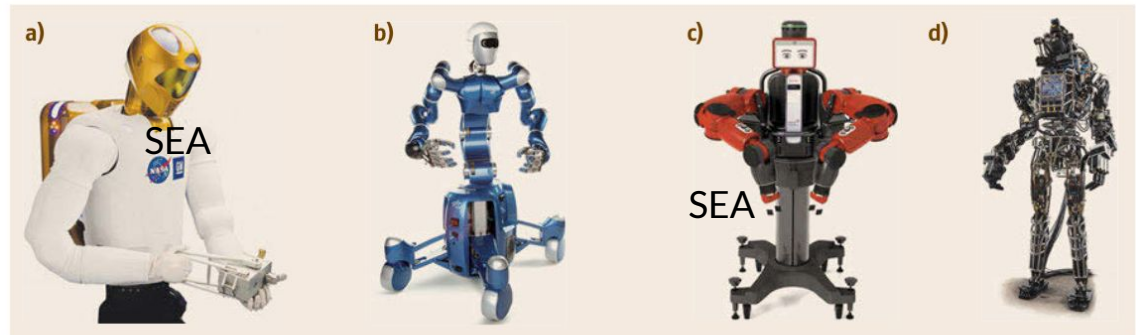
Haddadin, S., & Croft, E. (2016). Physical human–robot interaction. In *Springer handbook of robotics* (pp. 1835-1874). Springer, Cham.

# 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)



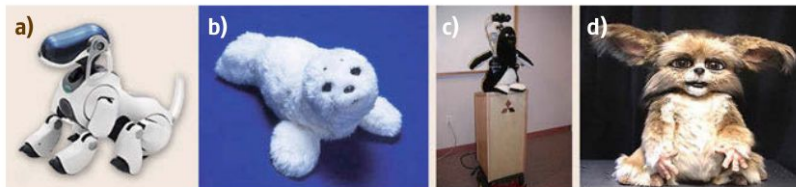
**Fig. 69.11** (a) NASA Robonaut 2, (b) DLR Rollin' Justin, (c) Rethink Robotics Baxter and (d) Boston Dynamics Atlas (courtesy of NASA, DLR, Rethink Robotics Inc., Boston Dynamics)

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

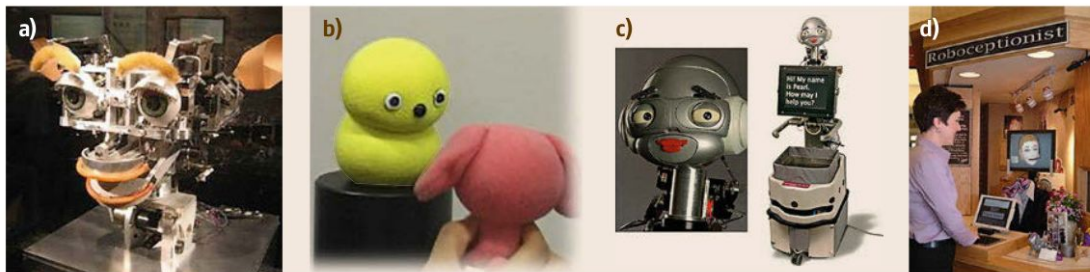
# Safe design for social HRI

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

Note: for iCub and Pepper, this is already not 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])

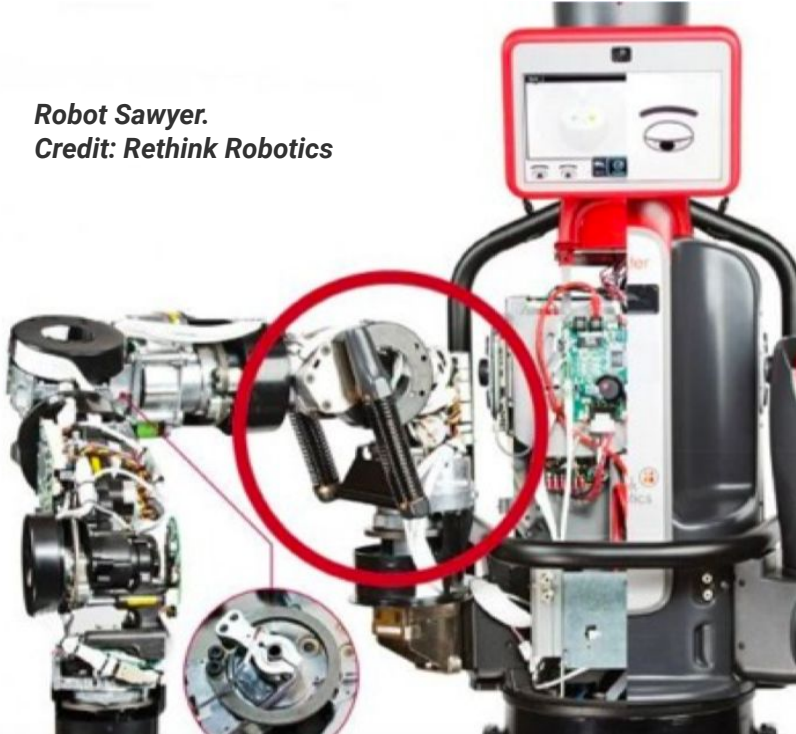


**Fig.72.4a-d** Examples of social robots that are neither humanoid nor zoomorphic but capture key social attributes: (a) Kismet (after [72.3]); (b) Keepon (after [72.34]); (c) Pearl (after [72.35]); (d) Valerie (after [72.36])

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

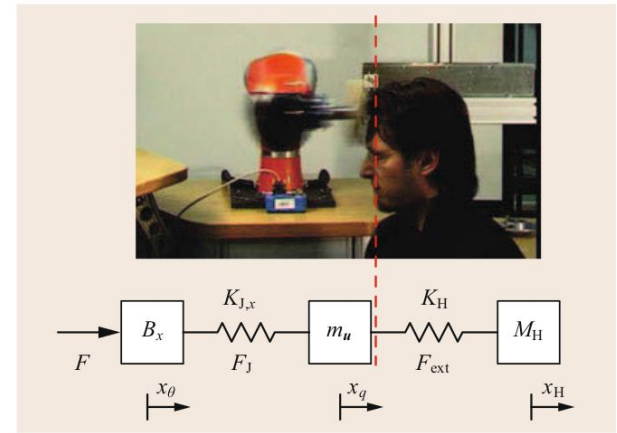
# Compliant collision

Robot Sawyer.  
Credit: Rethink Robotics

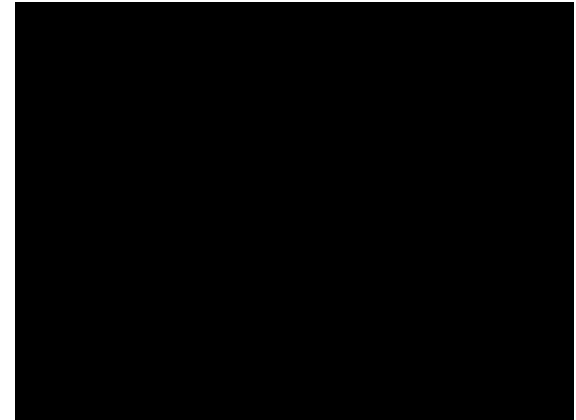


passive compliance ~ spring.

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



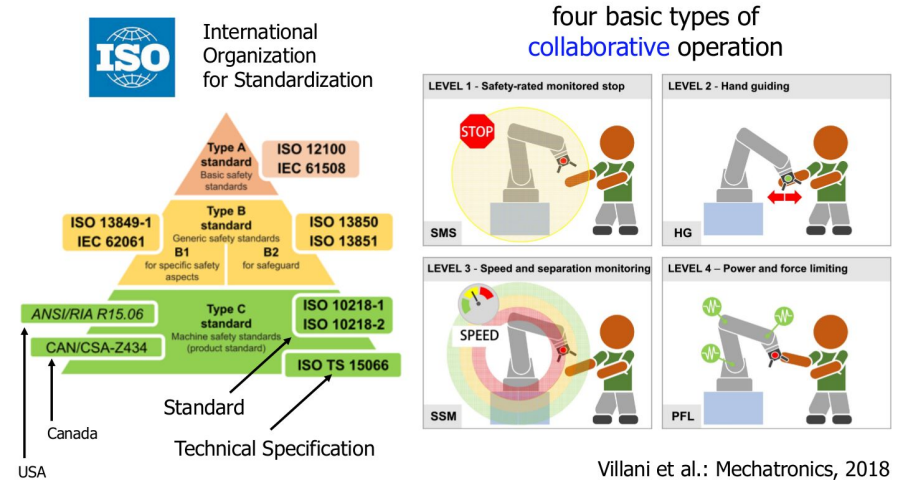
# Trade-off between safety and performance

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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Physical HRI - Lecture slides by Alessandro de Luca

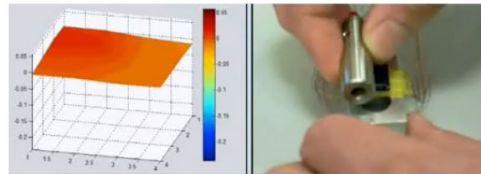
[http://www.diag.uniroma1.it/deluca/pHRI\\_elective/pHRI\\_Introduction.pdf](http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf)



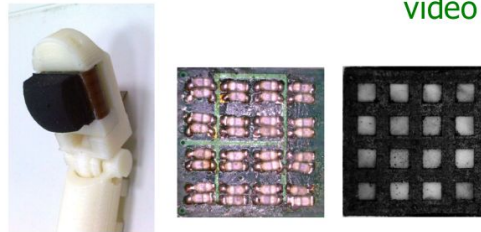


# Perception for interaction

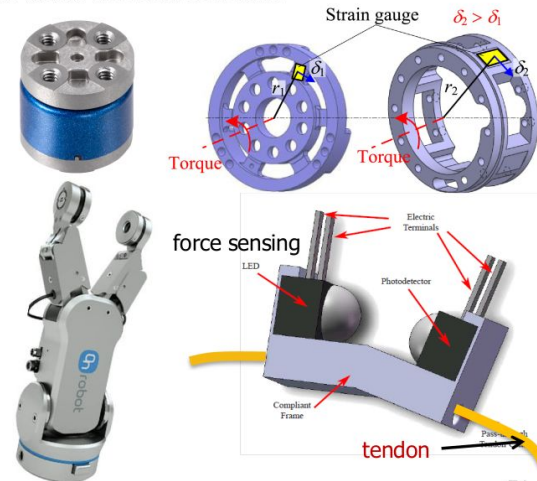
- proprioceptive and contact sensing
  - joint torque and tendon force sensing, stiffness sensing (indirect or by estimation), Force/Torque (F/T) sensors (in fingers and at the tip)
  - tactile sensing for distributed contact measurement



video



pHRI



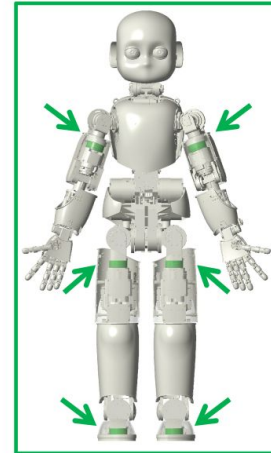
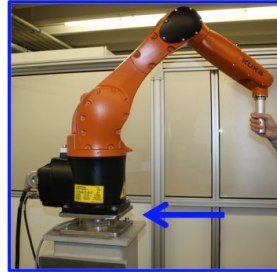
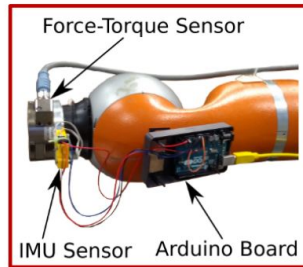
Physical HRI - Lecture slides by Alessandro de Luca

[http://www.diag.uniroma1.it/deluca/pHRI\\_elective/pHRI\\_Introduction.pdf](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](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

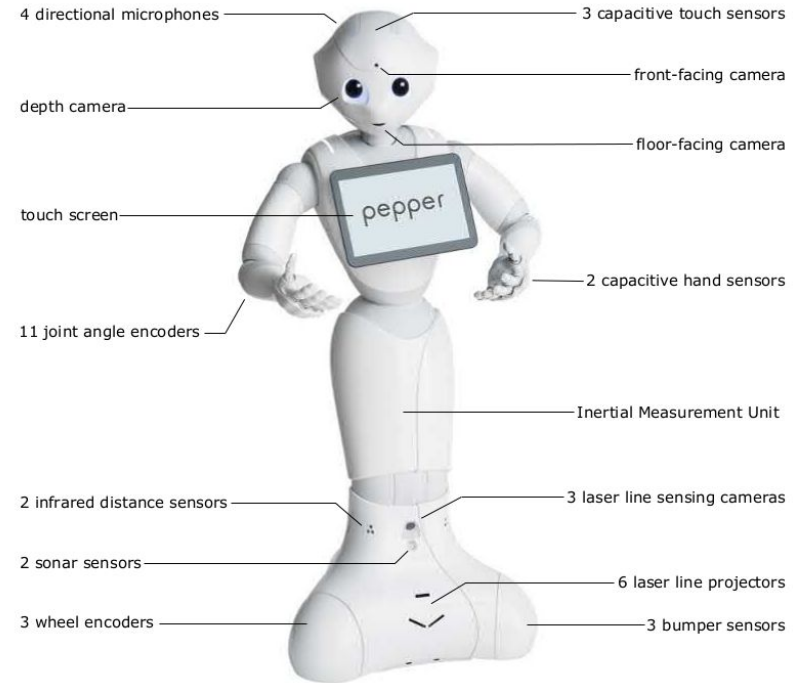


pHRI

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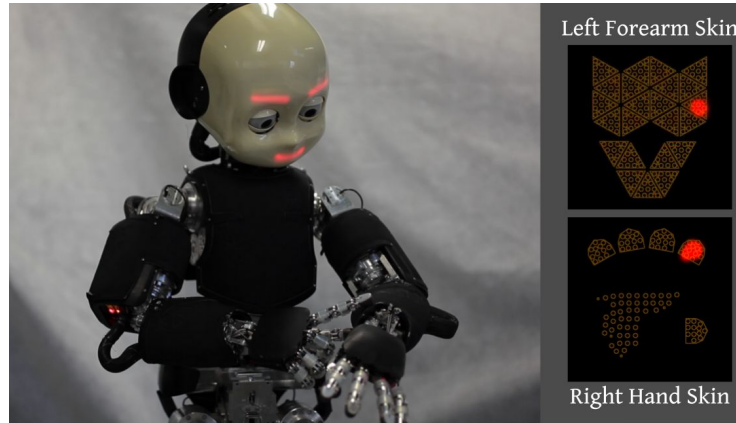
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[http://www.diag.uniroma1.it/deluca/pHRI\\_elective/pHRI\\_Introduction.pdf](http://www.diag.uniroma1.it/deluca/pHRI_elective/pHRI_Introduction.pdf)



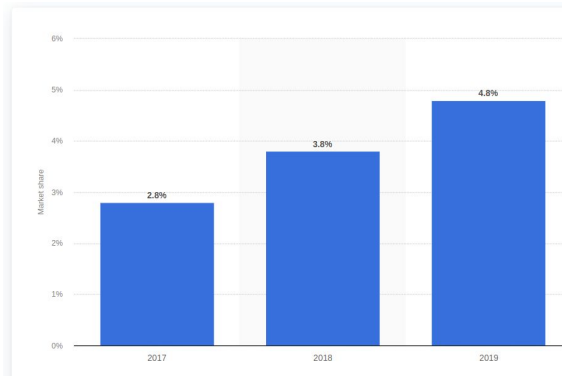
# Perception for interaction

## Electronic skin

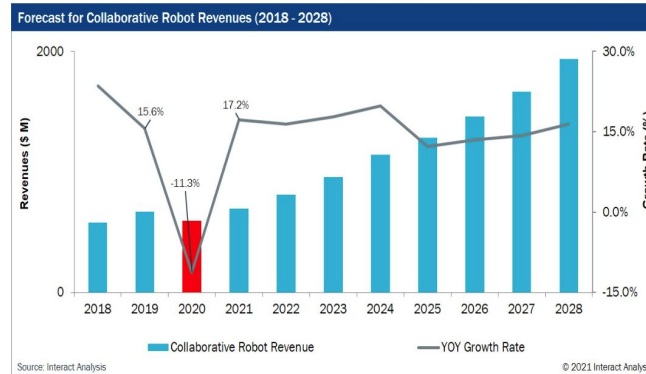
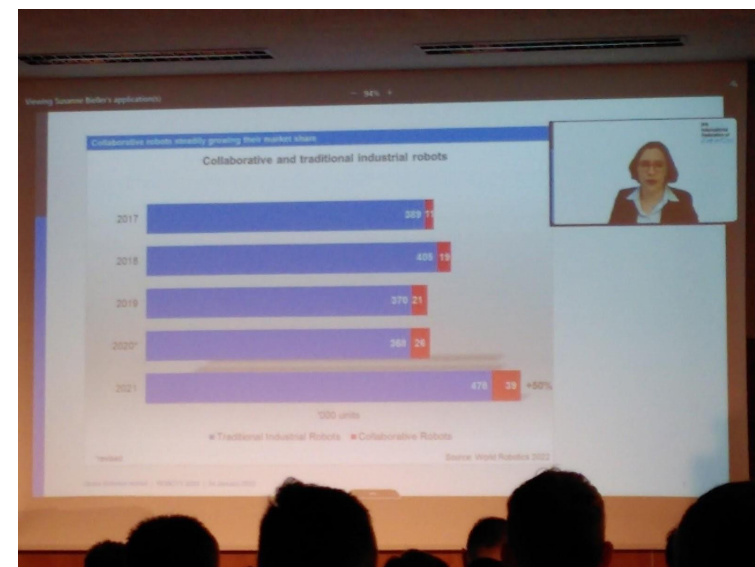


# Collaborative robots market

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



WELCOME TO  
IEEE RO-MAN 2022

31st IEEE International Conference on Robot & Human Interactive Communication



<https://www.icsr2022.it/>



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## ACM/IEEE International Conference on Human-Robot Interaction

March 13-16, 2023 Stockholm, SE

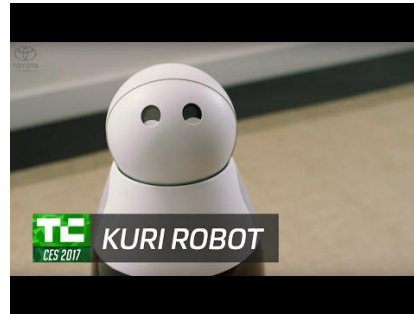


We are excited to announce the 18th Annual ACM/IEEE International Conference on Human Robot Interaction (HRI). HRI 2023 is the 18th annual conference for basic and applied HRI research. Researchers from across the world present their best work to HRI to exchange ideas about the theory, technology, data,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

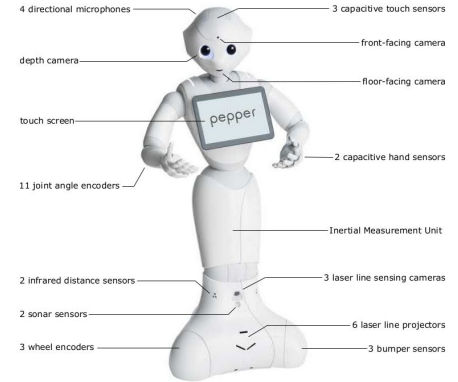
[https://humanrobotinter  
action.org/2023/](https://humanrobotinteraction.org/2023/)

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



[https://youtu.be/Gvle\\_O4vD18](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.



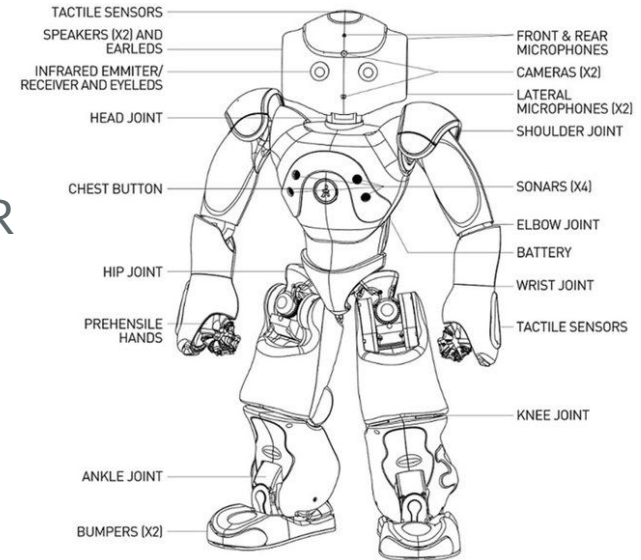
<https://spectrum.ieee.org/anki-jibo-and-kuri-what-we-can-learn-from-social-robotics-failures>

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](https://youtu.be/L_QI9P2-ybY)