Lecture 00: Course Introduction

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Department of Computer Science
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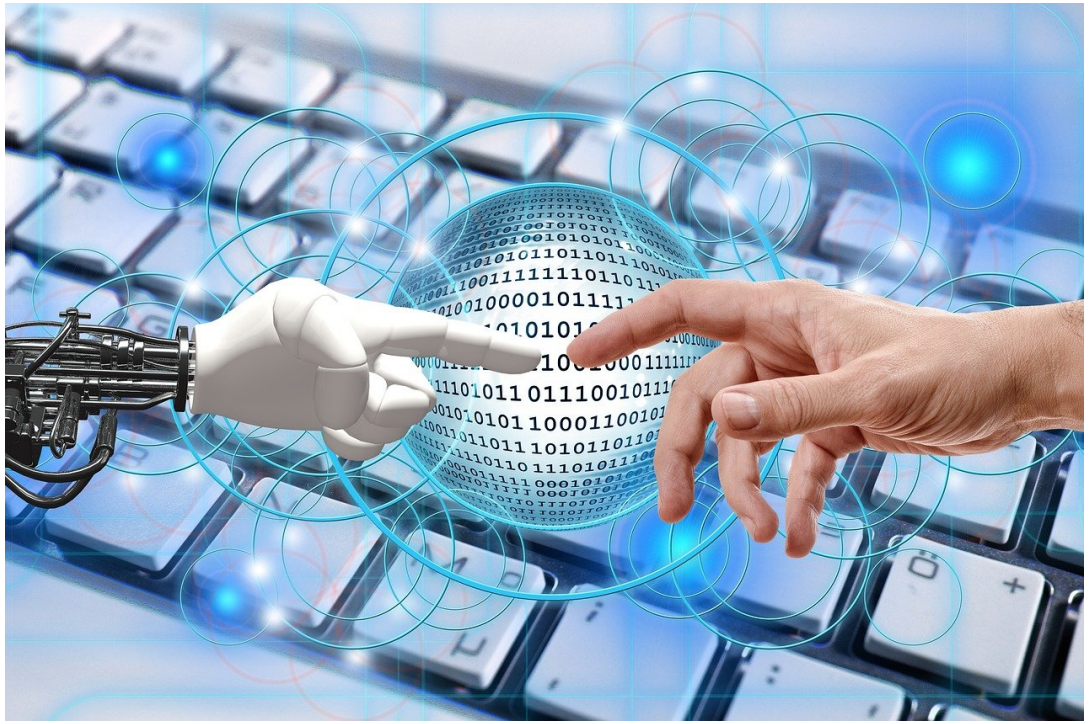
11th April 2024



Course Overview

- Lectures, tutorials, homework, reading assignment, examination
  - Check LEA for latest update
- Communication/Discussion platform: LEA forum
  - If you like, you can also set up a discord server.
- Be proactive! Contact Ritwik or me in case of questions or issues.
- Plagiarism is not acceptable:
  - Some guidelines: https://www.ox.ac.uk/students/academic/guidance/skills/plagiarism

Exam Booklets of Your Own!

- Create your own ONE A4 PAGE long hand-written notes summarizing the lecture.
  - E.g. in the form of a doodle, bulleted list, etc.
- Use ONLY the given template.

- Upload it as .pdf (photo or scan) in the „Individual-Exam-Booklet“ section in LEA.
  - Naming convention: HCIR_EB_Lxx_FirstnameLastname.jpg

- Only ONE A4 PAGE is permitted. If more pages are uploaded, only the first page will be considered.

- We will combine your notes into one PDF file at the end and make it available to you as a handout for your written exam. So, please write legibly and concisely.

Lecture 01: Introduction

Prof. Dr. Teena Hassan
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Department of Computer Science
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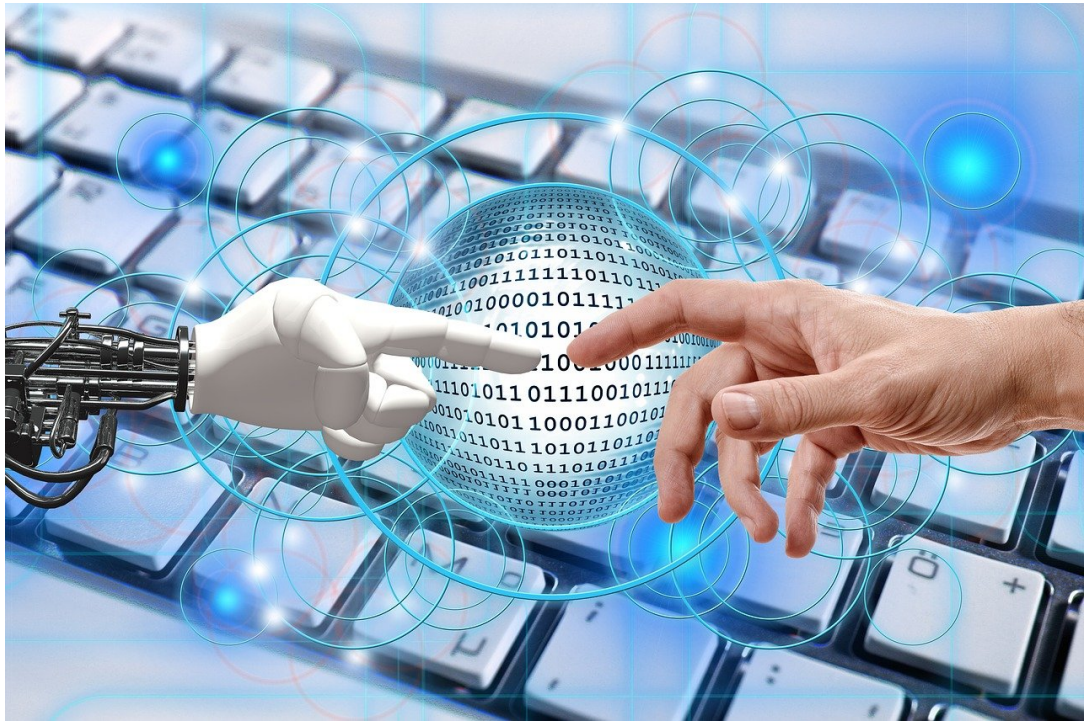
5th October 2023



Who Are We?

- What do you want to know about me and your tutor Ritwik Sinha?

About You…

- Three questions:
  1. Why do you find human-robot interaction interesting?
  2. Do you have prior experience in human-robot / human-computer interaction? If yes, describe.
  3. What do you expect to receive from this course?

Instructions:

- Three minutes to answer these questions.
- Discuss with your neighbour for another 3 minutes.
- Introduce your neighbour (Any volunteers?)

Learning Goal

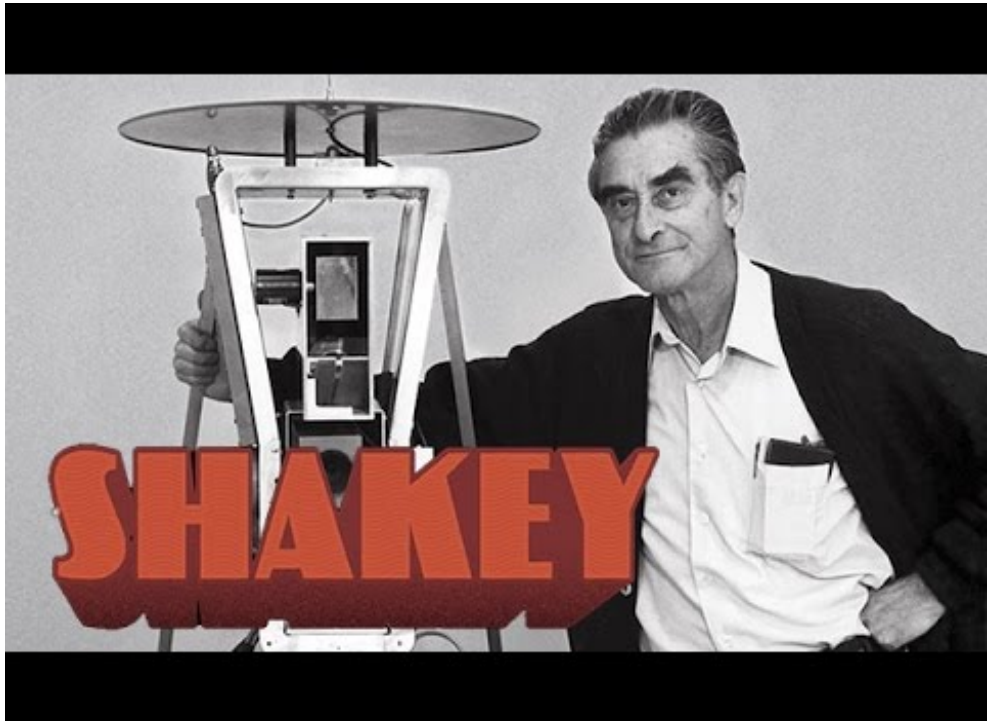
- At the end of today's lecture, you will be able to:
  1. Define a robot.
  2. List some of the application domains of robots.
  3. Describe the different levels of robot autonomy.
  4. Define the three levels of human-robot collaboration.
  5. Give examples of human-robot interaction from different application domains.
  6. List and explain the central aspects of human-centered interaction in robotics.

The Beginning of Modern-Day Robotics...

https://youtu.be/xyj6N-i6asQ

Unimate:

- Created by George C. Devol in 1954 and deployed at the General Motors in 1961.
- First programmable manipulator for the manufacturing industry for specialized tasks.



https://youtu.be/7bsEN8mwUB8
https://youtu.be/GmU7SimFkpU

Shakey:

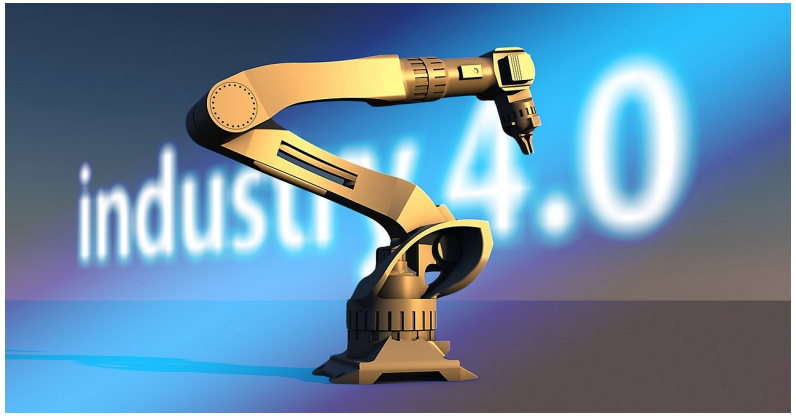
- Created by Charles Rosen and team at Stanford Research Institute during 1966-1972.
- First AI-enabled mobile intelligent robot.
  - Sense, reason, act
- IEEE Milestone Achievement Award!

What is a Robot?

- A robot is ..
  - ... a machine able to extract information from its environment and use knowledge about its world to act safely in a meaningful and purposeful manner (Ron Arkin, Behavior-based Robotics, 1998).
  - … *an atuonomous system which* ***exists*** *in the* ***physical world****, can* ***sense*** *its* ***environment****, and can* ***act*** *on it to* ***achieve*** *some* ***goals****.* (Maja J. Matarić, The Robotics Primer, 2007).
- Robotics...
  - … is the study of robots and addresses **perception** and **action** in the physical world (loosely based on (Maja J. Matarić, The Robotics Primer, 2007)).

Robots Today – Diverse Forms and Tasks

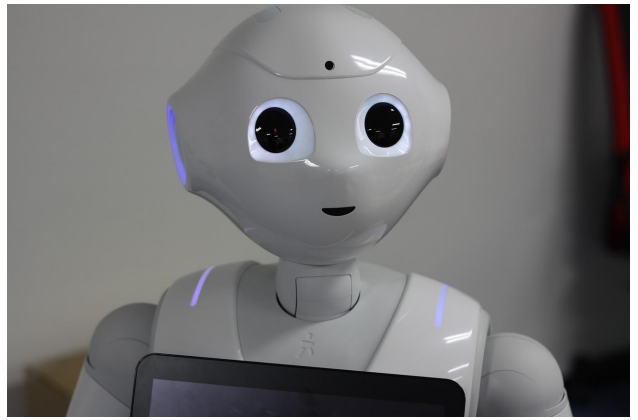
- Robots come in different **shapes** and **sizes**.
- They **interact** with humans through different **channels** to fulfil different **goals**.



Robotic arms in factories

Autonomous drones in warehouses

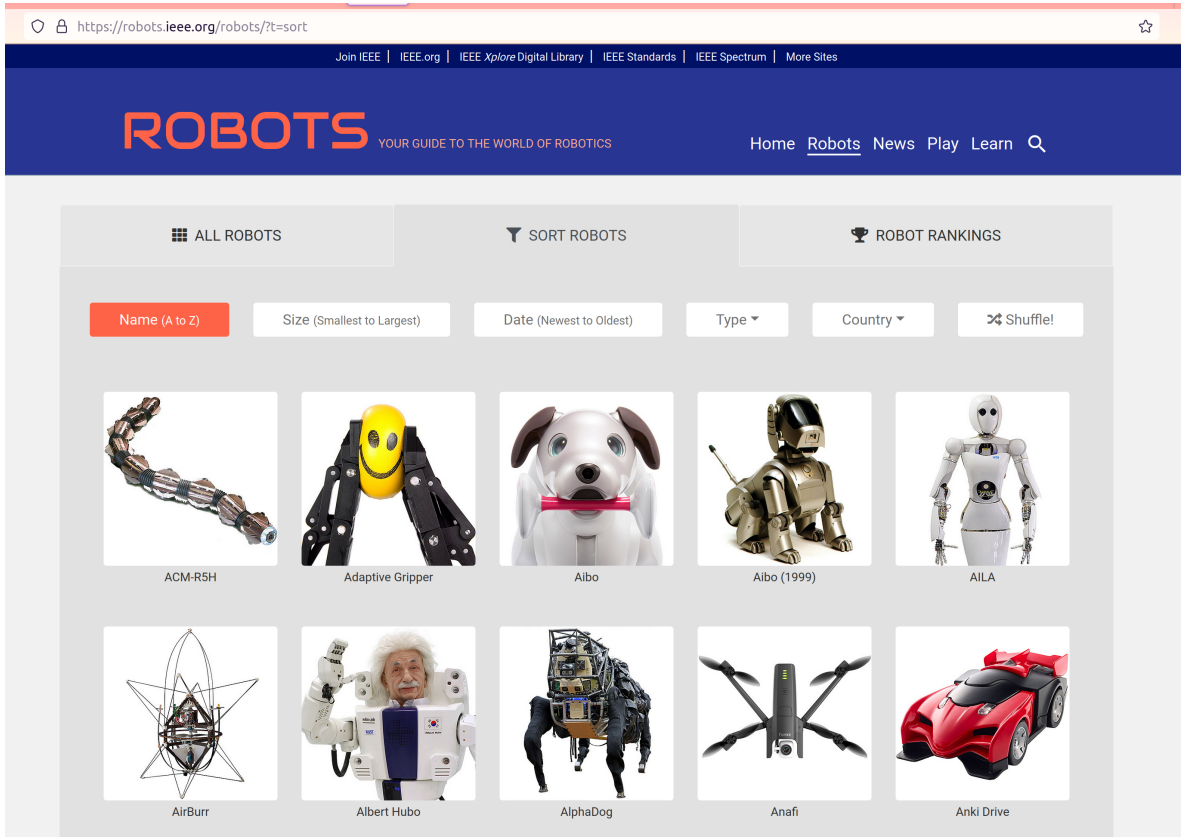
Vacuum cleaner robots



Social robots at homes

Robotics Application Domains

- Based on purpose, we have robots for (Baraka et al., 2020):
  - Healthcare and therapy
  - Education
  - Entertainment
  - Search and rescue
  - Telepresence
  - Military and security
  - Industry
  - Public service
  - Home and workplace
  - Research
  - ...



https://robots.ieee.org/robots/?t=sort

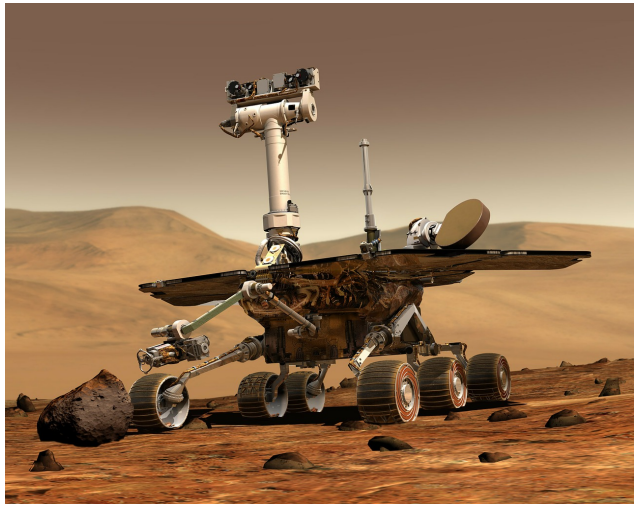
Baraka, K., Alves-Oliveira, P., Ribeiro, T. (2020). An Extended Framework for Characterizing Social Robots. In: *Jost, et al. (Eds.)* Human Robot Interaction – Evaluation Methods and Their Standardization. Springer, Cham. https://doi.org/10.1007/978-3-030-42307-0_2

Autonomous Robots

- Traditionally, the focus has been on making robots **more autonomous**, i.e. to make them **less dependent on human supervision** or **control** to fulfil their tasks.

Teleoperation

Completely controlled by a human
(not truly a robot)



Fully Autonomous

Makes decisions on its own and
operates without any human control

(Maja J. Mataric. 2007. The Robotics Primer (Intelligent Robotics and Autonomous Agents). The MIT Press.)

Levels of Autonomy – One-Dimensional View

- Sheridan and Verplank (1978) suggested 10 levels of autonomy (summarized as follows by (Parasuraman et al., 2000).

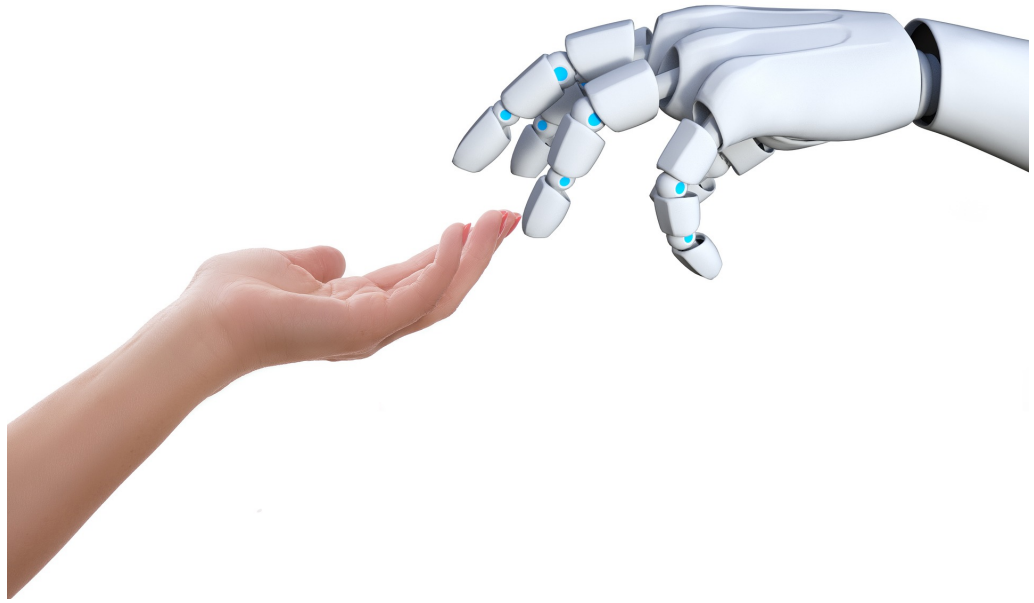
Level	Description (The computer...)
10 (High)	… **decides everything** and acts autonomously, **ignoring** the **human**.
9	… **informs** the human **only if it**, the computer, **decides to**.
8	… **informs** the human **only if asked**, or
7	… **executes automatically**, then **necessarily informs** the **human**, and
6	… **allows** the **human** a restricted **time to veto** before automatic execution, or
5	… **executes** that suggestion **if the human approves**, or
4	… **suggests** one **alternative**, or
3	… **narrows** the **selection** down to a few, or
2	… **offers** a complete set of decision/action **alternatives**, or
1 (Low)	… offers no assistance; the **human** must **take all decisions** and **actions**

- Sheridan, T. B., & Verplank, W. L. (1978).Human and computer control of undersea teleoperators. Massachusetts Institute of TechnologyCambridge Man-Machine Systems Lab.
- Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation.IEEETransactions on Systems, Man and Cybernetics-Part A: Systems andHumans,30(3), 286–297.

Humans and Autonomous Robots

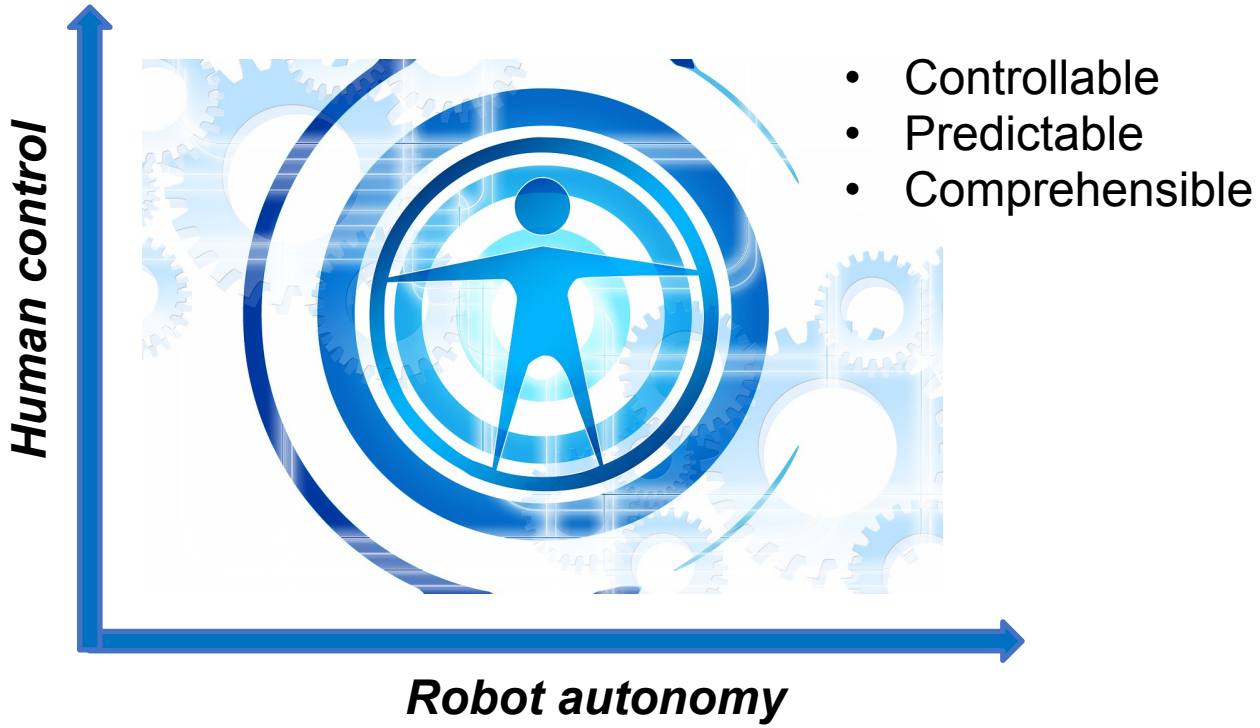
- **Nowadays, robots no longer exist only in isolation.**
- **Robots and humans are moving closer to each other** in a wide range of applications.

  - Industrial robotic manipulators and humans share the same workspace and collaborate to complete certain tasks.
  - Social robots coinhabit private or public spaces and provide services to people at homes, in shopping malls, or museums.
  - Space robots are being built to assist astronauts on future planetary missions.



Two-Dimensional, Human-Centered View

- No longer a question of whether robots need humans to act (autonomy).
- But, a question of how robots can **act together with** humans in a safe, reliable and trustworthy manner to **empower** and **enhance** human performance.



- Controllable
- Predictable
- Comprehensible

Source: Ben Shneiderman (2020) Human-Centered Artificial Intelligence: Reliable, Safe & Trustworthy, International Journal of Human–Computer Interaction, 36:6, 495-504, DOI: 10.1080/10447318.2020.1741118

The focus is now shifting towards the human interaction partner.
The human is at the center of human-robot interaction!

Industrial Human-Robot Collaboration -- Levels

Coexistence	<	Cooperation	<	Collaboration
• Human and robot **share (partially or fully)** the same **physical workspace**.		• Human and robot **coexist**, and have a **shared goal**.		• Human and robot **coexist**, have a **shared goal** and work on a **shared object**.
• But, **activities** of the human and the robot are **unrelated (no shared goals)**.		• Robot is aware of the human's involvement in task completion.		• Highest level of interaction.
		• Some coordination of activities.		• Higher joint effort and higher joint situation awareness.

Source: Iina Aaltonen, Timo Salmi, Ilari Marstio, Refining levels of collaboration to support the design and evaluation of human-robot interaction in the manufacturing industry, Procedia CIRP, Volume 72, 2018, Pages 93-98, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2018.03.214.

Industrial Human-Robot Collaboration -- Examples

- **No coexistence** => No interaction
  - E.g. robot stays and operates on its own behind a fence.
- **Coexistence** => Minimal or indirect interaction
  - Human enters robot's workspace to fetch an object and the robot slows down to ensure human safety.
- **Cooperation**
  - Robot stops when human enters its workspace to turn a welded object and continues welding when human leaves.
- **Collaboration**
  - Robot holds a machine part in place and the human tightens it.

Source: Iina Aaltonen, Timo Salmi, Ilari Marstio, Refining levels of collaboration to support the design and evaluation of human-robot interaction in the manufacturing industry, Procedia CIRP, Volume 72, 2018, Pages 93-98, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2018.03.214.

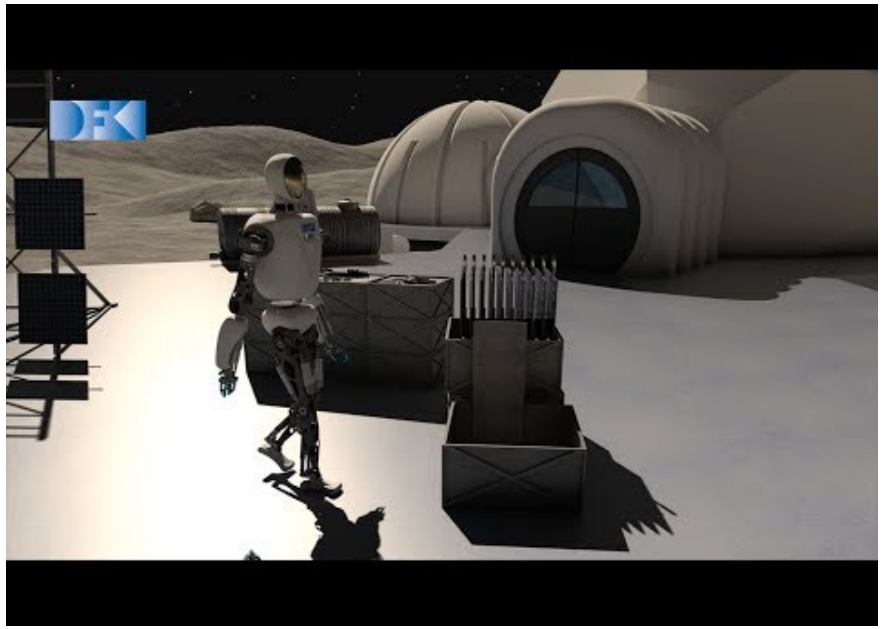
Find Your Examples…

- Form groups of three

- For 10 minutes:
  - Look for 2 example videos of human-robot collaboration on YouTube
  - Watch them together
  - Answer the following questions:
    - What level(s) of collaboration did you observe?
    - What were the goal(s) of the human and the robot?
    - What objects did they share?

- For 10 minutes:
  - Discussion of your examples in the class

Human-Robot Collaboration in Space



https://youtu.be/Uwl3XeXvAjo

- Varying levels of autonomy in robot's actions:
  - Teleoperation
  - Full autonomy

- Robot assistants in space are expected to closely collaborate with human astronauts.

- Shared physical space
  - e.g. a base station on a far away planet
- Shared goals
  - e.g. To set up solar panels
- Shared objects
  - e.g. solar panel

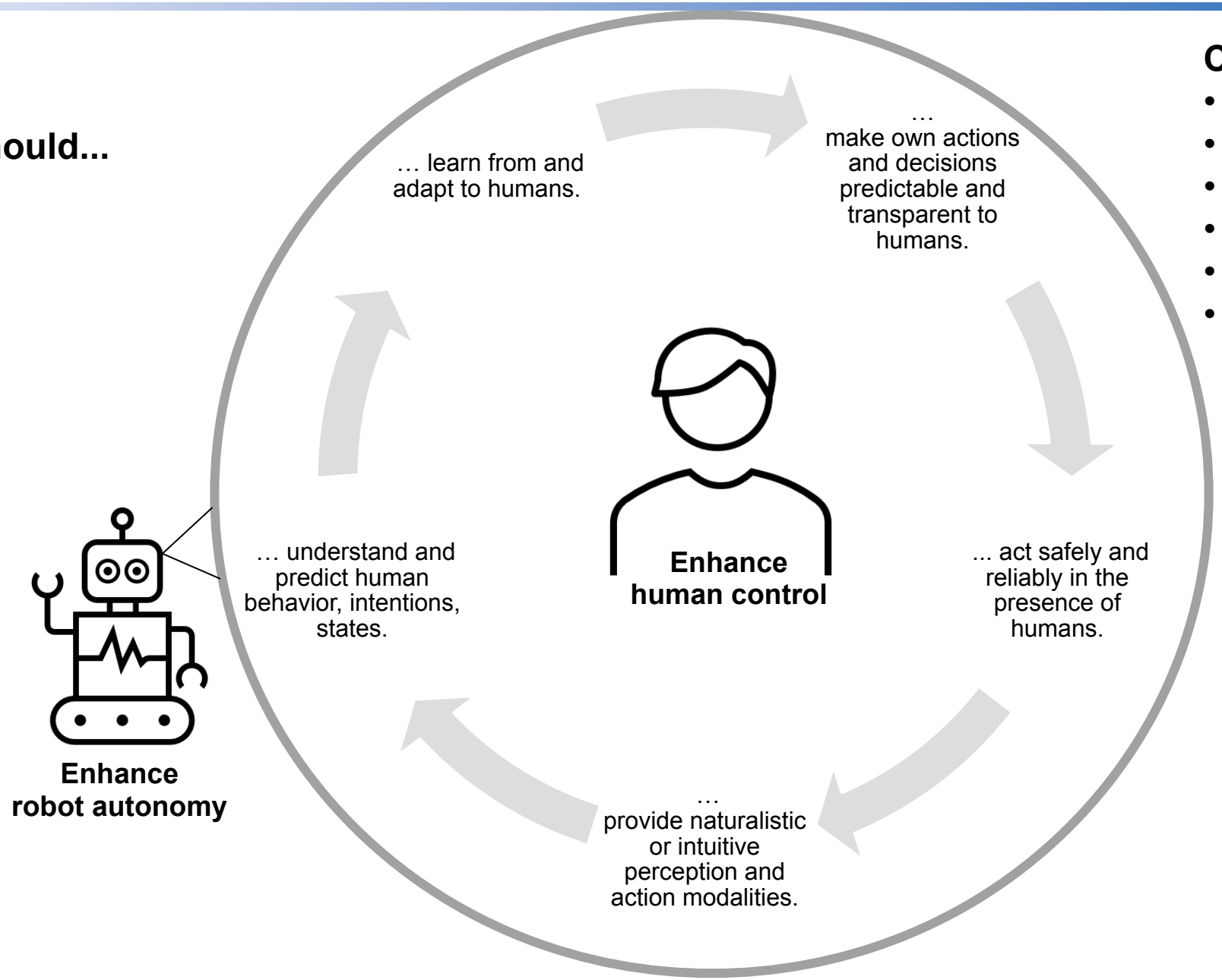
- **Safety** requirements change with the level of collaboration.

Interaction with Social Robot Companions

- Social companion robots: Engage with human users in social interaction in every day contexts.
- Social interaction: Less structured and more complex than task-based interaction in industrial contexts.
- Humans and robots: Coexistence or copresence in same unstructured and highly dynamic physical space.
- Robot goals: Conflicting goals possible, implying higher levels of robot autonomy and a higher need for **transparency** towards humans.

Human-Centered Interaction in Robotics

Robots should...



Consider ethical aspects:

- **Safety**
- **Privacy**
- **Fairness**
- **Transparency**
- **Trust**
- **...**

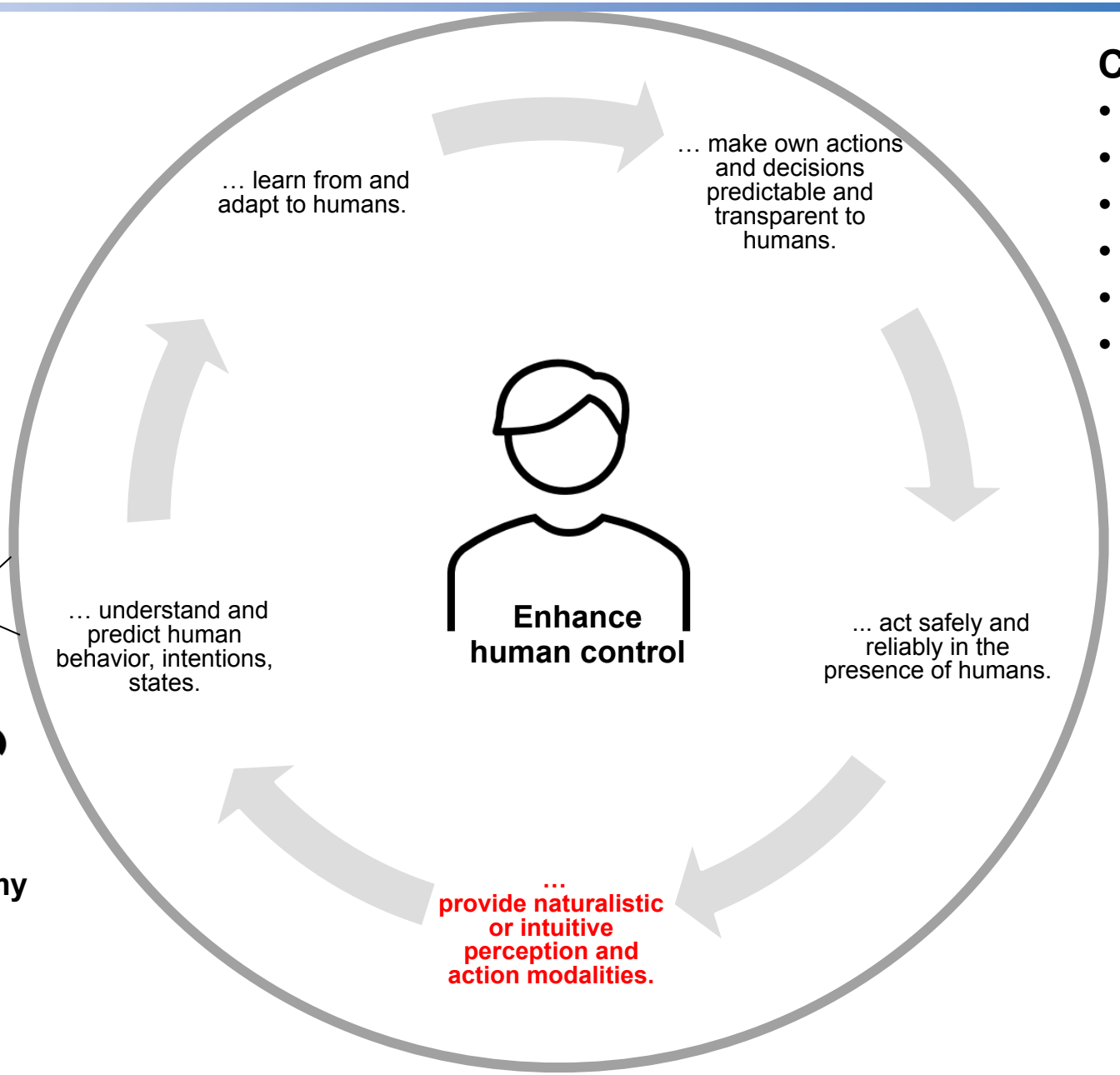
Leading to empowerment of humans!

Human-Centered Interaction in Robotics

1. Humans should be able **interact naturally** and **intuitively** with robots.
2. **Robots** should be able to **understand humans** (behavior, intentions, states).
3. **Robots** should be able to **learn from humans** and **adapt** to them.
4. **Humans** should be able to **understand robots** (behavior, intentions, states).
5. **Interaction** with robots should be **safe**, **reliable**, and **trustworthy** for humans.
6. Enhanced robot autonomy and **enhanced human control** should go hand-in-hand.
7. **Ethical issues** should be identified and **resolved** early.

Human-Centered Interaction in Robotics

Robots should...



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- **...**

Leading to empowerment of humans!

1. Verbal and Nonverbal Interaction

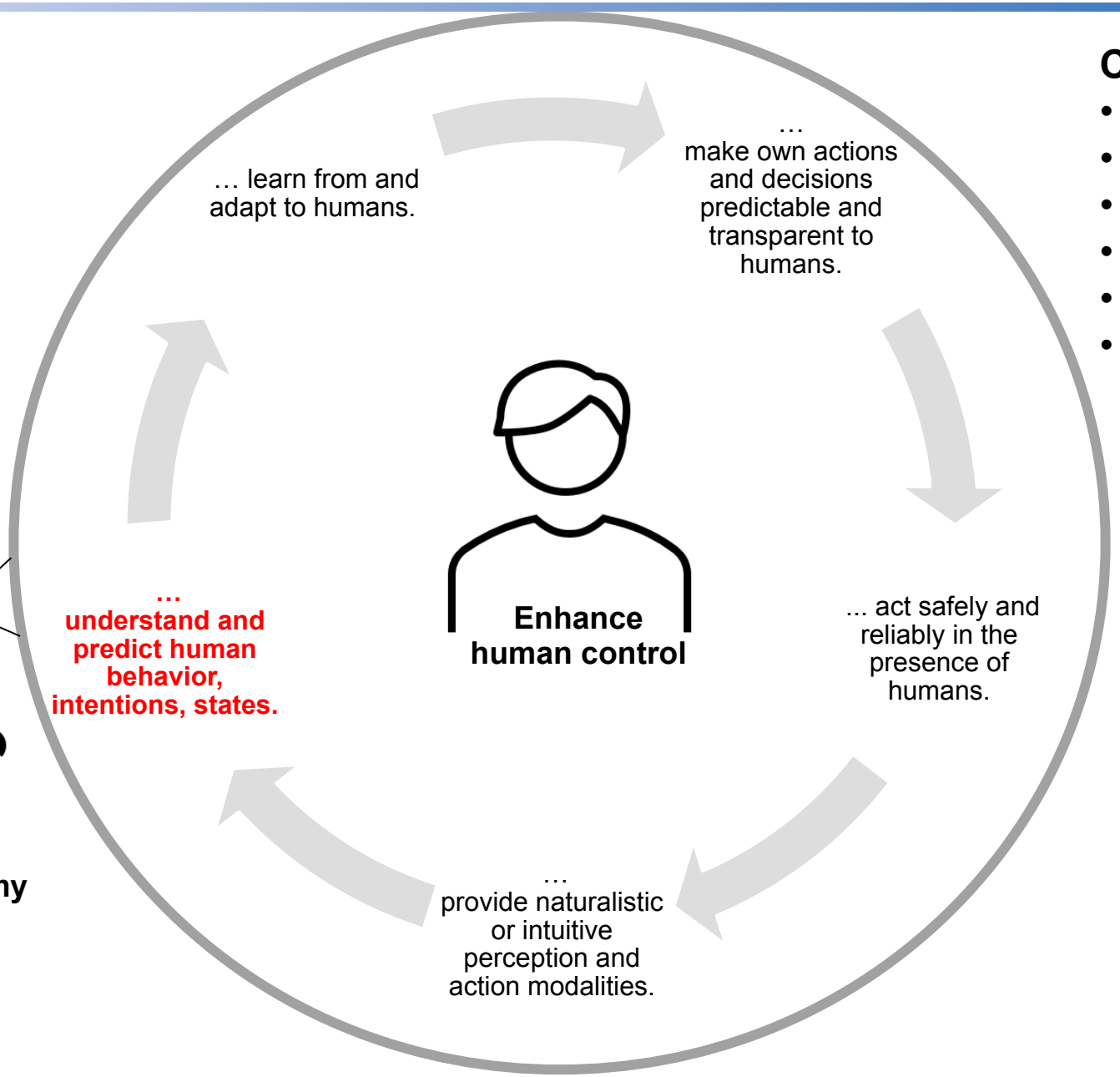
- Natural interaction modalities
  - Verbal: Speech
  - Nonverbal: Overt versus Covert
    - Gestures, facial expressions, body movements, touch, brain signals, etc.
- Alternate sensory and action modalities (e.g. touchscreens, LED displays, etc.) should be intuitive enough to require less effort from humans.

- One-way communication
  - From human to robot: Give verbal commands to the robot, point to something, etc.
  - From robot to human: Answer a question, ask for help, smile at the human, etc.
- Two-way communication
  - Engage in a conversation

Doncieux, S., Chatila, R., Straube, S. *et al.* Human-centered AI and robotics. *AI Perspect* 4, 1 (2022). https://doi.org/10.1186/s42467-021-00014-x

Human-Centered Interaction in Robotics

Robots should...



Consider ethical aspects:

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- **...**

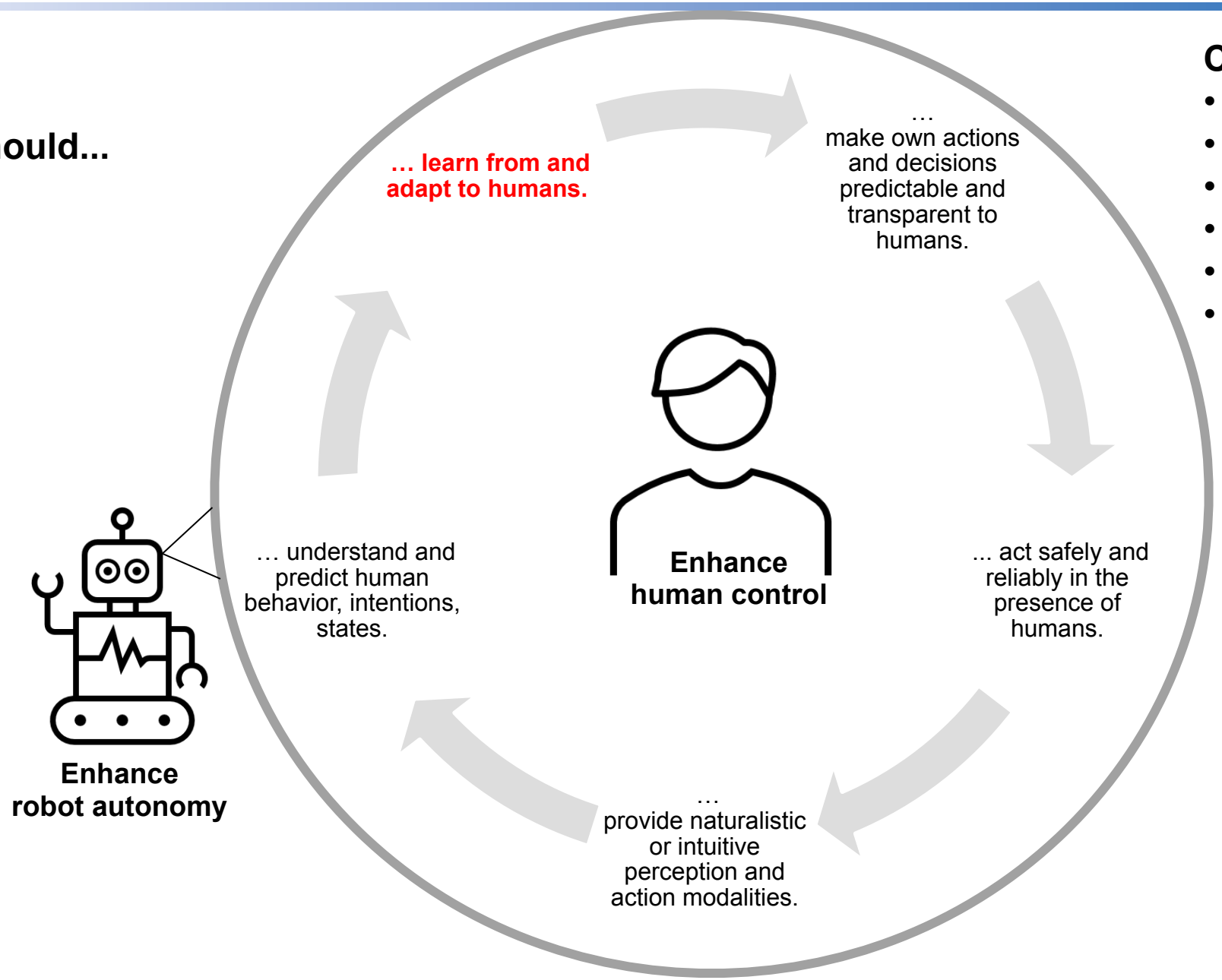
Leading to empowerment of humans!

2. Understanding Human Behavior

- Humans' behavior, beliefs, desires, intentions, emotions, etc.
  - **Interpersonal** differences in expression.
    - Each person is different at physical, physiological and cognitive levels.
    - Behavior and communication are influenced by several factors, including sociocultural ones.
  - **Intrapersonal** difference in expression.
    - Same person might show different behavior at different times and in different contexts.
  - **Multimodal** expression
    - Not one, but different types of signals (verbal, nonverbal) should be analyzed simultaneously to make good inferences.
  - **Context-based** semantic differences
    - Same signals might carry a different message or meaning depending on the context.

Human-Centered Interaction in Robotics

Robots should...



Consider ethical aspects:

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- **Trust**
- **...**

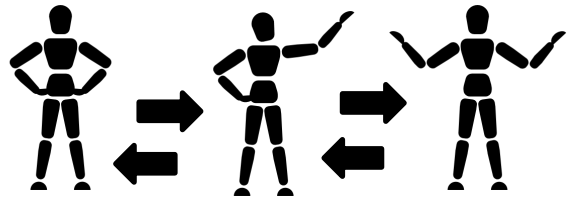
Leading to empowerment of humans!

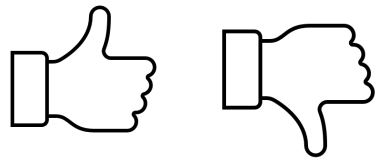
3. Learning from Humans

Interactive Reinforcement Learning

Human input could be used to guide and accelerate the robot's learning, or to change its optimal behaviour (personalisation).

- What types of human input can be given?
  - Demonstration
    - Inverse RL (learn reward function from demonstrations)
    - Imitation learning (learn the policy from demonstrations)
  - Advice or instruction (often verbally)
    - Converted into rules and added to knowledge-base.
    - Used for reward shaping and to learn reward functions.
  - Evaluative feedback -- How good or bad was the robot's action?
    - Explicit versus implicit feedback
    - Used as reward together with other reward functions.





Human-Centered Interaction in Robotics

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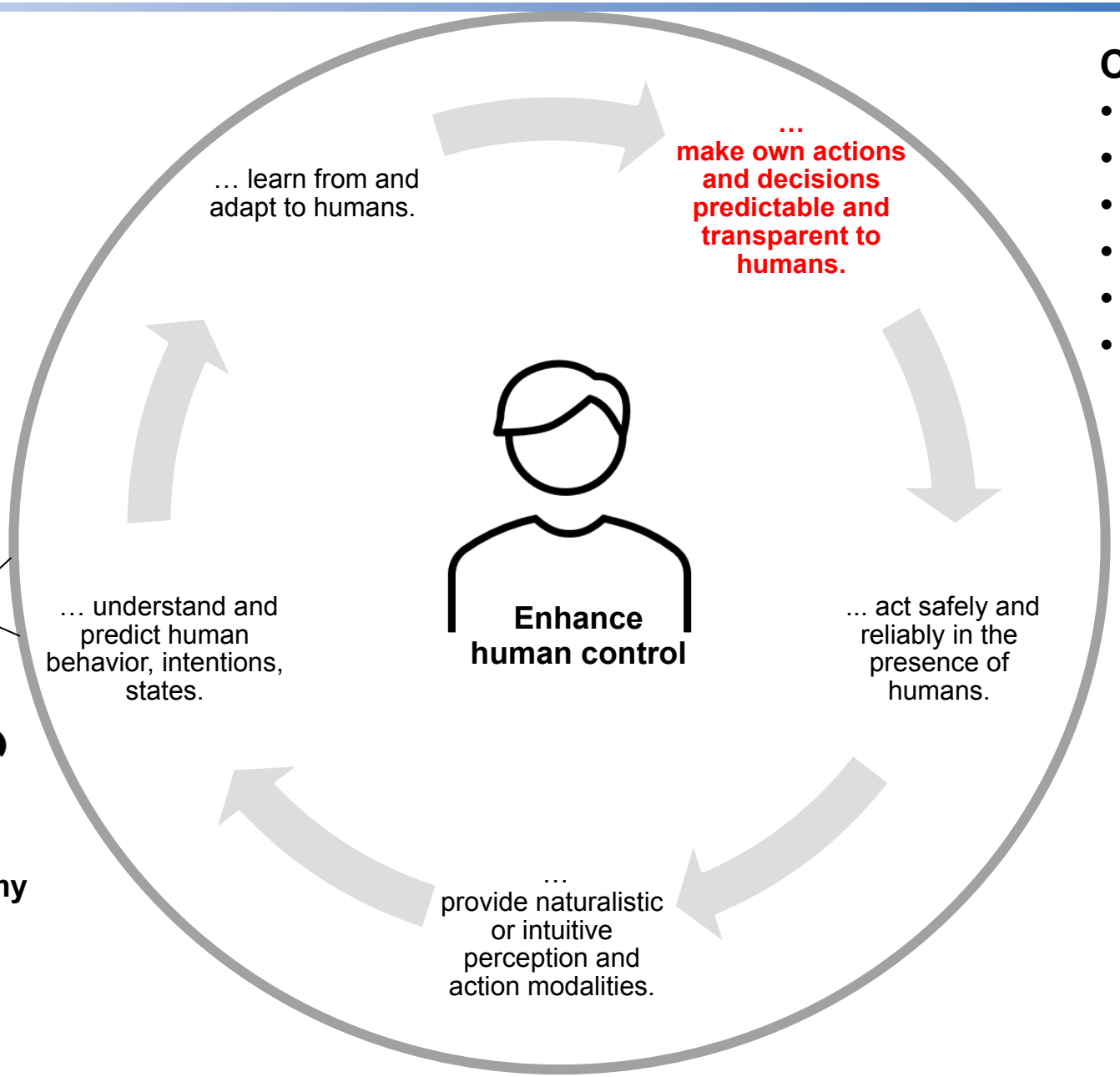

Consider ethical aspects:

- **Safety**
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- **Transparency**
- **Trust**
- **...**

Leading to empowerment of humans!

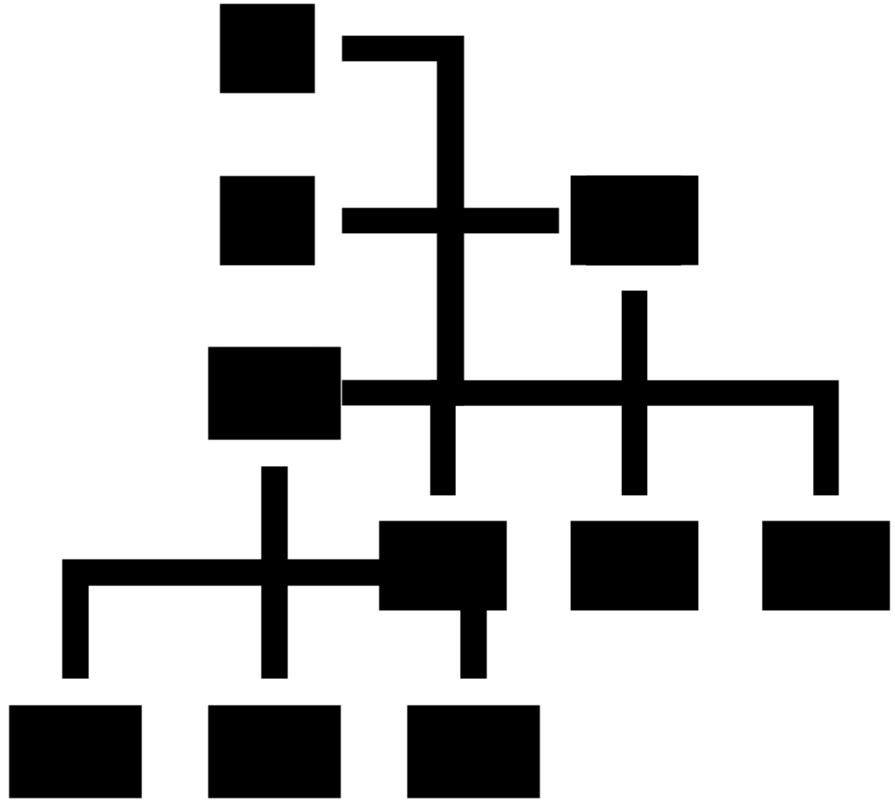
4. Understanding Robot's Capabilities and Intentions...

- Robot's capabilities should be transparent to the user:
  - **What can the robot do? What can it not do?**

- Robot's actions, intentions and decisions should be predictable, transparent and comprehensible to humans.
  - **What is the robot doing? Why is it doing it?**

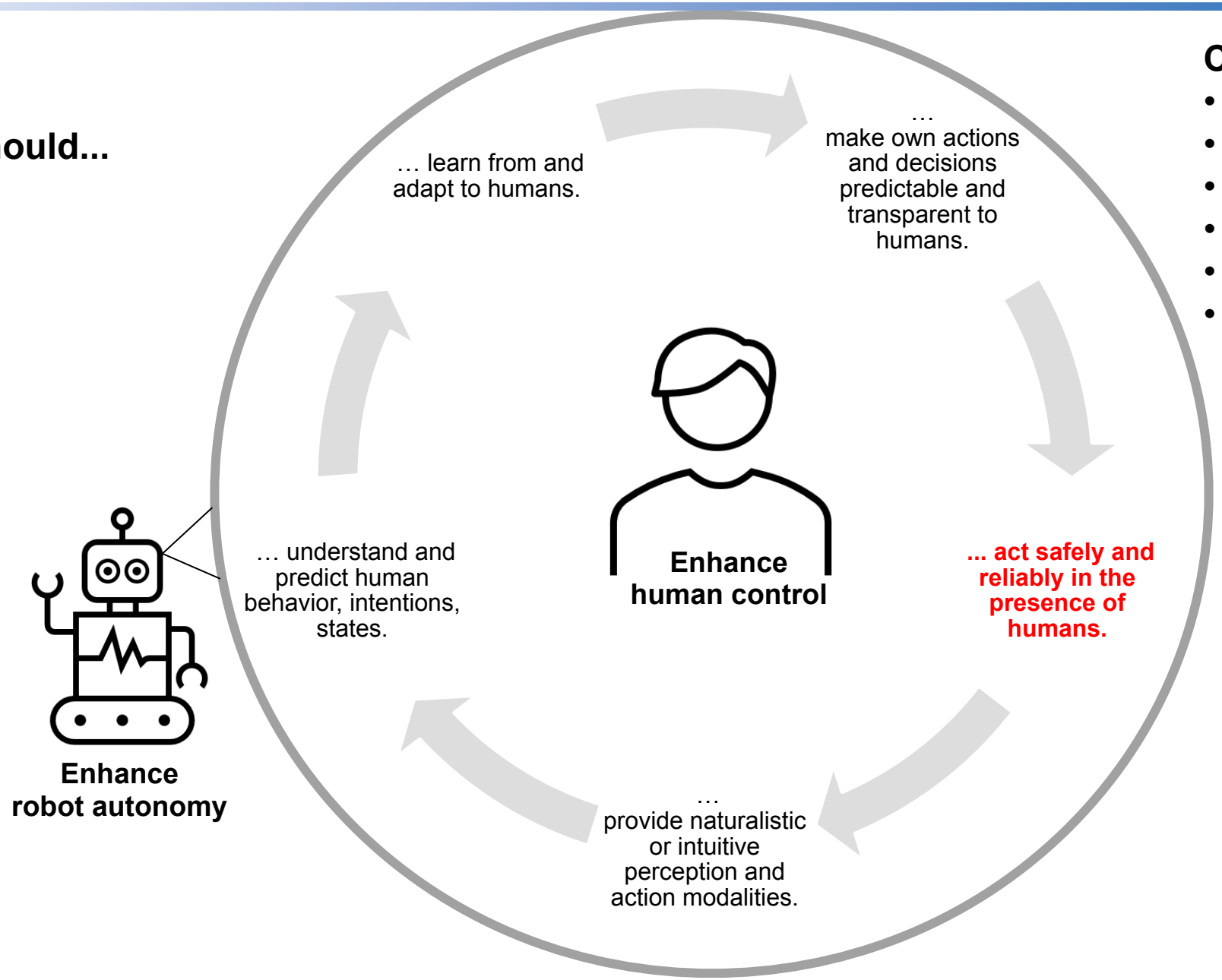
- Robot should be capable of explaining its own behavior and decision, if needed.
  - **Proactive** explanation versus **on-request** explanation
  - **Verbal** and/or **nonverbal** (e.g. gaze, gestures, etc.)
  - Eventually, robot behavior becomes understandable without requiring explicit explanation.

Explainable human-robot interaction architectures



Human-Centered Interaction in Robotics

Robots should...



Consider ethical aspects:

- **Safety**
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- **Trust**
- **...**

Leading to empowerment of humans!

5. Safe, Human-Aware Physical Interaction

Design levels for safety:

- Compliant materials and elements (e.g. springs)
  - Primarily to ensure safety of humans interacting physically with the robot.
- Compliant control based on haptic feedback
  - To reduce human effort in guiding or controlling robot movements, e.g. in exoskeletons for rehabilitation.

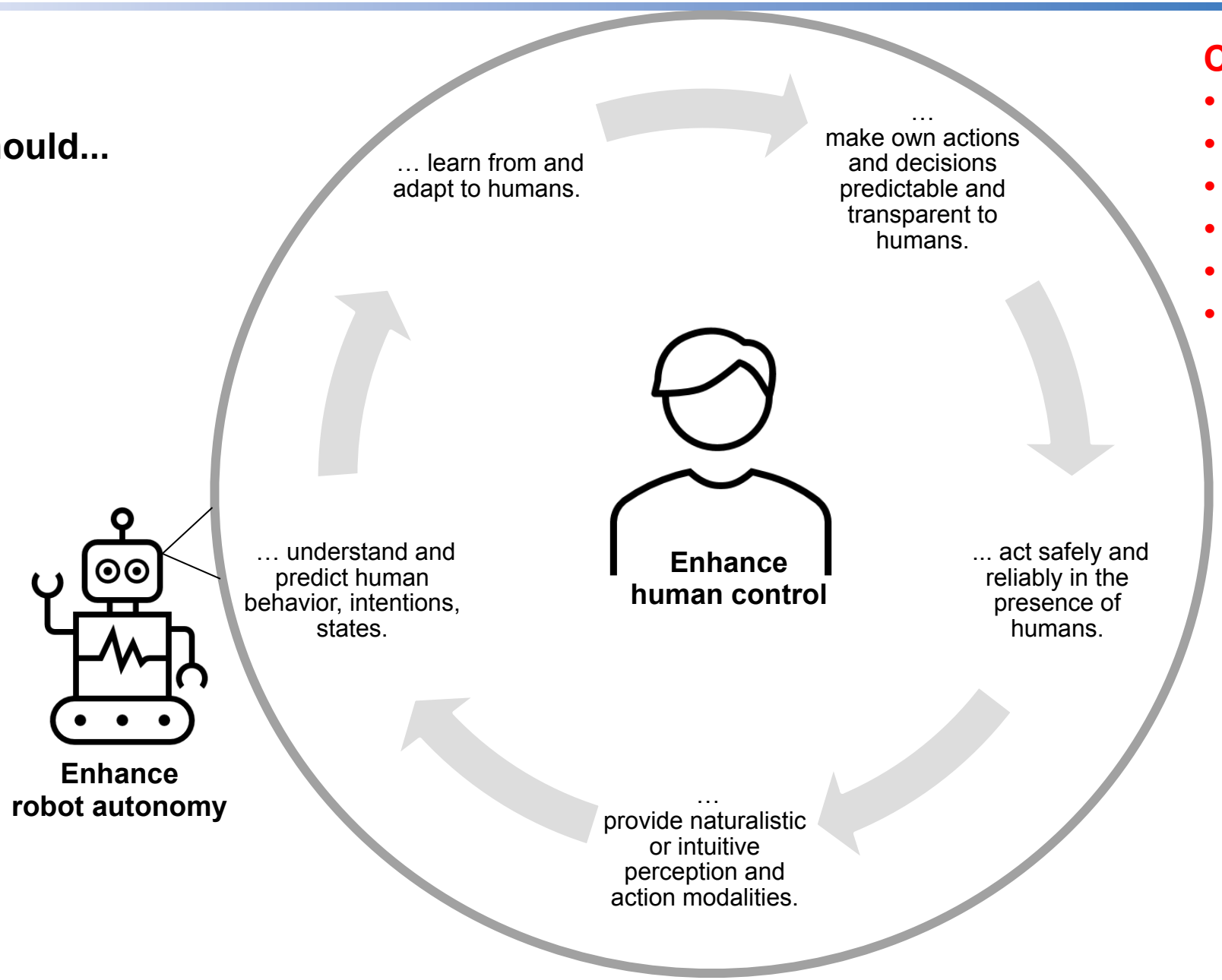
- Perception-based adaptive control
  - Adaptive control based on exteroceptive outputs, e.g. slow down robot's speed progressively when human approaches.
- Human-aware planning and execution
  - Understand beliefs, intentions, emotions, etc. of humans to jointly plan, coordinate and execute actions, e.g. hand-over of a tool.

Doncieux, S., Chatila, R., Straube, S. *et al.* Human-centered AI and robotics. *AI Perspect* 4, 1 (2022). https://doi.org/10.1186/s42467-021-00014-x

https://youtu.be/mDODMNMC5zc

Human-Centered Interaction in Robotics

Robots should...



Consider ethical aspects:

- **Safety**
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- **Transparency**
- **Trust**
- **...**

Leading to empowerment of humans!

6+7. User-Centered Design and Development

- User-centeredness in the design of robots and interaction:
  - Gather **user expectations** and **requirements** early on (from mechanical design onwards).
  - Iteratively **evaluate, analyze, and improve** the design.
  - Design **intuitive interfaces** that support ease and transparency during interaction.
  - Reduce the amount of **adaptation** needed on the side of the humans.
  - Identify, analyse and address **ethical issues** from the beginning of the process.
    - Violation of privacy
    - Potential for physical harm or exhaustion
    - Discrimination or violation of human dignity
    - Development of affective bonding with the robot
    - ...

7. Interaction Experiments

- Conduct qualitative and quantitative evaluations of interaction in well-defined and reproducible experiments.

- What are evaluated?
  - Technical efficiency and usage
  - Influence or impact on human interaction partner
    1. How do humans perceive the robotic interaction partner?
       - Likeable, trustworthy, predictable, human-like, etc.
    2. How do humans experience the interaction with the robot?
       - Engagement, effort, predictability, acceptability, etc.
    3. What impact does the interaction have on human skills or socioemotional state?
       - E.g. therapeutic effect, sociocognitive skills, motor skills, etc.
    - Immediate / short-term / long-term studies
  - Require clearance from an ethics committee!

Conclusion

- In today's lecture, you learnt to:
  1. Define a robot.
  2. List some of the application domains of robots.
  3. Describe Sheridan and Verplank's 10 levels of robot autonomy.
  4. Distinguish between co-existence, cooperation and collaboration.
  5. Give examples of human-robot interaction from different application domains.
  6. List and explain the central aspects of human-centered interaction in robotics.
     1. Intuitive interfaces for interaction
     2. Robots understanding humans
     3. Robots learning from and adapting to humans
     4. Humans understanding robots
     5. Safe, reliable, trustworthy interaction
     6. Enhanced human control
     7. Ethical considerations

References and Recommended Reading

1. Doncieux, S., Chatila, R., Straube, S. *et al.* Human-centered AI and robotics. *AI Perspect* **4,** 1 (2022). https://doi.org/10.1186/s42467-021-00014-x

2. Ben Shneiderman (2020) Human-Centered Artificial Intelligence: Reliable, Safe & Trustworthy, International Journal of Human–Computer Interaction, 36:6, 495-504, DOI: 10.1080/10447318.2020.1741118

[References 1 and 2 would be important for the exam.]

Next Session

- Lecture on "Structuring and Analyzing Human-Robot Interaction"
  - Flipped classroom: Please complete the reading assignment
  - Thursday, 18.04.2024 at 9 am
  - In: B060, GranthamAllee 20, 53757 Sankt Augustin