Perception and Planning

Week 10

Humanoid Robots

Humanoid Robots

- Humanoid robot history
  - Simple voice recognition and speech synthesis
- Humanoid applications
  - Entertainment
  - Carers
  - Industrial
- Humanoid interaction
  - Awareness of humans
  - Gesture and social interaction
  - Teleoperation

What is a Humanoid Robot?

- Humanoid refers to any being whose body structure resembles that of a human: head, torso, legs, arms, hands.
- It is also a robot made to resemble a human both in appearance and behaviour
- The difference between a robot and an android is only skin deep – looks exactly like a human on the outside, but with the internal mechanics of a robot.

Why Humanoids?

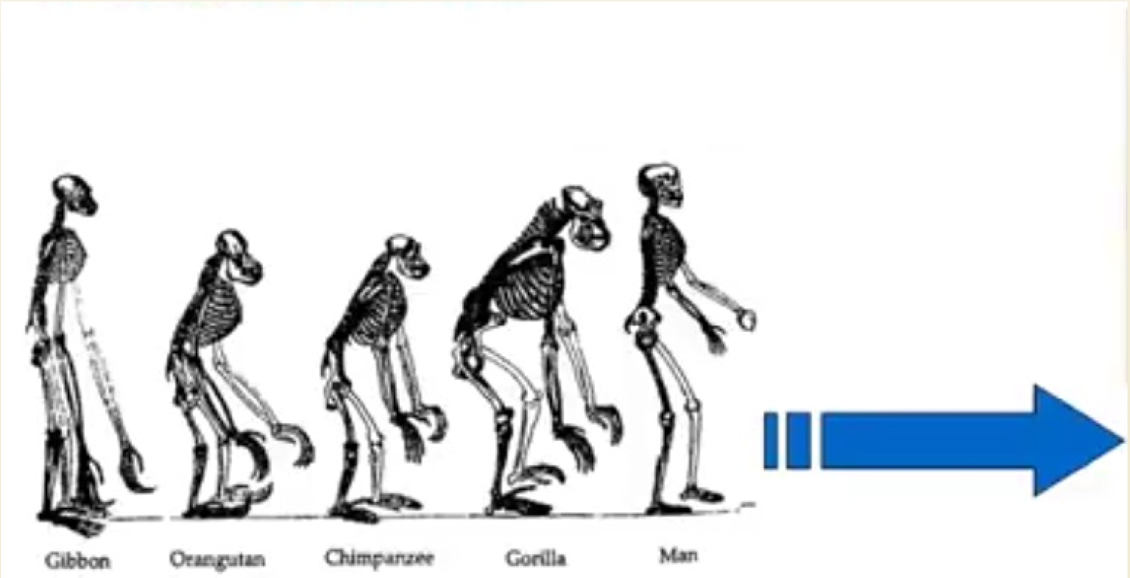
Why develop humanoid robots rather than appliance like robots?

- Robots with good aesthetic design, rich personalities, and social cognitive intelligence can connect more meaningfully with humans.
    - Uses in social interactions, social training, and entertainment purposes.
- To relieve human operators
    - Robots that can perform tasks in environments that are designed for humans.
- For research purposes
    - To push the boundaries of biology, cognitive science, and engineering.
    - Design robots that interact with humans and can use the whole body to perform complex tasks, climb ladders, enter confined spaces, etc.
- Because it is a dream of generations

Why Develop Humanoids? (cont.)

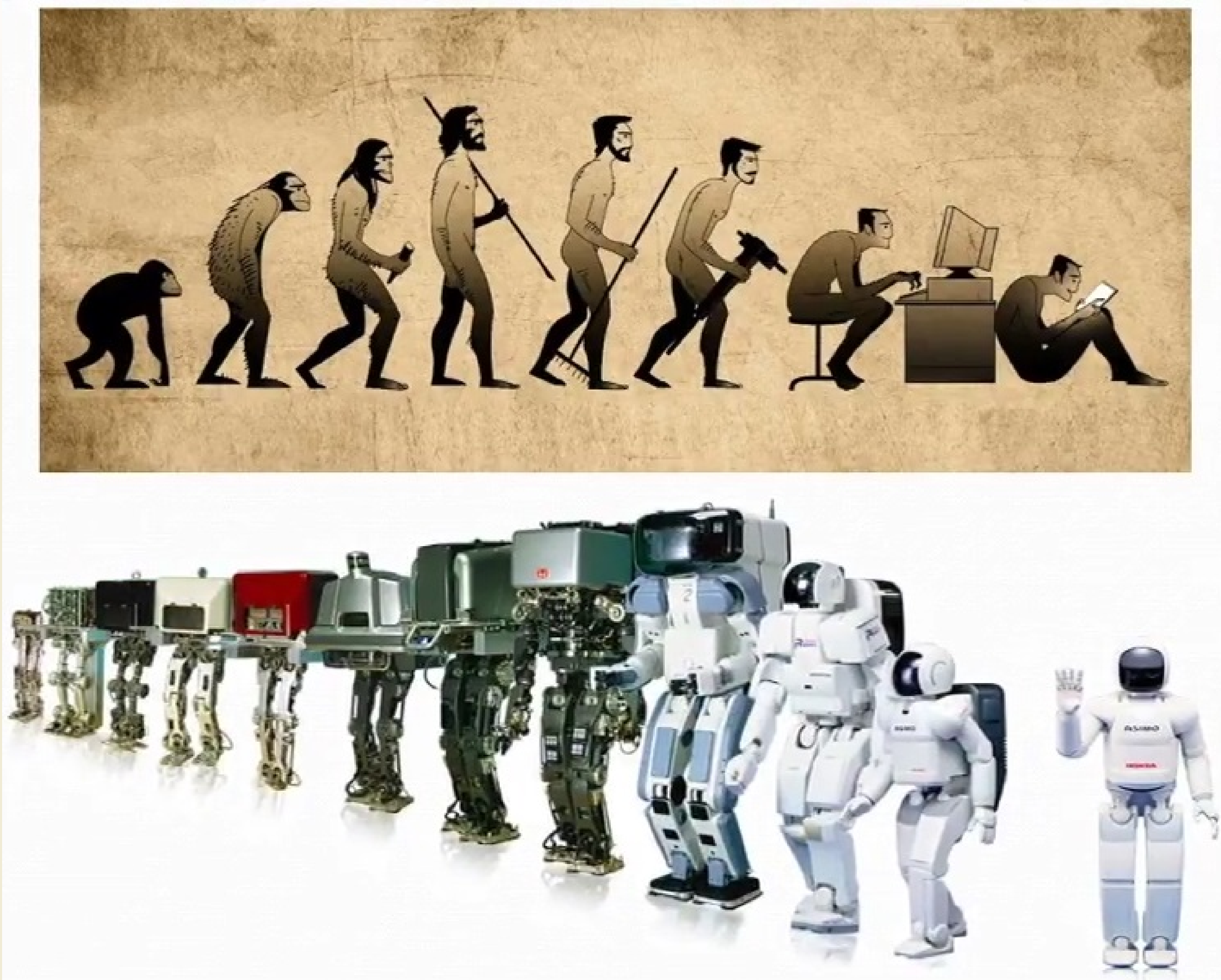
- Reasons
  - They can work in human environment without a need to adapt themselves or to change the environment.
  - Our environment and our tools are adapted for us, (and humanoids?)
  - So why adapt everything to robots?
  - It is easier for humans to interact with human-like beings.

Humanoid Robotics Evolution



Bipedism frees the hands
for creating and using tools

Humanoid Robotics Evolution

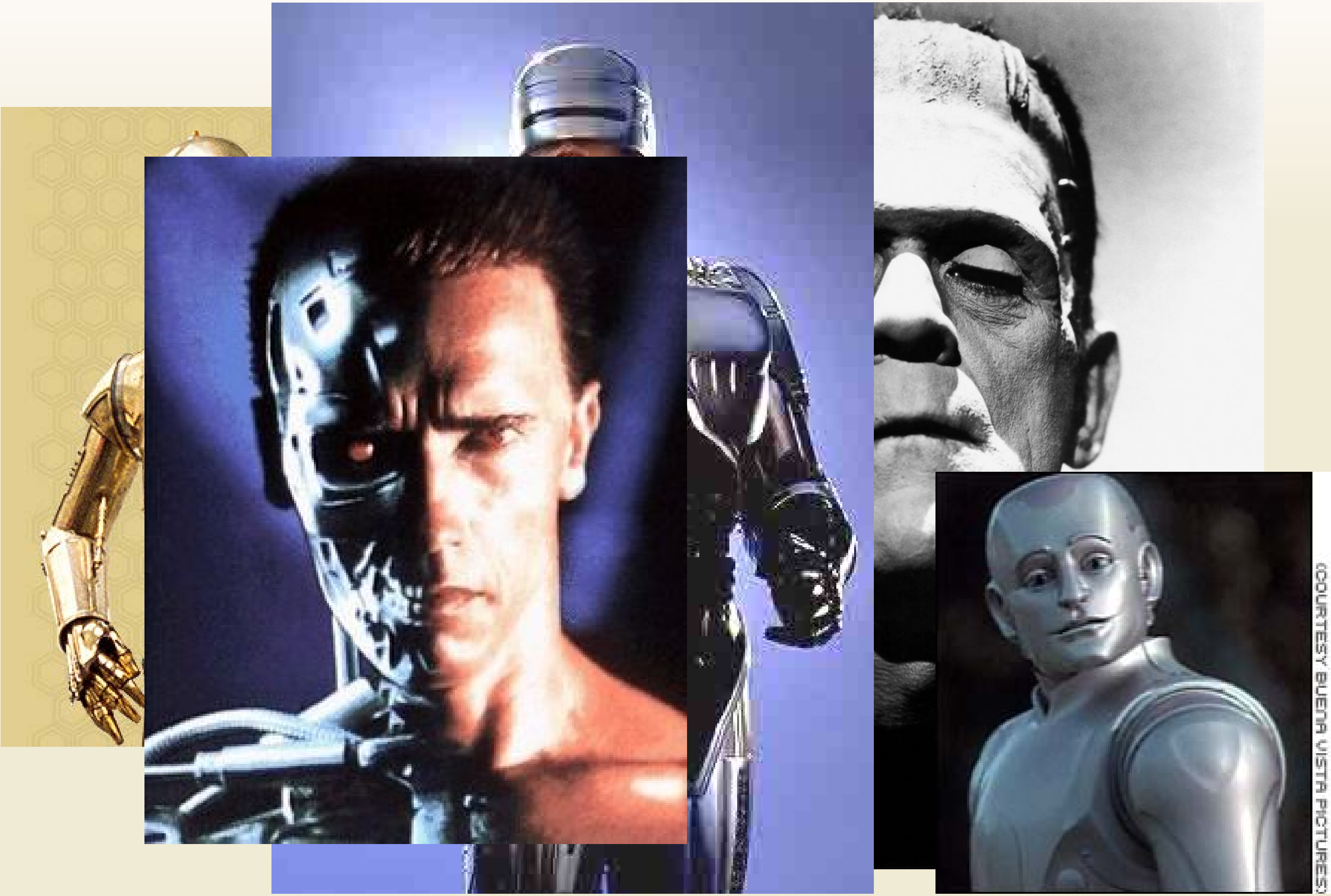


Evolution of Asimo

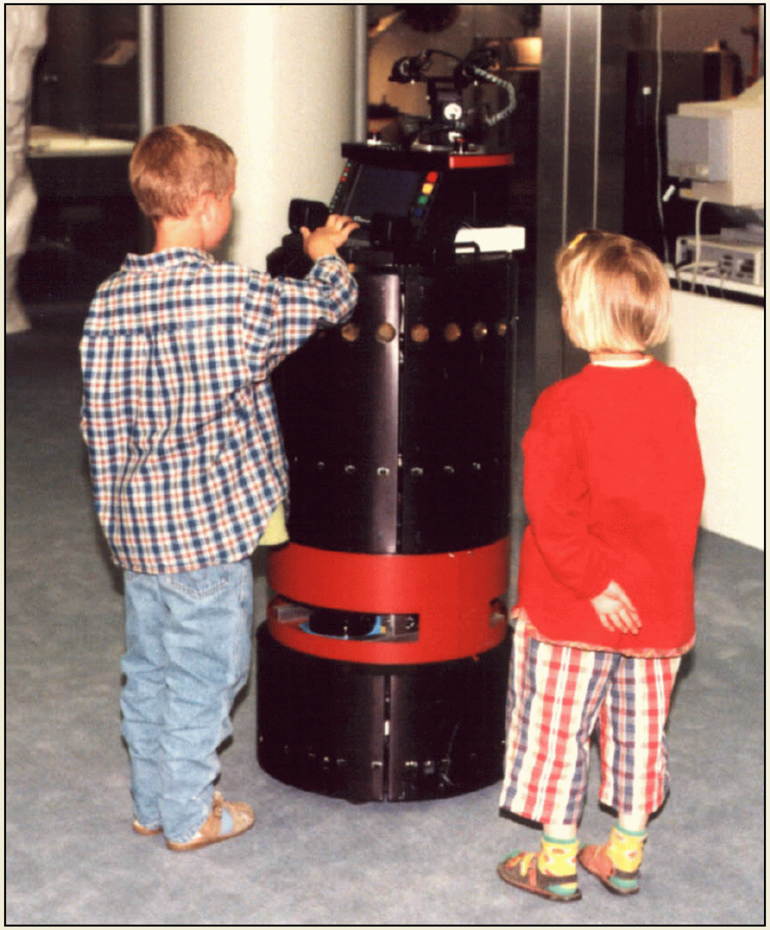
Humanoid Robot Applications

- Entertainment
- Education
- Art
- Search & Rescue
- Medical & Welfare
- Housework

Humanoid robots in entertainment



Museum Tour-Guide Robots



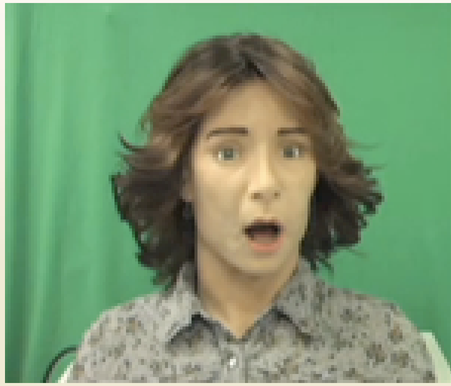
Rhino, 1997

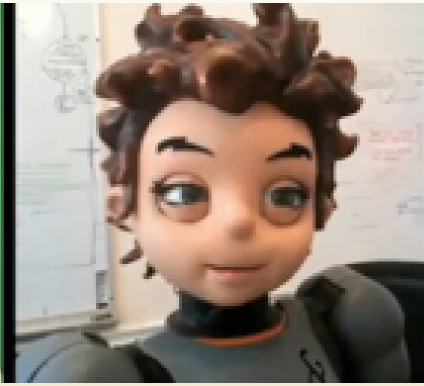
Minerva, 1998

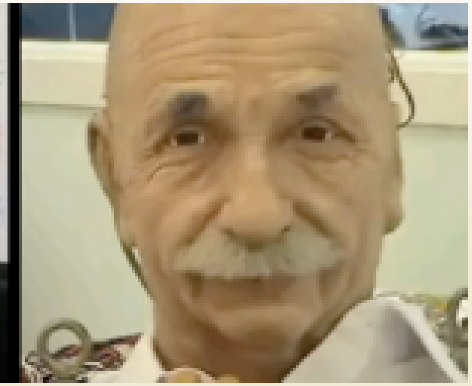
Example: The Nursebot Project

https://www.youtube.com/watch?v=7lLP5hGqKB8

Socially interacting robots


Alice


Zeno


Albert Hubo


Sophia

- News-reading robots.
- Companion robots interacting with autistic children, in age care, patients, …
  - Can use body language, (i.e. facial expressions) when communicating with humans.
- Sophia, a product of Hanson Robotics, a HK based firm, has been hugely successful, even receiving a citizenship in Saudi Arabia.

https://www.youtube.com/watch?v=omgJi5-YT6U

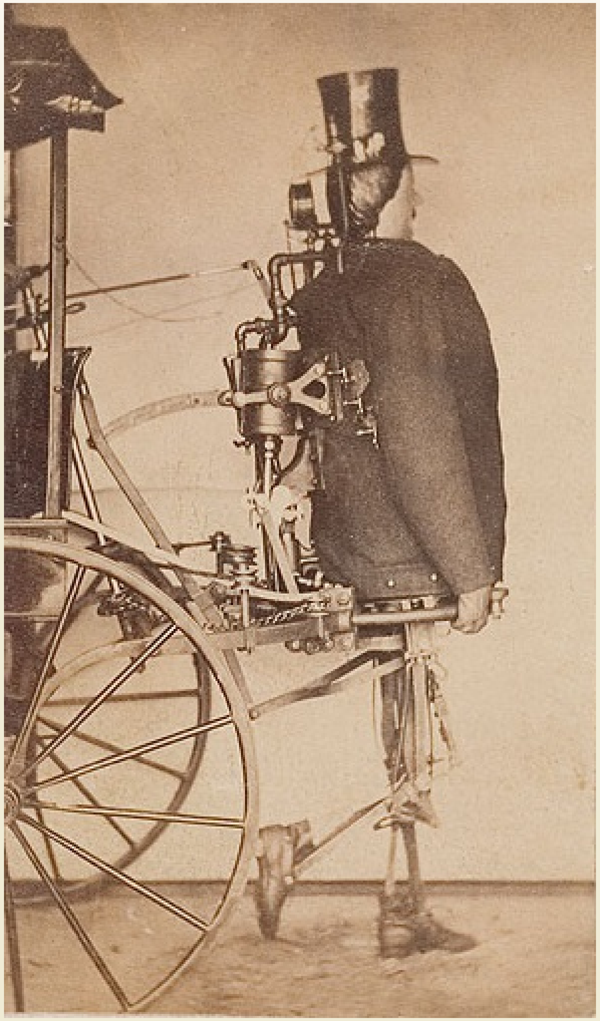
Humanoids in research

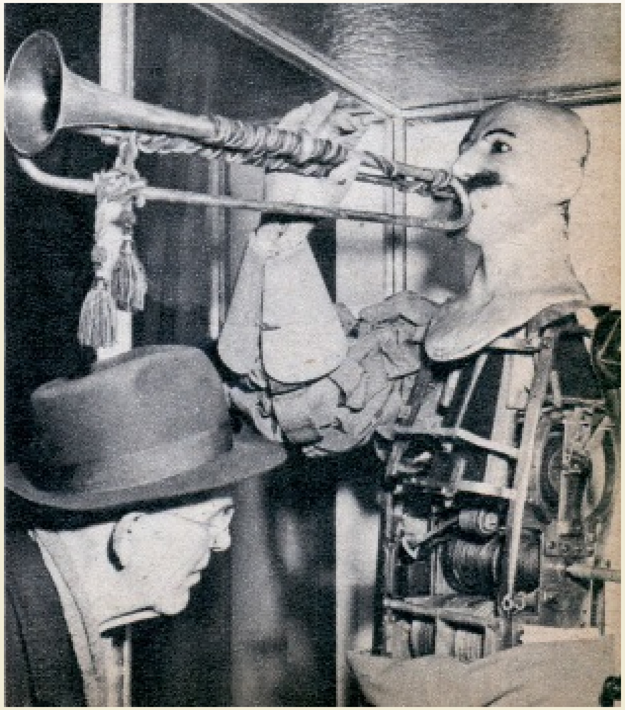
- Design “whole body” robots.
  - Speech recognition, visual perception, touch sensitivity, odor recognition, feel temperature,… and exhibit intelligent behavior.
  - Use arms, legs, fingers for propulsion and interaction with environment.

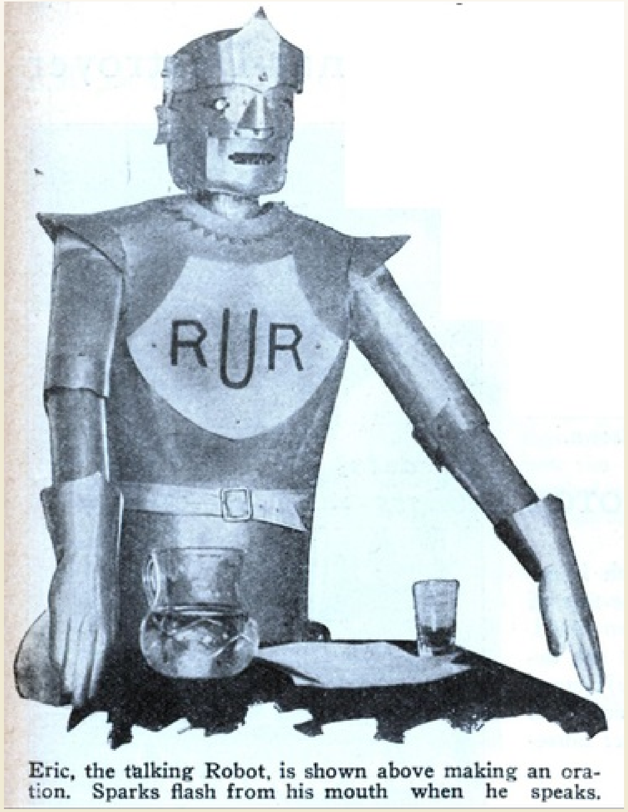
Humanoid Robot History

- AD 50 – Hero of Alexandria wine pouring robot.
- 1495 – Leonardo da Vinci designs human robot
- 1774 – Jacquet-Droz draughtsman robot
- 1937 – Electro by Westinghouse corporation
- 1973 – Wabot-1, first walking and talking humanoid
- 1993 – Honda Asimo P1 (prototype model 1)
- 1996 – Saika, lightweight low cost humanoid
- 2001 – Sony Dream Robot (entertainment)
- 2011 – Honda Asimo 2nd generation
- 2018 – Atlas by Boston Dynamics

Humanoid Robot History





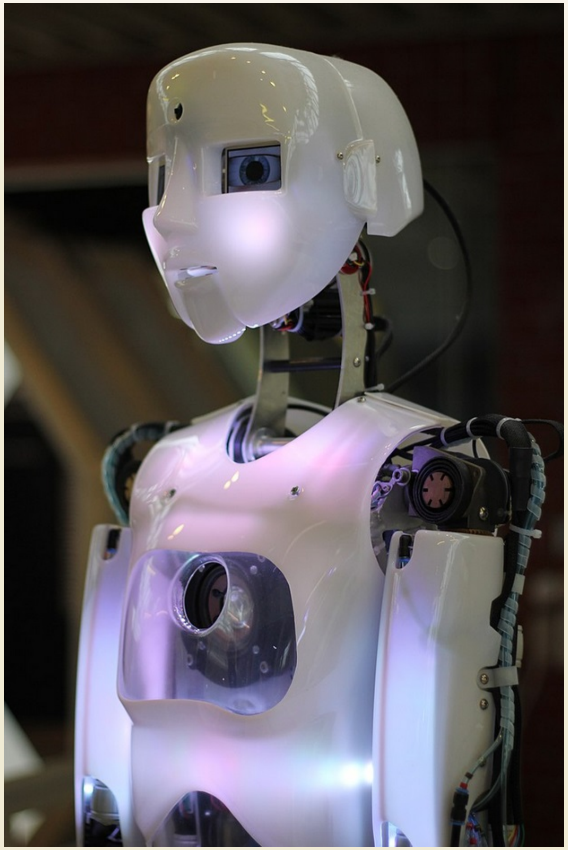


Early mechanical humanoid robots

Humanoid Robot History

Modern Humanoid Robots

Atlas



Robo Thespran

Sophia

https://www.aljazeera.com/news/2017/02/uk-science-museum-show-charts-robots-500-year-history-170207202629824.html

Critizism

- Presentation of robots as being more intelligent then they truly are.
- Humanoid robots are grotesque, unnatural.
- Possibility of overdevelopment and disobey.
- Will robots ever manage to take over the world?

Social Aspects & Ethics?

- Humanoid as a slave
  - New electrical appliance?
  - Will they be customised or adapted for the master?
  - Will they take us back to the age of slavery?
- Humanoid as a companion
  - Will they become socially accepted?
  - Will they have social rights?
  - Who will be responsible for them?
  - Will they be able to acquire a conscience?
  - Will they evolve?

Humanoid Interaction

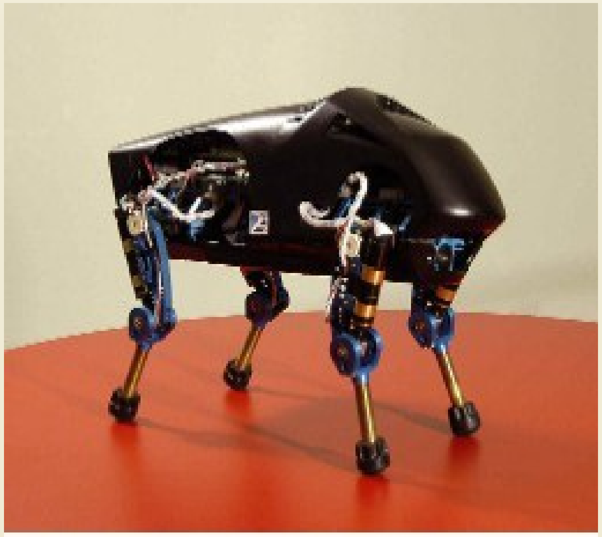
- Awareness of humans
  - Person tracking
  - Face detection; gaze tracking
  - Face recognition
  - Human's “perspective” considerations
- Gesture recognition
  - pointing
  - hand motions

Humanoid Interaction

- Social interaction
  - Gaze as indicator of attention
  - Facial expressions (e.g., Kismet)
  - Sound effects (R2D2, AIBO) vs. speech
  - Use of displays (Looking Glass project)

Social Interaction

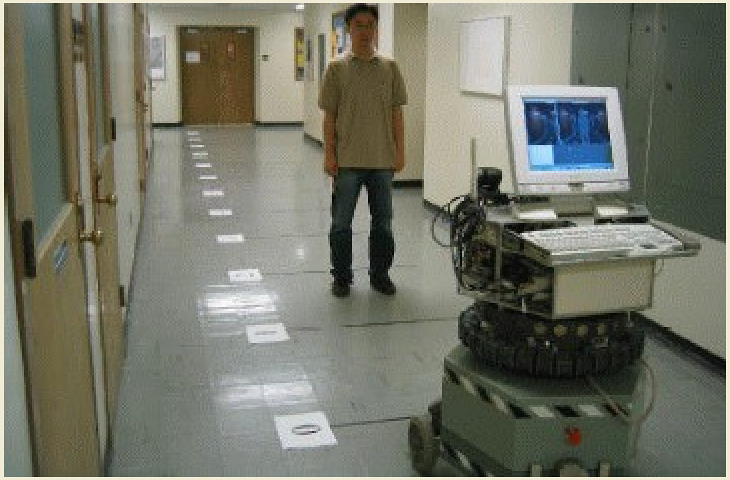
- Do robots need heads?
- What are heads used for?
  - Indicate focus of attention by gaze direction
  - Gestures such as nodding agreement
  - Anthropomorphism makes robots more acceptable to humans
- Headless robots are creepy



DARPA – Little Dog

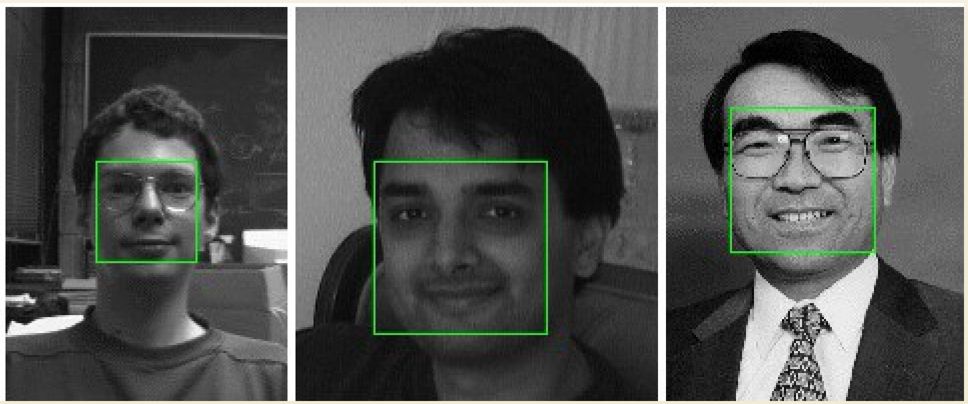
Awareness 1: Person Tracking

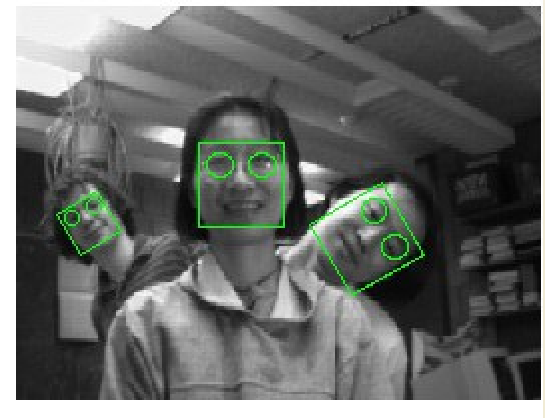
- Be aware of human presence
  - Follow a human (robot assistant)
  - Avoid the humans
  - Interact with humans (museum tour guide robots)
- Use skin color; look for legs (rangefinder); etc.



Awareness 2: Face Detection

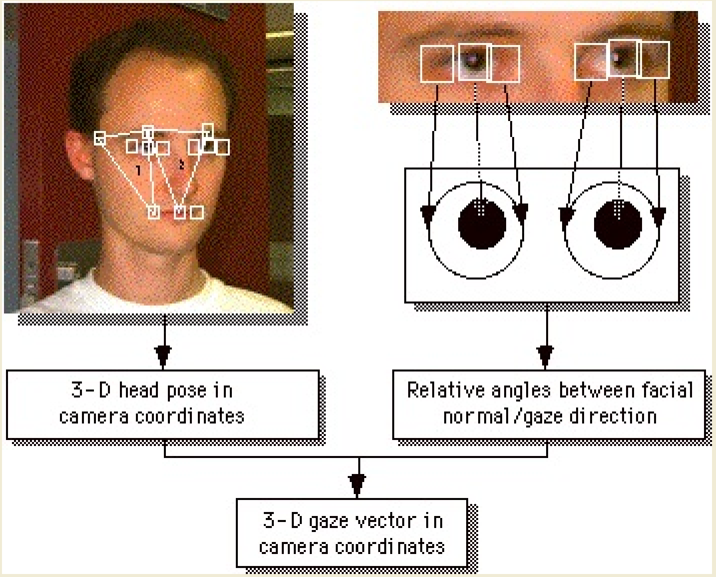
- Rowley, Baluja, and Kanade (1998) used a neural net:





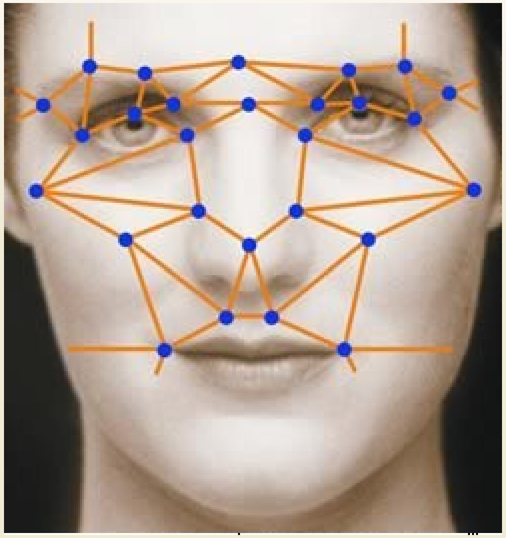
Awareness 3: Gaze Tracking

- What is the human looking at?
- Gaze has high social significance among primates.
- For robots, hard to measure gaze at a distance



Awareness 4: Face Recognition

- Which human is this?
- Lots of work in this area now for
- Security applications.
- Sony's AIBO, QRIO have
- Face recognition modules



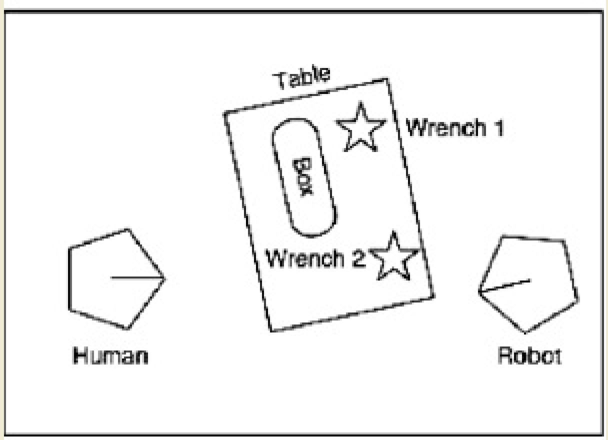
Face analysis

- Frauenhofer institute
- Recognize face
- Estimate age, gender
  - Over 97% accurate
- Identify emotion

https://www.youtube.com/watch?v=Suc5B79qjfE

Awareness 5: Co-awareness

- What can the human see from his present location?
- Trafton et al.: “Give me the wrench.”
- Robot sees two wrenches, but knows that the human can only see one



Awareness 6: Gesture Recognition

- Pointing
  - Point at objects to designate them to the robot
  - Point in a direction, or towards a goal location
- Hand gestures
  - “Come here” / “Come closer” / “Back off”
  - “Stop”
  - “Put that there”

Human-Robot Interfaces

- Existing technologies
  - Simple voice recognition and speech synthesis
  - Gesture recognition systems
  - On-screen, text-based interaction
- Research challenges
  - How to convey robot intentions?
  - How to infer user intent from visual observation (how can a robot imitate a human)?
  - How to keep the attention of a human on the robot?
  - How to integrate human input with autonomous operation?

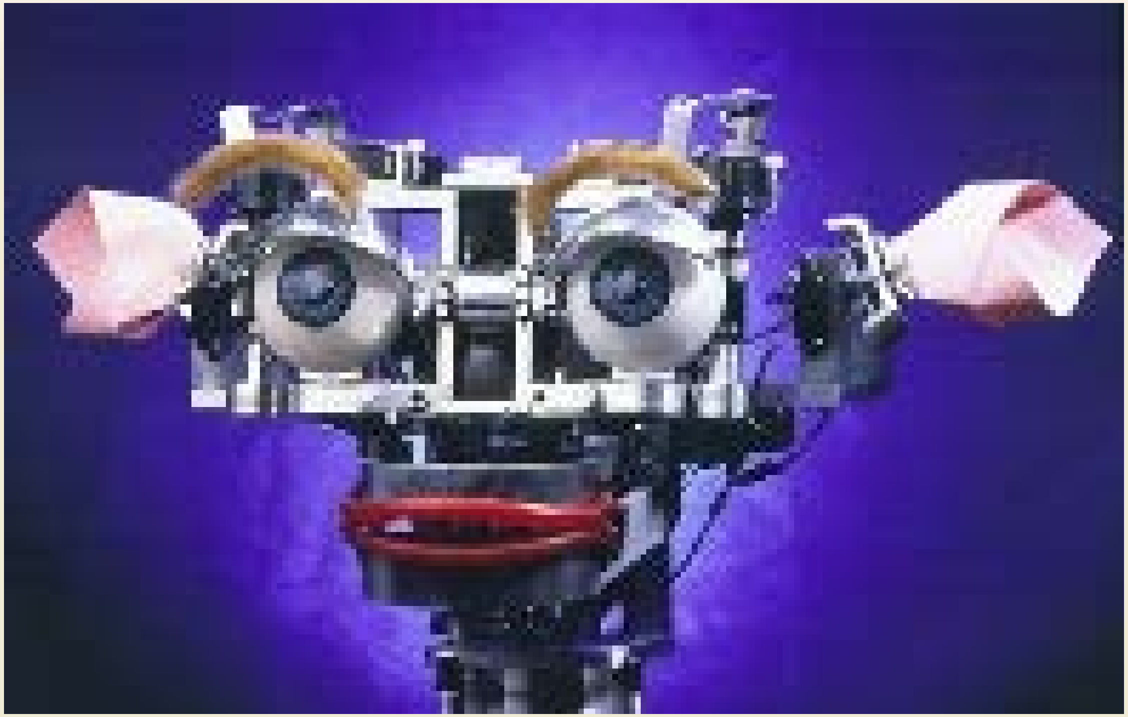
"Social" Robot Interactions

- To make robots acceptable to average users they should appear and behave “natural”
  - "Attentional" Robots
    - Robot focuses on the user or the task
    - Attention forms the first step to imitation
  - "Emotional" Robots
    - Robot exhibits “emotional” responses
    - Robot follows human social norms for behavior
      - Better acceptance by the user (users are more forgiving)
      - Human-machine interaction appears more “natural”
      - Robot can influence how the human reacts

"Social" Robot Interactions

- Advantages:
  - Robots that look human and that show “emotions” can make interactions more “natural”.
    - Humans tend to focus more attention on people than on objects.
    - Humans tend to be more forgiving when a mistake is made if it looks “human”.
  - Robots showing “emotions” can modify the way in which humans interact with them.
- Problems:
  - How can robots determine the right emotion?
  - How can “emotions” be expressed by a robot?

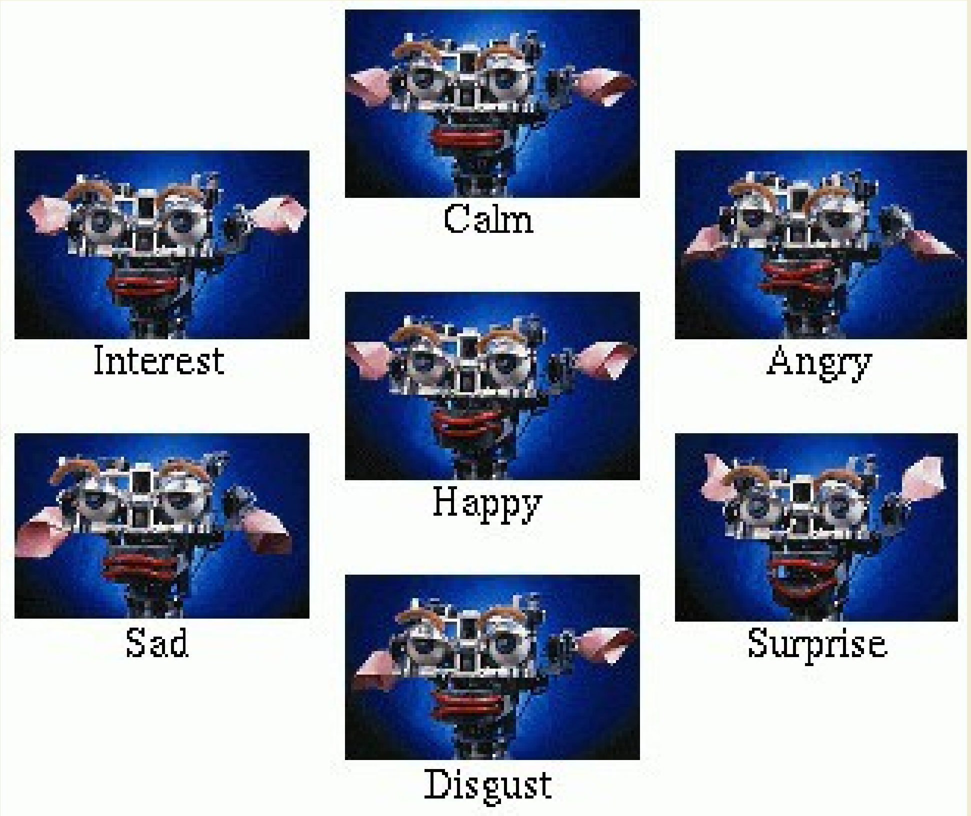
Emotional Robots: Cog & Kismet

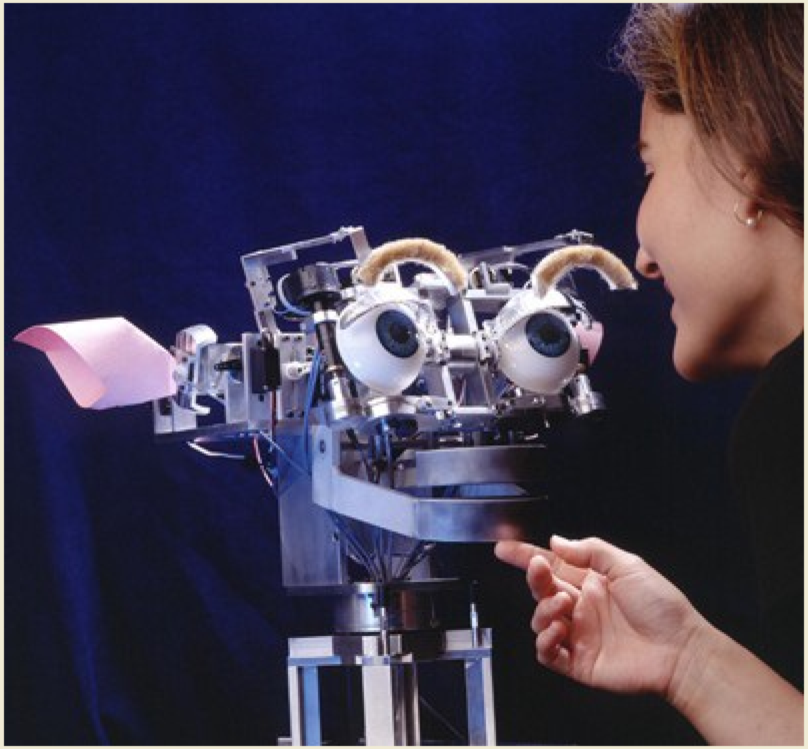


[Brooks et al., MIT AI Lab, 1993-today]

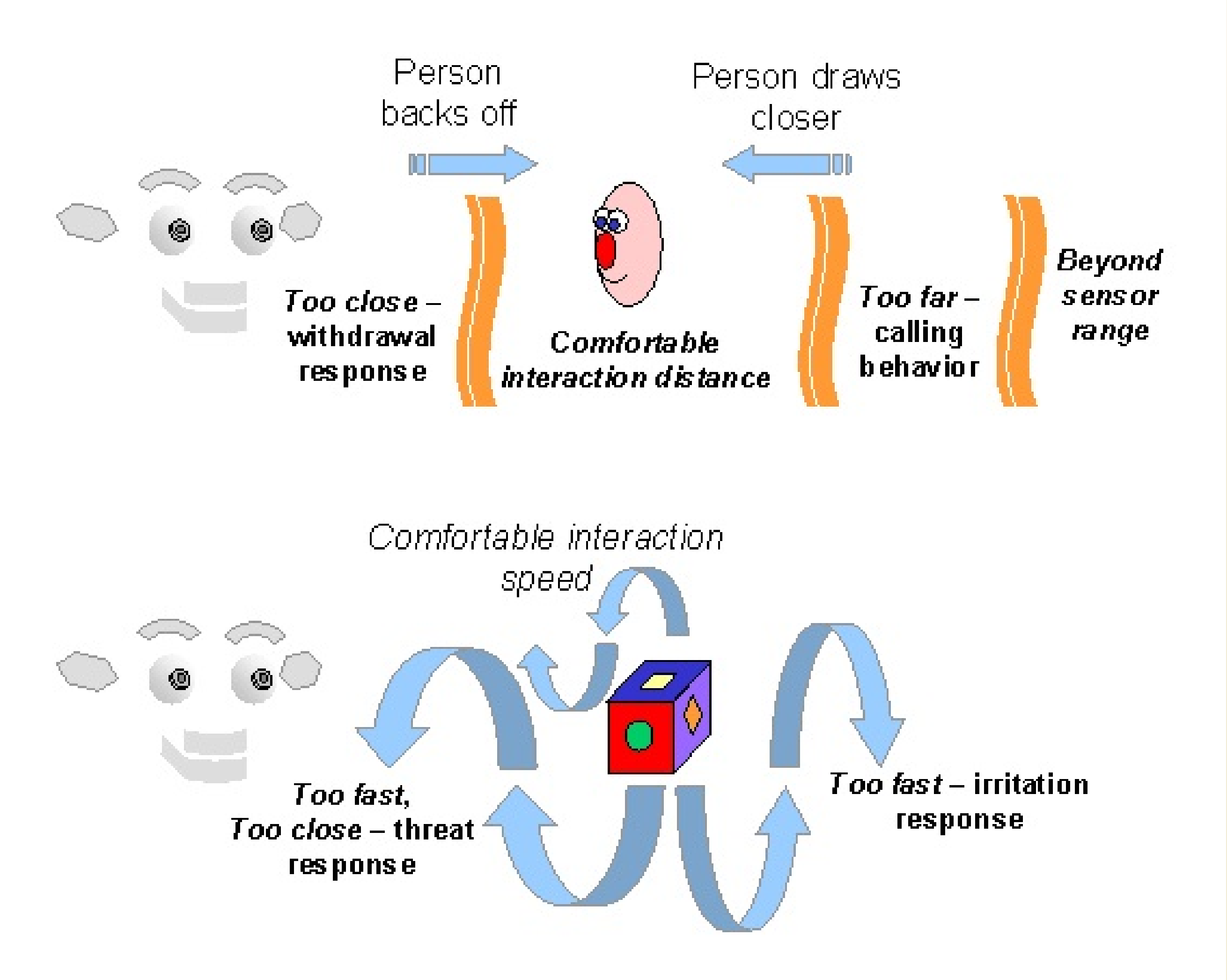
Facial Expression

- Kismet
  - Cynthia Breazeal, ca. 1999-2000





Kismet Facial Expression



https://www.youtube.com/watch?v=8KRZX5KL4fA

Human-Robot Interaction in Intelligent Environments

- Personal service robot controlled and used by untrained users.
  - Intuitive, easy to use interface.
  - Interface has to “filter” user input.
  - Eliminate dangerous instructions.
  - Find closest possible action.

Communicating with Humans

- Why should robots talk anyway?
  - R2D2 used sound effects to convey emotion.
  - AIBO and Kismet do likewise.
- Use of “canned” messages:
  - “Excuse me, you're blocking my path.”
  - Roboceptionist: “How may I help you?”
- Will people expect to be able to talk back to a robot?
  - Voice recognition gets harder when the robot is noisy.
- Use of display or lights to communicate status, mood.

Communicating with Humans

- Roboceptionist: “How may I help you?”
- Actroid...

- Will people want to talk back?

https://www.youtube.com/watch?v=QCuh1pPMvM4
https://www.forbes.com/sites/zarastone/2018/02/27/ten-incredibly-lifelike-humanoid-robots-to-get-on-your-radar/

Humanoid Robot Control

- Problems:
  - Many degrees of freedom (>100).
  - Must balance and remain upright.
  - Must move and maintain balance.
  - Coordination of arms, legs, spline required.
  - Skills required to perform most tasks.

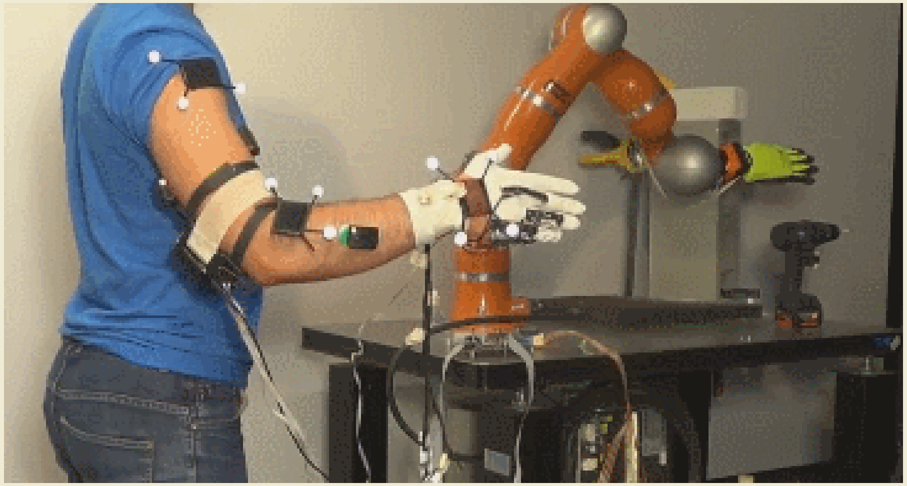
Active vs. Passive Locomotion

- Common humanoid uses all their DOF to perform the movement:
  - Continuous motor consumption (including arms).
  - Continuous motor control and synchronization.
  - Extremely complex real-time control.
- How is possible to reduce complexity?
  - Reducing number of active DOF.
  - Using DOF only when it is strictly necessary.
  - Using energy of previous step to generate the next.
  - These actions reduce also the consumption.

Teleoperated Robots

- Human act – Robot does
  - tele-operated humanoid that operates a backhoe.
  - Hazardous environments.
  - Bomb disposal.
  - Deep sea diving.
  - Telepresense.

Teleoperated Robots



Human-Robot Teleoperation

- Direct operation of the robot by the user
  - User uses a 3-D joystick or an exoskeleton to drive the robot
    - Simple to install
    - Removes user from dangerous areas
  - Problems:
    - Requires insight into the mechanism
    - Can be exhaustive
    - Easily leads to operation errors
    - Confines operator to robot

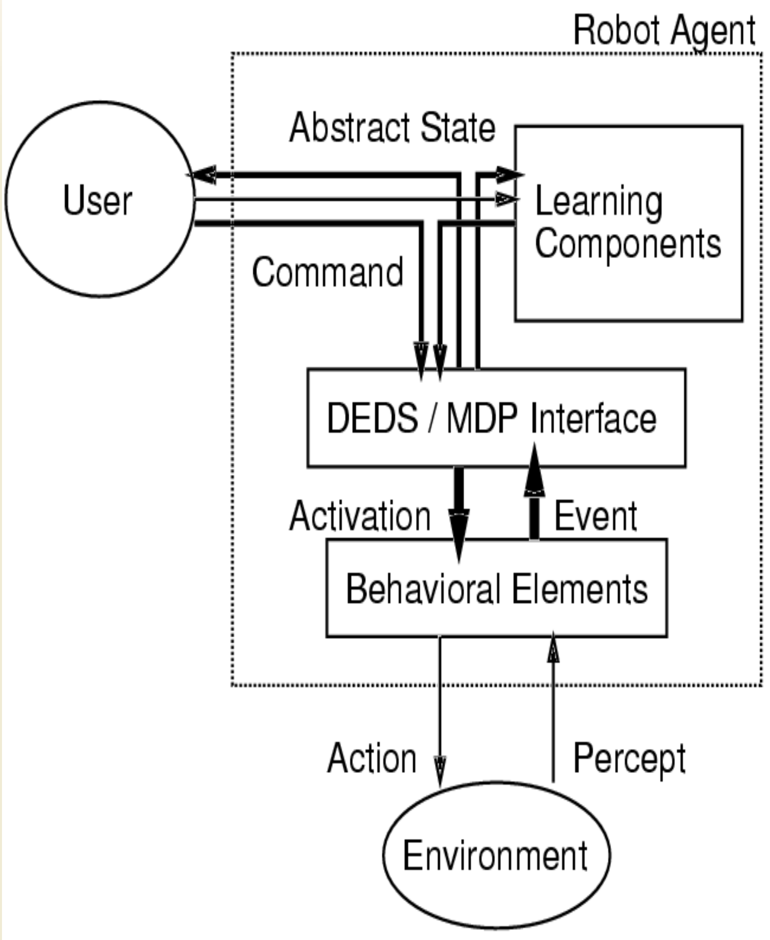
https://www.youtube.com/watch?v=TJmQqC1nHTU

Semi-autonomous Control

- Receive only intermittent commands
  - Robot requires autonomous capabilities
  - User commands can be at various levels of complexity
  - Control system merges instructions and autonomous operation
- Interact with a variety of humans
  - Humans have to feel “comfortable” around robots
  - Robots have to communicate intentions in a natural way

Semi-autonomous Control

- Adjustable Autonomy
  - The robot can operate at varying levels of autonomy
  - Operational modes:
    - Autonomous operation
    - User operation / teleoperation
    - Behavioral programming
    - Following user instructions
    - Imitation
  - Types of user commands:
    - Continuous, low-level instructions (teleoperation)
    - Goal specifications
    - Task demonstrations



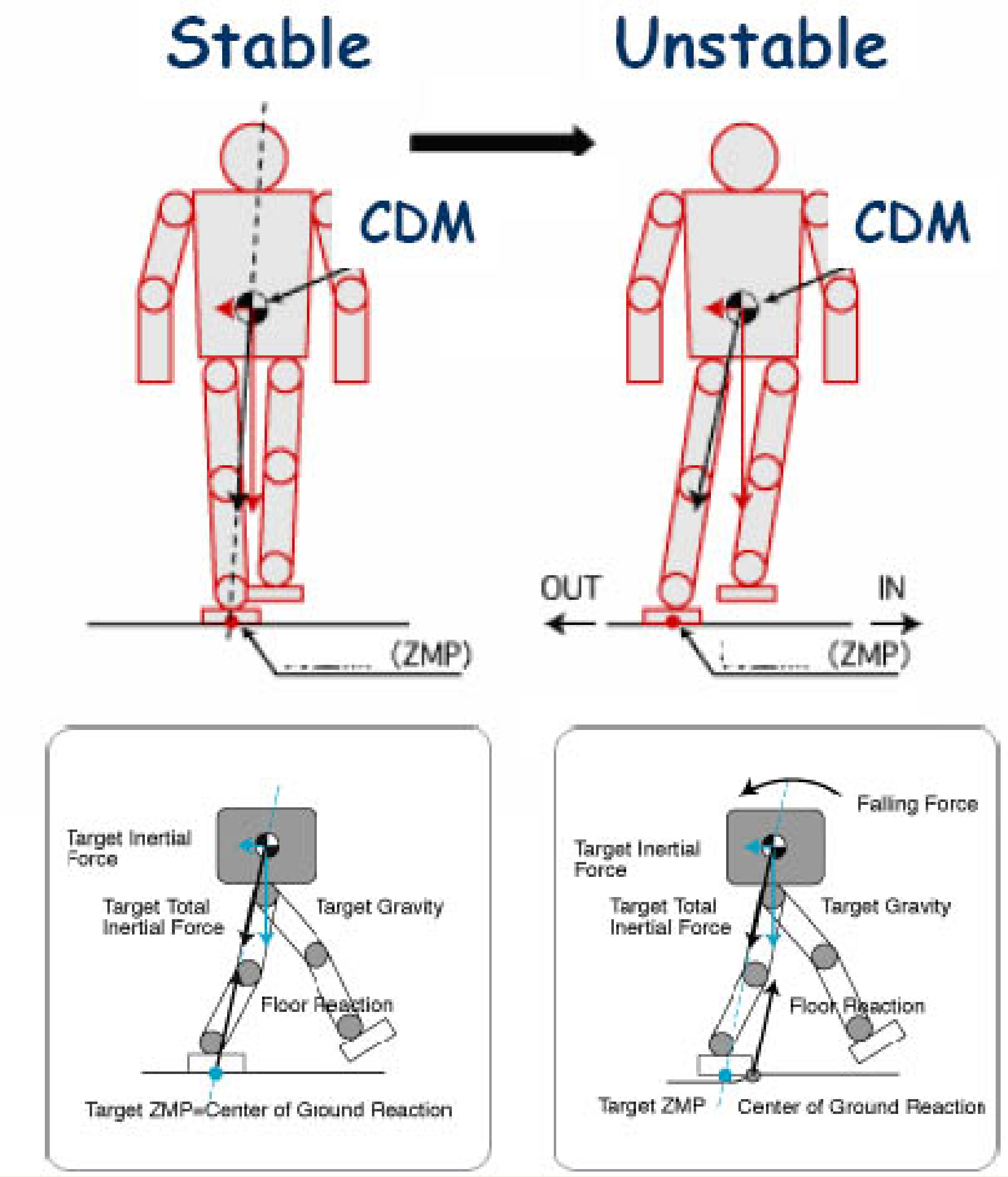
Example System

Autonomous Control

- Environments are non-stationary and change frequently, requiring robot to adapt
  - Adaptation to changes in the environment
  - Learning to address changes in inhabitant preferences
- Robots cannot frequently be pre-programmed
  - The environment is unknown
  - The list of tasks that the robot should perform might not be known beforehand
    - Home environment has changed
  - Different users have different preferences

Bipedal Locomotion

- **ZMP (Zero Moment Point)** specifies the point with respect to which dynamic reaction force at the contact of the foot with the ground does not produce any moment, i.e. the point where total inertia force equals 0 (zero).
- **ZMP is the indicator** of the stability of the robot:
  - if it is in the foot shadow – stable,
  - İf not – unstable.
- The shadow depends on single or double support phase.

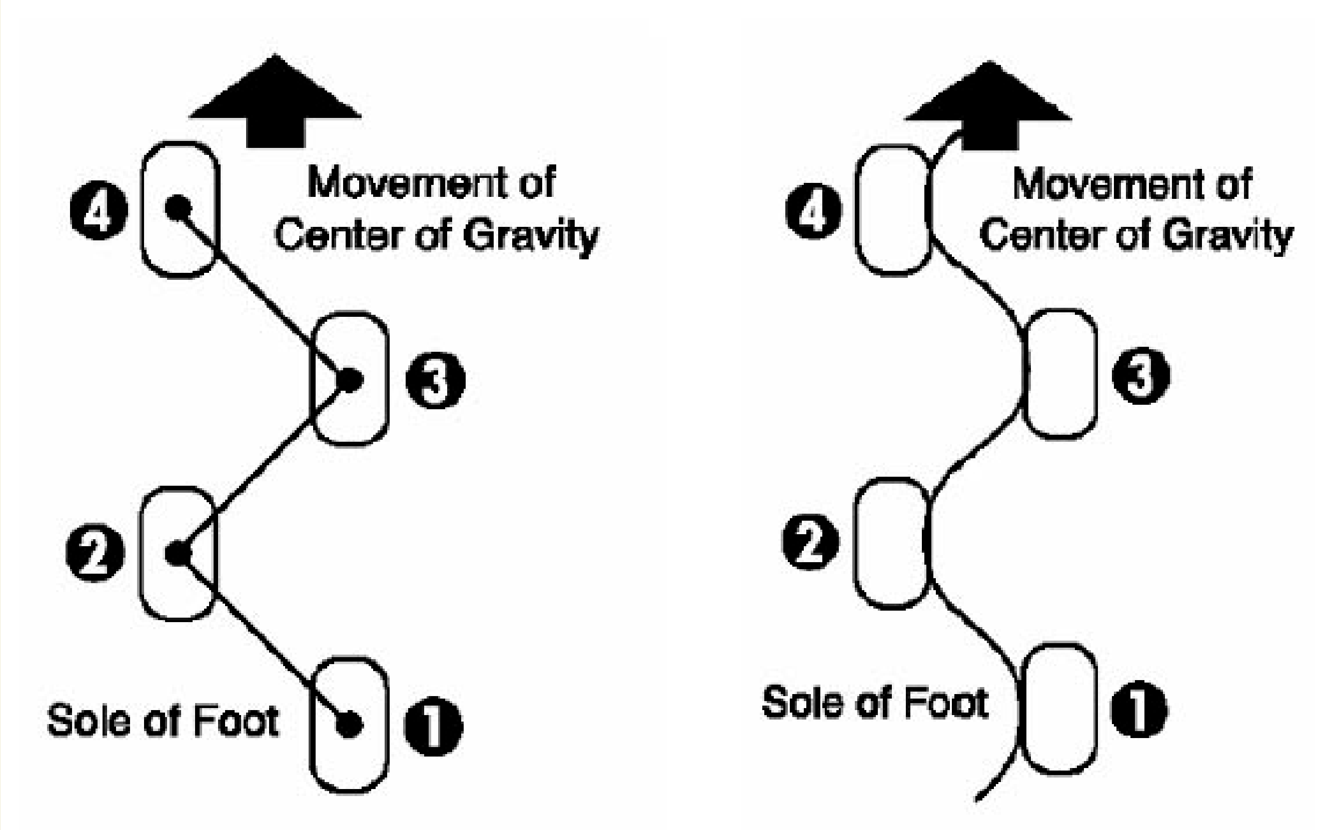


Passive Dynamic Walking

- Human walking strategy:
  - Let their legs swing as they would on their own,
  - Then add a little control and power, yielding a gait with inherently low energetic and control demands.
- Advantages:
  - In contrast to rigidly joint-controlled robots, walking robots based on passive-dynamic principles can have human-like efficiency and actuation requirements.
- Disadvantages:
  - Movements are mostly in sagital plane and in straight line, being extremely difficult to turn, go back, seat,etc. The motion is mostly symmetrical.

Passive Dynamic Walking (cont'd)

- **Active Gait :** Always stable
- **Passive Gait :** Sometimes unstable



Conclusions

- Humanoid robots are desirable
  - Automation.
  - Do work that humans don’t want to do.
  - Do work in hazardous places.
- Problems with humanoid robot
  - Autonomous control is difficult.
  - Natural human interface hard to achieve.
  - Adaptive and learning complex.
  - Robot has to maintain safety during operation.
- Teleoperation
  - Allows human to work via robot.
  - Telepresence is possible.
- Fully autonomous control
  - Still some time away .