Humanoid robots

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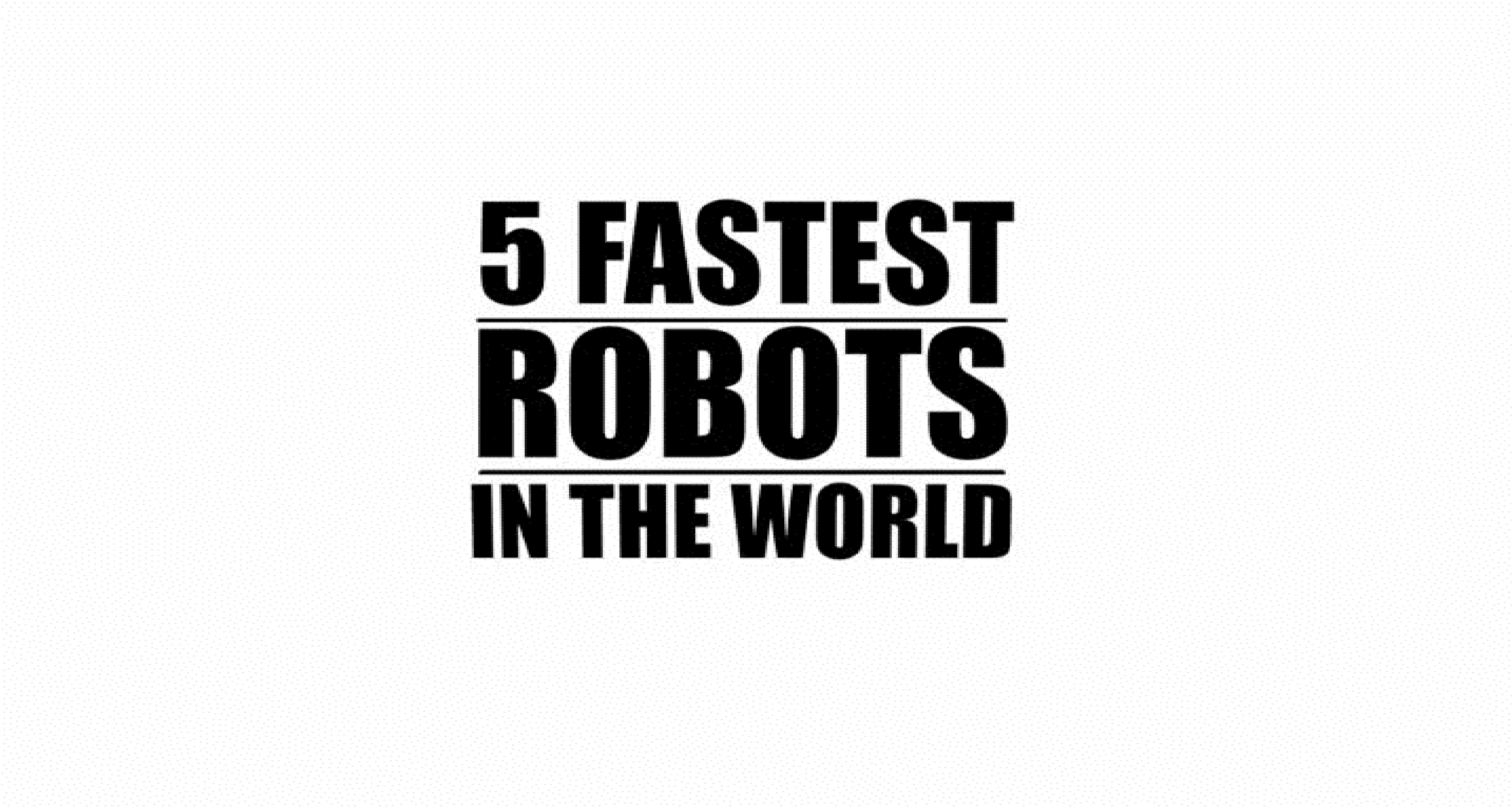
Appetizer, five fastest robots 2017-01



Humanoid robot, definition

- Humanoids are machines that have the form or function of humans.
  There is a tension in this definition while balancing form and function. The definition is proposed as a harmony of both.

  [WTEC Panel Report on international assessment of research and development in robotics, January 2006]

- Humanoid robots selectively emulate aspects of human form and behavior. Humanoids come in a variety of shapes and sizes, from complete human-size legged robots to isolated robotic heads with human-like sensing and expression.

  [Bruno Siciliano, Oussama Khatib (Eds.): Springer Handbook of Robotics, Ch 56 - Humanoids, Charles C. Kemp, Paul Fitzpatrick, Hirohisa Hirukawa, Kazuhito Yokoi, Kensuke Harada, Yoshio Matsumoto, 2008]

Why humanoids? (1)

Good reasons for aiming at humanoid robots

- Work in dangerous environments
- Exhaustive and repetitive tasks.
- Division of labour with humans in cooperative tasks
- Anthropomorphism
- Embodiment
- Interaction and Communication

Antropomorphism

- Humans have built complex environments, tools and equipment very much adapted to our selves.
- Robots with human-like morphology, motion capabilities, and perception have a greater potential acting in living environments created for humans.

Why humanoids? (2)

Interaction and communication with humans

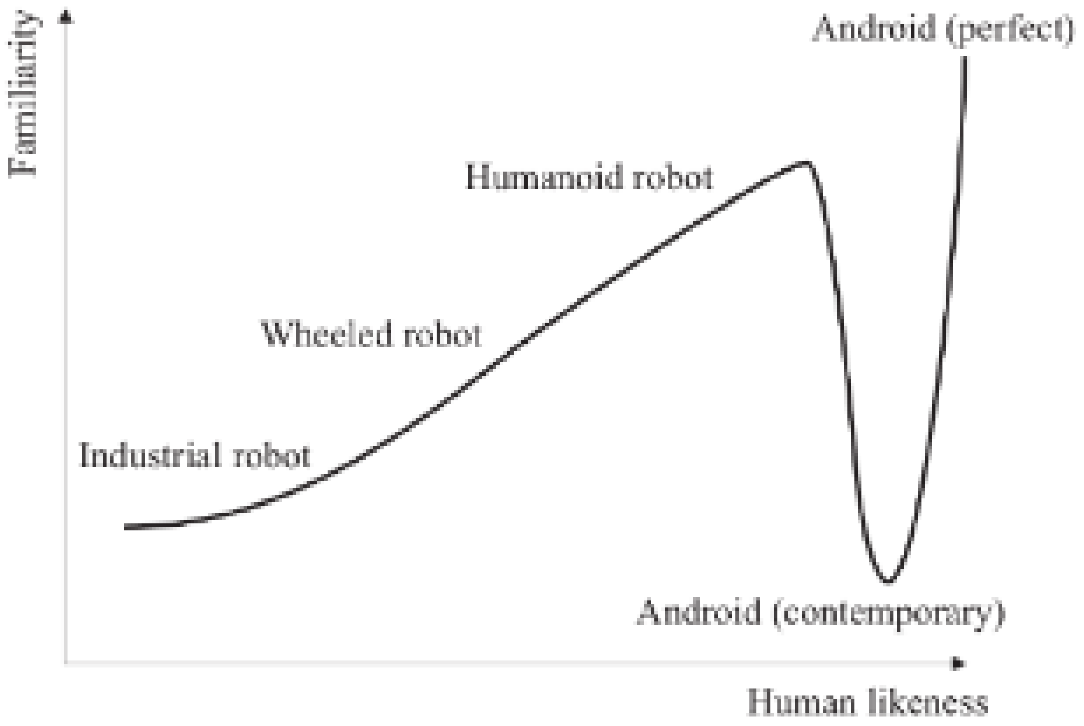
- Humanoids can *communicate in a manner that* supports the natural communication modalities of humans. Examples include: facial expression, body posture, gesture, gaze direction, and voice.
- If a robot has humanoid form, then it will be both easy and natural for humans to *interact with it in a humanlike* way.

Androids (robots)

- An android is a humanoid robot or synthetic organism designed to look and act like a human, especially one with a body having a flesh-like resemblance.
- Created by the group of Osaka University professor Hiroshi Ishiguro 2015.

The uncanny valley phenomenon

- The uncanny valley hypothesis was coined by Masahiro Mori in 1970.
- Until it is possible to build almost perfect androids, robots that are used outside research laboratories should look like robots rather than attempting to look like humans.



Control challenges

- Dexterity
  How can we create and execute advanced skills that **coordinate motion, force, and compliant multi-contact** behaviors?

- Interaction
  How can we model and respond to the **constrained physical interactions** associated with human environments?

- Autonomy
  How can we create **action primitives** that encapsulate advance **skills** and interface them with high level planners?

Interactions, problems and challenges

Interactions

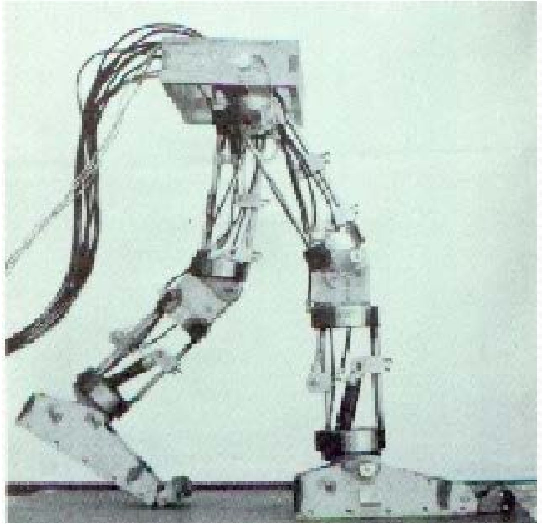
- Operate efficiently under arbitrary **multi-contact constraints**.
- Respond compliantly to **dynamic changes** of the environment.
- Plan **multi-contact maneuvers**.

Key challenges

- Find **representations** of the robot internal contact state.
- Express contact dependencies with respect to **frictional** properties of contact surfaces
- Develop controllers that can generate compliant whole-body **skills**.
- Plan feasible multi-contact behaviors.

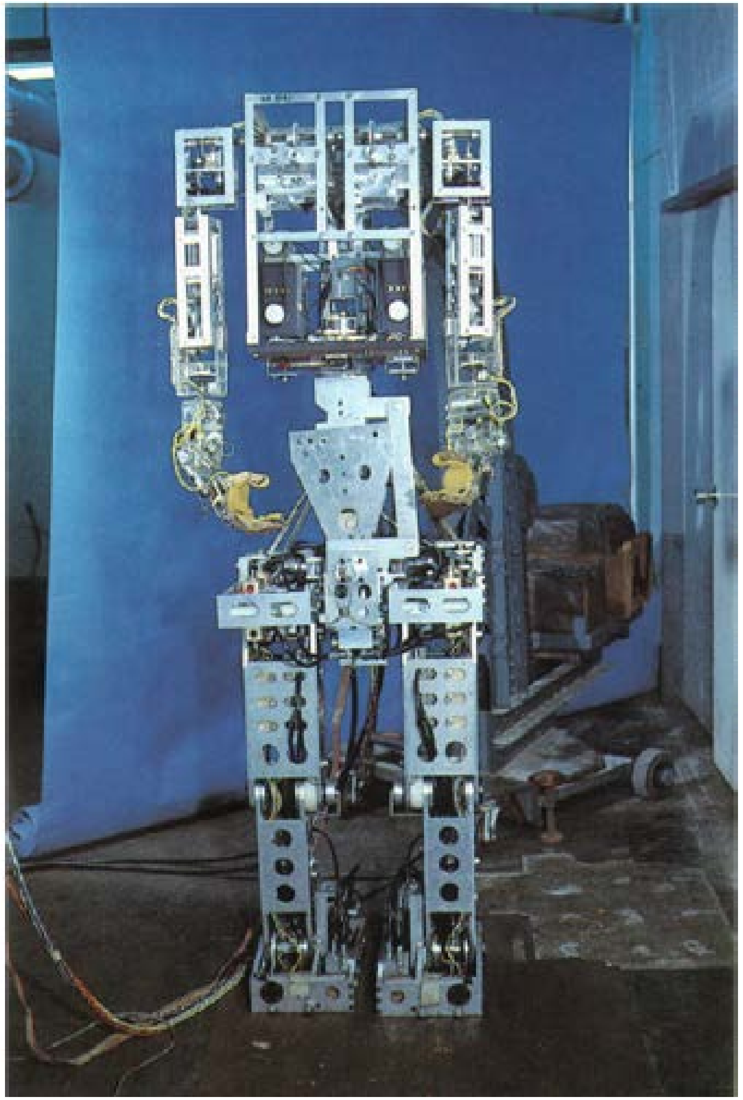
Modern history, bipedal locomotion

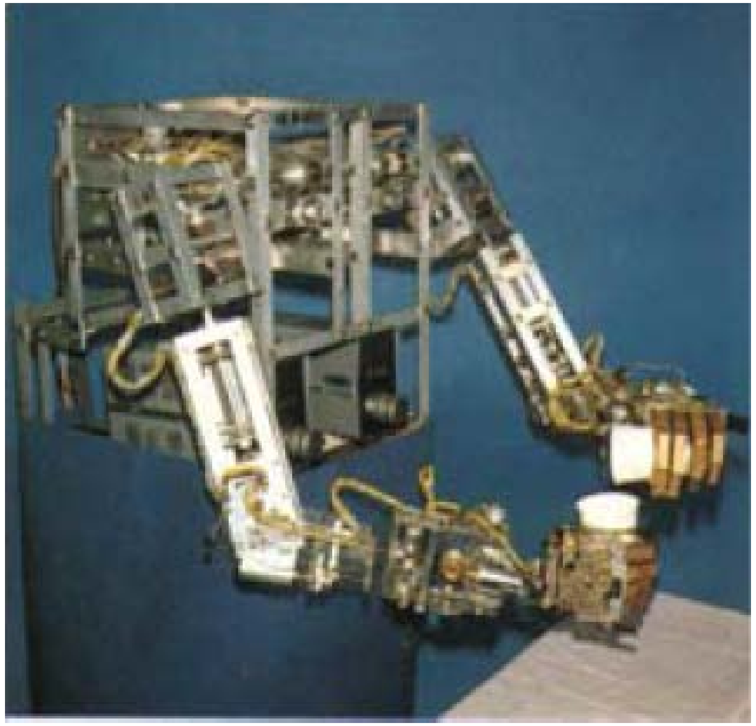
- Waseda University Leg (series), Ichiro Kato and his team, Tokyo 1967-1971
- The mechanical model of lower-limbs, WL-3 was constructed which had an electro-hydraulic servo-actuator in 1969. It achieved a human-like motion in a swing phase and a stance phase, and a standing and sitting motion.



Modern History - Wabot-1, 1973

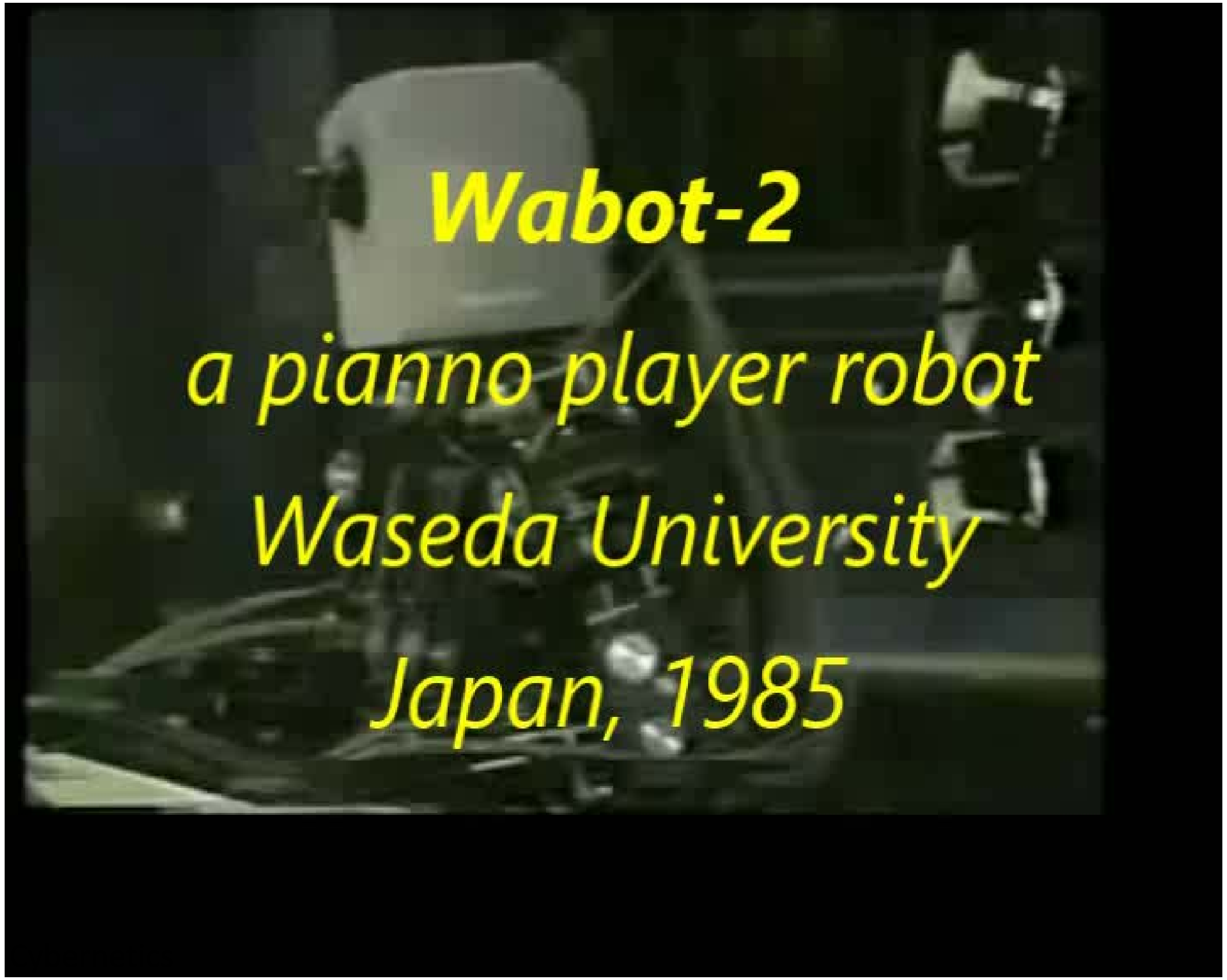
- Wabot-1 – by Ichiro Kato, Waseda University, Japan, 1973, a first full-scale humanoid robot.
- Integrated systems for sensing, locomotion and manipulation inspired by human capabilities.
- http://www.humanoid.waseda.ac.jp/history.html





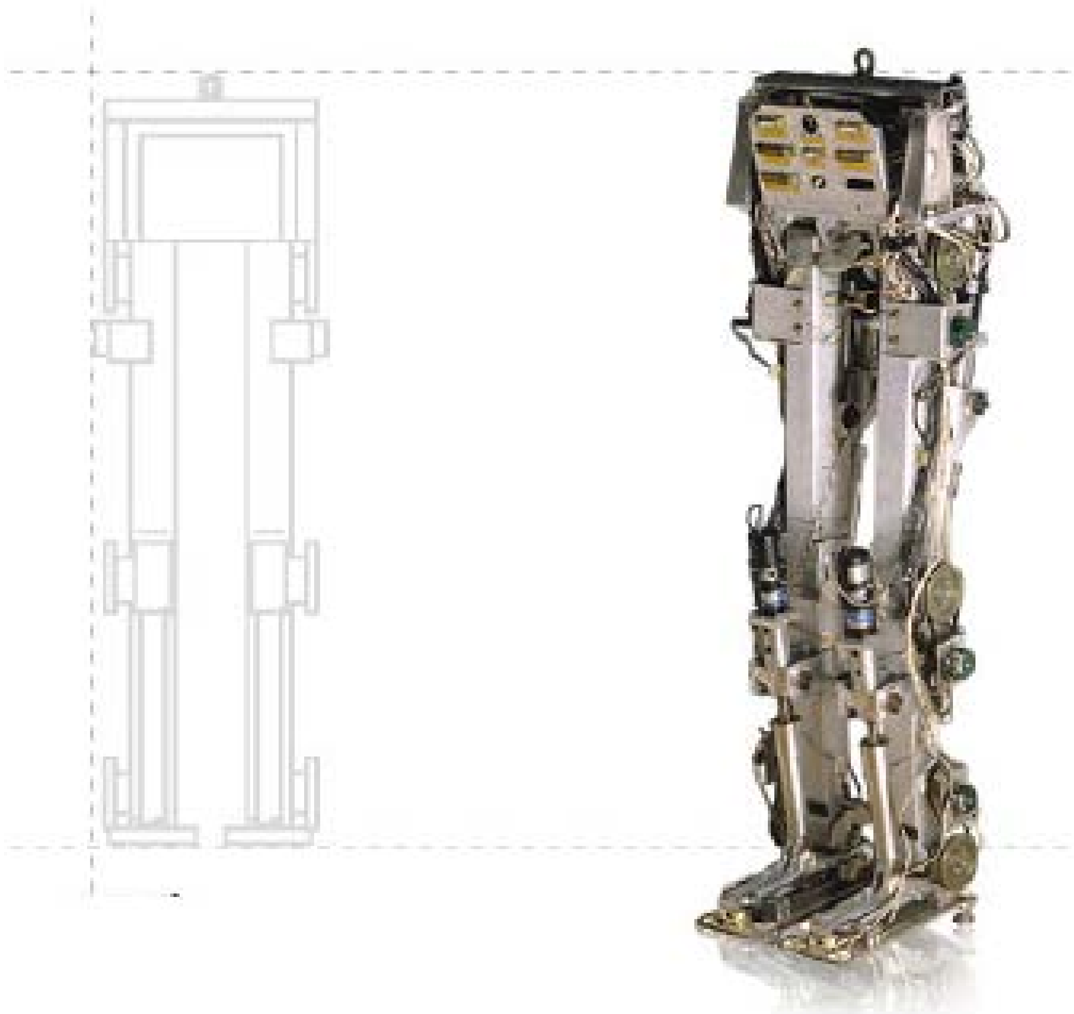
Modern History - Wabot-2, 1985

A musician robot Wabot-2 played a piano, Waseda University, Japan.



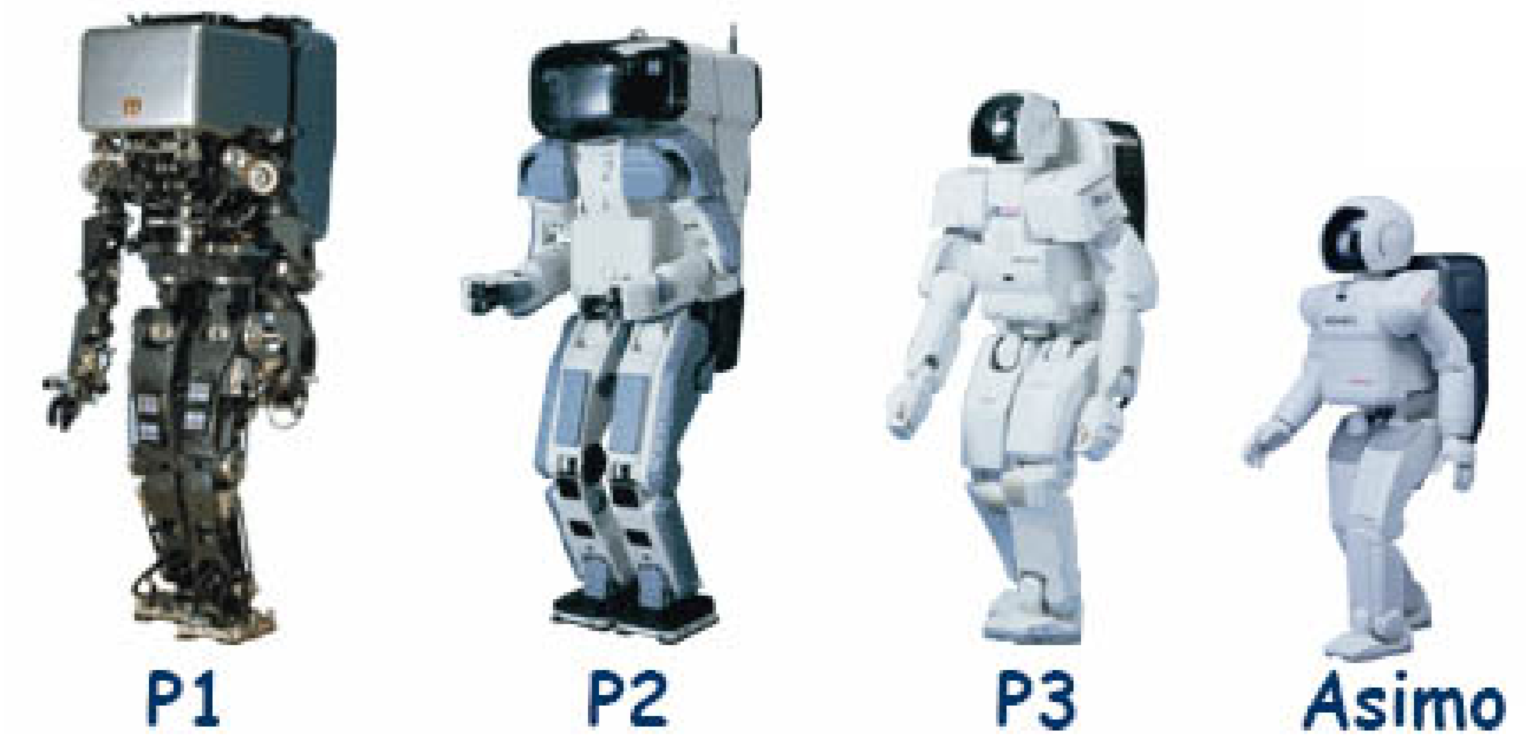
Honda E-Series(1986-1993)

- Experimental series to develop bipedal motion.
- Walking by putting one leg before the other was successfully achieved. However, taking nearly five seconds between steps, it walked very slowly in a straight line.



Honda P-Series(1983-1997)

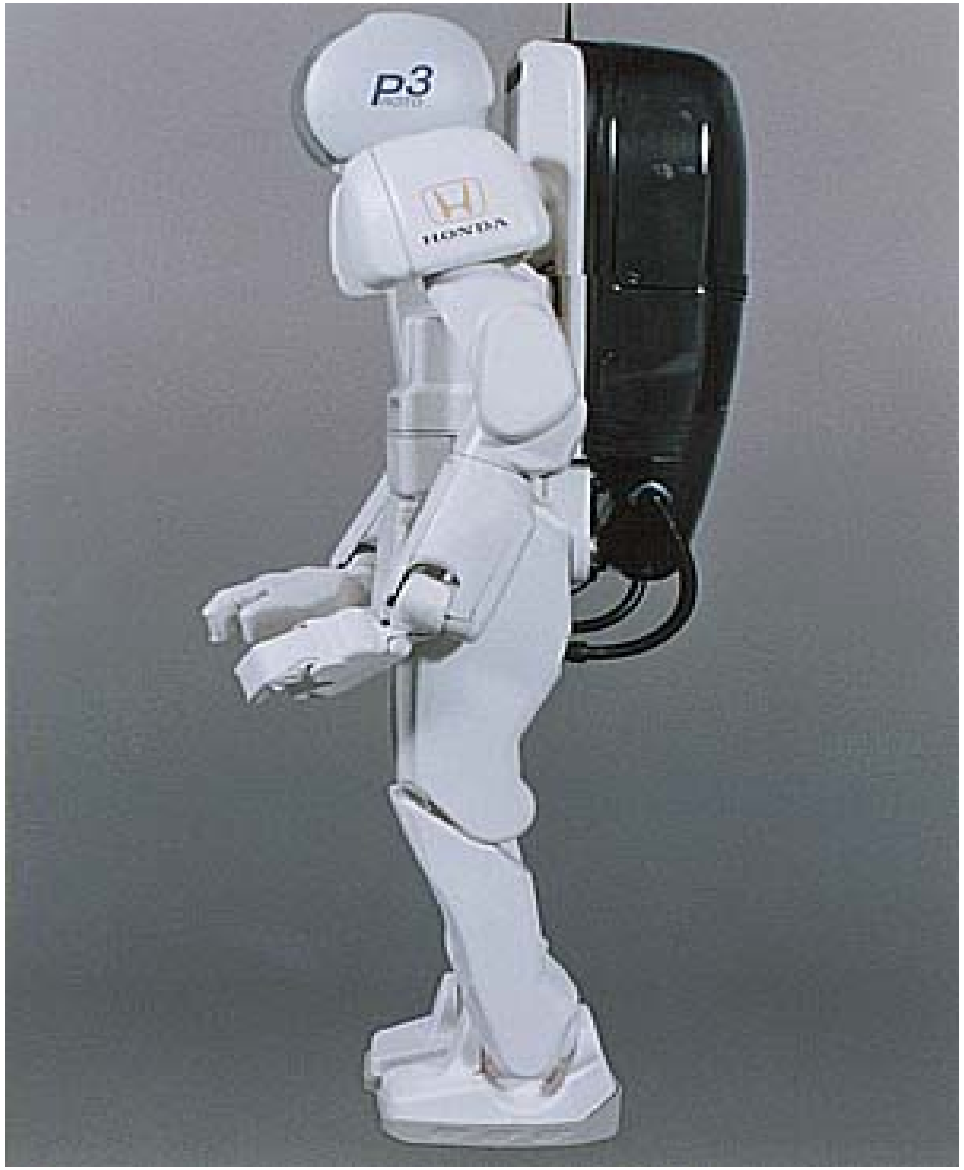
- Man-like, self-contained, humanoid robots
- Studies were carried out to determine what a humanoid robot should be like to function properly in society and in a human living environment. A prototype model of near-human size was completed.



P3 by Honda in 1997

Capabilities:

- Walk around
- Climb stairs
- Carry things
- Pick things up
- Push things
- Position itself accurately

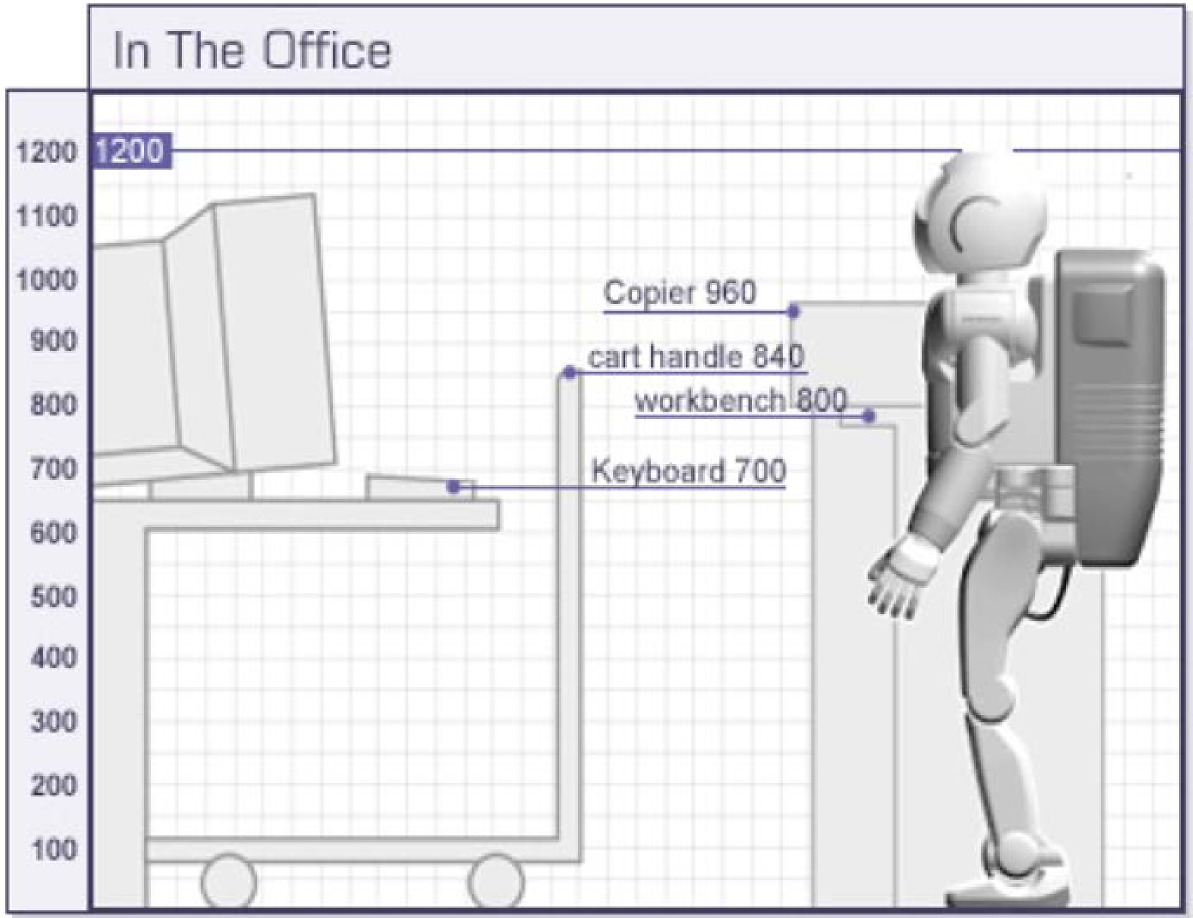


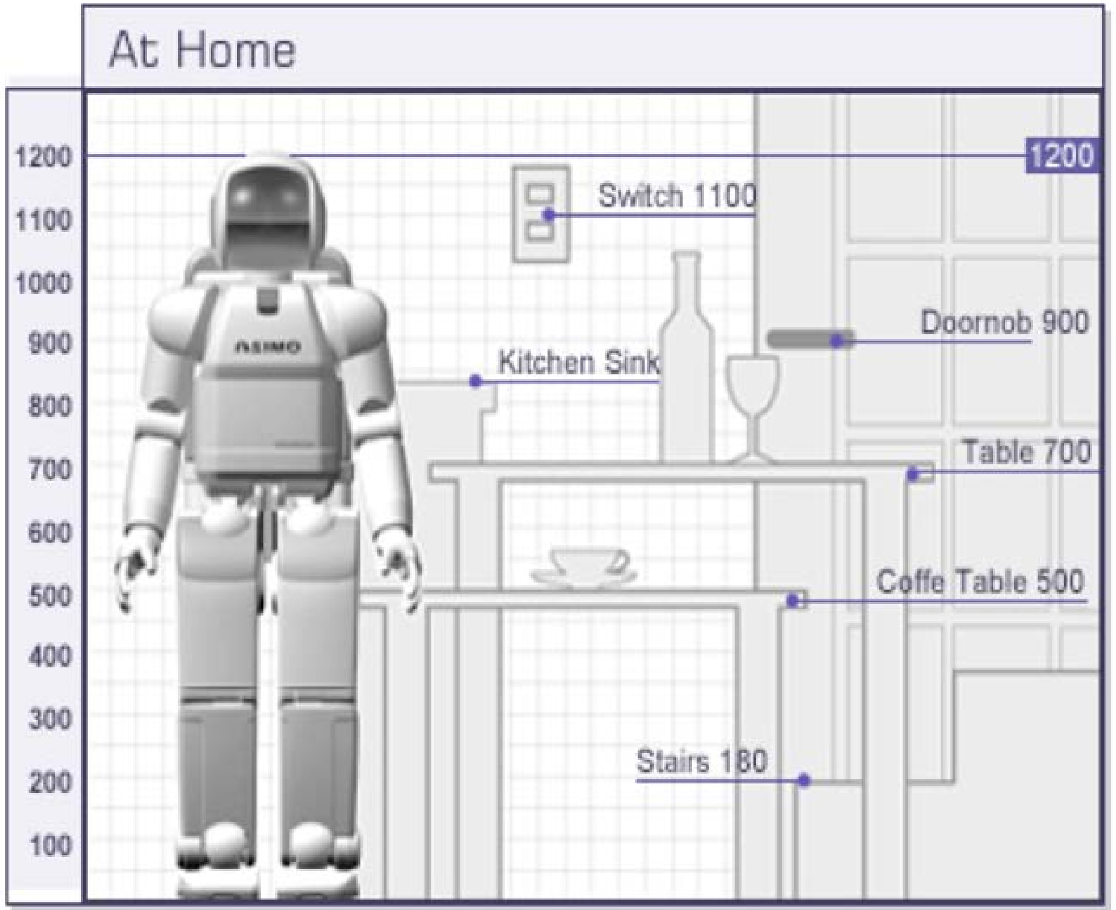
ASIMO by Honda

- ASIMO stands for Advanced Step in Innovative Mobility.
- A humanoid robot created in 2000 by Honda.
- 11th in line of successive bipedal humanoid model's by Honda.
- 4th man like humanoid robot by Honda.

- Weight: 52 kilograms
- Running Speed: 6 km/h
- Walking speed: 2.7 km/h
- Walking speed while carrying objects: 1.6 km/h
- Height: 130 cm
- Width: 45 cm
- Depth: 44 cm
- Continuous operating time: 40 min – 1 hr
- Degrees of Freedom: 34

Why was ASIMO created?





＊The above heights are examples to serve as a reference(mm).

ASIMO, climbing stairs, 2014

ASIMO, running, walking, 2014

ASIMO kicks the ball, 2014

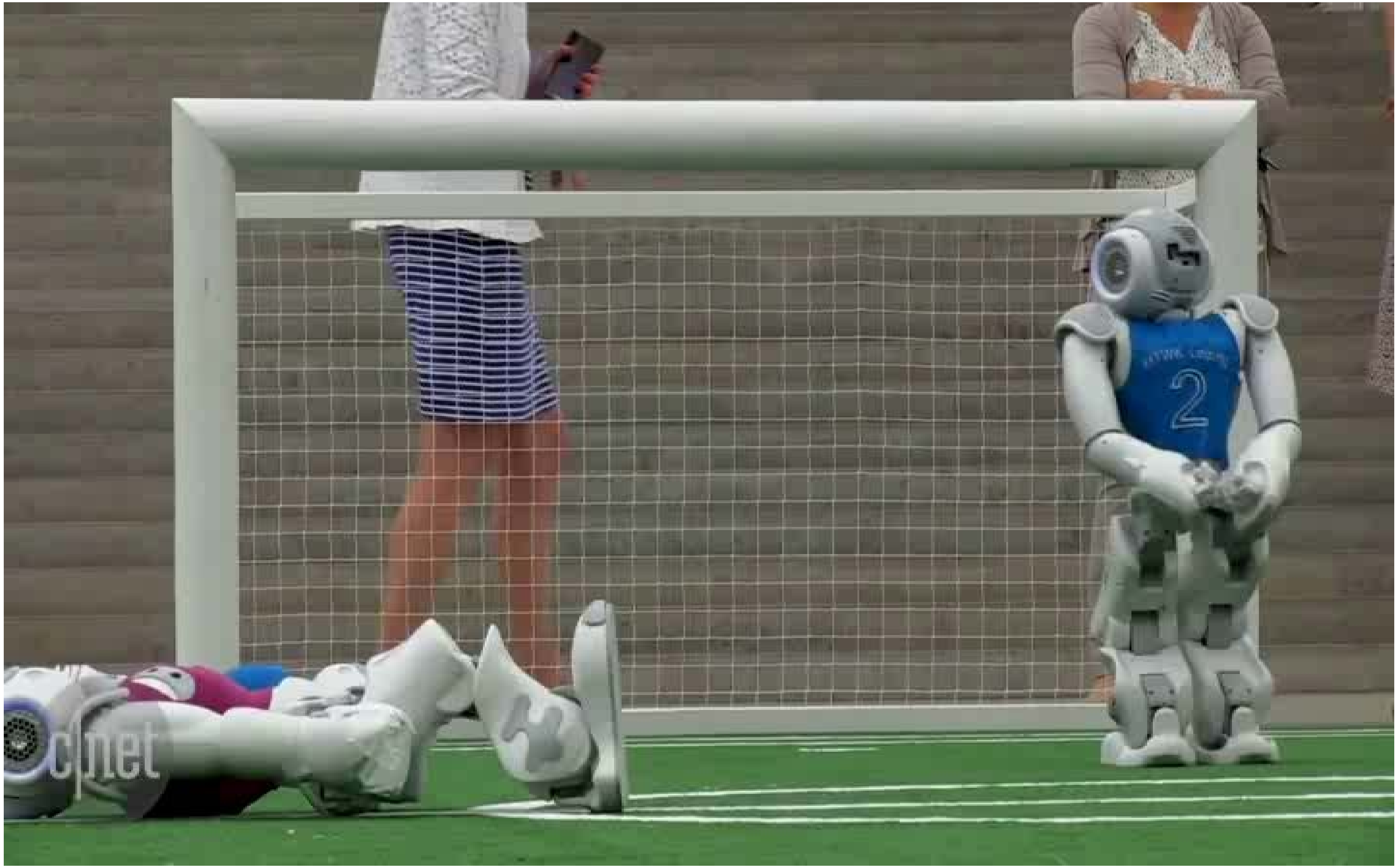
Application domains of Humanoid robots

- Technology demonstration - Showcase of corporate technology, attracts public attention and strengthens the brand.
- Scientific - Test-bed for theories and models (bio-mechanics, cognition, AI).
- Health care - Prosthetics, rehabilitation, social training of autistic children.
- Hazardous environments - Exploration or work in dangerous environments, space missons.
- Domestic helpers - Household work, look after children and the elderly, security guard.
- Edutainment - Aid in teaching technology, robot competitions.
- Other?

State-of-the-art, Robocup

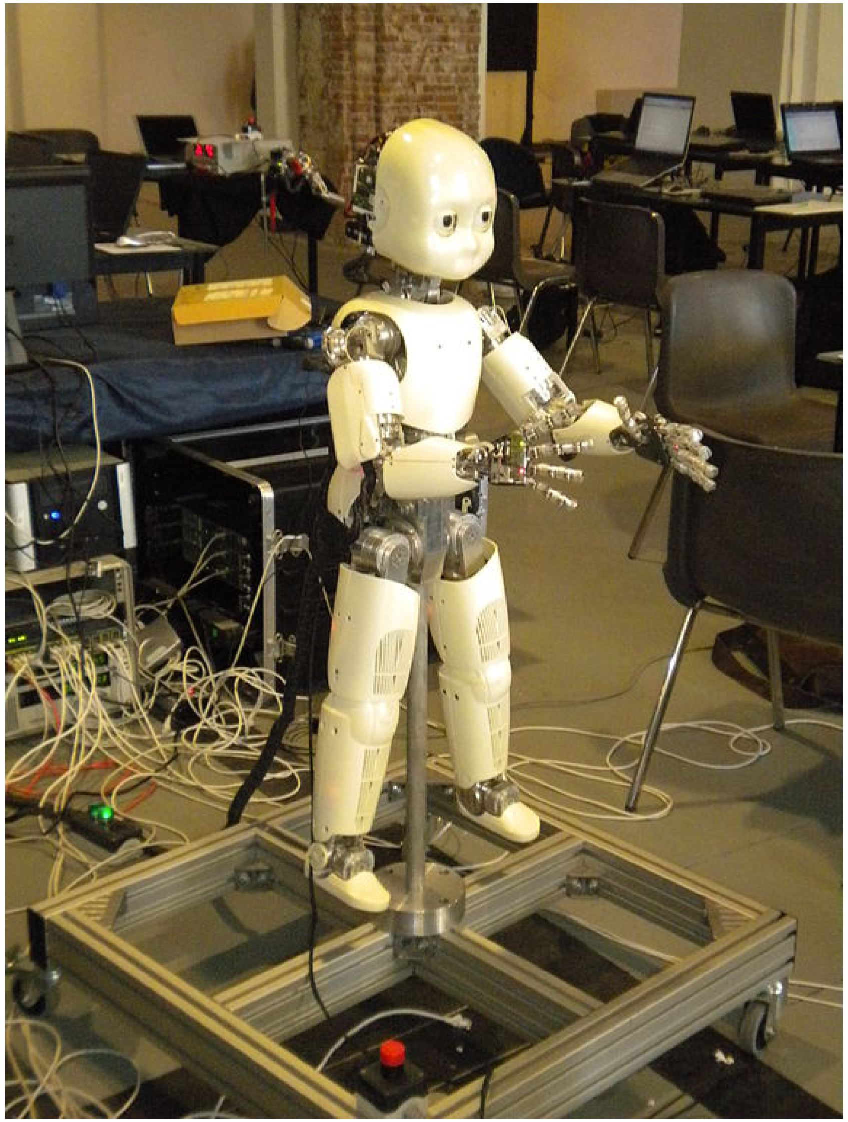
Robocup 2016, a qualification match

State-of-the-art, ASIMO, stairs, running



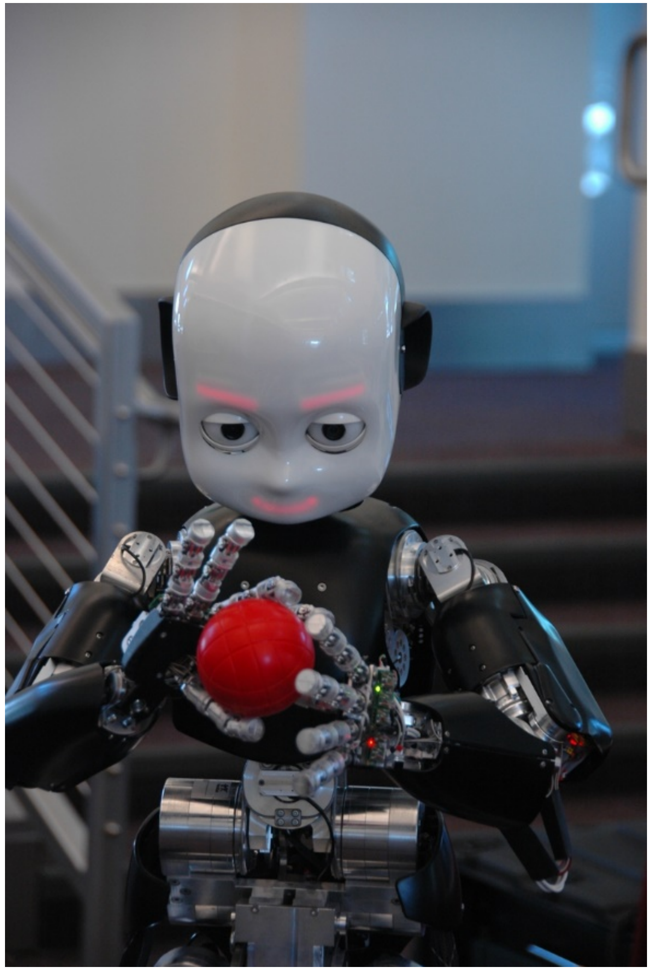
iCub, EU project 2004-2010, continues

- iCub is a 1 meter high humanoid robot testbed for research into human cognition and artificial intelligence.
- Built by the RobotCub Consortium of several European universities and built by Italian Institute of Technology. Financial support continues.
- The robot is open-source, with the hardware design, software and documentation all released under the GPL license.



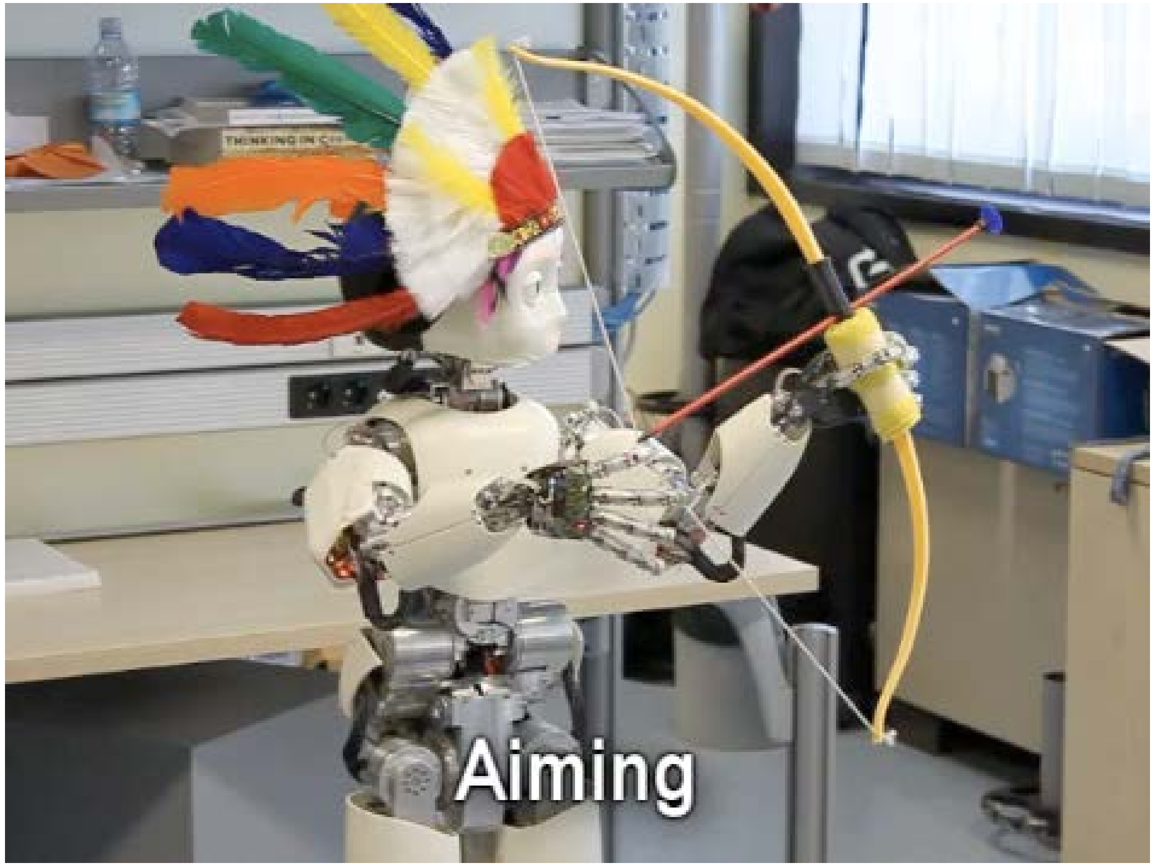
iCub, specifications

- Dimensions as 3½ years old child.
- PC 104 controller, CAN bus (became ISO standard).
- Original version: 53 actuated degrees of freedom. 7 in each arm. 9 in each hand. 6 in the head (3 for the neck and 3 for the cameras). 6 in each leg.
- Joint angles are measured using custom-designed Hall-effect sensors and the robot can be equipped with torque sensors. 3 in the torso/waist.



iCub, capabilities

- Force control, exploiting proximal force/torque sensors
- Crawling, using visual guidance with optic marker on the floor
- Grasping small objects, such as balls, plastic bottles
- Archery, shooting arrows with a bow
- Facial expressions, allowing the iCub to express emotions
- Collision avoidance, self-collision avoidance



iCub, walking

iCub, TaiChi, interaction with humans

iCub, research at ČVUT

Legged locomotion, why?

- Potentially less weight.
- Better handling of rough terrains. Only about a half of the world's land mass is accessible by current man-built vehicles.
- Do less damage to terrains.
- More energy-efficient.
- More maneuverability. Isolated footholds that optimize support and traction.
- Active suspension decouples the path of body from the path of feet.

Boston Dynamics, Robot dog, 2015-02

Why bipeds (two legged robots)?

Why 2 legs? 4 or 6 legs give more stability, don’t they?

- A biped robot body can be made shorter along the walking direction and can turn around in small areas.
- Light weight.
- More efficient due to less number of actuators needed.

Walking vs. running

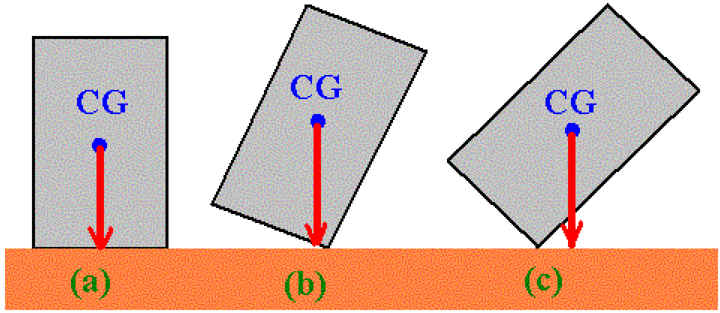
- Motion of a legged system is called walking if in all instances at least one leg is supporting the body.
- If there are instances where no legs are on the ground, it is called running.
- Walking can be statically or dynamically stable.
- Running is always dynamically stable if successful.

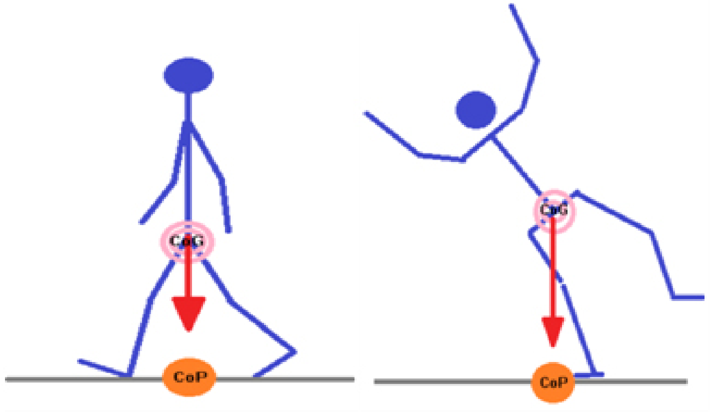
Stability

- Stability here means the capability to maintain the body posture given the control patterns.
- Statically stable walking implies that the posture can be achieved even if the legs are frozen / the motion is stopped at any time, without loss of stability.
- Dynamic stability implies that stability can only be achieved through active control of the leg motion.

Gaits and stability (1)

- People, and humanoid robots, are not statically stable.
- Standing up and walking appear effortless to us, but we are actually using active control of our balance. Humans use muscles and tendons. Robots use motors.
- In order to remain statically stable, the robot Center of Gravity must fall under its polygon of support.
  - The polygon is basically the projection between all of its support points onto the surface.
  - In two leg robots, the projection is a line between legs.





Gaits and stability (2)

- Consider a three leg (tripod organization) robot and its body above. Such a robot produces a stable polygon of support.
- It is possible for certain robot geometries with various number of legs to stay always statically stable while walking.
- This is very safe, but it is also very slow and energy inefficient.

Zero Moment Point (ZMP)

- Idea of Miomir Vukabratovic (*1931-†2012), Belgrade, proposed the Zero Moment Point in 1970.
- Zero Moment Point algorithm for dynamic walking
    1. Leg motion is prepared in advance.
    2. Upper body motion is calculated so that the Zero Moment Point exists in the expected supporting foot.
- Example: Estimate foot roll by considering ground reaction forces.
- Zero Moment Point = Center of Pressure.
- The foot will roll iff ZMP is on the edge of support polygon.

$$x_{zmp} = \frac{\sum r_i \times F_i}{\sum F_i}$$

Zero Moment Point: Benefits, challenges

- Benefits of ZMP
  - Easy to measure using force sensors in foot.
  - Can aalsolso estimateeestimate (inin simulation) using link accelerations.
  - ZMP can be moved by applying ankle torques.
  - Allows dynamic walking (Center of mass leaves the Stable Polygon).
- Human do not use ZMP
  - We allow our feet to roll (toe-off, heel-strike)
  - ZMP at edge of support polygon.
- ZMP cannot describe robots with point feet (walking on stilts) or running.