Humanoids

RSS 2010
Lecture # 19
Una-May O'Reilly

Lecture Outline

- Definition and motivation
  - Why humanoids?
  - What are humanoids?
  - Examples
- Locomotion

Why humanoids?

Capek, Paris Production, 1924

I Robot, Asimov, 2004 Movie w/ Will Smith

Examples: servants, entertainers, test-beds for theories from neuroscience and experimental psychology

Why humanoids?

- The urge to create a robot with versatility and skill comparable to humans
  - Including physical and/or intellectual mechanisms
  - Danger of being too literal in equivalence!
- Narcissism: ‘humans are humanity’s favorite subject’ [Springer Handbook of Robotics, Ch 56 - Humanoids, Kemp et al]…why?
  - We’re social, attuned to human characteristics
- Entertainment, culture, surrogates
- Understanding intelligence
- Interfacing with the human world

What is a humanoid robot?

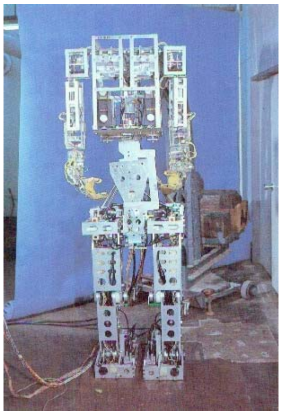
- 'there is a tension in the definition of the humanoid robot, as we try to balance form and function. The following definition is proposed as a harmony of both:

  Humanoids are machines that have the form or function of humans.'
  [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.'
  - [Springer Handbook of Robotics, Ch 56 - Humanoids, Charles C. Kemp, Paul Fitzpatrick, Hirohisa Hirukawa, Kazuhito Yokoi, Kensuke Harada, Yoshio Matsumoto]

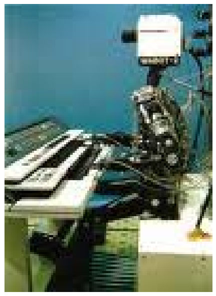
Modern History - Wabot-1, 1973

- Wabot-1 - by Kato, Waseda U. Japan, 1973
- Integrated systems for sensing, locomotion and manipulation inspired by human capabilities



Reference: http://www.humanoid.waseda.ac.jp

Modern History - Wabot-2



QuickTime™ and a
decompressor
are needed to see this picture.

- Wabot-2 could play a piano (1985)

Reference: http://www.humanoid.waseda.ac.jp, youtube video

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Modern History - Sony Lineage

http://world.honda.com/ASIMO/history/image/top/title_history.jpg

- Sony
  - Started with walking, stair climbing in 1986, onwards
  - First unveiled integrated humanoid was P2
    - » 180 cm tall, 210 KG
    - » P3: 160cm, 130 KG,
    - » Asimo: 120 cm, 43 kg

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iCub - LIRA Lab, Genoa, Italy

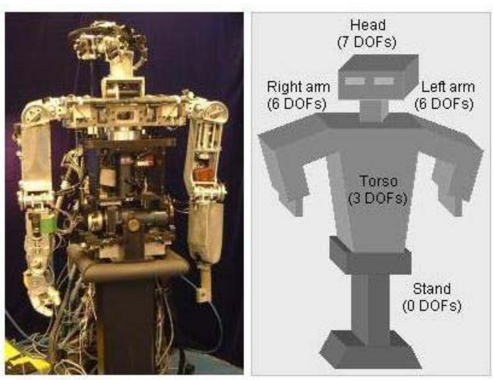
- iCub: 2 year old baby development with social interaction and ability to manipulate the world

QuickTime™ and a
decompressor
are needed to see this picture.

Reference: http://eris.liralab.it, youtube

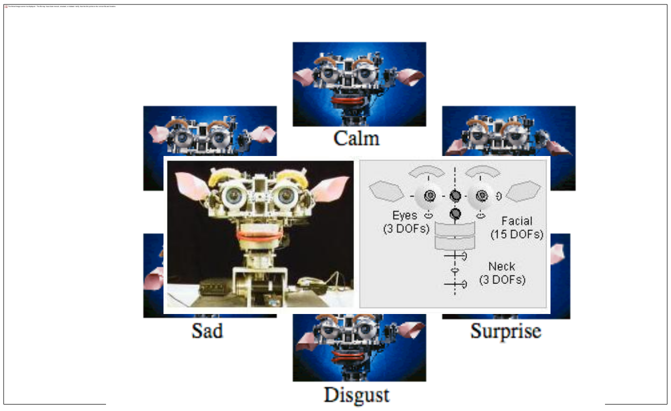
MIT Examples - COG

- MIT: Cog: 1993, 'learn to think by building on its bodily experiences to accomplish progressively more abstract tasks



Reference: http://www.ai.mit.edu/projects/humanoid-robotics-group/cog/

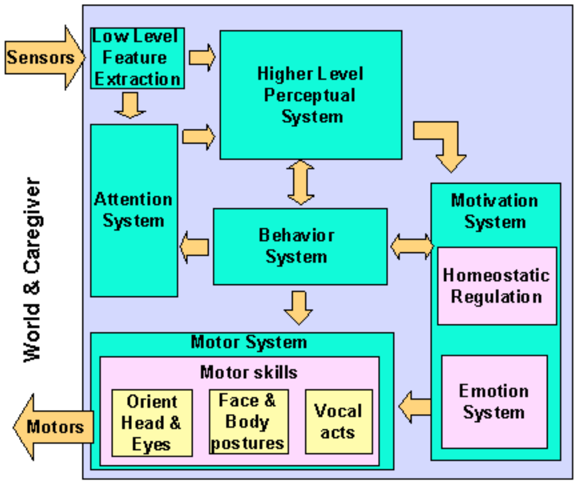
MIT Examples - Kismet



images © Peter Menzel

Reference: http://www.ai.mit.edu/projects/sociable

Kismet cont'd



Robonaut-2

- Announced Feb 9, 2010
- Joint Nasa JSC and General Motors
- Series elastic actuators in arms (compliant, force control)
- Command-based autonomy
- -lots of object modeling before interaction

QuickTime™ and a
decompressor
are needed to see this picture.

Legged Locomotion

Why Legs?

- 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 (environmentally conscious)
- More energy-efficient
- More maneuverability
  - Use of isolated footholds that optimize support and traction (i.e. ladder)
- Active suspension
  - Decouples the path of body from the path of feet
- Exploit discrete footholds

Sourced from Walking_robots_sun_hyn_park.ppt

Why Bipeds?

- 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
- Everything around us is built to be comfortable for use by human form
- Social interaction with robots and our perception (HRI perspective)
  - Form will become as important as functionality in the future
- Our instinctive desire to create a replica of ourselves (maybe?)

Sourced from Walking_robots_sun_hyn_park.ppt

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**

Sourced from **Walking_robots_sun_hyn_park.ppt**

Stability

- Stability **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**

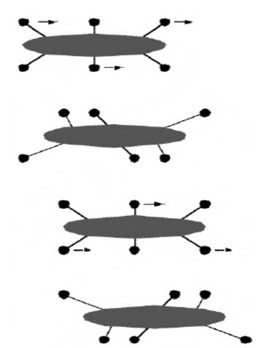
Gaits and Stability

- 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
  - We use muscles and tendons
  - Robots use motors
- In order to remain stable, the robot's 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

Sourced from Walking_robots_sun_hyn_park.ppt

Static 6 Leg Gait

- An example of a static gait with 6 legs



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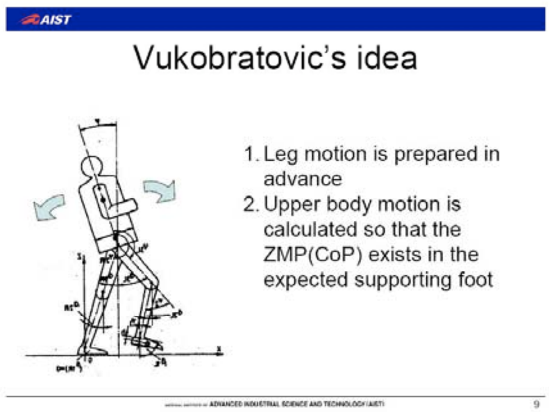
Zero Moment Point (ZMP)



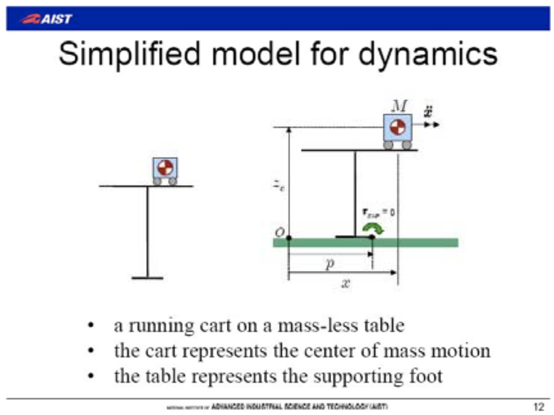
Zero Moment Point

- Estimate foot roll by considering ground reaction forces
- Zero Moment Point (ZMP) = Center of Pressure (COP):

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

- Foot will roll iff ZMP is on edge of support polygon.

Zero Moment Point (ZMP)



Static Stability

- Center of mass (CoM) is directly above the support polygon (SP)
- Static analysis: If joints are locked in place, and velocities are zero, then foot will not roll
- "Static walking" if CoM is over SP for the entire gait

Trained Static Walking

Honda's Dynamic Stability Controller

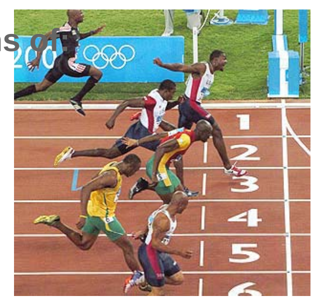
- Avoid under-actuated regime: constrain the dynamics
  - Keep foot flat on the ground (fully actuated)
  - Estimate danger of foot roll by measuring ground reaction forces
  - Carefully design desired trajectories via optimization
  - Keep knees bent (avoid singularity)
  - Adaptive trajectory tracking control (high feedback gains)

Asimo Walking

Asimo Running

Performance of Honda Control

- Works well on flat terrain, and even up stairs
- Trajectories are constrained by an overly restrictive measure of dynamic balance
- Can't compete with humans in terms of
  - Speed (0.44 m/s top speed)
  - Efficiency (uses roughly 20x
  - as much energy per unit
  - weight, per distance moved)
  - Robustness (no examples
  - of ASIMO walking on uneven
  - or unmodelled terrain)
- High torque requirement at the ankles
- High efficiency, harmonic drive, DC electric motors run hot



Zero Moment Point: Benefits, challenges

- Benefits of ZMP:
  - Easy to measure using force sensors in foot
  - Can also estimate (in simulation) using link accelerations
  - ZMP can be moved by applying ankle torques
  - Allows dynamic walking (CoM leaves SP)
- Humans don't use ZMP
  - We allow our feet to roll (toe-off, heel-strike)
  - ZMP at edge of support polygon
- Can't describe robots with point feet (walking on stilts) or running

Walking - further challenges

- the ability of these systems to walk truly autonomously on uneven and various terrains in a robust way, i. e., in daily life, remains to be demonstrated.

References

1. Springer Handbook of Robotics, Siciliano & Khatib, eds, 2008
   1. Ch 54. Humanoids
   2. Ch 16 Legged Robots
   3. Ch 58 Social Robots that Interact with People
2. *WTEC Panel Report on* INTERNATIONAL ASSESSMENT OF RESEARCH AND DEVELOPMENT IN ROBOTICS, January 2006
3. Presentation: Walking_robots_sun_hyn_park.ppt from https://collab.cc.gatech.edu/humanoids/sites/edu.humanoids/files
4. Honda robot images from: http://asimo.honda.com/Gallery.aspx
5. Presentation: overview_of_ZMP_based_biped_walking_Shuuji_Kajita.pdf by Shuuji KAJITA, AIST, Japan: http://asimo.honda.com/Gallery.aspx

Honda's Humanoids