UCLA Extension – Short Courses

Biologically Inspired Intelligent Robots

Lead instructor

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Introduction - Y. Bar-Cohen, JPL

Actuators - the muscles that drive robots

1 Introduction
2 Biological Muscles
3 Historical Review and Currently Available Active Polymers
4 Polymers with Controllable Properties or Shape
  4.1 Smart Structures and Materials
  4.2 Electrically Conductive and Photonic Polymers
  4.3 Non-Electrically Deformable Polymers
    4.3.1 Chemically Activated
    4.3.2 Shape Memory Polymers
    4.3.3 Inflatable Structures
      4.3.3.1 Aerobots and Balloons
      4.3.3.2 Mckibben Artificial Muscle
    4.3.4 Light Activated Polymers
    4.3.5 Magnetically Activated Polymers
    4.3.6 Thermally Activated Gels
5 Electroactive Polymers (EAP)
  5.1 Electric EAP
    5.1.1 Ferroelectric Polymers
    5.1.2 Dielectric EAP
    5.1.3 Electrostrictive Graft Elastomers
    5.1.4 Electrostrictive Paper
    5.1.5 Electro-Viscoelastic Elastomers
    5.1.6 Liquid Crystal Elastomer (LCE) Materials
  5.2 Ionic EAP
    5.2.1 Ionic Polymer Gels (IPG)
    5.2.2 Ionomeric Polymer-Metal Composites (IPMC)
    5.2.3 Conductive Polymers (CP)
    5.2.4 Carbon Nanotubes (CNT)
    5.2.5 Electrorheological Fluids (ERF)
6. Need for EAP Technology Infrastructure
7. Future Potentials

Sensors and Testing - the assurance of robots operation/performance - Y. Bar-Cohen, JPL

1. Sensor categories
   - 1.1 Imbedded
   - 1.2 Attached
   - 1.3 Remote
2. Sensor functions
   - 2.1 Distance gauging
   - 2.2 Strain gauging
   - 2.3 Temperature
   - 2.4 Tactile, forces, torque and other mechanical properties
   - 2.5 Vision
3. Nondestructive testing techniques
   - 3.1 Visual
   - 3.2 Eddy currents and electromagnetics
   - 3.3 Ultrasonics
   - 3.4 Radiography
   - 3.5 Holography, Thermography and others
4. Challenges and potential capabilities
5. Outlook

Telepresence, Prosthetics, Cyborg Technology - Y. Bar-Cohen, JPL

1. Biomimetics in multimedia (web, movies, art, theaters, etc.)
2. Computer Generated Images, and Computer Generated Organisms
3. Turning a Story into a Depiction of Life - animated movie
4. Interactive graphics -- Activation of animated creatures thru Performance and Motion Capture
5. Autonomous animated and interactive characters
6. "Slave and master" relations with biologically inspired robots
7. Remote MEchanical MIrroring using Controlled stiffness and Actuators (MEMICA)
8. Tactile interfaces and sensors
9. Virtual reality and remotely operated robots
10. Applications to exoskeletons, rehabilitations, virtual surgery
11. Space operations - Robonaut class robots
12. Robot prosthetics
13. Silicon-biology (man-machine interface)
14. Organic brain to robot motor control
15. Silicon sensors to organic brain (cochlear implant, retinal implant)
16. Exoskeletons

Making robots behave realistically using control and intelligence - M. Mataric, USC

1. Basic concepts:

1.1 defining robotics
1.2 a brief history
1.3 locomotion
1.4 manipulation
1.5 effectors & actuators
1.6 sensors, simple and complex

2. Robot control:

2.1 feedback control
2.2 control architectures
2.3 representation
2.4 reactive control
2.5 deliberative control
2.6 hybrid control
2.7 behavior-based control
2.8 behavior coordination, emergent-behavior

3. Special topics:

3.1 navigation
3.2 multi-robot coordination
    3.2.1 implicit & swarm robotics
    3.2.2 explicit coordination
    3.2.3 distributed task allocation
    3.2.3 a taxonomy of the problem
    3.2.4 formal models and algorithms
3.3 robot learning
3.4 humanoid robotics

4. Summary of recent USC work

4.1 multi-robot coordination
4.2 human-robot interaction
4.3 imitation learning
4.4 activity modeling

Making and operating limbed robots - B. Kennedy, JPL

1. history of the emulation of limbed creatures
   - 1.1 arms/hands
   - 1.2 legs/feet
   - 1.3 limbs
2. state-of-the-art
   - 2.1 arms/hands
     - 2.1.1 industrial arms
     - 2.1.2 research arms
   - 2.2 legs/feet
     - 2.2.1 monopod
     - 2.2.2 bipod
     - 2.2.3 polypod
   - 2.3 limbs
     - 2.3.1 LEMUR-like philosophy

3 Why do we emulate limb structures?
- 3.1 Unintentional convergent design (homoplasy)
- 3.2 Close match of operational regime
- 3.3 High dexterity requirement
- 3.4 High mobility requirement
- 3.5 Homology of mobility and dexterity requirements

4 How do we emulate limb structure design?
- 4.1 Using standard technology
  - 4.1.1 Making kinematically spherical joints
  - 4.1.2 Stuart platforms
  - 4.1.3 Cable-driven
- 4.2 Using upcoming technology
  - 4.2.1 New operational paradigms
    - 4.2.1.1 Ball & socket joints
    - 4.2.1.2 Actuator antagonism
    - 4.2.1.3 Energy storage
  - 4.2.2 How new technologies enable those new paradigms
    - 4.2.2.1 EAP
    - 4.2.2.2 McKibben
    - 4.2.2.3 Non-standard ultrasonics

5 How do we control limbs?
- 5.1 Legs
  - 5.1.1 Gait control
- 5.2 Arms
- 5.3 Limbs

6 Conclusions
- 6.1 Complexity vs. capability

Humanoids - making biomimetic robots that look like you and me - David Hanson, UT Dallas

1. Introduction
2. Cognition and Perception
    - 2.1 Micro-emulation: Computational Neuroscience
    - 2.2 Macro-emulation: a Society of Mind+Body
    - 2.3 Emulating Biological Sense and Perception: Vision, Speech, Touch, Balance, etc.
    - 2.4 Sensory Fusion
3. Locomotion and Manipulation
4. Socializing Robots, Investigating Human Communications,
    - 4.1 Social Cognition
    - 4.2 Aesthetics (human-paralinguistics)
    - 4.3 Narrative and Language
    - 4.4 Charting the "Uncanny Valley"—the relation between Realism and Human Social Acceptance
5. Processes of Construction, Including Considerations of Materials, Actuators, and Sensors
    - 5.1 Robotically Modeling Human Facial Expressions
        - 5.1.1 Matching the Compressive and Elongative Characteristics of Facial Soft Tissues with Novel Elastomers that match these characteristics
        - 5.1.2 Processes of Manufacturing Artificial Facial Skin and Skull
        - 5.1.3 Artificial Facial Mechanics and Actuation, Sensors and Controls
    - 5.2 Biped and Manipulation Implementation
        - 5.2.1 Biological models: Central Pattern Generators, Resonance as a Good Thing
        - 5.2.2 Digital vs. Analog (don't forget also: Mechanical Analog) Controls Strategy
    - 5.3 Electro-Active Polymers as Artificial Muscles for Humanoids
    - 5.4 Rapidly Advancing Materials and Processes of note
        - 5.4.1 Multi-function Materials (simultaneously computing, sensing, actuating, serving as mechanical structure, etc.)
        - 5.4.2 Engineered Bio-materials
            - 5.4.2.1 Living muscles
            - 5.4.2.2 Engineered proteins, dynein, DNA and RNA machines
        - 5.4.3 Rapid, digital manufacturing
            - 5.4.3.1 Shape Deposition Manufacturing
            - 5.4.3.2 Meso-systems, MEMS, and nano-systems for Humanoid Robotics
6. Applications of "Realistic" Humanoid robots
    - 6.1 Arts and Sciences: the Short Term Applications Sectors
        - 5.6.1 Fine Arts and Entertainment
        - 5.6.2 Sciences
            - 5.6.2.1 Cognitive Science, Study of Human Communications, HCI Studies
            - 5.6.2.2 AI and Robotics
            - 5.6.2.3 Materials Sciences
    - 6.2 Companions and Assistants
    - 6.3 Security and Peacekeeping
7. Humanoid Integration Infrastructure: how can research be organized so as to weave together a Society of Mind (and Body)?
8. Conclusion

The challenges and outlook for the field - Y. Bar-Cohen, JPL

1 Introduction
2 Biology as an Inspiring Model
  2.1 Desired Biomimetic Characteristics
  2.2 Inspired by Biology - Design Concepts for Reconfigurable Robots
  2.3 Potentials and Challenges to Using Artificial Muscles
  2.4 Operation as Individual and Social Robots
3 Turning Science Fiction into Science Reality
4 Challenges to Developing Biomimetic Intelligent Robots
  4.1 Challenges to Emulating Natural Muscles
  4.2 Challenges to the Creation of Animated Creatures
  4.3 Haptic Interfaces
  4.4 Cyborg Technology
  4.5 Aesthetic and Structural Elements of Robots
  4.6 Component Technologies of Robots
  4.7 Low-Level Control of Biomimetic Robots
  4.8 Cognitive Modeling of Robots
  4.9 Future Biomimetic Robots
5 Concluding Words
6 Acknowledgement
7 References