Survey of Humanoid Robots

Jacky Baltes
Intelligent Agent Laboratory
University of Manitoba
Winnipeg, Manitoba

http://www.cs.umanitoba.ca/~jacky
Email: jacky@cs.umanitoba.ca
Outline

• Humanoid robots
  – Approaches to humanoid robot design
  – Survey of Humanoid Robots
• Why work on humanoid robots
  – Research issues
  – Applications
• Humanoid robots at the University of Manitoba
• Humanoid robotics competitions as benchmarks
• Conclusions
Humanoid Robots 2003

- More than 30 teams worldwide
- Minimalistic designs: Vickie, Tao-Pie-Pie
- Small RC-servo based robots: Robo Erectus, RoboSapiens, Elvina, Footprints
- Small DC Motors: HansaRam, Rock Steady, Sony DXR4
- Medium: ISAAC
- Large: Honda Asimo, Murphy
Humanoid Robots 2003

- Competitors at FIRA-2003

Tao-Pie-Pie
University of Manitoba, Canada

HansaRam,
KAIST Deajon,
Korea

RoboSapiens
NUS
Singapore
Humanoid Robots

- Many teams in Asia
  - Korea, Japan, Singapore
- Few teams in Europe and North America
- Frankenstein Syndrome
  - Man vs. Machine
  - Slaves to the machines ...
- Engineering approach
  - Requirement analysis
  - Specification
  - Few needs for humanoid robots
Research issues in humanoid robotics

- Control of systems with many degrees of freedom (DOFs) and many sensors
- Motion planning
- Human Computer Interaction
Research Challenges
Gait Generation

- Walking gait generation
- Many approaches
  - Static/Dynamic balance
  - Center of mass (CoM), zero moment point (ZMP)
- Practical solutions exist for smooth even surfaces
- Future
  - Running
  - Uneven terrain
  - Motion planning for complex motions
Research Challenges

Human Computer Interaction

- Human Computer Interaction
  - Humanoid robots are more easily accepted
- Look like humans
- Interact like humans
  - Speech generation
  - Gesture generation
  - Speech recognition
  - Gesture recognition
Research Challenges
Human Computer Interaction

- MIT pervasive computing initiative
  - COG
- Form an emotional bond with objects
  - Emphatic response
- Very strong response in humans
  - Personify objects (e.g., computers)
  - Eliza, Alice
Research Challenges

Robotic Soccer

• Localization (Where am I on the playing field)
• Vision: Object tracking
• Local path planning
• These issues are not unique to humanoid robots
  - RoboSot (any local vision robot)
• Solutions for localization from other robotic soccer teams
Applications for Humanoid Robots

- Report to the European Union
- Short Term (2 – 5 years)
  - Entertainment
- Medium Term (5 – 10 years)
  - Special purpose assistants: Children, Elderly, Disabled
  - Office or construction assistants
- Long Term (10 – 100 years)
  - Personal assistant
  - Search and Rescue
  - All work done by robots
State of the Art 2003

- Open loop control for walking on smooth even terrain
- Active balancing used in the competition
  - Force sensors: HOAP, Sony, Morph 3
  - Gyroscopes: active balance on Tao-Pie-Pie
  - Accelerometers: Honda Asimo
Robotics at the University of Manitoba

- Dissertation in planning: Multi-strategy planning system DoLittle
- Robotics to ground research into AI
- Bought a camcorder and some toy cars and got an old computer
- Need wide angle lense
- Do not modify the environment/equipment
Robotics at the University of Manitoba

- But children can play soccer with RC cars.
- Use coarse actuators and inaccurate sensors and you will end up with a robust design.
Robotics at the University of Manitoba

- Reinforcement learning controller for car-like mobile robots
- Case-based path planning for highly dynamic domains
- Orientation and robot id
- Ego-motion estimation from lines
Humanoid Robotics at the University of Manitoba

• In 2001, started work on a cheap humanoid robot
• Minimalistic iterative design
• What is the minimum number of DOFs to allow a balanced walk?
• RX-78 and Zaku
Humanoid Robotics at the University of Manitoba

- Based on Gundam toy robots
- Implemented frontal sway (RX78) and shuffle (Zaku)
- Plastic broke too easily
Tao-Pie-Pie

• 3\textsuperscript{rd} generation
• Eyebot controller
  – MC68332, 1MB Ram, 1 MB Rom, 3 FPS
• Computer vision (from local vision robots)
  – Color predicates
    • 15 parameter model:
      • R, G, B, R-G, R-B, G-B, R_n, G_n, B_n
  – Segmentation
    • Compactness
    • Aspect ratios
Tao-Pie-Pie 2002

- Cyclical pattern generator (CPG)
- Open-loop control for smooth even terrain
- Graduate student algorithm
- Walking gaits: straight, turns, kick
- Desired control points for servos
- Used bezier curves/ cubic splines to interpolate control curves
  - Minimizes $2^{nd}$ derivative
  - Smooth curve
Tao-Pie-Pie 2003

- Closed loop control of walking gait using feedback from the gyroscopes
- More by Sara McGrath in the next session
Future for Humanoid Robots

- Advances in material sciences
- Better actuators
- Better power sources
  - Hydrogen fuel cells
- Better sensors
  - More types
  - Cheaper
- Better processing
  - Moore's law (quadruples every three years)
- More I/O Bandwidth
Goals of the HuroSot Competition

- Attract more teams
- Disseminate information to new teams
  - TPP/HIRO website
  - http://www.cs.umanitoba.ca/~jacky
- Provide benchmark problems for humanoid robots
- Publicity event
Robotics Competitions as Benchmarks for Research

- Benchmarks are important since they drive research and development
- Competitions are the only “real-world application” for robotics
- Performance of complex systems is hard to measure
The Used Robot Salesman

- Automobiles are also complex systems
- Which car is the best car?
- Some performance ratings
  - Top speed
  - Acceleration 0 – 100 km/h
  - Braking distance
  - Fuel efficiency
  - Robustness
- Subjective write-ups
Example Benchmarks
Micro-processors

- Computer systems
  - Too complex.
  - Application benchmarks (similar to robotic soccer)
  - Provides little guidance for research

- Computer architecture researchers are faced with two problems
  - Make computer run faster
  - Explain this to the marketing department
Processor Benchmarks

• MIPS and MFLOPS ratings (1980s)
• Humanoid robots
  – Vision frame rate, control cycle time, path planning time
• Undefined functions
  – What is the function of the video processor
• Processor performance is determined by
  – number of instructions,
  – average clocks/instruction,
  – and clock freq.
Processor Benchmarks

- Toy programs (1980s)
- AI toy problems (Blocksworld)
- Dhrystones and Wheatstones
- Easy to analyze and optimize
- DEC C Compiler -dhrystones
- SPEC benchmark group

- Quake 3 benchmark and ATI
- Change rendering of a scene
Benchmark Conclusions

- **Focused**
  - Measure specific system feature
- **Complete**
  - Complete application from the domain
  - Individual features are evaluated in context
- **Variety**
  - Single applications can easier be optimized.
Benchmark Conclusions

- Open
  - No special interest groups
- Portable
  - Applicable to many different systems
  - Generic tasks
- Adaptive
  - Must be adapted to new technology and development
- Debugging
  - Hidden bias must be removed
HuroSot Events in 2003

- Robot Dash
  - Stability
  - Speed of walking gait
- Penalty kick
  - Balance
  - Power of kick
- Obstacle run
  - Mobility
  - Perception
- Winner's Gala
  - Small demonstration by teams
  - New events for next year
New Events for the Future

- Balance and walking gait
  - '04 Stair climbing (up/down)
  - '04 Lift and carry (ball)
  - '06 Uneven terrain (gravel)
- Motion planning
  - '05 Robot limbo
  - '05 Lay down and get up
  - '06 Stack blocks
- Modify penalty kick
  - '04 free kick, 1 vs 1
  - '05 Team play
Conclusions

- Overview of current humanoid robotics research
- Development of robotics research at the University of Manitoba
- Robotic soccer competition as benchmarks for research
- Future plans for the HuroSot competition