Human-Robot Collaboration: An Augmented Reality Approach A Literature Review and Analysis

Scott A. Green[a,b], Mark Billinghurst[a], XiaoQi Chen[b] and J. Geoffrey Chase[b]

[a]Human Interface Technology Laboratory, New Zealand

[b]Department of Mechanical Engineering

University of Canterbury, Christchurch, New Zealand

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Human-Robot Collaboration (HRC): Motivation

NASA's vision for space exploration stresses cultivation of human-robot teams.*

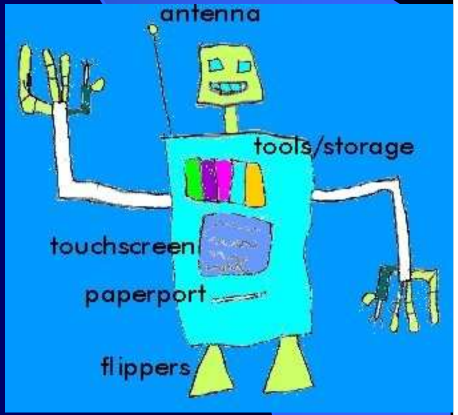
Little or no attention paid to developing human-robot teams.**

To reduce work load, costs, error and risk intelligent robotic systems needed.**

Industry: Toyota, Honda, and Sony etc.

Research: Cogniron Project (Europe), MERL, MIT, others

Human-Robot Interaction inaugural conference in 2006.



* NASA, "The Vision for Space Exploration: National Aeronautics and Space Administration, http://www.nasa.gov/pdf/55583main_vision_space_exploration2 .pdf," 2004

** T. Fong and I. R. Nourbakhsh, "Interaction challenges in human-robot space exploration," *Interactions*, vol. 12, pp. 42-45, 2005.

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Presentation Outline

Review of Human-Robot Interaction (HRI)

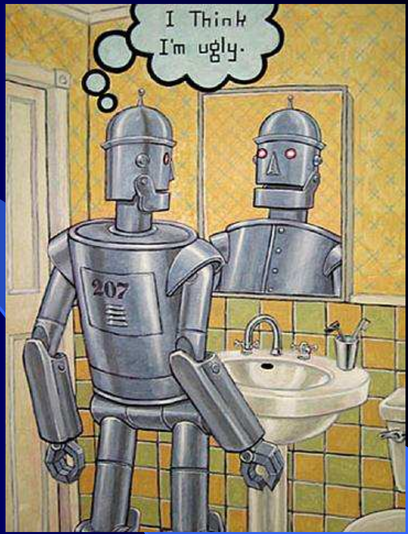
- Robot as Tools
- Guide, Hosting and Assistant Robots
- Humanoid Robots
- Robots in Collaborative Tasks
- Lessons Learned HRC Robotics

Intro to and Review of Augmented Reality (AR)

- AR in Collaboration
- AR in Robotics
- Why Augmented Reality for Human-Robot Collaboration?

Research Directions

Architectural Development



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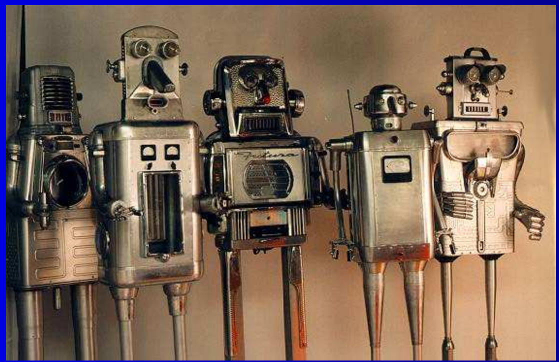
HRI Review: Robots as Tools

Melon Harvesting: Adjustable Autonomy increased positive detection rates (Becher and Eden 03)

Hazardous Tasks: Dynamic operating conditions, dynamic control scheme (Touskalas and Bargiotas 96) (Ishikawa and Suzuki 97)

Urban Search and Rescue (USAR): Lack of situational awareness, varying level of autonomy (Murphy 04) (Yanco, Drury *et.al.* 04) (Scholtz 02) (Nourbakhsh, Sycara *et.al.* 05)



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HRI Review: Guide, Hosting & Assistant Robots

Sage: Autonomous mobile robot in museum. Form of speech and non-verbal communication influence how well communication takes place (Nourbakhsh, Bobenage *et.al.* 99)

Robovie: Humanoid, use gesture, speech and eye contact in communication (Kanda, Ishiguro *et.al.* 02)

HRI Review: Guide, Hosting & Assistant Robots

Gestureman: Projectability → gaze direction situational awareness
(Kuzuoka, Yamazaki *et.al.* 04)

Cero: Humanoid figure enhanced grounding process (Huttenrauch, Green *et.al.* 04)

Mel: Hosting robot, effective use of gesture, gaze direction and speech in two-way communication (Sidner and Lee 05)

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HRI Review: Humanoid Robots

Robonaut: Anthropomorphic for one to one mapping (Glassmire, O'Malley *et.al.* 04) Interaction using Scholtz three roles (Scholtz 03)

- Remote human operator
- Monitor
- Co-worker

Kismet: Non-verbal communication cues, facial expressions, eye movement (Breazeal, Edsinger *et.al.* 01)

Leonardo: Learning by communicating verbally and non-verbally using deictic gestures (Breazeal, Brooks *et.al.* 03) (Breazeal 04)

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HRI Review: Collaborative Tasks

Perception and intention inference through language and behaviour (Inagaki, Sugie *et.al.* 95)

Hadaly-2: Communication improves with interaction synchronized with dialogue (Morita, Shibuya *et.al.* 98)

Ripley: Interpret environment from own perspective or from perspective of partner (Roy, Hsiao *et.al.* 04)

Multi-modal interface, dynamic levels of autonomy, sensor readings and grid map to assess spatial location of itself and objects (Skubric, Perzanowski *et.al.* 02) (Skubric, Perzanowski *et.al.* 04)

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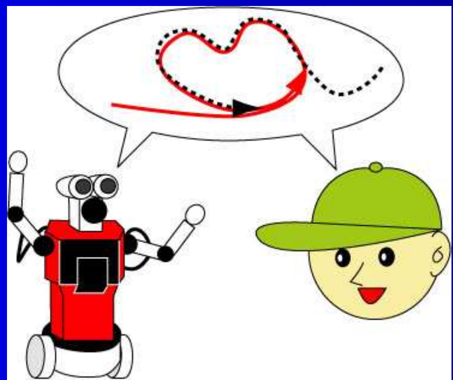
HRI Review: Collaborative Tasks

Intent through force feed back (Horiguchi, Sawaragi *et.al.* 00) (Fernandez, Balaguer *et.al.* 01)

Dynamic autonomy, robot asks for help when warranted (Fong, Thorpe *et.al.* 02) (Fong, Thorpe *et.al.* 03)

HRI/OS, human-robot teams, dialogue, spatial reasoning for tasks well defined and narrow in scope (Fong, Kunz *et.al.* 06)



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HRC: Lessons Learned Robotics

Adjustable Autonomy

Capitalize on strengths of human and robot

Communication through natural speech and gestures

Robot communication should use humor, emotion and non-verbal cues to appear natural to human team members

Robotic system should be able to ask for help

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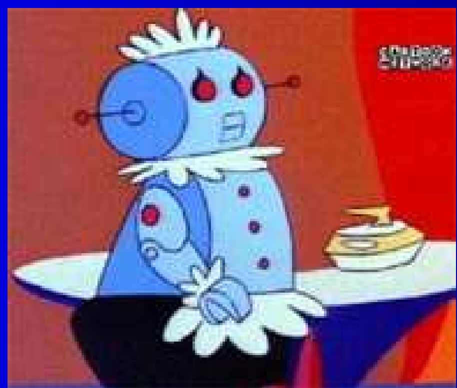
HRC: Lessons Learned Robotics

Grounding communication. Human needs to understand internal state and intentions of robot

Spatial referencing, use of common reference frames

Situational awareness: shared visual workspace to enhance collaborative efforts while increasing



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Augmented Reality (AR). What is it?

AR is the overlaying of 3D graphics onto the real world view of the user.

AR enhances rather than replaces reality (VR).

AR interfaces have three key ingredients:

- Combine real and virtual objects
- Virtual objects appear registered on the real world
- Virtual objects can be interacted with in real time

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AR: Collaboration

Shared Space: AR enhances face to face collaboration (Billinghurst, Poupyrev *et.al.* 00)

Multiple users could see each other's facial expressions, gestures and body language, intuitive to use

MagicBook: AR enhances collaboration, seamless transition from reality to virtuality (Billinghurst, Kato *et.al.* 01)

Supports multiple users, multiple viewpoints, maintain situational awareness

AR: Collaboration

Performance best in collaborative tasks when users were able to see each other (Kiyokawa, Billinghurst *et.al.* 02)

AR enables tangible user experience, physical objects are manipulated to effect change in the 3D scene (Billinghurst, Grasset *et.al.* 05)

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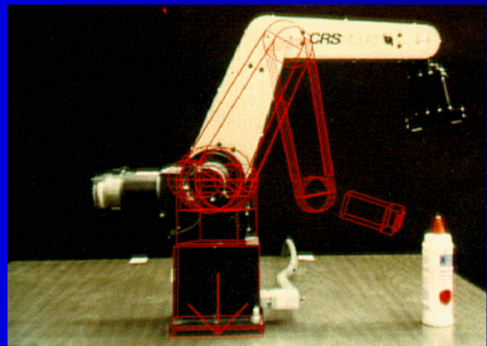
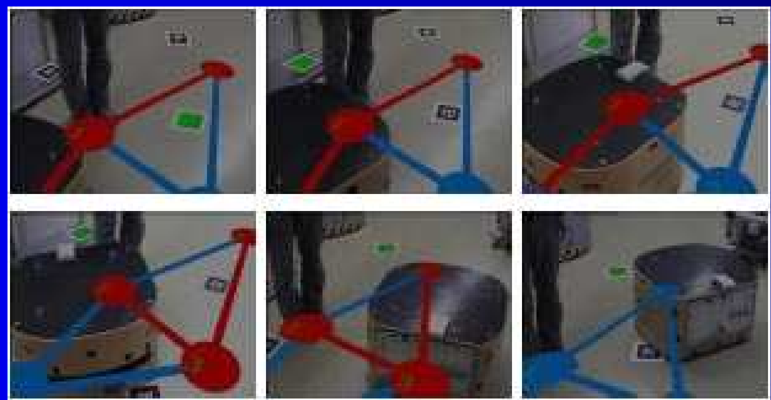
AR: Robotics

Combine strengths of human with strengths of robot, use spatial referencing (Milgram, Zhai *et.al.* 93)

- Highlighted need for system that can transfer actions that are natural for humans to precision required by machines.



Path node creation using speech and gesture, robot autonomous (Giesler, Salb *et.al.* 04)



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AR: Robotics

Improved situational awareness for operators of Unmanned Aerial Vehicles, increased comprehension of 3D spatial relationships (Drury, Richer *et.al.* 06)

Display robot sensor information on view of real world (Collett and MacDonald 06)

Augmented Reality for Human-Robot Collaboration

Shared visual of workspace
- Increased situational awareness
- Enhanced collaboration

Enables disambiguation of references frames

Use of deictic gestures and spatial dialog
- Tangible interaction with graphic 3D overlay

Augmented Reality for Human-Robot Collaboration

Display robot intentions and internal state

- Trust

Provides spatial cues necessary for both local and remote collaboration

Seamless transition from real world to immersive data space

- Aids in grounding and increases spatial awareness

HRC: Research Directions

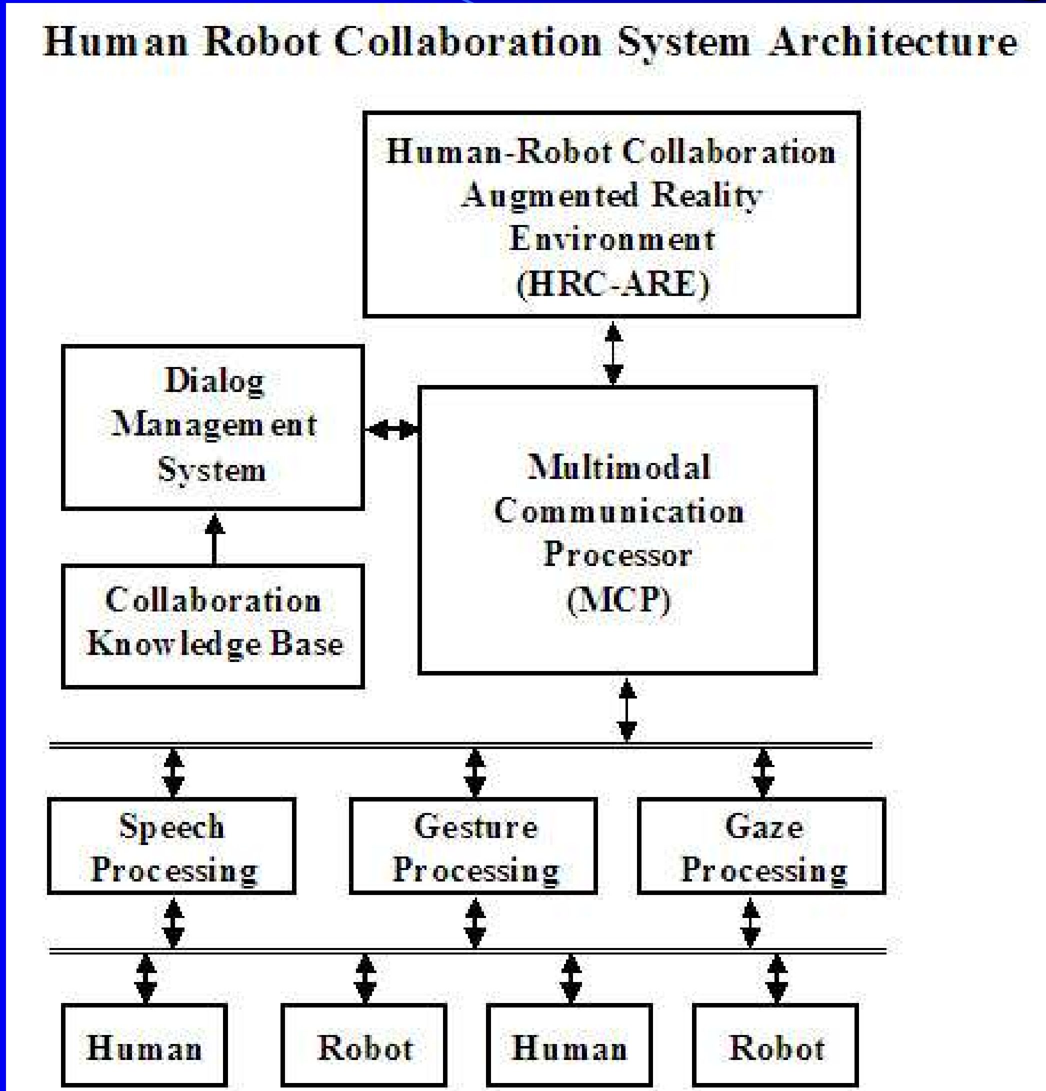
Robust dialogue management system

- Support on-going communication between robots and humans
- Enable robot to express intentions
- Enable robot to express understanding of situation
- Internal model of communication process
- Use of humour and emotion in robot dialogue, robot communication will seem more natural and effective
- Translate natural vague communication of humans into precise information necessary for robotic systems

HRC: Research Directions

- Robot must understand human gestures
  - Use of deictic gestures for natural communication for the human
- AR provide shared 3D environment for spatial referencing
  - Robot portray its intentions and beliefs as 3D overlays of its internal state, plans and understanding of situation
  - Allow use of common frames of reference for communication in a truly spatial manner
- Visual cues to enhance verbal communication
  - AR provide necessary visual cues

HRC: Architectural Design



Questions?

Scott A. Green
scott.green@canterbury.ac.nz

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