Sensing and Sensors

CMU SCS RI 16-722 S09

Sensors & Systems for Human Safety Assurance in Collaborative Exploration

Ned Fox

nfox@andrew.cmu.edu

Outline

- What is collaborative exploration?
- Humans sensing robots
- Robots sensing humans
- Overseers sensing both
- Inherently safe systems
- Applications in:
  - Home care
  - Planetary exploration
  - Space station
- Conclusion

What is Collaborative Exploration?

- Robots and humans working together
- Shared environments
- Robots are your partner – not your tool
- “Collaborative control” (Fong, Thorpe, Baur)

What is Collaborative Exploration?

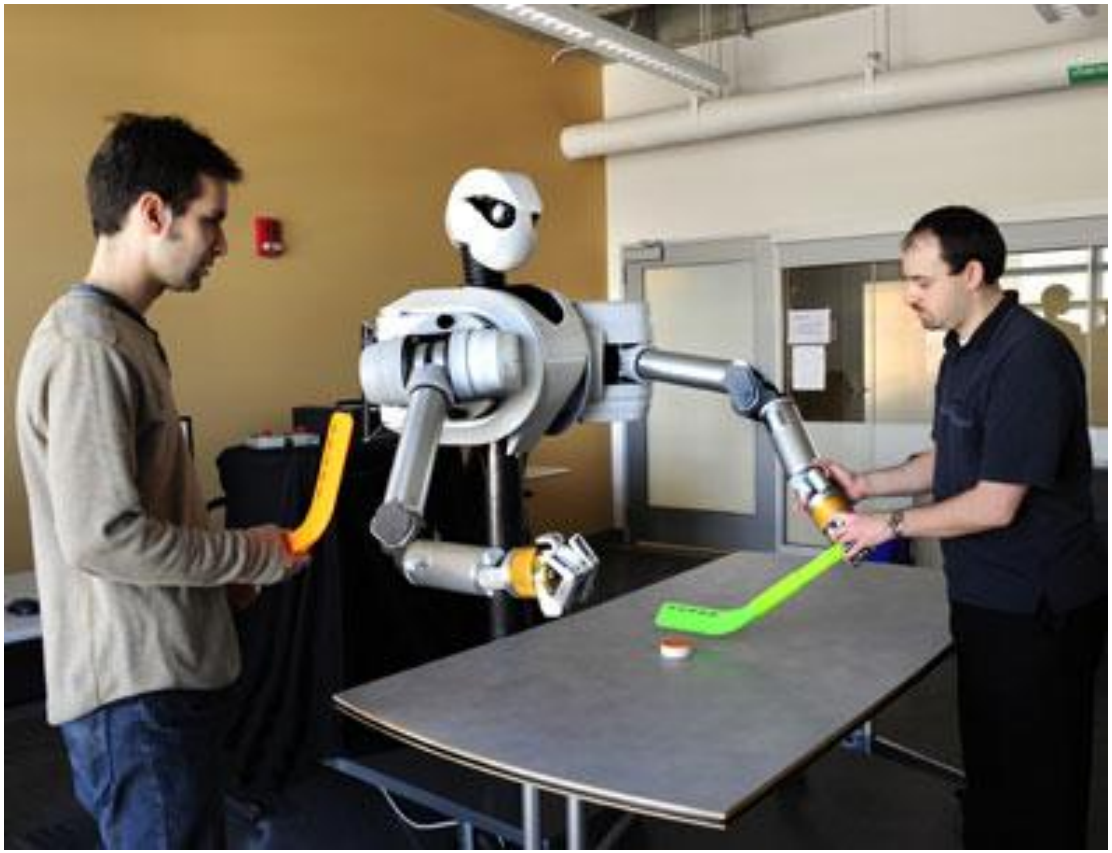
The way it was:

ISO 10218: "Manipulating Industrial Robot-Safety" , 1992. Robots should be isolated from humans and that they must be turned off when they cannot be isolated.

http://www.idspackaging.com/packaging/europe/packaging_software/244/products_category.html

What is Collaborative Exploration?

The way it will be in the future:



http://www.iastate.edu/Inside/2009/0130/alex.shtml

Where will robot collaborate?

Motivations
Robotic platforms
EU projects related to CWE
The Robot@CWE project
Human-robot collaboration
Conclusions

Construction industry

Surveillance - Reception

Factory

Defense - Rescue

Space

Robotics Lab

Napoli, 24/10/2008

Slide stolen from Pierro

Humans Sensing Robots

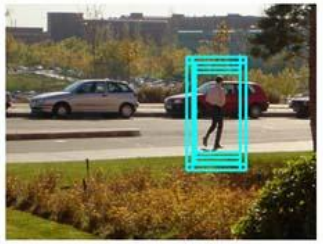
- Robot signature
  - Natural appearance/sound of robot
  - Adding identifiers to robot
- Augmenting senses
- Heads up display
- Emergency stop

http://www.stratos.com/HTML/work/moptical-display.shtml

Robots Sensing Humans

- Visual detection algorithms
  - Background subtraction, then look for human feature
  - Direct detection, then using classifier
  - (See “A survey of techniques for human detection from video” by Ogale)

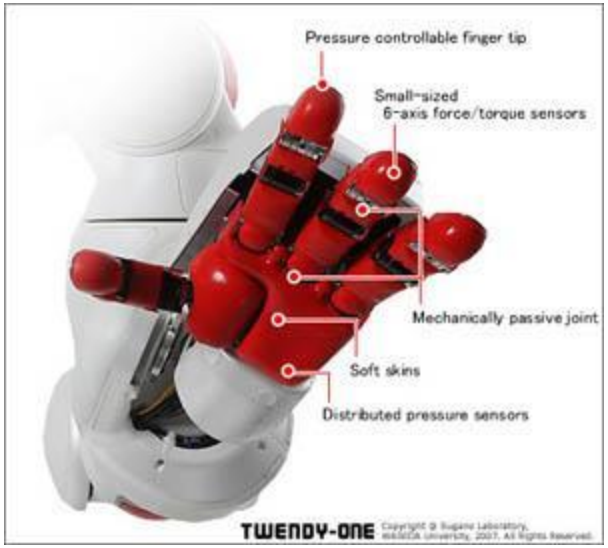


http://www.merl.com/projects/fasthumandetection/

Robots Sensing Humans

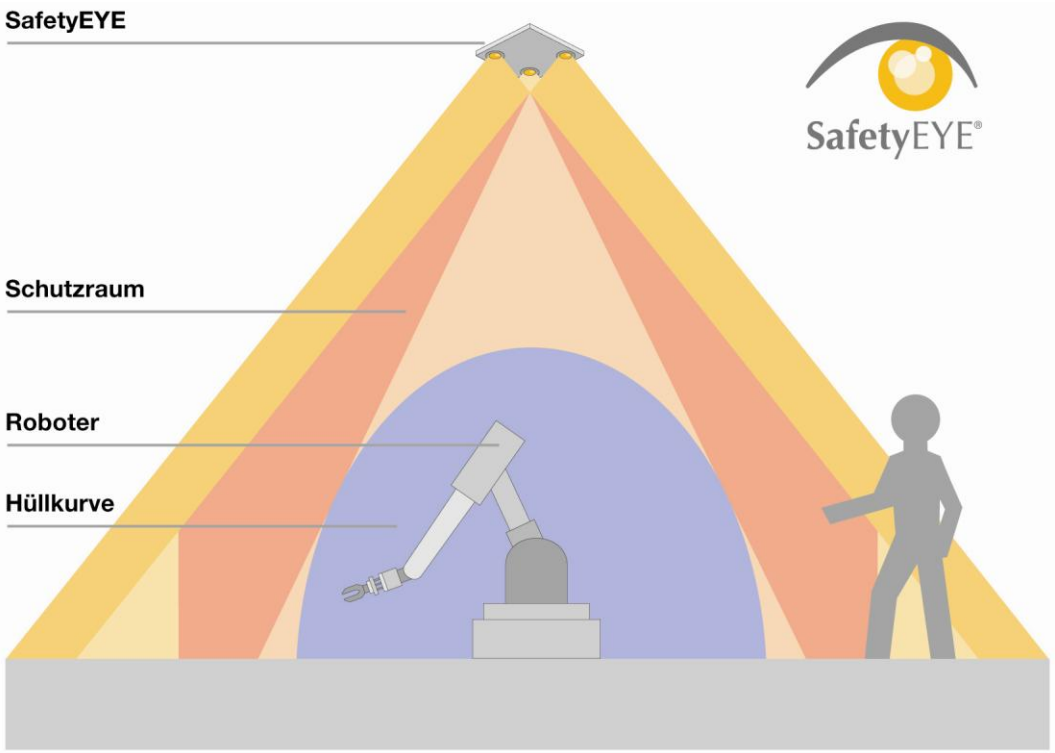
- Tactile sensing
  - Added benefit of robot safety
  - Finely tuned control system necessary
  - Combined with proprioception



http://www.globalspec.com/NpaPics/53/90918_010820097837_ExhibitPic.jpg

Overseers Sensing Both

- Pilz: SafetyEYE (developed in conjunction with DaimlerChrysler)
  - Three cameras provide three angles of video capture
  - A dedicated computer composites the streams into 3D video
  - Watches both robot and objects to make sure no collisions occur



Overseers Sensing Both

http://www.pilz.de/downloads/open/SafetyEYE_short_en_2007-12.wmv

Inherently Safe Systems

- If something known to be unsafe is about to occur, the system shuts down into a safe steady state
- eg: Nuclear reactors, joint limits on arms
- Not a safe system: http://www.youtube.com/watch?v=FAh_8erWyQw

Assignment

Watch the Star Wars clip (http://www.youtube.com/watch?v=FAh_8erWyQw).

What kinds of sensors and systems could be put in place to make it an inherently safe system? Would your system change if the Dianoga (http://starwars.wikia.com/wiki/Dianoga) that tries to eat the Jedis was a necessary part of the compactor? Make sure to pick sensors appropriate for the environment, and try to get at least one sensor for each category – Robot sensing human, human sensing robot, and overseer sensing both.

Applications: Home Care

- NurseBot (developed at CMU)
- Five primary functions:
  - Cognitive prosthesis
  - Safeguarding
  - Systematic data collection
  - Remote tele-medication
  - Social interaction
- Sensors on robot:
  - 16 ultrasonic range finders
  - SICK PLS laser range finder
  - Two CCD cameras (in eyes)
  - Microphone
- Methods of interaction with robot:
  - Touchscreen
  - Face to express “emotion”
  - Speaker
  - Remote web-access console

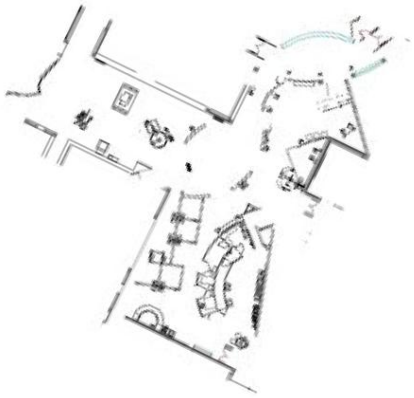
Applications: Home Care

- Cognitive prosthesis:
  - Helping the elderly perform cognitive tasks
  - Robot uses speech recognition to listen for commands
  - Can then look up an answer online
  - Also helps user remember certain things (where bathroom is, what time to take medication, etc)

User:	*Flo, hello.*
Flo:	*Hello. What can I do for you.*
User:	*Flo, what's the weather?*
Flo:	*Do you mean the today's weather, tomorrow's weather, or the current weather?*
User:	*Flo, the current weather.*
Flo:	*It is currently raining with a temperature of 54 degrees.*
User:	*Flo, thanks.*
User:	*Flo, what's on NBC today?*
Flo:	*NBC is currently airing the Today Show.*
User:	*Flo, good-bye.*
Flo:	*Good-bye.*

Applications: Home Care

- Safeguarding
  - Systematic monitoring and safeguarding of user
  - Utilizes rangefinders to map area and create a safe zone, and cameras to watch user to make sure they do not exit safe zone
  - Watches user for falls

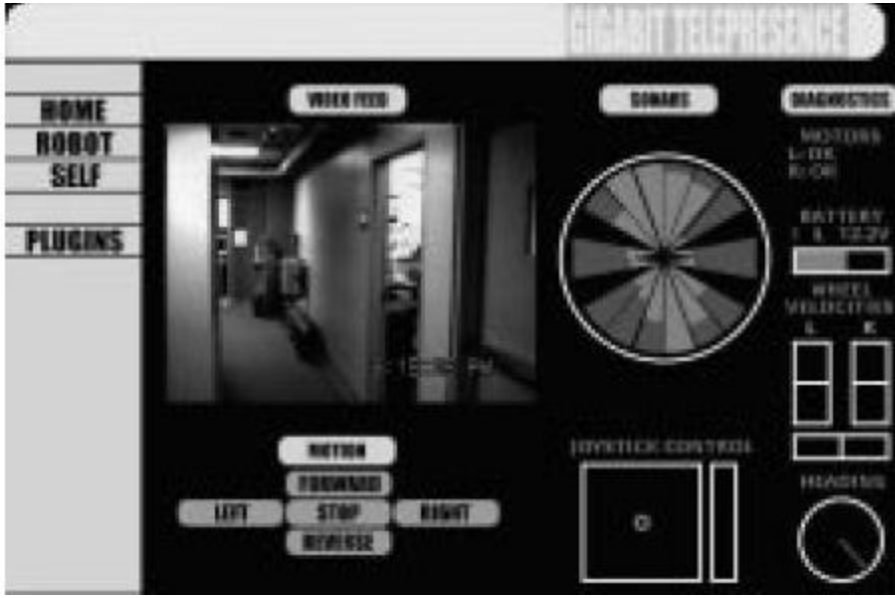


Applications: Home Care

- Systematic data collection
  - Collecting data about the elderly living in private homes to benefit the health care sector
  - Utilizes cameras and microphone
  - Examples of information collected:
    - When did the user take their medications?
    - What are their daily living activities?
    - Do they have any medical warning signs?

Applications: Home Care

- Remote tele-medicine
  - Relaying live video and audio to a remote physician
  - Utilizes cameras, microphone, speaker, mobile base and face
  - Manipulability of robot provides additional degrees of freedom than video conferencing



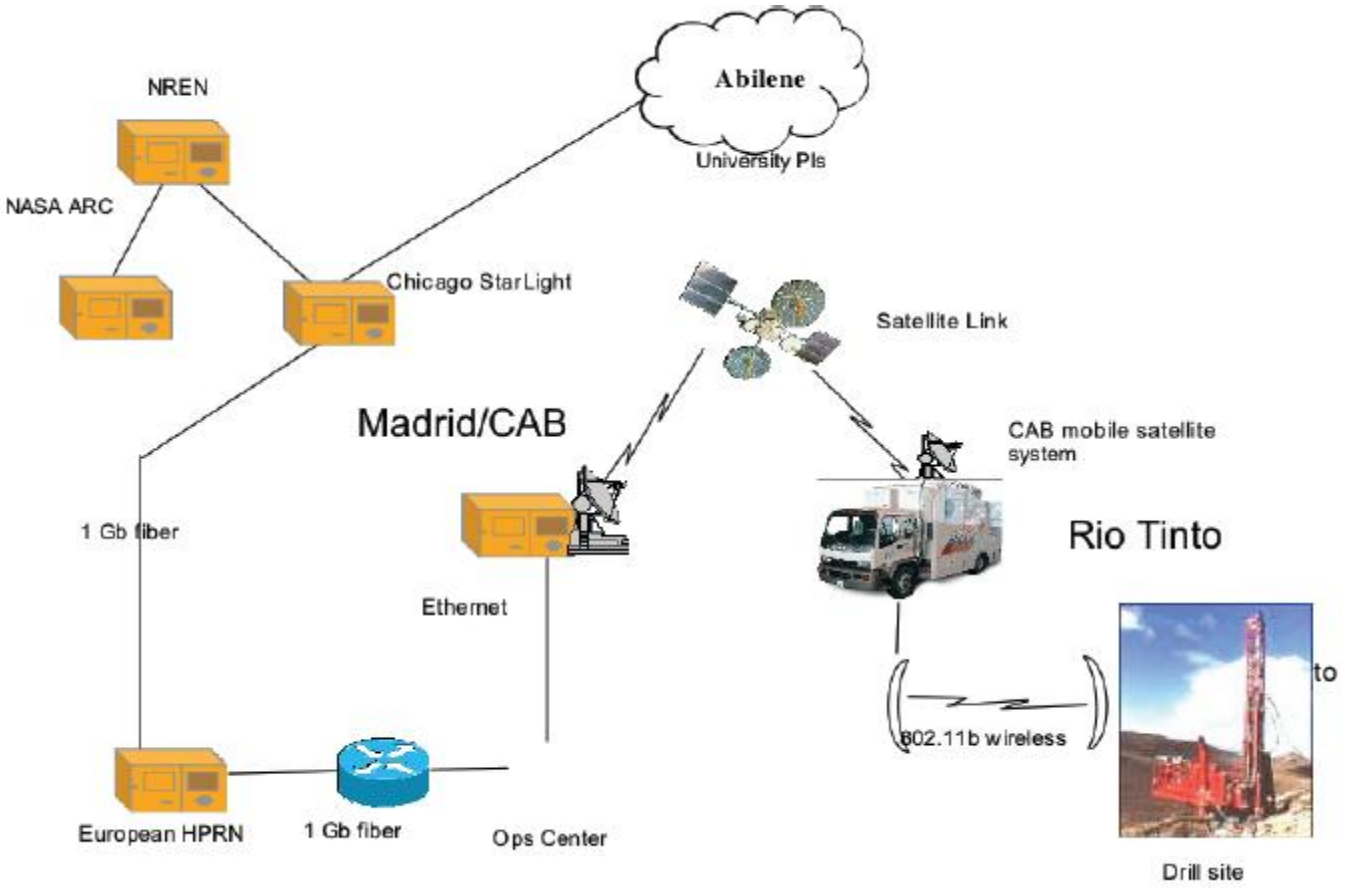
Applications: Home Care

- Social interaction
  - Communicating with the user and facilitating communication between two people
  - Utilizes camera, microphone, speaker, and face

Applications: Planetary Exploration

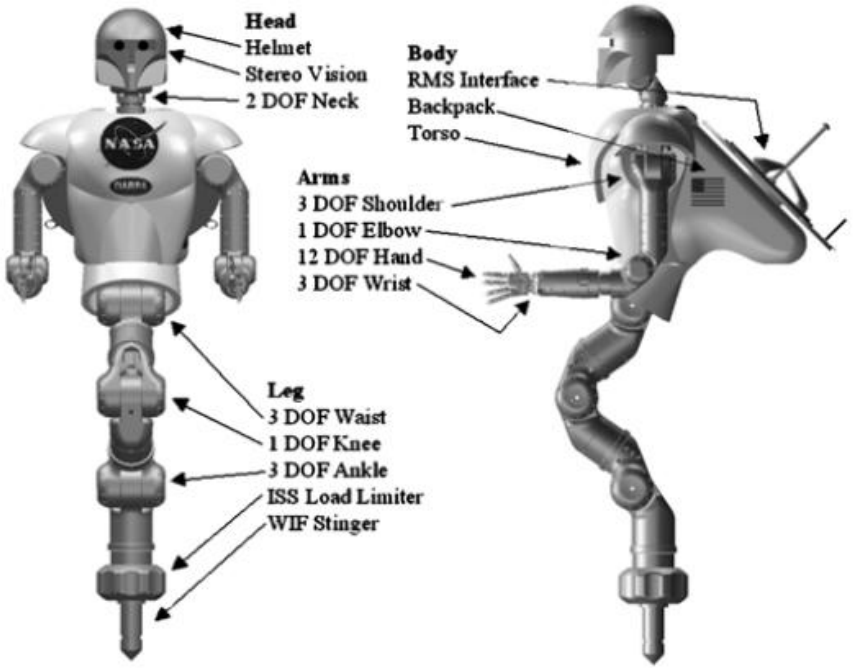
- The Drilling Automation for Mars Exploration (DAME) project (NASA)
- Objective: collaborative subsurface exploration of a Martian impact crater
- Why collaborative?
  - Can't be fully manned due to long lag time (3-22 minutes)
  - Fully autonomous may result in failure, not an option after being sent to Mars
- Drill uses two diagnostic agents:
  - Model-based reasoning from depth sensor values
  - Neural network that perceived the vibrational frequency and modal signatures of the drill shaft

Applications: Planetary Exploration



Applications: Space Station

- Robonaut
  - Humanoid robot with dexterity almost matching a suited astronaut
  - 51 degrees of freedom
  - Objective: collaborative robot that can work in same space as astronauts, performing Extra-Vehicular Activity (EVA)



Applications: Space Station

- Subassemblies:
  - Head
    - Four cameras and a infrared temperature sensor
      - Temperature sensor is to ensure robot does not come in contact with a surface whose temperature is outside of allowable limits
    - Pair of stereo microphones and speaker
  - Hands
    - Each hand has 43 sensors, each joint has an absolute position sensor (potentiometer), and each motor has an encoder
    - Lead screw assemblies and wrist ball joint links have embedded load cells to provide force feedback
  - Endoskeleton
    - Thee six-axis load cells (located at appendage joints) provide feedback of external forces on body

Applications: Space Station

Figure 23. Working with an EVA tether hook.

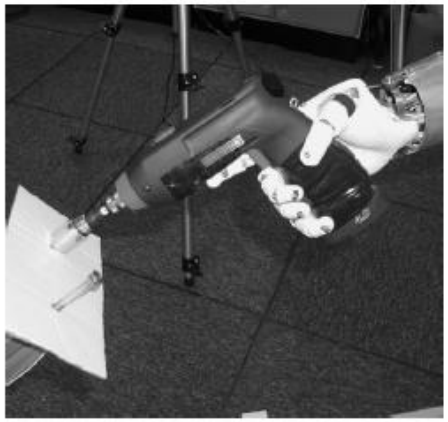


Figure 25. Working with EVA connectors.

ability to work with a variety of EVA tools are describe
in Ambrose et al. (2001).

Looking into the future when Robonaut might hav
applications beyond the microgravity environment,
number of experiments have been tried with mor
common tools and other non-space related objects
These objects include geological tools, bolts and nuts
crescent wrenches, socket wrenches, wire strippers
and flashlights, Figs. 26 and 27. Robonaut has als
performed cooperative tasks with a human including
soldering and taking electrical measurements.

In Fall 2001, a mockup of a Space Station modul
was built to represent a typical EVA worksite. Becaus
Robonaut is mounted to a stationary base, the mocku

Conclusion

- Collaborative robotics is the way of the future
- No new novel sensors
  - Integration of existing sensors is key
  - Intensive processing necessary to ensure safety
- Collaborative robots especially useful in dangerous environments