Special Application Robotics, Inc.

Good Practices for Robotic Technology in Nuclear Applications

Overview

- Introduction
- Robots – Myths and Misconceptions
- Types of Robotics
- General Pro/Con
- Selection for Decommissioning
- Project Example
- Savings in Time/Cost/Safety
- Conclusion

Introduction

- After 10+ years of designing robotics and remote systems I want to present general good practices for robotics
- I routinely encounter many misconceptions, prejudices, and misapplication of robotics around the world
- There are some features to avoid and other to strongly consider
- Choosing the right system is key to safety, cost, and schedule

Robots
Myths and Misconceptions

- "Where's the head"
- "When do we get to see the evil robots?"
- The word "Robot" is poorly defined
  - Which is a Robot:
    - Honda Asimo
    - Excavator
    - MSM
    - CNC Mill




Robots
Myths and Misconceptions

- Robot – Human-like, computer controlled, automated
- For the nuclear world, we typically mean an automated manipulator
- There is a major difference between industrial robotics and academic/R&D robotics
- What is technically possible may not be practical to deploy
  - e.g. vision systems, collision avoidance

Types of Robotics

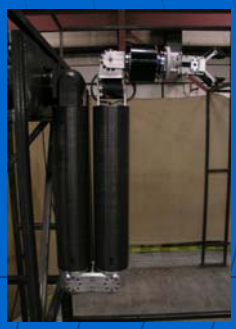
- By Environment
  - Nuclear
  - Automation/Commercial
  - Undersea
  - Ordinance/Bomb Squad
  - Consumer Market

Key Differences in Nuclear Robotics

- Limited Space
- Must Conform to Facility
- Generally High Payload, Moderate Precision
- Generally Human Controlled
- Specific Safety Issues
  - Remote Recovery
  - Contamination Control
- Low Volume Production
- Highly Variable Tasks, Facilities and Operations

Types of Robotics

- By Power Type
  - Electric
  - Hydraulic
  - Pneumatic



Pneumatic

- Pneumatic has many disadvantages
  - Low force potential (7 bar vs 200 bar)
  - Very limited position control (compressible fluid issue)
- Advantages
  - High Speed
  - No Secondary Waste (although vent issue can occur)
- In General, limited nuclear application
- Commercial Example: high speed part extraction

Electric vs. Hydraulic

- The key difference is not power or force
- The key difference is gearing
- Electric manipulators have vastly more gearing
  - Typical (light) motor rotates at 4000 rpm versus a robotic joint which rotates around 4 rpm (1000:1 ratio)
- High gearing also make electric more precise and controllable

Electrical

- Advantages
  - Precise
  - Advanced control options
  - Wide range of electrical components
  - Small utility supply lines
  - No fluid
  - Smaller sizes
  - Faster than hydraulic
    - However, Power = (Speed * Force), so high speed systems are also lower force for given power

Hydraulic

- Advantages
  - High Force (only because of gearing issues)
  - Long Reach
  - Better Recovery Options (remote valving)
  - Robust (fewer, higher strength parts)
  - Tolerance to Shock Loads
  - Light Weight / Payload ratio
    - Not on small scale
  - External Power Source
  - Can be Submerged

Projects that Favor Electrics

- Zero Tolerance for Fluid
- Small Scale (near human arm scale)
- High Accuracy/Precision
  - under +/- 25mm
  - note this simplistic and is in practice more involved
- Advanced Control Requirements
  - Accurate Velocity/Acceleration Control
  - Teach and Repeat

Electric Project Examples

Plut. Glovebox Cleaning Arm
(No Fluids, Low Payload)

Reactor Inspection Arm
(No Fluids, Advanced Controls)

Vit. Waste Canister Swabbing
(No Fluids, Advanced Controls, Low Payload)

Pipe Manipulator
(Tight Space)

Electric Project Examples

Munition Handling Robot
(Small Size)

Reactor Cutting Arm
(High Precision, Advanced Controls)

Tank Inspection Arm
(Small Penetration, Low Payload)

NASA Robot – Care of Robotics Research
(Very Advanced Controls)

Situations that Favor Hydraulics

- Shock Loading
- High Payload
- Long Reach
- Submerged
- Large Size
- Difficult Recovery Requirements
  - Very dependent on situation

Hydraulic Project Examples

Glovebox Size Reduction
(High Payload, Shock Loading)

External Hot Cell Decom.
(High Payload, Shock Loading)

Fuel Pool Decom.
(High Payload, Underwater)

Hydraulic Project Examples

Pallet Loading Arm
(Very High Payload, Moderate Controls)

Hot Cell Decom. Arm
(High Payload, Long Reach)

Graphite Reactor Decom. Arm
(Very High Payload, Very High Shock, Long Reach)

Features that Should Be Avoided

Note: These are only my opinions

- Advanced Operator Interfaces
  - Master Slave Controllers
  - Complex Force Feedback
- Collision Avoidance
- Absolute Accuracy
- Vision Systems
- Commercial Systems Used Inappropriately
- Complex Telescoping Tubes/Masts

Features to Consider

- Inverse Kinematics
  - Even on hydraulic system
  - Open-Loop or Closed-Loop
- Audible Tone Force Feedback
- Modified Commercial Robots
- 6 Axis Force Sensor
- PLCs and Touchscreens

Safety, Cost, and Time

- Simplicity, Simplicity, Simplicity
  - Start with key functionality and work to minimize additional functions
  - 90/10 rule (e.g. consider doing 90% robotically)
  - Use and modify commercial equipment
    - But don't force it, custom can be better
  - Minimize redundancy and interlocks
    - Use very simple recovery techniques

Conclusion

- Robotics are a necessary part of nuclear work
- Selecting the right robotics system is the key to being successful
- When designing, start with the simplest concept and carefully add features until the requirements are meet
- The nuclear market has unique requirements and solution in robotics