Project Update:
On-Orbit Satellite Servicing
Technologies for Remote Robotic Tele-manipulation with Time Delay

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Satellite Servicing Capabilities Office (SSCO NASA)

• Service missions to expand satellites operational life and capabilities, by using telerobotic system controlled from ground station

• Consists of two missions:
  – Robotic Refueling Mission
  – Robotic Servicing Mission

• Collaboration with the Satellite Servicing Capabilities Office (SSCO) at Goddard Space Flight Center and the Robotics Center at the West Virginia University
Project Overview

• Develop telerobotic system that can assist with the removal of insulating blanket flap that covers the spacecraft’s fuel access port

• Demonstrate using JHU da Vinci master console to teleoperate a Motoman robot at WVU CEMR Robotics Center and/or Goddard Space Flight Center (GSFC)

• Simulate round-trip time delay of 1-7 seconds
Blanket cutter tool

A: NASA RRM Cutter Tool

D: Cutter mounted on WAM (JHU)
Software Components

- bumblebee
  - BumblebeeClient
  - BumblebeeServer
- motoman
  - emulator
  - motoman
  - viewer
- wam
  - WAM
- teleopComponent
  - config.xml
  - frame xfrms
- delay components
  - mtsComponentAddLatency
  - DelayTelemetry
  - DelayCommand
- daVinci
  - MTMR
  - pedals
Component Viewer (local, excluding cameras)
FAIL: Singular Configuration
System Architecture

Notations:
- \( F_m \) = Frame of master
- \( F_c \) = Frame commanded
- \( F_b \) = Frame feedback
- \( V_i \) = Video stream
- \( X \) = UI commands

Components:
- Da Vinci Master
- Haptic Rendering
- Teleoperation Component
- Telemetry Delay Component
- Video Delay Component
- User Interface 3D
- Stereo Video Display
- Robot / Scene Model (OpenSceneGraph)
- SIA10D Controller (mtsSIA10D)
- SIA10D Robot @ WVU
- SIA10D Emulator
Cutting Trials with the WAM

- file://localhost/Users/robot/Work/presentations/2012/LabMeetingFeb27/cutting.mpg
What We Learned

• Transformations are tricky
  – camera-to-hand motion mapping for eye-in-hand setup
  – rotation about tip (rotation center offsets)
• Delays are bad
  – overshoot
  – move-and-wait
• Need sensor feedback
  – force sensor $\rightarrow$ fewer broken tips?
• Model based teleoperation
  – virtual fixtures
Model-Based Teleoperation w/ Virtual Fixture
Virtual Fixtures Library

• Define and modify a virtual fixture interactively
• Update VF during procedure based on sensor feedback
3DUserInterface library

- Information rich environment for tele-manipulation
- "Masters as mice" mode to interact with data/model
- Based on OpenSceneGraph for visualization
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