Toward Bilateral Teleoperation over the Internet

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Motivation
Enable humans to mechanically manipulate and sense a remote environment with the Internet as communication medium

Some applications
- space teleoperation
- robotic tele-surgery
- remote construction
- remote micro-assembly
- Internet
- time-varying delays
- packet loss
- Sensable Technology
- NASA space teleoperation
- Intuitive Surgical robotic tele-surgery
- tbray.com remote construction
- University of Tokyo Internet remote micro-assembly

Challenges:
- Internet communication suffers from time-varying delays and packet loss, which can not only degrade system performance but also cause unstable and dangerous behaviors
- Behaviors of the Internet traffic is difficult to be captured by a simple deterministic model

Wheeled-Mobile Robot Teleoperation
Wheeled mobile robots enhance mobility of teleoperation systems, thus, promising for many tasks requiring coverage of large domains (e.g. exploration and rescue)

Challenges
- Kinematic discrepancy: master joystick has limited workspace, but that of slave mobile robot is not
- Nomholonomic constraints: wheels cannot go sideway
- Passive with (constant) communication delays
- Haptic-feedback without extra proximity/force sensors

Approach
- Car-driving like human interface:
  1) 1-DOF as a gas-pedal: \(q_1 + \lambda q_1 \rightarrow v\)
  2) 1-DOF as a steering-wheel: \(q_2 \rightarrow \phi\)

Experimental Setup
- Data-buffering to achieve constant time-delay and prevent packet time-reordering

Experimental Comparison for Internet Teleoperation

Objective: many control schemes are available today for bilateral teleoperation. However, how will they behave under the Internet communication?

- Following representative bilateral teleoperation control schemes are evaluated under the Internet:
  - Wave scattering transformation
  - Digital wave-data reconstruction
  - Wave integral & reconstruction filter
  - Position and position/velocity feedback control
  - Redefined input-output mapping
  - Wave predictor & energy regulator

Evaluation Criteria: interaction stability, position coordination, sharpness of force feedback (z-width)