AI-Enhanced Force Estimation in Telesurgery

Bridging complex system dynamics with miniature force/torque sensing

Case Study

Yang et al. (2026). Shaft-integrated Force Sensing with Transformed-based Dynamics Compensation for Telesurgery.

Challenges

No direct 6-axis force sensing at the tool tip in commercial instruments

Nonlinear dynamics, e.g. friction, cable compliance, and hysteresis

Limited accuracy of state-of-the-art sensorless approaches

Solution

Hybrid concept:

1) Distal 6-axis force sensor integrated into the instrument shaft

2) Robot state information (position, velocity, torque) as model inputs

3) Transformer neural network to estimate 3-axis distal tip forces

Results

Best force estimation accuracy of < 5% compared to baseline setups

Robust performance across varying conditions, soft tissue vs. rigid contact

Accessability: commercial 8 mm tip sensor and open-source code (GitHub)

Impact

Safer robotic procedures and improved operator control through force feedback from the distal tip

Scientific Paper

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