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Tension reduction system for tethered robots in complex environments

Stanford scientists have developed a tension reduction system for tethered robots that enables navigation through complex environments. Using a series of connected devices along the tether or tail, the system applies distributed pulling forces, significantly reducing the total tension required for movement. This technology allows robots to traverse extremely long, tortuous pathways while maintaining reliable tether function for power, data, and retrieval.

Tethered robots face significant challenges when navigating confined and tortuous environments such as industrial pipelines, HVAC systems, or nuclear facilities. As these robots traverse longer distances and navigate multiple turns, friction between the tether and the environment increases exponentially, eventually exceeding the robot's propulsive capabilities. Current solutions like lubricating tethers or using simple roller dollies provide only marginal benefits and fail in extreme conditions. This limitation has severely restricted the operational range of inspection robots in complex industrial facilities, creating an unmet need for more effective tether management systems that would enable comprehensive inspection, blockage removal, and repair operations without requiring direct human access.

The tension reduction system uses a series of interconnected devices positioned along a robot's tether or tail. Each device contains motorized rollers that actively apply tension to specific sections of the tether, dividing the total friction load across multiple points rather than requiring the robot to overcome cumulative friction. The devices are linked by a thin control rope that coordinates their movement and tension distribution. Testing with vine robots demonstrated the system's ability to navigate complex paths with approximately 360 degrees of turning that would otherwise be impassable. By adding more devices, the system can be scaled for

increasingly complex environments, significantly extending the operational range of tethered robots in applications like industrial inspection and search and rescue.

Stage of Development:
Proof of concept
Continued research: Prototyping and characterization work

Applications

- Inspection of confined industrial spaces such as pipelines, ventilation systems, and power plant infrastructure
- Blockage removal and repair operations in complex conduit systems
- Medical devices navigating tortuous anatomical pathways
- Search and rescue operations in collapsed structures or hazardous environments
- Underground or underwater exploration with tethered vehicles
- Growing vine robots for agricultural or surveillance applications

Advantages

- Dramatically reduces the total propulsive force required from the robot
- Maintains reliable tether function for power, data transmission, and retrieval
- Scalable design allows adaptation to increasingly complex environments
- Can be implemented on existing tethered robot platforms
- Functions in both deployment and retrieval operations
- Simpler and more effective than alternative approaches like lubricants or passive rollers

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