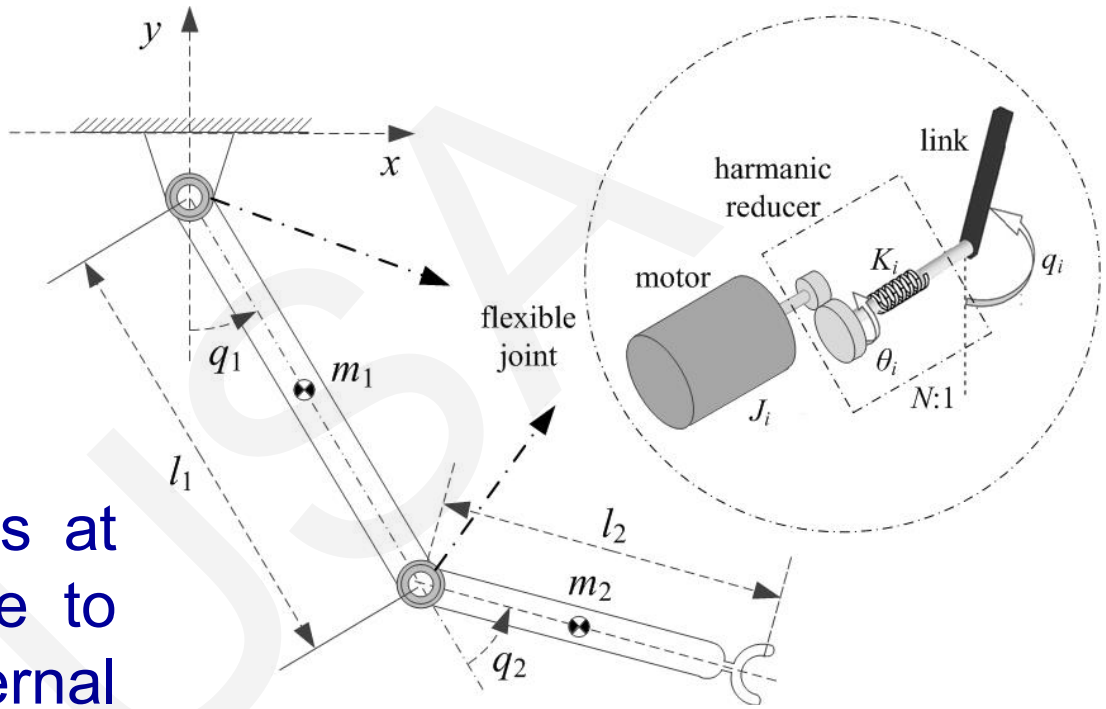
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Bounded adaptive output feedback tracking control for flexible-joint robot manipulators

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Problem Statement



Flexible-joint robot manipulators

1) Velocity measurements at joints and links are liable to be contaminated with external noise, and are frequently absent due to cost reduction of system hardware.

2) The joint actuators cannot offer the arbitrarily large torque required by the control law due to their limited power, and there always exist parametric uncertainties of the system model.

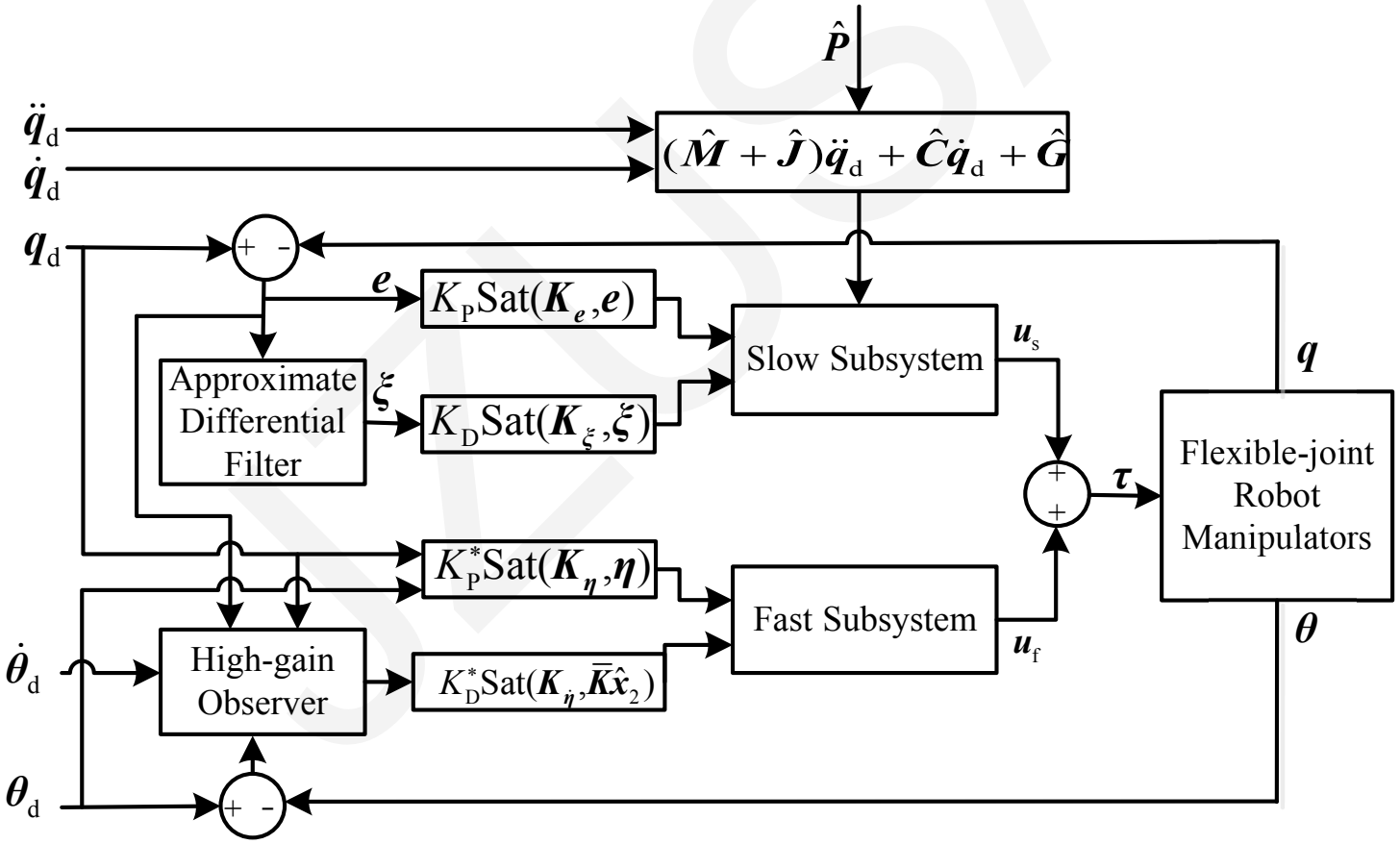
Main Contribution

- This is the first time that the bounded OFT control problem for flexible-joint robot manipulators considering different joint flexibility, in the frame of singular perturbation theory has been systematically addressed.

- The bound of both (slow and fast) sub-controllers and composite controllers is assured by a class of smooth saturation functions and an adaptive control law of projection type that is also used to handle the parametric uncertainties.

- An approximate differential filter and a high gain observer are applied to achieve OFT control and to guarantee the whole closed-loop control with only position measurements of motors and links.

The controller block diagram for robot manipulators with weak joint flexibility

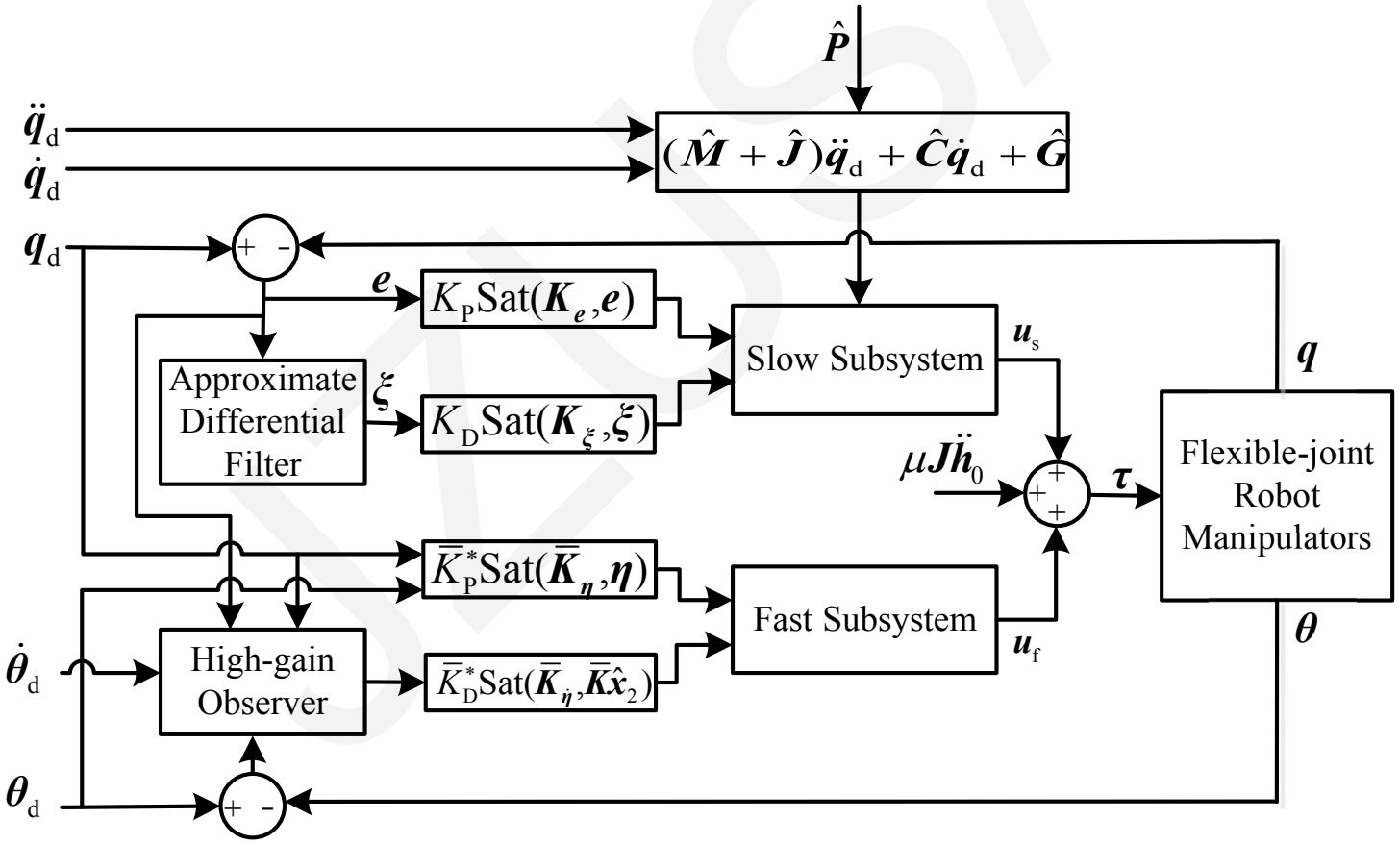


Comparisons of controllers for a robot manipulator with weak joint flexibility

		TA-OFT	TA-OFT+SF	**BA-OFT**
Adjusting time (s)	joint 1	0.54	0.50	**0.47**
	joint 2	0.45	0.43	**0.34**
Maximum torque (Nm)	joint 1	271.27	141.69	**68.39**
	joint 2	143.92	83.26	**38.54**
RMS (rad)	e_1	0.0823	0.0795	**0.0668**
	e_2	0.0804	0.0781	**0.0693**
	$\boldsymbol{e}$	0.1139	0.1090	**0.0967**
Computing cycle (ms)		6.27	9.85	**11.32**

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The controller block diagram for robot manipulators with strong joint flexibility



Comparisons of controllers for a robot manipulator with strong joint flexibility

		TA-OFT +FC	BA-OFT +FC	**BA-OFT +CC**
Adjusting time (s)	joint 1	0.57	0.55	**0.42**
	joint 2	0.45	0.42	**0.39**
Maximum torque (Nm)	joint 1	284.55	133.76	**89.45**
	joint 2	139.23	92.43	**47.73**
RMS (rad)	e_1	0.0953	0.0983	**0.0096**
	e_2	0.0876	0.0689	**0.0612**
	$\boldsymbol{e}$	0.1308	0.1193	**0.0792**
Computing cycle (ms)		14.56	17.84	**19.59**

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Conclusions

- The proposed controllers have superior dynamic performance and the controllers using our bounded control strategy can effectively restrict the torque control inputs within the limit of the joint actuators.

- The proposed bounded adaptive OFT controller with corrective control is verified as adaptable to robot manipulators with different joint flexibilities.

- The control approaches for robot manipulators with weak flexibility and with strong flexibility at joints are shown to have high computing efficiency, that good real-time performance will be beneficial to engineering applications.