Reduced Deformation Transport of Flexible Objects using Decentralized Robot Networks

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Contribution

The main contribution of this work is the development of decentralized approach to reduce deformation of flexible objects during transport, without increasing transport time.

Introduction

Decentralized network control strategies use only local information for cooperative motion in robotic networks, for instance transporting flexible objects using local force sensing with multiple robots. However, cohesion during transitions in the robot network can be lost when using only decentralized information, which can lead to large deformations and damage in the flexible objects. Current decentralized theories only ensure the cohesion at the end, but **not** during transition. Thus this work proposes a method to transport flexible objects using delayed self reinforcement (DSR) which uses only local measurements to reinforce robots' responses, thus allows the transport to be more cohesive, which results in reduction of deformation during transport.

System Schematic

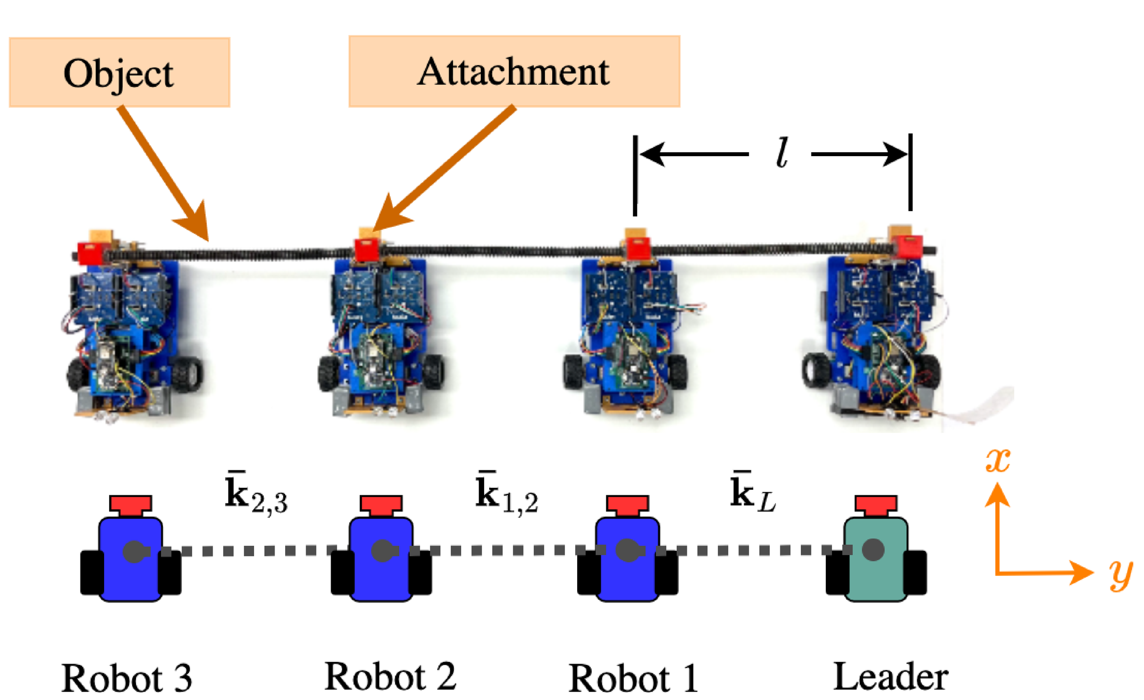

Figure: The schematic network model of the system (bottom) shows how each robot is connected to its neighbor.

Standard Approach

The standard consensus approach can be written as:

$$\mathbf{P}[m+1] = (\mathbf{I} - \gamma\mathbf{K})\mathbf{P}[m] + \gamma\mathbf{B}p_d[m] \quad (1)$$

where,

$\mathbf{Y}$ = position states of all robots
$\mathbf{K}$ = Stiffness matrix
$\mathbf{B}$ = connectivity to desired trajectory
p_d = desired trajectory
γ = update gain

DSR-based Approach

The DSR-based approach is:

$$\mathbf{P}[m+1] = \mathbf{P}[m] - \alpha\beta\delta_t\mathbf{K}\mathbf{P}[m] + \alpha\beta\delta_t\mathbf{B}p_d[m] + [\mathbf{I} - \beta\mathbf{K}](\mathbf{P}[m] - \mathbf{P}[m-1]) \quad (2)$$

where,

α, β = DSR gains
δ_t = sampling time period

Note that this is a modification of the standard approach shown in Eq. (1).

Results

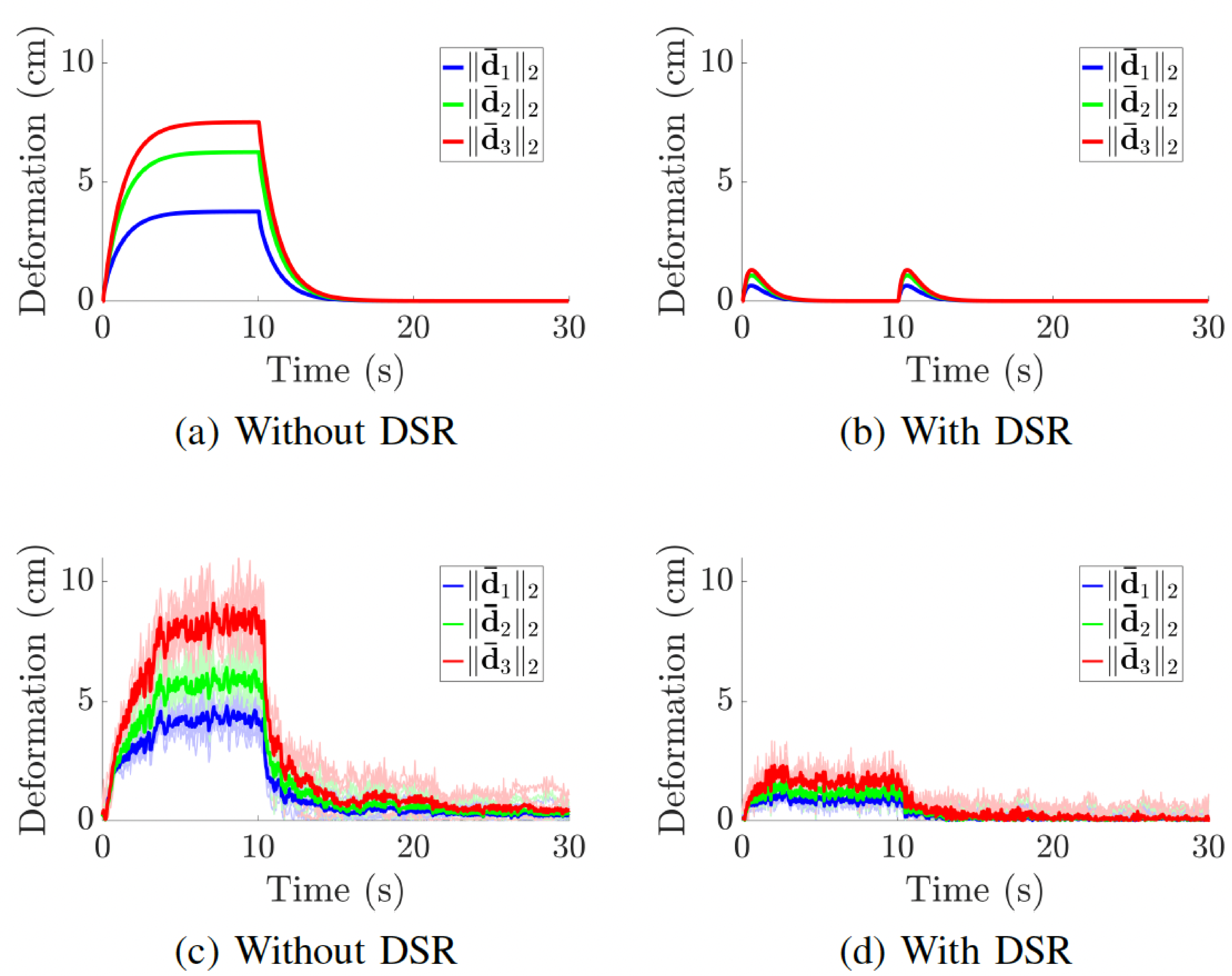

Figure: Comparative evaluation of force and deformation with and without DSR, and similarity of simulations (top row) and experimental results (bottom row). Experimental results are shown for 7 trials (shown in thin lines), and the means are shown in thick lines.

Notes:

1 Video of the experiment can be seen on YouTube: https://www.youtube.com/watch?v=tzDfnMbgIgA

Selection of Parameters

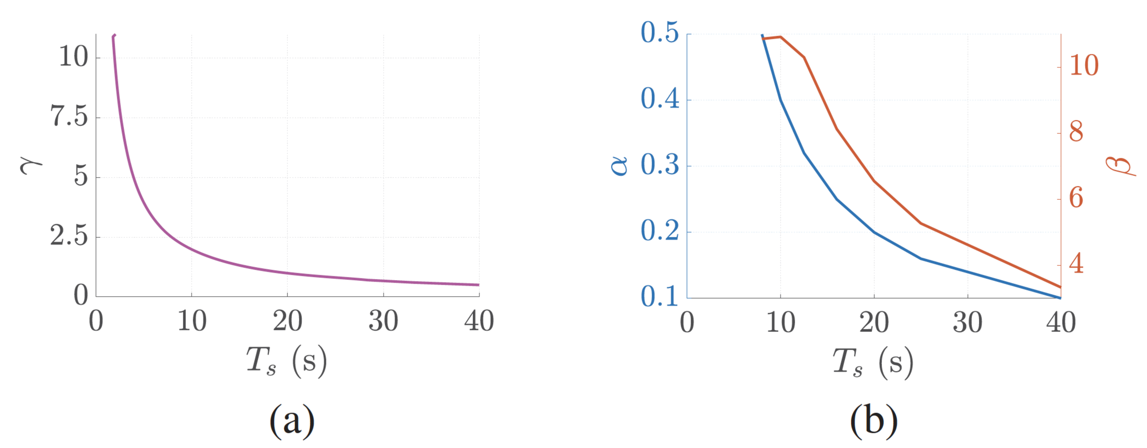

Figure: Selection of control parameters with respect to settling time T_s: (a) The update gain γ for the case without DSR, (b) DSR parameters α and β for the case with cohesive DSR.

Quantitative Outcome

Sim./Exp.	Method	$D^*(cm)$ ($\mu \pm \sigma$)
Sim.	Without DSR	7.51
	With DSR	1.30
	Improvement (%)	82%
Exp.	Without DSR	9.61 ± 0.61
	With DSR	2.44 ± 0.17
	Improvement (%)	$75 \pm 3\%$

Conclusion

This work proposes a DSR-based approach to reduce deformation of objects during transport using decentralized robot networks, without changing the speed of transport. The results have shown that cohesive DSR reduces the deformation and force by almost **75%** as compared to the case without it.

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