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Reduced Deformation Transport of Flexible Objects using Decentralized Robot Networks

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***Abstract*—This work presents new control approaches for flexible object transport using robot networks. Recent works have investigated bio-inspired strategies to transport objects using decentralized robot networks that only use local measurements without the need for communication between robots [1], [2]. However, current decentralized theories focus on ensuring state consensus at the end of the transition and not during transition. Deviation of states during transition causes large deformation, which can lead to damage of the object transported. With current methods, deformation can only be reduced by increasing the transport time. In contrast, this work develops a delayed-self-reinforcement (DSR) [3] approach for transport tasks to reduce deformation during transport of flexible objects, without increasing transport time. An advantage of the DSR method is that it only uses a delayed self reinforcement of each robot's actions using prior available data and does not require additional information from the network. Furthermore, experimental results are presented to show that the proposed DSR-based transport method can reduce the deformation by at least 75% for the same transport time, when compared to the case without DSR.**

***Index Terms*—Cooperating robots, object transport, agent-based systems, networked robots**

I. Results

The experiment setup is shown in Fig. 1. The system consists of four mobile robots carrying a flexible object (coiled-spring) with length of $90cm$. In the robot network, the most right robot is a leader, which has access to desired trajectory, which is a straight line of $50cm$. In this particular case, the leader robot does not have a force feedback, and the follower robots update their positions based only on force feedback measurement at the contact point with the object.

The deformation of the object during transport is measured by inferring force measurements and computed the displacement at each robot location. Results in Fig. 2 show that the case with DSR approach reduces object's deformation during transport from $7.51cm$ to $1.30cm$ in simulation, which is a 82% in improvement as compared to the case without DSR. Similar reduction of deformation also observed in the experimental trials, where the mean maximum deformation is reduced by $75 \pm 1.6\%$, from $(9.61 \pm 0.61)cm$ without DSR to $(2.44 \pm 0.17)cm$ with DSR.

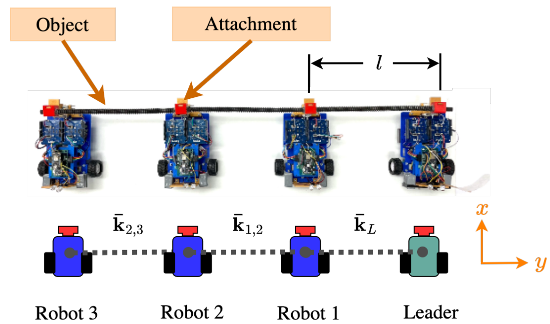
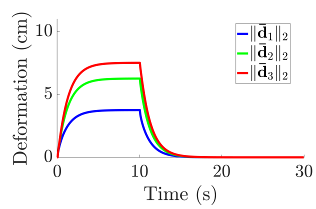
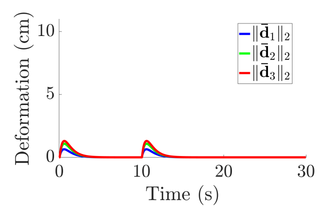


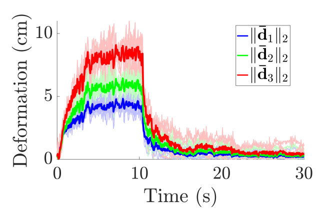
Fig. 1. Network model of the experimental system with 4 robots carrying a flexible object. The length of each segment (element) of the spring is $l = 30cm$. Each robot communicates with its neighbors implicitly through the object by sensing the force measured at the contact point.



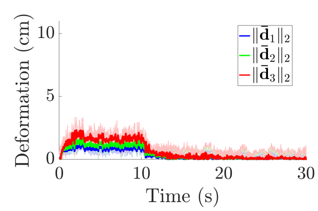
(a) Without DSR



(b) With DSR



(c) Without DSR



(d) With DSR

Fig. 2. Comparative evaluation of results from simulation (top row, a,b) and experiments (bottom row c,d) – without DSR (left column, a,c) and with DSR (right column, b,d). Deformation is quantified through $\|\bar{\mathbf{d}}_i\|_2$ where $\bar{\mathbf{d}}_i = [\bar{d}_{xi}, \bar{d}_{yi}]$ for $i = \{1, 2, 3\}$ for both approaches, with and without DSR. Experimental results are shown for 7 trials (shown in thin lines), and the means are shown in thick lines.

References

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