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Communication-free Decentralized Controller Design for Flexible Object Transport

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***Abstract*— Bio-inspired decentralized approaches for transporting objects with robot networks seek to use locally-sensed information such as object-robot interaction forces, without the need for robot-to-robot communication [1]. However, the design of the decentralized controller to achieve a specified network performance (e.g., to achieve a desired network settling time T_s) depends on the particular network/object connectivity and therefore tends to be a centralized decision. Such centralized controller design is not biomimetic and might not be viable if communication is not available between agents to achieve decentralized consensus on the controller parameters. Decentralized behavior is observed in natural systems, for instance, when ants cooperatively transport food. Studies have shown that ants only use local small vibrations and forces from the interactions with the object to infer the collective intent of the group, rather than communicating directly with each other [2], [3]. Similarly, in bio-inspired object transport, the goal is to use a team of robots for transporting objects from one place to another by using only local measurements without communication. However, local communication is often needed to partition the net force amongst all the robots [4], [5] and to ensure that the net force aligns with the desired transport direction [6], [7]. The need for communication can be avoided when the object is flexible since the local interaction forces implicitly contain information about the forces acting on the object. Specifically, local measured forces can be used to find robot motion updates to achieve decentralized implementation of cooperative transport [8]–[10]. Recent works have also developed approaches that use delayed self-reinforcement (DSR) to reduce the deformation with decentralized transport of flexible objects [11], [12].**

Nevertheless, even with a decentralized implementation of the transport task, centralized design (with centralized estimation of the object's stiffness) is still needed to select controller parameters [13], [14]. In contrast, the main contribution of this article is a decentralized controller design approach using local measurements, which does not require prior knowledge of the robot network or object properties. Rather, only the desired network-level performance (such as network settling time) is needed to select controller parameters with the proposed delayed self-reinforcement (DSR) approach, which decentralizes the ideal case where each robot has information about the transport task. Additionally, experimental results show that the DSR approach (with decentralized parameter selection) reduces deformation substantially by 66% for a linear object using mobile robots and by 57% for the planar transport of a cylindrical object using industrial robots, when compared to the standard (without DSR) case, even with a centralized design of parameters.

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