Integrating Uncertainty-Aware Human Motion Prediction into Graph-Based Manipulator Motion Planning

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There has been a growing utilization of industrial robots as complementary collaborators for human workers in re-manufacturing sites. Such a human-robot collaboration (HRC) aims to assist human workers in improving the flexibility and efficiency of labor-intensive tasks. In this paper, we propose a human-aware motion planning framework for HRC to effectively compute collision-free motions for manipulators when conducting collaborative tasks with humans. We employ a neural human motion prediction model to enable proactive planning for manipulators. Particularly, rather than blindly trusting and utilizing predicted human trajectories in the manipulator planning, we quantify uncertainties of the neural prediction model to further ensure human safety. Moreover, we integrate the uncertainty-aware prediction into a graph that captures key workspace elements and illustrates their interconnections. Then a graph neural network is leveraged to operate on the constructed graph. Consequently, robot motion planning considers both the dependencies among all the elements in the workspace and the potential influence of future movements of human workers. We experimentally validate the proposed planning framework using a 6-degree-of-freedom manipulator in a shared workspace where a human is performing disassembling tasks. The results demonstrate the benefits of our approach in terms of improving the smoothness and safety of HRC. A brief video introduction of this work is available as supplemental materials.

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