Extension of Haptic Shared Control Enabling Transition Between Fully Manual and Fully Autonomous Control

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Abstract (should be within 1st page)

Teleoperation in special environments is highly challenging due to limited visibility, resulting in significant workload even for skilled operators. Consequently, the demand for human–machine cooperative control has increased. Among cooperative control approaches, methods in which human and machine control coexist are referred to as Shared Control (SC), positioned between fully manual and fully autonomous control (F-AC). Haptic Shared Control (HSC) integrates human and machine control through haptic feedback. In HSC, the operator's intervention difficulty is adjusted by varying the Level of Haptic Authority (LoHA), enabling a smooth transition between manual and autonomous control. However, HSC faces two key challenges: (1) adjusting LoHA is difficult, and effective human–machine communication has not been established; (2) even with increased LoHA, control performance remains inferior to F-AC due to high-order dynamics that include the input terminal. To address these issues, this study proposes an extended cooperative control framework that seamlessly connects fully manual control and F-AC. Specifically, we propose (1) a method that enables operators to determine LoHA using a system state transfer interface, and (2) a control scheme that integrates HSC and F-AC by regulating the influence of the input terminal. The LoHA determination method introduces a new interface that allows operators to determine LoHA and perceive sensor reliability. For HSC–F-AC integration, a region representing the operator's intent is defined and continuously adjusted via HSC. Only within this region is F-AC applied. This causes the system to ignore the input terminals and reduce the order of the system dynamics while maintaining the operator's intent. Human-in-the-loop experiments demonstrate that the proposed framework reduces mental workload without increasing physical workload and improves control performance when operation is delegated to autonomous systems.