Inverse optimal control of nonlinear evolution systems

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Video Abstract

Keywords: slender beams engineering nonlinear systems Euclidean spaces Hilbert spaces Hamilton-Jacobi-Bellman equation stabilization closed-loop system Lyapunov function differential equations boundary stabilization extensible beams shearable slender beams offshore engineering structural engineering control laws beam control systems asymptotic stability exponential stability pervasive complex systems

Posted Date: September 20th, 2019

DOI: <https://doi.org/10.21203/rs.2.14991/v1>

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Abstract

A new control design could help engineers improve the stability and optimality of long, slender beams, including those used for offshore engineering. Numerous important dynamical systems are governed by nonlinear partial differential equations: from chemical reactions to epidemics to engineering structures. While optimal control designs have been attempted for these highly complex systems, doing so is extremely difficult. The inverse control approach has proven useful for extending optimal designs from linear to nonlinear systems but, for the most part, only for Euclidean spaces. Extension to Hilbert spaces faces difficulties due to infinite-dimension and the formidable obstacle of having to solve a Hamilton–Jacobi–Bellman equation. Now, researchers have found a way to surmount that barrier, formulating a control design that can be used to reliably stabilize extensible and shearable beams. The team first formulated an optimal stabilization problem through an inverse approach and solved for nonlinear evolution systems in Hilbert spaces. The optimal control design possesses two highly attractive features. First, it ensures both global well-posedness and global practical K_∞ exponential stability of the closed-loop system. And second, it minimizes a cost functional that appropriately penalizes both state and control such that it is positive-definite in the state and control. All without having to solve a Hamilton–Jacobi–Bellman equation. The Lyapunov functional used in the control design explicitly solves a family of such equations. The team applied the results to design inverse optimal boundary stabilization control laws for extensible and shearable slender beams governed by fully nonlinear partial differential equations. Structures like these are found in numerous applications in offshore and structural engineering. The resulting control laws are optimal in the sense that both the motion of the beams and the boundary controls are minimized, thereby improving current beam control systems. More work is needed to meet the more rigorous standard of asymptotic rather than simply exponential stability as for some systems exponential stability is not achievable. And, of course, tests in real-world settings are in order. But these early findings might already be remarkably useful, as the new control design overcomes a long-standing barrier to achieving stability and optimality in many pervasive complex systems.