

# Immersion and invariance: a new tool in stabilization and adaptive control of nonlinear systems

A Astolfi

Imperial College  
London, UK

## Abstract

A new method to design asymptotically stabilizing and adaptive control laws for nonlinear systems is presented. The method relies upon the notions of system immersion and manifold invariance and does not require the knowledge of a (control) Lyapunov function. The construction of the stabilizing control laws resembles the construction used in nonlinear regulator theory to derive the (invariant) output zeroing manifold and its friend. The method is well suited in situations where we know a stabilizing controller of a nominal reduced order model, which we would like to robustify with respect to high order dynamics. This is achieved by designing a control law that immerses the full system dynamics into the reduced order one. We also show that in this new framework the adaptive control problem can be formulated from a new perspective that, under some suitable structural assumptions, allows to modify the classical certainty equivalent controller and derive parameter update laws such that stabilization is achieved. The construction does not require a linear parameterization, furthermore, viewed from a Lyapunov perspective, it provides a procedure to add cross terms between the parameter estimates and the plant states. Finally, it is shown that the proposed approach yields new stabilizing control laws for systems in feedback and feedforward form and allows to relax one of the classical standing assumptions of forwarding, *i.e.* the local exponential stability of one subsystem. The method is illustrated with several practical examples, including a mechanical system with flexibility modes, an electromechanical system with parasitic actuator dynamics and an adaptive nonlinearly parameterized visual servoing application.