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Abstract

Ever growing performance requirements as well as new technologies require an increasing number of control systems being designed on the basis of mathematical models comprising partial differential equations or time delays. These classes of models, and control methods adapted to them, may be expected to play an important role in high-technology applications in the next few years, similar to what happened for nonlinear systems and nonlinear control in the last decade.

The notion of differential flatness of nonlinear finite dimensional systems, described by ordinary differential equations, has given rise to various powerful methods for motion planning and control design. It plays an increasing role in industrial applications of nonlinear control. Flatness based control methods place an emphasis on trajectory design and open-loop control. Unfortunately, this aspect has not always attracted the consideration it requires both in the control theoretic literature and in control education.

The careful design of feed-forward, or steering, control gains even more importance in infinite dimension, namely for distributed parameter systems with boundary control action, the mathematical models of which comprise partial differential equations, and also for the subclass of (linear and nonlinear) time delay systems.

As a consequence, the flatness based approach has been generalized to the infinite dimensional case. Parameterizing the system trajectories by a so-called flat output, for many infinite dimensional systems efficient motion planning and open-loop (feed-forward) control design can now be achieved in a way similar to the one followed with nonlinear flat systems. The feedback linearization and eigenvalue assignment methods known from nonlinear finite dimensional systems have also been shown to generalize to delay systems.

The emphasis of the present notes is put on the generalization of the flatness property to distributed parameter systems and to its use in trajectory planning and open-loop control design. Time invariant linear systems with spatially distributed parameters and boundary controls are treated in a systematic manner. Basic ingredients of the method are operational calculus, series expansions, and integral representations. An extension to further classes of distributed parameter systems (nonlinear, time invariant, in three space dimensions) is shown to be possible through a discussion of several examples.

Before dealing with distributed parameter systems, the flatness based approach to finite dimensional nonlinear systems is briefly recalled and its generalization to linear and nonlinear systems with (constant) time delays is outlined, too.

A considerable number of examples illustrates the use of the methods proposed.