WELL-POSED LINEAR SYSTEMS IN L^1 AND L^∞ ARE REGULAR

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Abstract. We study well-posed linear system with locally L^p inputs and outputs, where $1 \leq p \leq \infty$, and whose input, state and output spaces are Banach spaces. Like in the usual Hilbert space theory, we call such a system regular if each of its step responses has a right Cesaro limit at zero. In this case, the system has a feedthrough operator: the Cesaro limit is given by the feed-through operator applied to the constant value of the input step. Regular systems have a simple representation. We show that the system is regular if $p = \infty$, or if $p = 1$ and the state space is reflexive. We also present an application to a quadratic cost minimization problem for a parabolic equation.

Key Words. Well-posed linear system, regular linear system, feedthrough operator, parabolic equation, LQ-problem, spectral factorization.

1. Introduction

Many infinite-dimensional systems can be described by the equations

$$x'(t) = Ax(t) + Bu(t),$$
$$y(t) = Cx(t) + Du(t), \quad t \geq 0, \qquad (1)$$
$$x(0) = x_0.$$

on a triple of Banach spaces, namely, the input space U, the state space X, and the output space Y. We have $u(t) \in U$, $x(t) \in X$ and $y(t) \in Y$. The operators A, B and C are usually unbounded. It is often convenient to use the "integral" representation of the system, which consists of the four operators from the initial state x_0 and the input function u to the final state $x(t)$ and the output function y:

$$x(t) = A^t x_0 + B\tau^t \pi_+ u,$$
$$y = C x_0 + D\pi_+ u. \qquad (2)$$

Here, A^t is the semigroup generated by A (which maps the initial state x_0 into the final state $x(t)$), $B\tau^t\pi_+$ is the map from the input u to the final state $x(t)$, C is the map from the initial state x_0 to the output y, and $D\pi_+$ is the input-output map from u to y (see the notation in Section 2).

The well-posedness assumption is that (2) behaves well in an L^p-setting, i.e., $x(t) \in X$ and $y \in L^p_{loc}(\mathbf{R}^+; Y)$ depend continuously on $x_0 \in X$ and on $u \in L^p_{loc}(\mathbf{R}^+; U)$. If this is the case, we call the operators (A, B, C, D) a well-posed linear system. There is an almost one-to-one correspondence between (1) and (2): most well-posed linear systems can be represented as in (1). These systems are called regular. They are characterized by the fact that their transfer function has a strong limit at $+\infty$ (along the real axis), see Weiss [22]. However, there do exist irregular well-posed systems, and this may happen, for example, in the most commonly studied case where $p = 2$ and U, X, Y are Hilbert spaces. For example, any realization of the transfer function

$$G(s) = \cos(\log s)$$

is irregular (this example is due to Kirsten Morris). Such realizations exist with $p = 2$. We show that in the case $p = \infty$, every well-posed linear system has a representation of the form (1) (for a restricted class of inputs u). A similar statement is true when $p = 1$ (in this case, there is no extra limitation on the input function, but the state space should be reflexive). In particular, the transfer function G defined above has no realizations with $p = 1$ or $p = \infty$.

A simple example to which this theory applies is a system whose semigroup A^t is analytic on a reflexive state space and whose control operator B and observation operator C are not too unbounded, i.e., there exists some $\alpha < 1$ such that $C(\gamma I - A)^{-\alpha} B$ is a bounded linear operator for some (hence for every) γ in the resolvent set of A. In this case it is possible to use any value of p, $1 \leq p \leq \infty$, as long as the state space X is adapted to the value of p. The values $p = 1$ and $p = \infty$

Well Posed Linear Systems

Milan Sonka,Vaclav Hlavac,Roger Boyle

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Well-Posed Linear Systems Olof J. Staffans,2005-02-24 Publisher Description *Mathematical Systems Theory in Biology, Communications, Computation and Finance* Joachim Rosenthal,David S. Gilliam,2012-12-06 Mathematical systems theory is a vibrant research area in its own right The theory has an impact in numerous applications areas including aeronautics biological systems chemical engineering communication systems financial engineering and robotics to name just a few This volume contains survey and research articles by some of the leading researchers in mathematical systems theory Many authors have taken special care that their articles are self contained and accessible also to non specialists The articles contained in this volume are from those presented as plenary lectures invited one hour lectures and minisymposia at the 15th International Symposium on the Mathematical Theory of Networks and Systems held at the University of Notre Dame August 12 16 2002 **Systems and Control in the Twenty-First Century** Christopher I. Byrnes,Biswa N. Datta,Clyde F. Martin,2013-12-11 The mathematical theory of networks and systems has a long and rich history with antecedents in circuit synthesis and the analysis design and synthesis of actuators sensors and active elements in both electrical and mechanical systems Fundamental paradigms such as the state space real ization of an input output system or the use of feedback to prescribe the behavior of a closed loop system have proved to be as resilient to change as were the practitioners who used them This volume celebrates the resiliency to change of the fundamental con cepts underlying the mathematical theory of networks and systems The articles presented here are among those presented as plenary addresses invited addresses and minisymposia presented at the 12th International Symposium on the Mathematical Theory of Networks and Systems held in St Louis Missouri from June 24 28 1996 Incorporating models and methods drawn from biology computing materials science and math ematics these articles have been written by leading researchers who are on the vanguard of the development of systems control and estimation for the next century as evidenced by the application of new methodologies in distributed parameter systems linear nonlinear systems and stochastic sys tems for solving problems in areas such as aircraft design circuit simulation imaging speech synthesis and visionics *Systems, Approximation, Singular Integral Operators, and Related Topics* Alexander A. Borichev,Nikolai K. Nikolski,2012-12-06 This book is devoted to some topical problems and applications of operator theory and its interplay with modern complex analysis It consists of 20 selected survey papers that represent updated mainly plenary addresses to the IWOTA 2000 conference held at Bordeaux from June 13 to 16 2000 The main subjects of the volume include spectral analysis of periodic differential operators and delay equations stabilizing controllers Fourier multipliers multivariable operator theory model theory commutant lifting theorems coisometric realizations Hankel operators and forms operator algebras the Bellman function approach in singular integrals and harmonic analysis singular integral operators and integral representations approximation in holomorphic spaces These subjects are unified by the common operator theoretic approach and the systematic use of modern function theory techniques Hankel

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