Doctoral Dissertation
Doctoral Program in Computer and Control Engineering (31stcycle)

Abstract

A set-membership approach to direct data-driven control design

By

Mohammad Abuabiah

******

Supervisor(s):
Prof. Vito Cerone
Prof. Diego Regruto, *Co-Supervisor*

Politecnico di Torino
2019

Abstract

Significant research efforts have been devoted in recent years to the problem of designing a control system under the assumption that a mathematical model for the plant is not available. In particular, several interesting results have been obtained through the direct data-driven controller (DDDC) design approach, that is the direct design of the controller from a set of input-output experimental data characterizing the plant behaviour.

The DDDC design approach has a wide representation capability for designing the controller for different dynamical systems and this framework of the DDDC approach is also recently supported by a well worked out research and some industrial applications. Despite the advances of the DDDC field, designing of such a controller without the availability of a mathematical model is still in its immature state, due to many open problems of DDDC design theory. One of the most important problem in the DDDC approach is that, in practice, the available experimental data is always imperfect, as it is affected by measurement noise. Therefore, this thesis focuses on the development of a novel non-iterative direct data-driven technique to deal with linear-time-invariant (LTI) controller design, such that the controller is directly identified from a collected experimental input/output data corrupted by bounded additive noise. Based on the assumption of corrupting bounded noise, the design problem is formulated then in the framework of set-membership (SM) identification theory.

In this work, we propose two original non-iterative direct data-driven techniques to deal with a linear-time-invariant (LTI) controller design, such that the controller is directly identified from input/output data without plant identification step:

1. **Fixed structure controllers**: in this approach, we formulate the problem of designing a fixed controller in order to match the behaviour of a given reference model, in terms of an equivalent set-membership errors-in-variables problem and we define the feasible controller parameter set. Then, we design the controller parameters by applying recent results in the field of set-membership errors-in-variables identification.

2. **Nonparametric controllers**: we present a novel non-iterative approach to direct data-driven nonparametric controller design. In this approach, the DDDC problem is formulated in the robust Reproducing kernel Hilbert space (RKHS) framework. First, by assuming that the available input-output data are corrupted by bounded noise, we formulate the problem of designing a controller in order to match the behaviour of an assigned reference model. Then, the controller is designed by means of a non-parametric approach, inspired by recent results in the field of RKHS approach.

Moreover, in this work, we present an original approach to design, in a systematic way, the reference model M to be able to meet performance specifications. In the proposed method, the desired performance specifications of the closed-loop system are translated into a model reference design paradigm in the framework of the DDDC approach. The design of a suitable reference model M is carried out based on H_∞ control design approach by using a suitable fictitious plant. Then, stability conditions both for stable minimum-phase plant and stable non-minimum phase plant are discussed and analyzed to guarantee the internal stability of the designed closed-loop system.

Finally, the obtained design algorithm is applied to different electronic test bench networks to show the effectiveness of the proposed approach.