MRCD (Multiobjective Robust Control Design) Genetic Algorithm: Mechanics and Evaluation

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Abstract. The MRCD genetic algorithm has been designed to solve multiobjective control problems formulated in parametric form. This algorithm has been evaluated with respect to other GAs and other multiobjective control methods.

1 Introduction

In modern control theory, a design problem is formulated as an optimization problem of a performance measure of the controlled system. The most common performance measures are norms of some characteristic closed-loop properties of the system. However, the control design problem is a multiobjective problem and any effective design method should allow one to deal with several objectives that could possibly be expressed with various types of norms. The multiobjective robust control applications via GAs is an active research area. However, many of the references deal only with very specific design problems.

The design of a generic controller by GAs involves two important problems, the choice of an *a priori* structure for the controller, and the selection of the initial parameter space search limits. In the literature, a lot of GA-based procedures for SISO (single input, single output) controllers with a fixed structure, *e.g. PIDs* are found. However, the MIMO (multiple input, multiple output) case, where the controller is defined by a parametric canonical form (state-space realization) has still not been studied. The use of generic structures requires the optimization of a large number of parameters and the limits of the search space are unknown *a priori*. On the other hand, the choice of different canonical forms produces different optimization problems with different search spaces, and the convergence properties also change.

2 MRCD: Mechanism.

In [4], a genetic algorithm for solving generic multiobjective control design problems was proposed. The MRCD algorithm has been developed in order to design multiobjective robust controllers with a generic structure given as a canonical parametric form. It is a multiobjective GA that uses the Pareto front concept

to obtain a final set of individuals as a solution (direct method). The MRCD algorithm uses the "ranking" function [2], the binary tournament [5], a filtered elite and other operators to converge towards the Pareto front and to obtain diversity. The MRCD algorithm also incorporates specific operators to solve the problem of unknown search limits: (1) Parallel structure. The MRCD algorithm has different subpopulations with different initial search limits. There is internal migration between the subpopulation and external migration of new individuals after a given number of generations. (2) Dynamic search space limits. The search space limits are changed as a function of the individual parameter values after a given number of generations. (3) Constraints as objectives. For a greater flexibility in the initial search space the constraints are introduced as new objectives. The controller design problem has a fixed constraint, the closed-loop stability. The MRCD algorithm can obtain optimal solutions from an initial population of destabilizing controllers.

3 MRCD: Evaluation.

In [3], an exhaustive study and evalution of the MRCD has been carried out. Firstly, the MRCD algorithm has been evaluated with respect to ten different multiobjective test problems described in [6]. There, four algorithms (MOGA, MOMGA, NPGA and NSGA) were evaluated with respect to those test problems. The results for the MRCD algorithm are excellent. The MRCD algorithm is at least similar in performance to those algorithms and even better for most of the test cases. Fig. 1 shows the solution obtained for the Osyczka function with a $\mathbb{R}^6$ search space and six hard constraints. The squares ($\square$) are individuals over the attained Pareto front. The dots ($\cdot$) are individuals that satisfy the constraint, from a randomly chosen population of 40,000 samples in the search space.

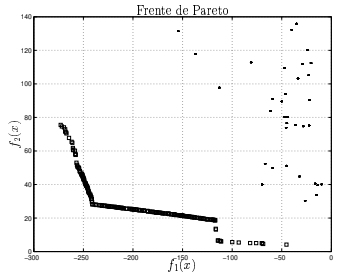

Fig. 1. Pareto front obtained by the MRCD algorithm for the Osyczka test function

Secondly, the MRCD algorithm has been evaluated for multiobjective control design problems. Here, the performance of the algorithm for solving the class of problems that it was designed for, is analyzed.

Two typical mixed controller $\mathcal{H}_2/\mathcal{H}_\infty$ problems were designed and the results were compared with respect to the upper bounds obtained by algorithms based

on LMI methods. These problems were repeated for thirteen benchmark systems, and each of them for three different controller parametric forms (controllable, diagonal and balanced), see [3]. Fig. 2 shows the results for a design example of state and output feedback controllers. On the left, the results obtained by the MRCD algorithm ($\cdot$) are compared with those obtained by the LMI method (solid line) for the state feedback case. On the right, feedback output controllers obtained by the MRCD algorithm for different parametric forms (controlable ($*$) , diagonal ($+$) and balanced ($\circ$)) and by the LMI approach (solid line) are compared. In all cases, the results obtained by the MRCD algorithm, using the controllable form, improve the upper bound solution obtained by LMI methods. The other parametrizations are more restrictive, in the sense that not every feasible controller can be parametrized. Nevertheless, the results obtained are good for the restricted set of controllers represented by each parametrization.

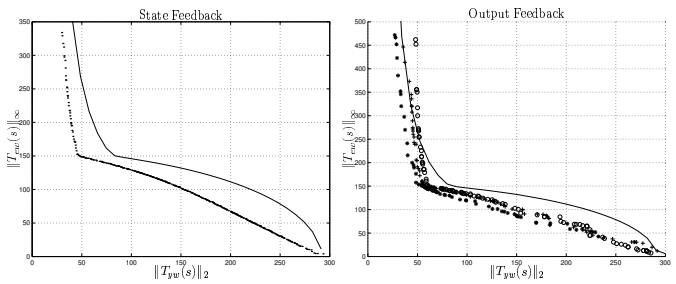

Fig. 2. Comparison of the Pareto fronts obtained for an example of design of mixed $\mathcal{H}_2/\mathcal{H}_\infty$ controllers using the MRCD algorithm and the LMI approach

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