Multi-stage Procedure for PI controller design of the Boiler Benchmark problem

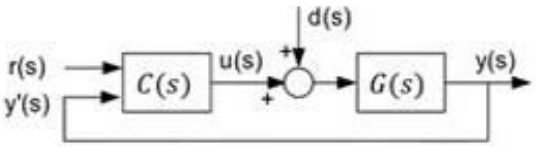
H. Sánchez, G. Reynoso-Meza, R. Vilanova, X. Blasco
{helemsabina.sanchez, ramon.vilanova}@uab.cat, g.reynosomeza@pucpr.br, xblasco@isa.upv.es

Abstract

- A multi-stage approach is proposed merging a deterministic and evolutionary algorithm [1] for PI controller tuning.
- This technique is formulated through the design of a multi-objective optimization procedure, to ensure the construction of a Pareto frontier that guarantees a well distribution and exclude the non-Pareto and local Pareto points.
- This procedure focuses on reliability-based optimization instances.

PI Control System

The process under consideration is the *Control Benchmark 2012* described by [2]. The control of boilers has been an important problem for a long time. The process will be controlled by a proportional-integral controller (*PI*). A conventional control scheme is assumed:



The identified nominal model to be used is:

$$G(s) = \frac{0.3934}{1+45.6794s} e^{-3.42s}$$

This model was obtained with a step response experiment using the standard identification toolbox from Matlab© with a standard step response.

System Requirements

The objectives design for the controller tuning, according to the control loop are:

- $J_1(\theta)$: the most natural way to measure the performance is the integrated-absolute-error (IAE).
- $J_2(\theta)$: some results in [3] show that we can directly associate the robustness (M_s) to the performance index (TV) in such a way, we will have a single index which gives a measure for the input usage and system robustness.
- $J_3(\theta)$: Reliability based optimization instances concern is to guarantee a given performance by minimizing the nominal performance degradation when we consider a set of potential models instead of a singleton such a style nominal model.

Acknowledgment

This work was partially supported by the **Spanish Ministry of Economy and Competitiveness** program under grant DPI2013-47825-C3-1-R and by the **National Council of Scientific and Technologic Development of Brazil (CNPq)** with the fellowship BJT-304804/2014-2.

References

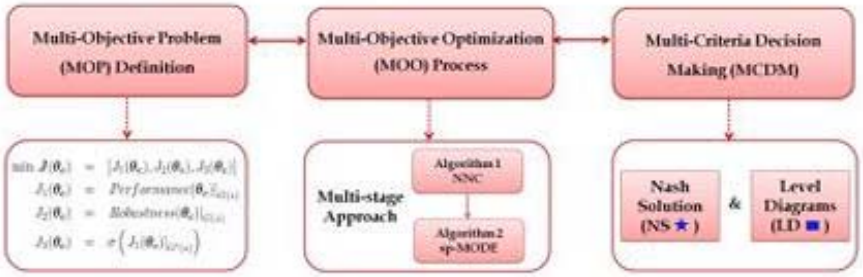
[1] G. Reynoso-Meza, "NNC algorithm for multi-objective optimization & Multiobjective Differential Evolution Algorithm with Spherical Pruning." *Both algorithms are available in Matlab Central.*

[2] Fernando Morilla, "Benchmark for PID control based on the boiler control problem." *Internal report, UNED Spain-2012.*

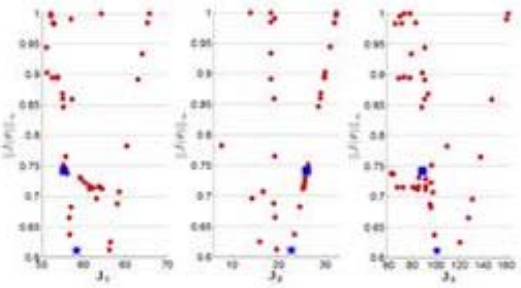
[3] H.S. Sánchez , R. Vilanova, "Multiobjective tuning of PI controller using the NNC Method: Simplified problem definition and guidelines for decision making," *18th IEEE Conference on Emerging Technologies & Factory Automation (ETFA), 10-13 September, Cagliari, Italy, 2013.*

Methodology

Multi-objective Optimization Design (MOOD) Procedure



Pareto Front approximation

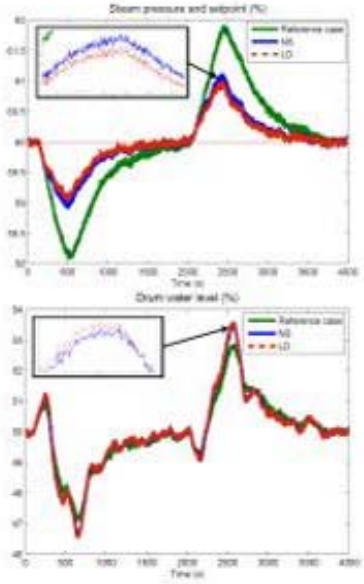


Two solutions were selected from the Pareto front:

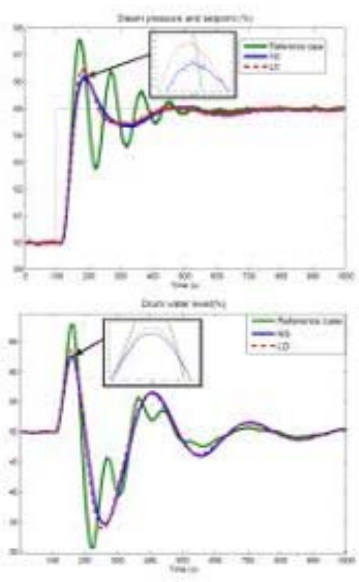
- NS $[\theta_c] = [2.31, 22.16]$
- LD $[\theta_c] = [2.54, 21.25]$

Results & Discussions

- Test type 1: Performance of the PI controller selected with the **NS** ($I_b = 0.8616$), **LD** ($I_b = 0.8464$) and its comparison with the reference case in the benchmark setup.



- Test type 2: Performance of the PI controller selected with the **NS** ($I_b = 0.8325$), **LD** ($I_b = 0.8161$) and its comparison with the reference case in the benchmark setup.



Conclusion

The approach has been shown effective by its application to a Boiler Benchmark problem; bringing a good approximation of the Pareto front, ensure the accurate convergence and diversity. As it can be noticed both design alternative bring an effective controller that fulfill all the requirements, with a better performance than the reference controller. It seems that the multistage approach brings a suitable framework and also includes the reliability on MOOD procedure.