Pritesh Shah, Sudhir Agashe, Anand J. Kulkarni, 2018. Design of a fractional $PI^{\lambda}D^{\mu}$ controller using the cohort intelligence method. *Frontiers of Information Technology & Electronic Engineering*, 19(3):437-445. https://doi.org/10.1631/FITEE.1601495

Design of a fractional $PI^{\lambda}D^{\mu}$ controller using the cohort intelligence method

Key words: Cohort intelligence; Fractional calculus; Fractional PID controller; Tuning

Corresponding author: Pritesh Shah, pritesh.ic@gmail.com
ORCID: http://orcid.org/0000-0002-7504-2323

Novelty

The novelty of this study is the application of the CI algorithm to design the fractional PID controllers for solving different benchmarks (Cao and Cao, 2006; Biswas et al., 2009; Lee and Chang, 2010). The control performance of the proposed method is compared with those of recent studies in terms of the cost function, the number of function counts, and the computation time.

Main idea

The CI algorithm was inspired by the social behavior of cohort candidates. A cohort refers to a group of candidates which are interacting and competing with one another to achieve a common goal.

In a cohort, each candidate iteratively attempts to improve its own behavior by observing the behavior of other candidates. Eventually, when all the candidates converge on a particular behavior, the learning procedure is terminated and the convergence/saturation condition is reached. Details about the CI algorithm can be found in Kulkarni et al. (2016)

Method

The framework of the CI method (Kulkarni O et al., 2016) can be summarized as follows:

Step 1: The parameters of the controller are considered qualities of candidates in the process of optimization. These qualities are randomly generated within the upper and lower bounds of the search space.

Step 2: The behavior is evaluated for all the candidates, and is referred to as the cost function. In the case of the control system, the cost function is the error function to be minimized.

Method (Cont'd)

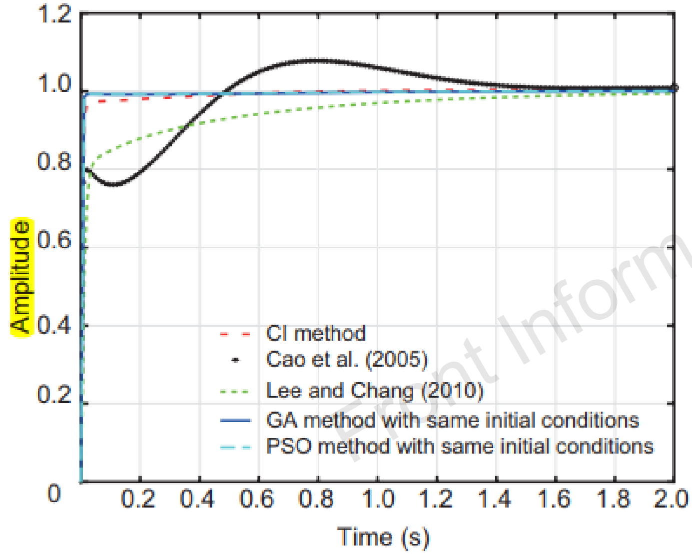
- Step 3: The probability for each candidate followed by other candidates is evaluated based on its cost function. The candidate with the best cost function has the maximum probability of being followed by other candidates, and vice versa.
- Step 4: Each candidate employs a roulette wheel approach to follow a behavior in the cohort, and it improves the value of its cost function by expanding or reducing the lower and upper bounds of the parameters.
- Step 5: The value of the cost function is assumed to converge when the difference between the behavior of each candidate becomes insignificant.

Major results

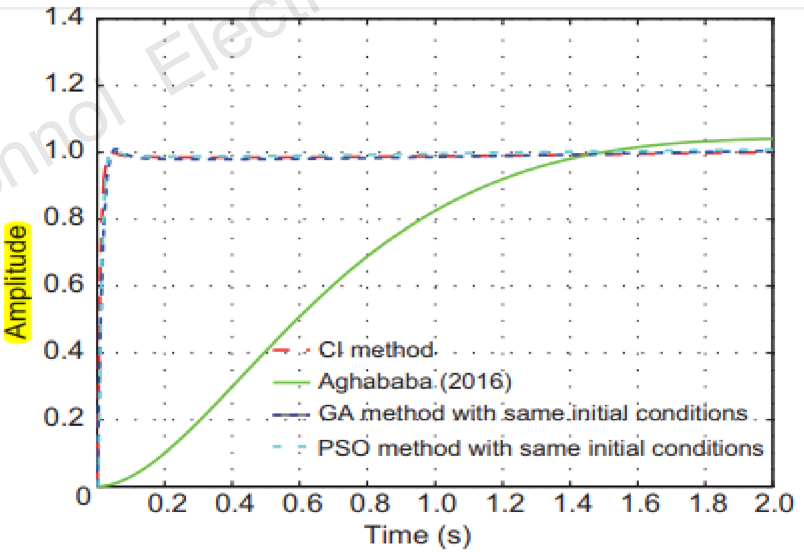
- Using the CI method, the cost function ISE was reduced to 0.0051.
- Using the other methods, the values of ISE were 0.0971 and 0.0811, respectively.
- There was an improvement of 93% in the ISE value compared with the other methods.
- The CI method yielded not only a better ISE value but also a lower computation time, compared with that produced by the EM algorithm (2.5055 s for CI vs. 4.107 s in the EM algorithm (Lee and Chang, 2010)), which was approximately 39% faster.

Major results (Cont’d)

The closed-loop response of plant 1 has the following time-domain specifications: rise time (T_r), 0.0012 s; maximum overshoot (M_p), 0%; peak time (T_p), 0.0239 s; settling time (T_{ss}), 0.2 s; steady state error (E_{ss}), 0.



(a)



(b)

Step response of the closed-loop system designed using CI: (a) plant 1; (b) plant 2

Conclusions

1. It is the first time to use the emerging cohort intelligence (CI) method in the control domain to design a fractional PID controller.
2. Simulations demonstrated that compared with other optimization methods (PSO, modified version of PSO, and EM), the CI method yielded better results when used to tune the parameters of the fractional PID controller.
3. The CI method converges towards the best values of the controller for different plants of a control system.