

Chapter 18

A Comparison among Multi-Agent Stochastic Optimization Algorithms for State Feedback Regulator Design of a Twin Rotor MIMO System

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ABSTRACT

Multi-agent optimization or population based search techniques are increasingly become popular compared to its single-agent counterpart. The single-agent gradient based search algorithms are very prone to be trapped in local optima and also the computational cost is higher. Multi-Agent Stochastic Optimization (MASO) algorithms are much powerful to overcome most of the drawbacks. This chapter presents a comparison of five MASO algorithms, namely genetic algorithm, particle swarm optimization, differential evolution, harmony search algorithm, and gravitational search algorithm. These MASO algorithms are utilized here to design the state feedback regulator for a Twin Rotor MIMO System (TRMS). TRMS is a multi-modal process and the design of its state feedback regulator is quite difficult using conventional methods available. MASO algorithms are typically suitable for such complex process optimizations. The performances of different MASO algorithms are presented and discussed in light of designing the state regulator for TRMS.

INTRODUCTION

In the past years, the use of multi-agent stochastic optimization methods, such as the GA (Holland, 1975), (Goldberg, 1989), PSO (Eberhart & Kennedy, A new optimizer using particle swarm theory, 1995), (Kennedy & Eberhart, 1995), DE (Storn & Price, 1995), HS algorithm (Geem, Kim, & Loganathan, 2001), GSA (Rashedi, Nezamabadi-pour, & Saryazdi, 2009) etc., in the domain control system design

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showed very encouraging results. Stochastic optimization techniques are general purpose techniques based on mostly empirical evolutionary laws and are frequently mimic the nature inspired strategies (Konar, 2005), (Engelbrecht, 2006). Furthermore, stochastic algorithms are very flexible in nature and they can be successfully applied to many types of function optimizations with constraints (Da Ros, Colusso, Weschenfelder, Castilhos, Corazza, & Schwaab, 2013). Although these methods usually found a solution that is near optimal but suffices the approximations required for that optimization problem. Again the stochastic algorithms can be used to solve the problems with n number (n may be large enough) of parameters to be optimized and the algorithms are not very sensitive to the initial parameter guesses. One of the main advantage of these type of algorithms is that they do not required to compute the derivatives of the objective functions and are able to find the global optimum (Engelbrecht, 2006).

In this chapter, a control problem involving a popular experimental benchmark model called the twin rotor MIMO system (TRMS) (Feedback Company, 2010), (Feedback Company, 2014), whose behavior is much resemblance to that of a practical helicopter, has been utilized to compare the performance of several contemporary stochastic algorithms. The TRMS model can freely rotate both in the horizontal and vertical axes responding to azimuth or yaw and elevation or pitch moments, respectively over a beam, with a pivot and a counter balance attached to it. At each end of the beam there are two rotors, driven by DC motors, commonly known as main and tail rotors. The main rotor produce a lifting force allowing the beam to raise vertically, manipulating the pitch angle, and the tail rotor is used to control the beam to turn left or right, manipulating the yaw angle. Both of the motors produce aerodynamic forces through the rotor blades and also provide the coupling effect between the rotors (Biswas, Maiti, Kolay, Das Sharma, & Sarkar, 2014). Therefore, TRMS can be considered as a higher order nonlinear system with prominent cross-couplings between the main rotor and the tail rotor (González, Rivera, & Bernal, 2012; Ahmed, Bhatti, & Iqbal, 2009), and posing a challenge to the control engineering researchers (Nejjari, Rotondo, Puig, & Innocenti, 2011; Pratap & Purwar, 2010; Tao, Taur, Chang, & Chang, 2010; Ahmad, Shaheed, Chipperfield, & Tokhi, 2000; Rahideh & Shaheed, 2007; Christensen, 2006; Juang, Huang, & Liu, PID control using presearched genetic algorithms for a MIMO system, 2008).

In case of single-input single-output (SISO) systems, if the system is controllable, the feedback gains to achieve the desired regulator performance, are unique for some given eigenvalues. For multi-input multi-output (MIMO) systems, the feedback gains are not unique, and thus, an additional design autonomy ensures the optimal / suboptimal solution (Ogata, System Dynamics, 1992). The application of MASO algorithms are quite effective in searching the proper feedback gains to design a state feedback regulator keeping in mind the tradeoffs between robustness, performance, and control effort.

The rest of the chapter is organized as follows: Different multi-agent stochastic optimization (MASO) techniques, such as GA, PSO, DE, HS algorithm and GSA are presented next. Then the problem statement and details of the modeling of the twin rotor MIMO system, basic calculations of state feedback regulator design and finally how a stochastic algorithm can be employed to design the state feedback regulator are presented. After that the results of performances of regulator design of TRMS by different MASO algorithms are depicted and also their merits and demerits are discussed. Finally a conclusion concludes the chapter.

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