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Solving Parameter Identification of Frequency Modulation Sounds Problem by Modified Adaptive Tabu Search under Management Agent

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1. Introduction

Parameters identification of the frequency modulation sounds system (FMS) [1,2] has been a good choice to test a new search algorithms since its complex characteristics and six degrees of freedom for input arguments. FMS was also chosen here to. This paper proposed a new search algorithms from adopting an
efficient management agent (MA) [5] procedure to collaborate with modified adaptive tabu search (mATS) [10] as some search cores of MA. This paper consists of six sections as follows. First is an introduction, second section is a review of MA and mATS, third section is description of FMS problem, the forth section is the proposed algorithms for FMS, namely modified adaptive tabu search under management agent or MA(mATS). The last two topics are simulation results and conclusions, respectively.

2. Reviews of MA and mATS

2.1 Management agent (MA)

Tabu search[3] has played an important role in solving many fields of optimization problems for more than two decades with two mains strategies, intensification strategy and diversification strategy. Later on 2004, adaptive tabu search algorithms[4] has been launched with two key mechanisms, adaptive search radius mechanisms (AR) to accelerate search process toward the near optimum and backtracking mechanism (BT) to escape an entrapment. One of the way to develop ATS for having better performance, management agent (MA) for ATS have been introduced[5,7]. MA manages several search core ATS with three main mechanisms, partitioning mechanism (PM) to devide search space into many sub search space according to the number of search core ATS at the search beginning, sequencing mechanism (SM) to arrange all ATSs working sequentially, discarding mechanism (DM) to remove any low quality ATS search unit(s) from MA(ATS) loop.

The MA(ATS) algorithms can be read step by step as follows:

**STEP 0: Initialization (PM)**

Divide search space into sub search space as many as the number of search units (ATS), initialize all search units, then provide each initial solution of ATS from each sub search space by random method.

**STEP 1: Iteration (SM)**

Sequentially iterate from 1st to nth all search unit ATSs until DM is invoked. All ATSs operate independently but also can terminate MA(ATS) if the termination criteria (TC) is met.

**STEP 2: Aspiration (DM)**

When DM is invoked, all search units will be evaluated the quality and henceforth the poor search units are discarded from MA loop for saving time approach.

**STEP 3: Termination**

MA(ATS) exit or stop searching process whenever a termination criterion (TC), optimal solution threshold and iteration limit, of an ATS in the MA loop is met, otherwise go to STEP 1.

MA has been applied to solve control system problems in tuning parameters of controller [6,8] and searching a set of proper parameters in system identification work [9].

2.2 Modified adaptive tabu search (mATS)

MATS[10] has been modified from ATS by adding an effective mechanism, namely adaptive neighborhood mechanism (AN), which varies the number of candidate neighbor around a current solution to be the next elite solution. AN is frequently invoked simultaneously with AR but it is not always necessary. There two type of ANs, the first one is increasing number of neighbor for keeping condense and the second type is to decreasing the number of neighbor in order to relax the computational time consumed.
3. Frequency Modulation Sound System (FMS)

Parameter identification problem of FMS is a highly complex multimodal optimization. The aim of solving this problem is to minimize the error between evolved data and model data. The classic genetic algorithm (GA) and its modified forms have previously been applied on the FMS problem [1,2].

The problem is to specify six parameters of the FMS model represented in equation (1)

\[
y(t) = a_1 \sin(\omega_1 t \theta) + a_2 \sin(\omega_2 t \theta + a_3 \sin(\omega_3 t \theta))
\]

where \( \theta = 2\pi/100 \). The objective function is defined as the summation of square errors between the evolved data and the model data as follows:

\[
J(a_1, a_2, a_3, \omega_2, \omega_3, \omega_4) = \sum_{t=0}^{100} (y(t) - y_0(t))^2
\]

and the model data are given by the following equation,

\[
y_0(t) = 1.0 \sin(5.0t \theta + 1.5 \sin(4.8t \theta + 2.0 \sin(4.9t \theta)))
\]

4. Proposed MA(mATS) Algorithms for Solving FMS Problem

mATS has been adopted to be search cores of MA, then we obtained MA(mATS).

4.1. Setting parameters for MA

The FMS problem is formulated to optimization problem form with the objective function \( J \) shown in equation equation (2). There are six inputs of function \( J \), we also selected six sub search unit-mATSs into MA(mATS) too. All six inputs are bounded in the same range -6.4 to 6.35, such that (0,0,0,0,0,0) is the middle cored solution that will be used in PM. The sub search spaces are obtained as shown in Table 1.

Table 1. Setting parameters of MA (PM)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub search spaces: upper</td>
<td>6.35 0 0 0 0 0</td>
<td>0 6.35 0 0 0</td>
<td>0 0.635 0 0 0</td>
<td>0 0 0 6.35 0</td>
<td>0 0 0 0 6.35</td>
<td>0 0 0 0 6.35</td>
</tr>
<tr>
<td>lower</td>
<td>-6.4 0 0 0 0 0</td>
<td>-6.4 0 0 0 0</td>
<td>-6.4 0 0 0 0</td>
<td>-6.4 0 0 0 0</td>
<td>-6.4 0 0 0 0</td>
<td>-6.4 0 0 0 0</td>
</tr>
</tbody>
</table>

There two stages of DM to work after MA(mATS) begins. The first stage of DM will be called in the 300th iteration and reduce the number of mATS from six to three units. Then the proposed MA(mATS) algorithm runs to the 600th iteration, the second stage of DM will again reduce the low quality of mATSs from three to one. The selected last one mATS will remain in the main loop until one the termination criterion is met.
4.2. Setting parameters for MA

Each mATS has the same search conditions including same search space except its own initial solution from its sub search space in PM period. Default search radius (R) is 1. From Table 2, there are five stages of AR and only four stage of AN.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Initialization 1st (if J ≤ 25)</th>
<th>2nd (if J ≤ 23)</th>
<th>3rd (if J ≤ 20)</th>
<th>4th (if J ≤ 12)</th>
<th>5th (if J ≤ 0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR</td>
<td>R=1.0</td>
<td>R=0.2</td>
<td>R=0.002</td>
<td>R=2 x 10⁻⁴</td>
<td>R=2 x 10⁻⁷</td>
</tr>
<tr>
<td>AN</td>
<td>N = 30</td>
<td>N = 35</td>
<td>N = 40</td>
<td>N = 45</td>
<td>N = 50</td>
</tr>
</tbody>
</table>

MA(mATS) can be terminated when one of two criterions, limited 100,000 iterations and/or expected global solution, is met. Next section will explain the simulation results.

5. Simulation Results

The simulation was codee in MATLAB and tested on the PC Intel 2.6 GHz CPU with 1 GB RAM and 60 GB HDD. The objective function in equation (2) has the nearly global solution with J(x*)=0. Much more effort in many trials, we appropriately obtained results which can be seen throughout the convergence curves shown in Fig. 1 below.

Fig. 1. (a) over all curves of MA(mATS) on FMS problem; (b) zoom up to monitor PM and DM.
Convergence property of MA(mATS) on the FMS problem in Fig. 1 (a) shows that MA(mATS) obviously converges to the global solution. At the beginning, all six mATSs units start with the same objective values \((J=31.0140)\) and then until the DM stage, 300th to 600th iterations, the mATS#1, mATS#3 and mATS#4, mATS#2 and mATS#6 are discarded from iteration loop, respectively. Let mATS#5 search lonely to the global solution, see Fig. 1 (b) for more details of DM. Finally, MA(mATS)

![Fig. 2. Initial solution and the global solution of the 5th path mATS on FMS problem.](image)

spent 1 hours 11 minutes and 15.22 seconds within 56,052 iterations to meet the required global solution under the termination criteria \(J<1.0 \times 10^{-3}\).

Fig. 2 illustrates the initial solution and the end solution of the winner search path (mATS#5) of MA(mATS). The initial solution from PM is \((0, 0, 0, 0, 5.2228, 0)\) with \(J=31.0140\) and the global solution or the end of path is \((-0.9914, -5.0005, -1.5025, -4.7957, 1.9989, -4.9000)\) with \(J=0.99946 \times 10^{-3}\).

6. Conclusions

The proposed MA(mATS) with six search units for solving the system identification of FMS, is elaborated in this paper. PM in the MA has divided the search space along the search core solution \((0, 0, 0, 0, 0, 0)\) and then has provided each initial solution for each sub search mATS. MA(mATS) consists of two DM stage which is set into the 300th and 600th iterations. Many trials, MA(mATS) can obtained the proper solution by mATS#5 with the objective function value, \(J=0.99946 \times 10^{-3}\) at the 56,052th iteration about an hour searching time. The disadvantage of MA(mATS) for the FMS problem is on a very long searching time spent. But it may gain higher degree of the diversification strategy instead. From the guided meaning, the future works will focusing on reducing overall search time along the MA parameters, particularly PM and DM.

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