A Simulation of Nominal Group Technique using Particle Swarm Optimization

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Abstract. The nominal group technique (NGT) is a pattern of group decision-making technique in organizational behavior. Its research work is mainly focused on applications in different fields, and there is less research on algorithm simulation. In this paper, a method of NGT-PSO is proposed in which NGT will be introduced into PSO and an attempt will be made to simulate NGT using PSO. From the perspective of PSO, PSO using NGT adds group decision-making technique. It characterizes the activity of individual and group through the grouping, individual optimizing, small-group discussion operation, large-group discussion operation and large-group decision operation. From the perspective of NGT, the decision process of NGT is simulated by PSO. The results show that the simulations of the algorithm are effective. The simulations show that small-group decision is better than or equal to individual decision and large-group decision is better than or equal to small-group decision. This is consistent with the basic principles of organizational behavior and it provides a good explanation for the relationship between NGT and PSO.

1. Introduction
Organizational behavior investigates the impact that individuals, groups, and structure have on behavior within organizations[1]. Its main goal is to make organizations work more effectively. The nominal group technique (NGT) is a pattern of group decision-making technique in organizational behavior[2].

The NGT has an important characteristic that it maximizes the number of ideas generated by individuals anonymously and balances the participation of all group members[2]. It has been successfully applied in many fields. Living kidney donors identified outcomes of donation, ranked them in order of importance, and discussed the reasons for their preferences by NGT[3]. It was applied to identify and rank factors considered important for medication adherence[4]. It was even applied in ecology and conservation and provided a depolarizing approach to the study and management of conservation issues[5]. It was used to outline the problems faced by ABC Company and discuss the expected solutions out of the ERP system[6]. It was also a useful and practical course evaluation tool to find a course’s strengths and weaknesses[7].

Particle Swarm Optimization (PSO) is the study of swarm behavior in intelligent computing. It studies how population use the information provided by individuals to find the optimal value in the problem domain. Its research involves individuals, swarm, and neighbor topology[8-9]. The concepts of sub-swarms[10], family[11] and multi-role[12] were introduced in PSO. In this research, inspired
by the characteristics of NGT and PSO, we propose a method of NGTPSO in which NGT will be introduced into PSO and an attempt will be made to simulate NGT using PSO.

The rest of this paper is organized as follows. Section 2 describes the framework of the details of NGTPSO algorithm. Extensive experiments about NGTPSO on the CEC2014 test suite [13] are introduced in Section 3. Moreover, a simulation of NGT is also detailed in this section. Finally, conclusions are given in Section 4.

2. Method

2.1. NGT

In organizational behavior, many decisions are made by groups or teams. By aggregating the resources of several individuals, groups bring more information into the decision process[1]. The NGT that is one of group decision making may be widely used in organizations. The process of NGT is the following steps[2,7]:

(1) Present evaluation questions;
(2) Silent Phase
   - Learners form small groups;
   - Elect a scribe;
   - Any discussion doesn’t take place and everyone writes down ideas independently;
(3) Round-robin Phase
   - Everyone presents ideas to group;
   - No discussion takes place;
(4) Discussion
   - The scribe summarizes the grouped items.
   - The scribe makes sure the themes;
(5) Preliminary voting Phase
   - Each group member rank-orders the ideas;
(6) Small-group Data Gathering
   - The scribe produces a rank-ordered list.
(7) Large-group Data Combining
   - Combine the scores from the small groups.
   - Produce a final rank-ordered list.
(8) Large-group Discussion
   - Produce the final decision.

The process of NGT can be summarized as individual decision, small-group decision and large-group decision.

2.2. PSO

In PSO, each particle characterizes by two variables $x_i$ and $v_i$. They are updated according to the following equations:

$$ v_i(t + 1) = \omega v_i(t) + c_1 \varphi_1 (p_i(t) - x_i(t)) + c_2 \varphi_2 (g(t) - x_i(t)) $$ (1)

$$ x_i(t + 1) = x_i(t) + v_i(t + 1) $$ (2)

where $t$ is the iteration; $\omega$ is inertia factor; $c_1$ and $c_2$ are affect acceleration; $\varphi_1$ and $\varphi_2$ are random variables in the range (0,1); $p_i$ is the personal best position of the $i$-th particle; $g$ is the best position of all the particles[8].

A individual finds a potential solution and provides the information to the population. The population uses the collected information to guide individual search direction.
2.3. NGTPSO Model

2.3.1. NGTPSO Model Design
NGTPSO Model characterizes groups as proceeding through the grouping, individual decision optimizing, small-group discussion operation, large-group discussion operation and large-group decision operation.

Grouping operation:
Particle swarm can be divided into different small groups. The way of random grouping is be used.

Individual decision operation:
Individual development is organized according to Eqs. (3) and (4) at this phase. The movement of the i-th particle is closely related to the personal best position.

\[ v_i(t + 1) = \omega v_i(t) + c_1 \varphi_1 (p_i(t) - x_i(t)) \]  
\[ x_i(t + 1) = x_i(t) + v_i(t + 1) \]  
where \( c_1 = 2, p_i(t) \) is the best fitness value of the i-th particle.

Small-group discussion operation:
Group development is organized according to Eqs. (5) and (6) at this phase. The i-th particle belongs to the k-th group and the movement of the i-th particle is closely related to members of the k-th group.

\[ v_i(t + 1) = \omega v_i(t) + c_2 \varphi_2 (F_k(t) - x_i(t)) \]  
\[ x_i(t + 1) = x_i(t) + v_i(t + 1) \]  
where \( c_2 = 2, F_k(t) \) is the best fitness value of the k-th group.

Large-group discussion operation:
The particles belong to one swarm, and the movement of the i-th particle is closely related to the best fitness value of every particle. Two methods can be used in this operation.

Method 1: swarm development is organized according to Eqs. (7) and (8) at this phase.

\[ v_i(t + 1) = \omega v_i(t) + \sum_{j \in \text{all}} c_i \varphi_i (p_j(t) - x_i(t)) \]  
\[ x_i(t + 1) = x_i(t) + v_i(t + 1) \]  
where \( c_i = 1/\text{the number of members of the swarm}, p_j(t) \) is the best fitness value of the j-th particle.

Method 2: swarm development is organized according to Eqs. (9) and (10) at this phase. The movement of the i-th particle will pay more attention to the best fitness value of all particles.

\[ v_i(t + 1) = \omega v_i(t) + \sum_{j \in \text{all}} c_i \varphi_i (p_j(t) - x_i(t)) + c_g \varphi_g (g(t) - x_i(t)) \]  
\[ x_i(t + 1) = x_i(t) + v_i(t + 1) \]  
where \( c_g = 2, g(t) \) is the best fitness value of all particles.

Large-group decision operation:
Swarm development is organized according to Eqs. (11) and (12) at this phase. The particles belong to one swarm, and the movement of the i-th particle is closely related to the best fitness value of all particles.

\[ v_i(t + 1) = \omega v_i(t) + c_3 \varphi_3 (g(t) - x_i(t)) \]  
\[ x_i(t + 1) = x_i(t) + v_i(t + 1) \]  
where \( c_3 = 1/\text{the number of members of the swarm}, g(t) \) is the best fitness value of all particles.

2.3.2. Main Framework
The main framework of NGTPSO is shown in Table 1.
Table 1. The procedure of NGTPSO.

Algorithm. The procedure of NGTPSO

1: Population parameters initialization
Initialize $N$ individuals $[X_1, X_2, \ldots, X_N], [V_1, V_2, \ldots, V_N]$ $(X_i = (x_{i1}, x_{i2}, \ldots, x_{in}), V_i = (v_{i1}, v_{i2}, \ldots, v_{in}))$ with the $n$ dimension;

2: Group parameters initialization
$N = \sum_{i=1}^{num} group\_num(i),\ c_i = 1/group\_num(i)\ (i=1,2,\ldots,num)$.

3: Initialize $t_1, t_2, t_3, t_4$ $(t_i$ is the number of exact function evaluations at the $i$-th stage, $i=1,2,3,4)$

4: Individual decision operation
4.1: Do
4.2: For each particle
4.3: Update the particle’s velocity and position by using Eqs. (3) and (4), respectively.
4.4: Determine the personal best position, $p_i$
4.5: EndFor
4.6: While $t \leq t_i$

5: Small-group discussion operation
5.1: Do
5.2: For each particle
5.3: Update the particle’s velocity and position by using Eqs. (5) and (6), respectively.
5.4: Determine the personal best position, $p_i$
5.5: Determine each group’s best position, $F_k$
5.6: EndFor
5.7: While $t \leq t_2$

6: Large-group discussion operation
6.1: Do
6.2: For each particle
6.3: Update the particle’s velocity and position by using Eqs. (7)-(8) or (9)-(10), respectively.
6.4: Determine the personal best position, $p_i$
6.5: Determine the current global best positions, $g$
6.6: EndFor
6.7: While $t \leq t_3$

7: Large-group decision operation
7.1: Do
7.2: For each particle
7.3: Update the particle’s velocity and position by using Eqs. (11) and (12), respectively.
7.4: Determine the personal best position, $p_i$
7.5: EndFor
7.6: Determine the current global best positions, $g$
7.7: While $t \leq t_4$

3. Experiments

3.1. Test Problems and Parameter Setting
To validate the performance of NGTPSO, we test it on a set of benchmark functions from CEC2014 test suits[13]. The parameters of PSO[8] are: $c_1 = c_2 = 2$, $\omega$ is from 0.9 to 0.4 according to the linear decrease. In order to facilitate the comparison, three methods of NGTPSO are be used. NGTPSO-1 has individual decision optimizing, small-group discussion operation and large-group decision operation. Large-group discussion operation isn’t included in NGTPSO-1. NGTPSO-2
uses Eqs. (7) and (8) to exact large-group discussion operation. NGTPSO-3 uses Eqs. (9) and (10) to exact large-group discussion operation.

The swarm which has 100 particles is divided into 25 groups \((\text{num} = 25)\) and every group has 4 particles \((\text{group}\_\text{num}(i) = 4)\) in NGTPSO. All algorithms are implemented in MATLAB platform and 50 independent runs are performed for each algorithm. 17 error values \((F_i(x) - F_i(x^0))\) are recorded for each function for each run.

3.2. Experiment Results
From the perspective of PSO, PSO using NGT adds group decision-making technique. When MaxFES is equal to 10000, sort the error values achieved after MaxFES in 50 runs and the best, worst, mean, median, standard variance of 10-dimenensional functions are listed in Table 2. The bold value is the best result for the same test function using different algorithms. The results show that the mean error values of NGTPSO have smaller values at MaxFES than PSO on \(f_5, f_3, f_5\). NGTPSO-3 has the best results than other methods on \(f_5, f_7\).

From the perspective of NGT, the decision process of NGT is simulated by PSO. NGTPSO-1 simulates three decision process: individual decision, small-group decision and large-group decision. NGTPSO-3 adds large-group discussion to NGTPSO-1 and the advantage of everyone is absorbed. NGTPSO-2 absorbs the advantage of leader to NGTPSO-3. The results show that the fitness values of 2-th individual of swarm are shown on different functions in Fig. 1-3. Blue lines represent that the 2-th individual uses one decision in Fig. 1-3 (a). In Fig. 1-3 (b), blue lines represent individual decision, green lines represent small-group decision and red lines represent large-group decision. In Fig. 1-3 (c) and (d), blue lines represent individual decision, magenta lines represent small-group decision, green lines represent large-group discussion and red lines represent large-group decision.

| Table 2. Results of the error values at MaxFES by PSO and NGTPSO. |
|----------------|------|------|------|------|------|
| Fun | Algorithm | Best | Worst | Median | Mean |
| \(f_5\) | PSO | 20.03624275 | 20.28460387 | 20.18797603 | 20.1825025 | **0.053914656** |
| | NGTPSO-1 | 9.385696316 | 19.99999996 | 19.9998602 | 19.57831348 | 2.081339393 |
| | NGTPSO-2 | 8.890066032 | 19.99999999 | 19.99999111 | 19.12463668 | 2.998622346 |
| | NGTPSO-3 | **5.68E-14** | **1.64E22633** | **1.14E-13** | **0.032924473** | 0.232811179 |
| \(f_6\) | PSO | 0 | 4.607430387 | **1.30706527** | **1.256612888** | 1.140939797 |
| | NGTPSO-1 | 0.000128575 | **3.44943654** | 1.582319408 | 1.455298515 | **1.004739214** |
| | NGTPSO-2 | 0 | 3.551935811 | 1.502057289 | 1.483354613 | 1.130245521 |
| | NGTPSO-3 | **1.14E-13** | 3.61615083 | 1.562732378 | 1.447698968 | 1.03684129 |
| \(f_7\) | PSO | 2.158793803 | 5.171724477 | 3.619456677 | 3.687069352 | 0.701803838 |
| | NGTPSO-1 | 2.652784008 | 11.89659512 | 7.215074156 | 7.40166331 | 1.855119081 |
| | NGTPSO-2 | 3.346164157 | 9.430291719 | 5.729081336 | 5.920152757 | 1.107868385 |
| | NGTPSO-3 | **0.27125384** | **0.300228256** | **1.49997676** | **0.151039654** | **0.070608772** |
| \(f_8\) | PSO | 7.340112057 | 8.979544817 | 8.130939434 | 8.088188997 | **0.313595978** |
| | NGTPSO-1 | 7.992687208 | 12.2459369 | 8.896305542 | 9.052147607 | 0.977476055 |
| | NGTPSO-2 | 7.974402374 | 15.0106335 | 8.970703727 | 9.338358821 | 1.336126828 |
| | NGTPSO-3 | 0 | **6.964708362** | **1.989918114** | **1.970018631** | **1.48381702** |
| \(f_{10}\) | PSO | **803.0883537** | 1618.852793 | **1009.908963** | **1046.521941** | 152.8290212 |
| | NGTPSO-1 | 972.2848205 | 1309.083984 | 1101.795321 | 1114.142085 | **70.39206913** |
| | NGTPSO-2 | 986.6586201 | **1303.711803** | 1129.25446 | 1131.43979 | 71.2293226 |
| | NGTPSO-3 | 1000.152788 | 1391.125637 | 1095.03692 | 1124.353572 | 83.8446448 |
Figure 1. The fitness values of $f_6$ at different iterations. Different colors represent different stages.

Figure 2. The fitness values of $f_8$ at different iterations. Different colors represent different stages.
Figure 3. The fitness values of $f_{10}$ at different iterations. Different colors represent different stages.

The results show that small-group decision is better than or equal to individual decision and large-group decision is better than or equal to small-group decision in the first, second and fourth phase. The process of large-group discussion is complicated in the third phase. Furthermore, experiments show that NGT can be simulated by PSO.

4. Conclusions
From the perspective of PSO, PSO using NGT adds group decision-making technique. It characterizes the activity of individual and group through the grouping, individual decision optimizing, small-group discussion operation, large-group discussion operation and large-group decision operation. From the perspective of NGT, the decision process of NGT is simulated by PSO. The results show that small-group decision is better than or equal to individual decision and large-group decision is better than or equal to small-group decision. This provides a good explanation for the relationship between NGT and PSO.

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