Task Scheduling in Cloud Computing Based on Swarm Intelligence Algorithm

CHEN Hai-yan
(Department of Computer Science and Technology, East China University of Political Science and Law, Shanghai 201620, China)

Abstract In order to improve the QoS of task scheduling of cloud computing, this paper proposes a cloud computing task scheduling model based on swarm intelligence algorithm. Firstly, genetic algorithm which has global search ability is used to quickly find the optimal solutions of cloud computing task scheduling problem, and then the optimal solutions are converted to the initial pheromone of ant colony optimization algorithm. Finally, the global optimal solution of cloud computing task scheduling is obtained by information communication and feedback among ants. The simulated experiment was carried out on cloudsim platform. The experimental results show that compared with other models, the proposed model significantly improves the efficiency of cloud computing tasks scheduling and reduces the completion time.

Keywords Cloud computing, Genetic algorithm, Ant colony optimization algorithm, Task scheduling

Cloud computing is an emerging distributed platform that is more and more popular. Its main purpose is to provide many users with a service, but to ensure the reliability and efficiency of the cloud service, it is necessary to ensure the performance of the cloud system. Therefore, a good task scheduling algorithm is essential to ensure the reliability and efficiency of the cloud system. In this paper, a task scheduling model based on swarm intelligence algorithm is proposed. Firstly, genetic algorithm is used to find the optimal solutions of cloud computing task scheduling problem quickly. Then, the optimal solutions are converted to the initial pheromone of ant colony optimization algorithm. Finally, the global optimal solution of cloud computing task scheduling is obtained by information communication and feedback among ants. The simulated experiment was carried out on cloudsim platform. The experimental results show that compared with other models, the proposed model significantly improves the efficiency of cloud computing tasks scheduling and reduces the completion time.

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对图1进行分析可知，在 \( t_{0} \sim t_{10} \) 时间段，ACO搜索速度较快，在 \( t_{10} \)之后，性能逐渐变慢。在 \( t_{11} \sim t_{12} \) 时间段，ACO搜索速度相当慢。在 \( t_{12} \)之后，随着信息素不断积累，性能大幅提升，自此，将ACO作为算法核心。在 \( t_{12} \sim t_{13} \) 阶段，首先采用GA对云计算任务调度问题进行求解，得到问题较优的解。然后将较优解转换成ACO的初始解，再通过信息交互和反馈对较优解进一步优化，最后得到云计算任务调度问题的最优解。

### 2.2 GA设计

#### 2.2.1 染色体的编码

在采用GA对云计算任务调度问题进行求解的过程中，首先对单任务进行编码，再对多任务进行编码。根据云计算资源调度的特点，采用间隔编码方式，对每个任务占用的资源进行编码。即\( d_{1}, d_{2}, \ldots, d_{n} \)，其中\( d_{i} \)表小第\( i \)个资源，编码长度取决于任务的个数，一个染色体编码形式为：\( 4, 6, 2, 9, 8, 3, 1, 10 \)，表示4个任务与资源的对应关系，见表1。

<table>
<thead>
<tr>
<th>任务号</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>资源号</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

#### 2.2.2 种群初始化

初始化种群时，首先对云计算任务调度问题解求解相当关键，因此GA采用随机方式产生初始种群。对个体在空间中分布不均匀，产生随机现象，导致种群进化过程中种群退化率较高，陷入局部最优解的概率大。为此，本文采用均匀分布种群初始化种群，使其在解空间中分布均匀，提高种群的多样性。

#### 2.2.3 适应度函数

GA与云计算任务调度问题接口为适应度函数。因此，需要将适应度函数与云计算任务调度问题目标统一起来，因此第i个染色体的适应度函数定义如下，

\[
F_{a} = \sum_{i=1}^{n} F_{a} (j)
\]

式中，\( F_{a} (j) \)表示第j个任务完成的CPU使用时间。

#### 2.2.4 适宜操作

适宜操作主要包括选择、交叉和变异操作，其中选择操作采用部分最优个体进入下一代，其余个体采用轮盘赌方式进入下一代方式，交叉（\( P_{c} \)）和变异（\( P_{m} \），采用自适应方式进行。

\[
P_{c} = \begin{cases} k_{1} (f_{c} - f') / (f_{c} - f), & f' > f \\ k_{1}, & f' \leq f \end{cases}
\]

\[
P_{m} = \begin{cases} k_{2} (f_{m} - f') / (f_{m} - f), & f' > f \\ k_{3}, & f' < f \end{cases}
\]

式中，\( k_{1} = 0.5, k_{2} = 0.05, k_{3} = 1, k_{4} = 0.1 \)。为种群的最大适应值，\( f' \)为交叉的个体中最大个体的适应值，\( f \)为种群的平均适应值。\( f' \)为变异个体的适应值。

### 2.3 ACO设计

#### 2.3.1 计算信息素衰减

根据Ahn所获得的云计算任务调度问题较优解转换为ACO

![ACO](http://example.com/image.png)

### 2.3.2 ACO求解算法

ACO算法的基本思想是通过不断地迭代，模拟蚂蚁在寻找食物的过程中，通过信息素的引导，逐渐找到最优路径。ACO算法的步骤如下：

1. 初始化：设定一初始解，通常为随机解。
2. 信息素更新：根据蚂蚁在解空间中的路径选择信息素的增减。
3. 概率性选择：蚂蚁在下个节点的选择概率与该节点的信息素成正比，与距离成反比。
4. 信息素衰减：经过一定时间后，信息素会逐渐衰减，以鼓励新的搜索路径。
5. 循环：重复步骤2-4，直到满足终止条件。

ACO算法通过模拟蚂蚁的行为，能够有效地解决云计算任务调度问题，找到最优或接近最优的解。
初始信息素，即，
\[ \tau_0(0) = f(t) \]  \hspace{1cm} (11)

(2) 节点选择规则
在，时刻，根据信息素浓度选择下一个云计算资源节点，具体方式为，
\[ \rho(i) = \frac{[\tau(i)]^p [\eta(i)]^{1-p}}{\sum_j [\tau(i)]^p [\eta(j)]^{1-p}} \]  \hspace{1cm} (12)

(3) 信息素更新规则
信息素残存因子，其取值为 0～1 之间的随机数，变化方式为，
\[ \rho(t) = \rho(t) \times r(t) + \Delta \tau \]  \hspace{1cm} (13)

式中，\( \rho \) 表示信息素残存因子，其取值为 0～1 之间的随机数，变化方式为，
\[ \rho = 0.1 \times \frac{\log(t)}{c_{\text{max}}} \]  \hspace{1cm} (14)

式中，\( t \) 为当前代数，\( c_{\text{max}} \) 为最大代数。

2.4 群智能算法的云计算任务调度步骤
(1) 用户提交任务，根据任务设置 GA 的种群大小，选择交叉、变异概率、最大进化代数。
(2) 根据云计算任务调度问题对种群进行初始化。
(3) 对个体进行解码，计算其适应度值。
(4) 根据适应度值对个体进行排序，选择部分较优进入下一代，然后按轮盘赌方式选择其它个体进行下一代。
(5) 根据 \( P_c, P_m \) 对个体进行交叉和变异操作，然后比较新个体与父个体之间的优劣，选择较强者进行下一代。
(6) 若达到最大进化代数，则停止寻找，否则跳转步骤(3)继续进化。
(7) 将 GA 找到的云计算任务调度方案转换成 ACO 的信息素初始值。
(8) 将每只蚂蚁随机分布于云计算资源节点上。
(9) 根据各资源节点的信息素浓度选择下一个任务执行的资源节点。
(10) 当每一只蚂蚁都找到一个云计算任务调度方案后，对资源节点信息素进行更新。
(11) 当算法达到结束条件，输出云计算任务调度方案最优解，否则，跳转步骤(3)继续进行寻找。
具体流程如图 2 所示。

3 仿真实验
3.1 数据及参数设置
在云计算仿真平台 CloudSim 进行模拟，任务数量分别为 20, 40, 60, 80, 120, 140, 160, 180, 200，其参数如表 2，云计算系统资源节点数为 10 个，任务节点的参数见表 3。为了使 GA-ACO 仿真结果更具说服力，在相同实验条件下，采用 GA-ACO 算法进行对比实验。GA-ACO 的参数为 GA 个体数为 20, \( P_c = 0.9, P_m = 0.1 \)，ACO 的蚂蚁数为 10，\( a = 1, \beta = 2, \) 最大迭代次数为 1000。

![图表](https://example.com/chart1.png)

表 2 任务参数列表
<table>
<thead>
<tr>
<th>参数名称</th>
<th>参数范围</th>
</tr>
</thead>
<tbody>
<tr>
<td>任务数</td>
<td>1000～10000</td>
</tr>
<tr>
<td>用户提交时间</td>
<td>10～100 秒</td>
</tr>
<tr>
<td>用户对安全性的要求</td>
<td>1/2, 3/4, 1/4, 1/4</td>
</tr>
</tbody>
</table>

![图表](https://example.com/chart2.png)

表 3 资源参数列表
<table>
<thead>
<tr>
<th>参数编号</th>
<th>安全性</th>
<th>资源价格</th>
<th>处理能力</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>0.15</td>
<td>0.15</td>
</tr>
</tbody>
</table>

3.2 结果与分析
随着任务数的变化，GA-ACO, GA-ACO 的总用时变化如图 3 所示。从图 3 可知，GA-ACO 的总用时优于 GA-ACO 获得的云计算任务调度方案，对比结果表明，本文将 GA 和 ACO 进行融合，较好利用了两者的优势，克服了各自的不足，可以获得最优的云计算任务调度方案。

![图表](https://example.com/chart3.png)

图 3 不同任务数下的总用时

为了全面对 GA, ACO, GA-ACO 的性能进行比较，采用费用、时间维度，总运行作为评价指标，对它的性能进行综合评价，结果如图 4～图 6 所示。

![图表](https://example.com/chart4.png)

图 4 不同任务数下的总用时
图5 不同任务数下的总时间跨度

图6 不同任务数下的总延迟

从图5-图6可以看出，单独使用GA或ACO进行云计算系统的任务调度问题求解，得到的调度方案的总任务延迟大，用户等待的时间长，而且总费用相对较高，算法收敛效果不好。而GA-ACO集成了GA和ACO的优点，在求解过程中采用GA对云计算任务调度问题求解，可以较快地找到较优解，然后采用ACO对GA获得的解进行精细寻优，加快了收敛速度，获得了更加令人满意的云计算任务调度方案。

结束语 云计算具有规模大、可动态伸缩等特点，任务调度十分复杂，针对当前云计算任务调度算法存在的不足，基于组合优化理论，提出一种多群智能算法的云计算任务调度策略，通过实际验证了GA-ACO在云计算任务调度求解中的有效性和正确性。

参考文献


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