Multi Objective Intelligent Allocation Algorithm for Agricultural Machinery

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Abstract. Aiming at the problem of non-scientific and rational allocation of agricultural land in China's agricultural machinery, this paper proposes a multi objective intelligent allocation algorithm (MAA), and establishes an optimization model with the optimal income as the goal. MAA algorithm is based on the idea of deep search and dynamic planning, according to natural factors such as weather, road conditions, location, agricultural machinery factors such as the master subjective factors, machine capacity, farmland factors such as operating prices, operating time windows and other constraints, generates multiple set of job paths sorted by earnings. Finally, the simulation results show that the MAA algorithm can provide the global optimal scheme of the job path for the owner, and the average performance of the MAA algorithm are increased by 32% compared with the general allocation algorithm (GAA), which can effectively to solve the current agricultural equipment deployment problem.

Introduction

In the process of rapid development of agriculture in China, agricultural mechanization through the way of replenishing labor to promote the rapid development of agricultural modernization level [¹]. At present, China is a developing agricultural country. With the continuous improvement on agricultural productivity, China's agriculture will develop in the direction of intensification, factorization and specialization, and finally form a new modern agricultural production and management mode [²].

The current status of domestic agricultural operations are that agricultural machinery owner’s spontaneous operation, relying on experience to select the farm work, the emergence of agricultural machinery "in short supply" or "oversupply" situation. For the owner of the machine, because there is no scientific and reasonable deployment plan, may be due to unreasonable route or farmland, resulting in low efficiency and high cost of the operation process.

Zhang Fan [³,4] studied the heuristic precedence rule based on the agricultural machinery dispatching algorithm, systematically studied the theory and method of agricultural machinery deployment. Cao Mengru et al [⁵] studied the design and construction of the remote monitoring and dispatching platform of agricultural machinery based on Android, and designed and realized the remote monitoring and dispatching platform of agricultural machinery based on Android to meet the needs of farmers' "anytime, anywhere," to view agricultural information. However, most of the researches on agricultural machinery deployment algorithms in China are theoretical research. Without practical test, the practical application will lead to impractical and difficult to use problems due to the limitation of various factors.

Based on the above problems, this paper proposed a multi-objective strategy for the deployment of agricultural machinery, to provide a practical and effective deployment plan for the owner, the deployment plan has planned operations to improve operational efficiency and achieve higher returns.
**Model Building**

The problem of agricultural machinery deployment is a multi-objective, multi-constrained, global optimal problem. Formal description is as follows:

As shown in Figure 1, there are $n$ farmland operating points $F_1, F_2, ..., F_n$ in the area where the agricultural machinery $M$ is located.

![Figure 1. Distribution diagram of farm machinery scheduling and allocating.](Image)

Machinery current latitude and longitude $[\lambda_m, \varphi_m]$, estimated operating time window (date) $[T_{ms}, T_{me}]$, daily working hours (hours)$T_w$, machinery speeds $V_r$ (km/h), run fuel consumption $F_r$ (yuan/km), working speed $V_w$ (mu/h), working fuel consumption $F_w$ (yuan/mu).

1. The time windows $[T_{sn}, T_{en}]$ of a farmland operating point $F_n$ is pretreated, and the date of each work farm sudden weather is $T_b$, expressed as:

\[
\begin{align*}
\begin{cases}
Can't \ be \ harvested, & T_b \leq T_{sn} \\
[T_{sn}, T_b], & T_{sn} < T_b \leq T_{en}
\end{cases} \quad (1)
\end{align*}
\]

2. If the master planning time windows is $[T_{ms}, T_{me}]$, the expected working time (hours) $T_{max}$ is:

\[
T_{max} = (T_{me} - T_{ms} + 1) \times T_w \quad (2)
\]

3. The initial cost of the agricultural machinery to the first operating farm point $F_a$ is $R_0$, the distance is $D_{0a}$, the time is $T_{0a}$, expressed as:

\[
R_0 = D_{0a} \times F_r \quad (3)
\]

\[
T_{0a} = D_{0a} \div V_r \quad (4)
\]

4. Then the transfer equation is as follows:

\[
\begin{align*}
\begin{cases}
R_j = R_i + S_j \times (P_j - F_w) - D_{ij} \times F_r, & i \geq 1 \\
R_j = S_j \times (P_j - F_w) - R_0, & i = 0
\end{cases}
\end{align*} \quad (5)
\]

\[
\begin{align*}
\begin{cases}
T_j = T_i + D_{ij} \div V_r + S_j \div V_w, & i \geq 1 \\
T_j = T_{0a} + S_j \div V_w, & i = 0
\end{cases}
\end{align*} \quad (6)
\]

The final scheduling model is as follows:

\[
\text{Maximum benefit } R_{max} = \max\{ R_0, R_1, ..., R_n \} \quad (7)
\]

\[
\text{Restrictions } T_j < T_{max}, 0 \leq j \leq n \quad (8)
\]

The objective function is shown as the formula (7), and the constraint condition is shown in formula (8). The formula (7) indicates that the maximum benefit is obtained when the agricultural machinery is operating on a certain farmland.
Algorithm Design

General Agricultural Machinery Distribution Algorithm

According to the deployment of the target, this paper designed the general agricultural machinery allocation process, denoted as GAA (General Assignment Algorithm), the algorithm mainly uses the idea of backtracking, a simple description is as follows:

For known $n$ block operating fields ($F_1, F_2, \ldots, F_n$), the agricultural machinery from the starting point of the $n$ pieces of farmland depth to explore the solution of the tree, if the maximum depth of the farmland; does not meet the time window; the window exceeds the time machine main planning, record the farmland path for the current selection, the final calculation of income, and save the results.

Multi Objective Intelligent Allocation Algorithm

According to the distribution model, this paper designs the process of agricultural intelligent allocation algorithm for multiple targets, denoted as MAA (Multi Objective Intelligent Allocation Algorithm), algorithm is based on depth search and dynamic planning, reasonable pruning of the search process with multiple constraints and dynamic programming method, the operation path generated up to five groups the optimal revenue, as described below:

Step1 initialization:
- a. According to weather pretreatment farmland time window;
- b. The main working time is $T_{max} = (T_{max} - T_{ms} + 1) \times T_{w}$;
- c. Initialize the income array $P[ ]$ and farmland queue has been done $Done[ ]$;
- d. Initialization array $Farm[n][n]$.

Step2 for $a$ from 1 to $n$
if $T_{0a} \leq T_{max}$ then enter Step3.

Step3 Agricultural machinery to reach the first farmland $Fa$
$Done[].add (Fa), depth = 2, backTag = 0, $Farm[depth][a] = 1$.

Step4 while depth $> 1$, enter Step5, else enter Step2.

Step5 for $i$ from 1 to $n$
if $Farm[depth][i] = 0$ && $Farm[depth][i]$ not in the $Done[ ]$ then enter Step6;
else enter Step7.

Step6 Select farmland point $Fi$, set $Farm[depth][i]$=1, backTag = 0, enter Step8.

Step7 if backTag = 0 then
- a. The current revenue into the income array $P[ ]$;
- b. Save the relevant farmland path, sort according to the income;
- c. if $P[].size > 5$ then del min($P[ ]$);
- d. Make depth--., backTag = 1, del the last element of the array $Done[ ]$, return Step4;

Step8 Set after the completion of farmland point $Fi$, earnings $R_i$, using $T_i$.
if $T_i \leq T_{max}$ $Fi$, then enter Step9, else $Farm[depth][i] = 1$, return Step5.

Step9 If the remaining time is assumed to be a task, then $P_{pre} = (T_{max} - T_i) \times (S_i - F_w)$
if $P_i + P_{pre} < \min(P[ ])$, then $Farm[depth][i] = 1$, return Step4; else enter Step10.

Step10 if depth + 1 $\leq n$ then depth++, $Done.add (Fi)$, return Step4; else return Step4.

Step11 calculation completed

Algorithm Verification

Algorithm Data Simulation

In order to verify the algorithm, the simulation data are as follows:
Table 1. Farmland simulation data.

<table>
<thead>
<tr>
<th>farmland</th>
<th>longitude</th>
<th>latitude</th>
<th>area</th>
<th>unit</th>
<th>start date</th>
<th>finish date</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>114.9682652</td>
<td>36.7227172</td>
<td>50</td>
<td>60</td>
<td>2016-05-20</td>
<td>2016-05-22</td>
</tr>
<tr>
<td>F2</td>
<td>115.0372371</td>
<td>36.7307369</td>
<td>200</td>
<td>55</td>
<td>2016-05-21</td>
<td>2016-05-22</td>
</tr>
<tr>
<td>F3</td>
<td>115.0046110</td>
<td>36.6168160</td>
<td>80</td>
<td>60</td>
<td>2016-05-20</td>
<td>2016-05-22</td>
</tr>
<tr>
<td>F4</td>
<td>114.7028159</td>
<td>36.4697937</td>
<td>180</td>
<td>50</td>
<td>2016-05-20</td>
<td>2016-05-21</td>
</tr>
<tr>
<td>F5</td>
<td>114.9555362</td>
<td>36.7102920</td>
<td>180</td>
<td>50</td>
<td>2016-05-20</td>
<td>2016-05-22</td>
</tr>
<tr>
<td>F6</td>
<td>114.9088423</td>
<td>36.7810120</td>
<td>30</td>
<td>55</td>
<td>2016-05-20</td>
<td>2016-05-21</td>
</tr>
</tbody>
</table>

Agricultural machinery initialize latitude and longitude as [114.7964920, 36.5908570], daily working time 24 hours, working time window [2016-05-20,2016-05-23], speed 30 (km/h), fuel consumption 0.5(yuan/km), working speed (10mu/h), working oil consumption (15 yuan / mu).

Algorithm Results

Set expected time window [2016-05-20,2016-05-23], and algorithm results as follows:

Table 2. Algorithm results.

<table>
<thead>
<tr>
<th>No.</th>
<th>result</th>
<th>net income (yuan)</th>
<th>cost (yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M-&gt;F2-&gt;F6-&gt;F2-&gt;F2-&gt;F3</td>
<td>25341.2</td>
<td>10108.8</td>
</tr>
<tr>
<td>2</td>
<td>M-&gt;F2-&gt;F6-&gt;F2-&gt;F2-&gt;F3</td>
<td>25338.2</td>
<td>10111.8</td>
</tr>
<tr>
<td>3</td>
<td>M-&gt;F2-&gt;F6-&gt;F2-&gt;F2-&gt;F2</td>
<td>25337.2</td>
<td>10112.8</td>
</tr>
<tr>
<td>4</td>
<td>M-&gt;F2-&gt;F6-&gt;F2-&gt;F2-&gt;F3</td>
<td>25335.9</td>
<td>10114.1</td>
</tr>
<tr>
<td>5</td>
<td>M-&gt;F2-&gt;F6-&gt;F2-&gt;F2-&gt;F3</td>
<td>25335.9</td>
<td>10114.1</td>
</tr>
</tbody>
</table>

After verification, the above 5 results for the global optimization of agricultural machinery allocation path of the 5 solutions, the algorithm results are true and effective.

Random Operation Time

According to the daily deployment situation, select 6 pieces of farmland and through 5 random test, the operation time is as follows:

Table 3. Algorithm random operation time.

<table>
<thead>
<tr>
<th>No.</th>
<th>GAA(s)</th>
<th>MAA(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.578</td>
<td>1.578</td>
</tr>
<tr>
<td>2</td>
<td>2.394</td>
<td>1.692</td>
</tr>
<tr>
<td>3</td>
<td>2.32</td>
<td>1.520</td>
</tr>
<tr>
<td>4</td>
<td>2.773</td>
<td>1.773</td>
</tr>
<tr>
<td>5</td>
<td>2.412</td>
<td>1.912</td>
</tr>
<tr>
<td>average</td>
<td>2.495</td>
<td>1.695</td>
</tr>
</tbody>
</table>

The average computation time of GAA is 2.495s, and MAA is about 1.695s, MAA relative GAA performance is optimized by 32%.

Effect of Farmland Quantity on the Algorithm

Table 4. Effect of farmland quantity on the algorithm.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>operation time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 fields</td>
</tr>
<tr>
<td>GAA</td>
<td>0.931</td>
</tr>
<tr>
<td>MAA</td>
<td>0.67</td>
</tr>
<tr>
<td>optimal rate</td>
<td>28%</td>
</tr>
</tbody>
</table>

Through data analysis, we can get two points:

a. The computation time increases exponentially with the increase of farmland;

b. MAA algorithm in the number of farmland increased, the relative GAA algorithm performance optimization rate gradually become larger, MAA performance relative to GAA algorithm optimization of 32%.

In summary, this MAA algorithm can generate the optimal solution, and can surely help users improve work efficiency and increase the work income.
Conclusion

In this paper, according to the characteristics and existing problems of domestic agricultural machinery, the multi-objective intelligent agricultural machinery allocation algorithm (MAA) is proposed, through the test data and simulation of the algorithm, the results show that the algorithm can provide optimal result, while the performance relative to the average allocation algorithm (GAA) the average increase of 32%, in the computation time can meet the needs of the owner's deployment in daily use. Agricultural machinery in the actual deployment process, the impact of many factors and complex relationship, the algorithm itself has limitations, such as the choice of the number of planning work field too much, will lead to the rise in the form of computing time index. Therefore, the algorithm needs further research and improvement.

References


