An innovative Approach of Tabu Search in Prediction of Pod Yield of Mustard Plant

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Abstract: *The productivity of plant can be measured in terms of pod yields produce by that plant. The production of plant dependent on various parameters of the plant like shoot length, number of leaves, root length , root numbers etc. Some other factors like soil, crop and distance management are also taken care of to produce maximum amount of yield. It is not desirable to use the no of leaves of the tree to calculate the growth of the plant because when the plant is growing some leaves may be lost and some new leaves may appear. It is also very difficult to measure the number of roots and length of growth of root in several time instances as it grows underground. So, it is very convenient to measure the plant growth on the basis of shoot length. In this paper, an effort has been made to predict the shoot length of mustard plant by Tabu Search (TS). The average error has been calculated based on the actual shoot and predicted shoot length. A comparitive study has been made among the different methods applied on same data set and one method has been selected based on minimum average error. The shoot length at maturity has been predicted by applying least square method on predicted data set with minimum average error. Finally, pod yield at maturity has been predicted by shoot length at maturity.*

Keywords: *Tabu search, Soft Computing, Prediction, Forecasting, Average Error, Pod Yield*

1. Introduction

The productivity of plant can be measured in terms of pod yields produce by that plant. The production of plant dependent on various parameters of the plant like shoot length, number of leaves, root length , root numbers etc. Some other factors like soil, crop and distance management are also taken care of to produce maximum amount of yield. It is not desirable to use the no of leaves of the tree to calculate the growth of the plant because when the plant is growing some leaves may be lost and some new leaves may appear. It is also very difficult to measure the number of roots and length of growth of root in several time instances as it grows underground. So, it is very convenient to measure the plant growth on the basis of shoot length. The data of the growth of shoot length of some mustard plant at the initial stage (7, 14, 21 & 28 days after plantation) is available from the statistical survey by group of scientists under the supervision of prof. Dilip Dey. In this paper the initial shoot length of B59 (a variety of mustard plant) has been used as an initial data. Agricultural scientists and researchers often face the challenge to predict the future growth of a plant to calculate its yield. Various methods have been proposed from time to time to provide us with more accurate results with minimized errors. Traditionally various statistical methods are used for this purpose. However with the introduction of soft computing models we can get more accurate and better results of the prediction [3].

Webster's dictionary defines the word Tabu or Taboo to mean "banned on grounds of morality or taste or as constituting a risk…" Tabu Search (TS) is an optimization method designed to help a search negotiate difficult region (i.e. to escape from local minima or to cross infeasible region of the search space) by imposing restriction ([8]–[11]). It was originally developed as a method for solving combinatorial optimization problem ([1], [2]), and was later developed for the prediction of rainfall [5].

Tabu search is one of meta-heuristic methods for solving a combinatorial optimization problem ([1], [2]).The basic mechanism of TS introduces an adaptive memory called tabu list into the neighborhood search on the hill-climbing method (HCM). HCM iteratively carries out local search in a neighborhood around the solution. However, HCM easily gets stuck in a local minimum. On the other hand TS can continue search process to escape from local minimum due to the function of adaptive memory. That called tabu list plays an important role in TS. It prevents the search process from short-term circulation by means of storing some attributes and making it unchangeable for a while. Attributes in the tabu list is updated in each iteration. Once a new attribute enters into tabu list and becomes the fixed attribute, the oldest one is released from it ad becomes free attribute. The period of holding one attribute is refers to as the tbu list size.

The main work of this paper is to apply Tabu Search on the statistical data of initial shoot growth of mustard plant to predict the shoot length at the stage of maturity. The objective is to find out if a plant can grow at a desired level or not. In other words, if a plant grows as per desired levels then that plant is kept and maintained for proper growth, otherwise not.

Over the last few years, a hundred papers presenting applications of Tabu Search (TS) a metaheuristic method proposed by Glover in 1986 to various problem[1] . In several cases, the methods described provide solution very close to optimality and are among the most effective, if not the best, to tackle the difficult problem

2. Data used in this paper

A statistical survey has been conducted by a group of certain agricultural scientists on different mustard plants under the supervision of Prof. Dilip De, Bidhan Chandra Krishi Viswavidayalay, West Bengal, India. The data for shoot length of the initial stage (growing stage) of the plant are also available, which are measured at different time instances (after an interval of 7 days, 14 days, 21 days, 28 days). The ultimate aim is to develop a model using Tabu Search that will estimate which plant is growing as per desired standard. The objective of the survey is to find out the production of a particular type of plant using certain initial parameters. In this paper, the value of shoot length measured at initial stage after plantation has been taken as input data of a particular type of mustard plant. The value of shoot length (measured with equal time intervals within 28 days after plantation) and final shoot length and pod yield after 95 days for mustard plant (B-59) have been taken and furnished in Table 1(a) and Table 1(b) respectively.

Time Instance	B – 59 (Mustard)
1	19
2	24
3	28
4	33
5	37
6	41
7	45
8	49
9	54
10	57
11	59
12	63
13	66

Table 1(a): Shoot Length of mustard plant (B-59)

Shoot Length (Height)	Pod Yield
122.6	3.991
134	2.679
140.8	7.281
141.8	7.47
144.6	7.401
146	7.5
149.5	7.64

Table 1(b): Pod Yield and Shoot Length of B-59

2. Theory

Tabu Search (TS) is powerful searching algorithm suitable for solving highly nonlinear problems. The main component of TS include (1) Initial solution, (2) Neighborhood and movement (3) Tabu list, (4) Tabu tenure, (5) Aspiration criteria, and (6) Stopping criteria. The functionality of each component is briefly introduced as the following [7].

2.1. Initial Solution

The beauty of TS is the initial solution can be randomly selected and through the optimization process embedded in TS to reduce the deviation of the optimums due to such improper selection of initial guesses.

2.2 Neighborhood and Movement

A neighborhood is constructed to identify adjacent solutions that can be reached from current solution [8]. The essential idea of TS optimization is to move from one solution to the best solution, which is not prohibited by tabu list, among its neighboring solution domain. If the newly found optimal solution is better than any previously explored optimal solutions recorded in the tabu list, the list will be updated with this solution.

2.3 Tabu List

Tabu list record a limited number of attributes of solutions (moves, selections, assignments, etc) to be discouraged in order to prevent revisiting a visited solution.The length of the list should not be too short, otherwise there is a risk of the search entering cycling trap. However if the list is too long the search process may become inefficient. Glover (1990) suggested the magic number 7 could be the first guess [2].

2.4 Tabu Tenure

Tabu tenure is a length of tabu list i.e. number of iterations a tabu move is considered to remain tabu.

2.5 Aspiration Criteria

If a tabu solution encountered at the current iteration is better than the best solution found so far, then its tabu status is overridden. Other aspiration criteria are possible, e.g. setting the tabu tenure shorter for better solutions.

2.6 Stopping Criteria

Stopping criteria serve as a restriction for not to proceed further searching when the potential optimal solution is reached. It can be given as: (1) a required optimal solution (2) a maximum iteration number or (3) a number of successive iterations where solutions are not improved. There is no predominant practice for the best selection of this type of criteria.

2.7 Fitness Function

The fitness function measures the performance of the system. This function is problem specific. For prediction and estimation problems, the function will be the inverse of mean square or absolute distance error.

3. Methodology

3.1 Proposed algorithm based on tabu search:

The algorithm has a very simple concept and is implemented with a theoretical background of stochastic derivative. It has been successfully applied and tested with various benchmark and real-world problems [8-9]. The Tabu Search Algorithm (TSA) and the flow chart are shown in Table 2 and Figure 1 respectively.

Input	Tabu list size, value of Tabu tenure, Lower and upper bounds of decision variables, Maximum number of iteration, *f(x)(Fitness Function)*
Output	Best solution (X_{best})
Step 1. 1:	Define Fitness Function f(x)
Step 1. 2:	Initialize the Optimization Problem for minimizing f(x).
Step 2:	Find an initial solution x_0 ε X, set $x_{now} = x_{best} = x_0$ initialize memory
Step 3.1:	Intensification phase:
Step 3.2:	If termination condition (e.g. simple iteration count, no admissible improving move, no change in xbest in so many iterations) is satisfied, then go to step 4.1
Step 3.3:	Choose x_{next} ε N (x_{now}) using formula $\boldsymbol{x}_i = \boldsymbol{x}_i \pm$ (m*m)/(n+1) such that x_{next} is not in tabu list.
Step 3.4:	Move from x_{now} to x_{next} , i.e. set $x_{now} = x_{next}$
Step 3.5:	If x_{now} is better than x_{best} than set $x_{best} = x_{now}$
Step 3.6:	Update recency based memory (tabu list), return to step 3.2
Step 4.1:	If termination condition is satisfied, then stop
Step 4.2:	Return (x_{best})

Table 2: Tabu Search Algorithm

3.2 Flow chart of the propopsed algorithm:

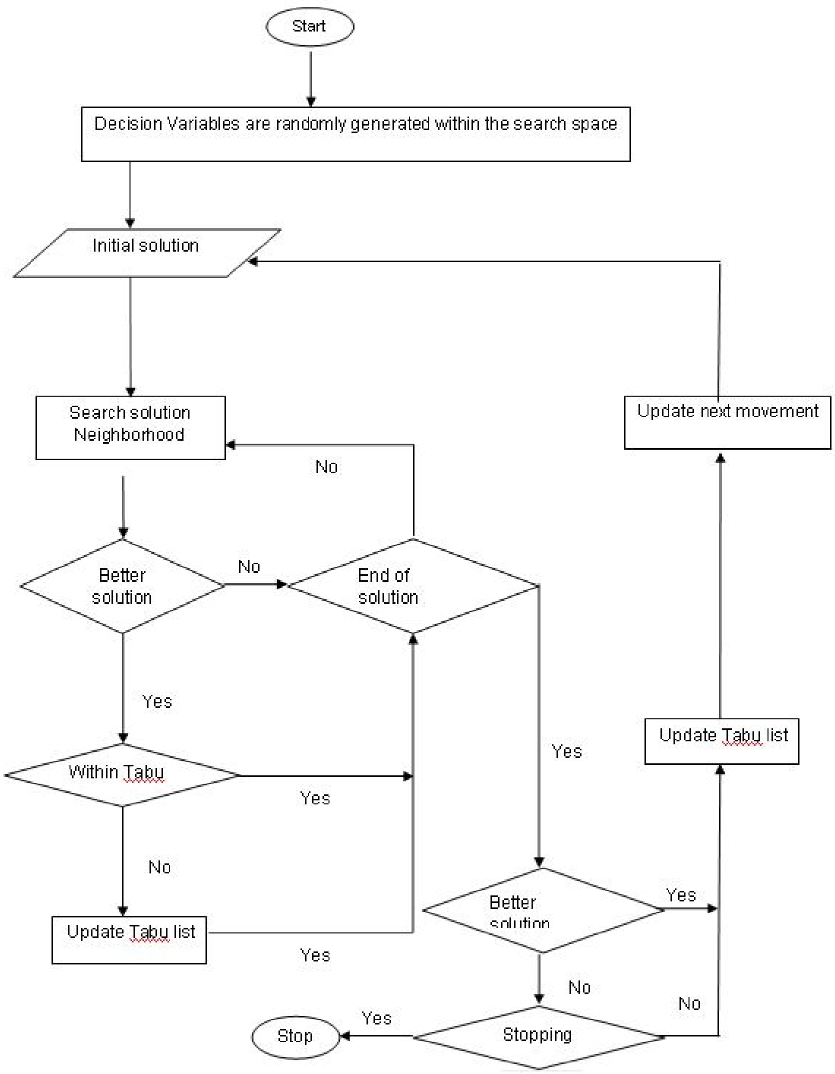

Figure 1: Flow-chart of Tabu Search Algorithm

3.3 Error Analysis: The following errors are to be analyzed:

Forecasting error = | Forecasted Value – Actual Value | / (Actual Value) * 100 %

Average Forecasting Error = (Sum of Forecasting errors) / (Total number of errors).

4. Implementation

In this paper, an effort has been made on the initial shoot length of B-59 mustard plant to predict its production at maturity with the help of Tabu search algorithm.

Step 1: The parameters are initialized as follows:

Tabu list size = 10;

Tabu tenure = 7;

Number of decision variables in a Tabu vector is 13;

The upper and lower limit of decision variables are: x_{min} = 15 and x_{max} = 70, they are defined as per available data;

Number of iteration = 10000;

The initial solution is generated with the help of a random generator (*rand()*). The random number between x_{min} and x_{max} is generated by the formula:

$$x_i = x_{min}[\,i\,] + (x_{max}[\,i\,] - x_{min}[\,i\,]).rand();$$

where *i* represents i^{th} element of the decision variable.

Step 2: The error (e) is calculated as follows:

e = | Actual Value – Forecasted value |

Step 3: Find neighborhood solution using formula [5].

$$x_i = x_i \pm (m*m) / (n+1)$$

Where m is the step correction amount initialized to a value of 0.05 and n is the number of decision variables set to 13. Therefore the neighborhood solution contains a total of 26 possible combinations because there exists 13 decision variables each with two possible trials, increase or decrease.

Step 4: The next move is to proceed to a better solution in the neighborhood if it is not prohibited by the tabu list, otherwise the iteration function is followed and the next move leads to a better solution in the neighborhood. If the better solution of the neighborhood is superior to the current global best solution then it will be recorded as the best solution.

Step 5: After successful iterations, i.e., after the termination criteria is satisfied, the best fitness value is obtained. The predictions are done with these obtained values.

Step 6: The predicted values of the shoot length along with error percentage are calculated, from the best fitness value, which are furnished in Table 3 below.

Actual Value	Predicted Value	Predicted Error (%)
19	19.1	0.53
24	23.47	2.18
28	28.85	3.04
33	32.54	1.37
37	37.02	0.07
41	40.98	0.04
45	45	0.01
49	48.95	0.08
54	53.91	0.14
57	57.34	0.6
59	58.26	0.4
63	63.02	0.03
66	65.96	0.05

Average Error 0.66 %

Table 3: Forecasted Value and Forecasted Error of shoot length using Tabu Search

5. Result Analysis

The Average error between various methods, i.e., Statistical and other soft computing methods has been compared with Tabu Search and the results obtained have been furnished in Table 4.

Hence it is found that Tabu Search gives us much better results than the other methods. The forcasted values from tabu search are applied to least square method to predict the future growth of the shoot length of mustard plant, i.e, at maturity. The calculated value thus obtained is 138.46 cm and the corresponding pod yield is found out by using Table 1(b), which is approximatey 7 gm.

Method	Average Error
Least Square Technique based on Linear Equation	3.66%
Least Square Technique based on Exponential Equation	7.52%
Least Square Technique based on Logarithmic Equation	3.73%
Least Square Technique based on Asymptotic Equation	2.44%
Fuzzy Time series	4.98%
Artificial Neural Network with Fuzzy Input	1.01%
Neuro-Fuzzy-Genetic system	0.88%
Tabu Search system	0.66%

Table 4: Average Error

6. Conclusion and Future Scopes

In this paper, tabu search has been applied to predict the pod yield of mustard plant. The result produced by this method has been proved better than the other applied methods. The same approach will be applied on different plant to verify the result in future. Other optimization mehods will be applied on the same data set in future.

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