Selecting Optimal Access Roads for Mobile Crane in Wind Farm Project

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Abstract: Wind farms, always constructed on sites of uneven terrain or topography. So, mobile crane used to lift and assembly of wind turbine is faced with problem of unpaved access roads which have a negative influence on wind farm construction time. Therefore the selection of the shortest access road routes is essential to minimize wind farm construction time. This paper presents a formulation based on technique of Genetic Algorithms (GA) to find the optimal access roads routes, this formulation consider a good fast tool used for planning the construction process. To verify the efficiency of the proposed formulation, illustrative example has implemented in MAT LAB and results of this example are clarified.

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1. Introduction

1.1 Nature of Wind Farm Construction

Electric energy generated by Wind farms reaches 600 GW, 53.9 GW added in 2018 [1]. Wind farm construction is a repetitive linear construction project that involves lifting heavy components of wind turbine to large heights using cranes with various capacities. As a result of this linear nature of wind farm project, the selection of access roads routes will significantly affecting the overall project time.

1.2 Genetic Algorithm (GA)

Genetic algorithm (GA) is an optimization tool based on the principles of natural evolution, which were first introduced in 1970 [2]. Genetic algorithms considered a branch of study named as evolutionary computation [3], in that they similar to the biological processes of natural selection to reach the optimal solution [4]. As in evolution, genetic algorithmstages are random, however this optimization tool allows setting the levels of randomization of control [4]. The technique of (GA) starts from a population of randomly generated chromosome. Through any generation, basically three genetic operators (selection, crossover and mutation) are implemented to each chromosome [4]. In genetic algorithms, the search space consists of chromosomes each of them representing a solution for the problem. Value of the objective function for each chromosome is representing its fitness value, and the Population is consisting of a set of chromosomes, while the generated population in each iteration of the (GA) is called generation [5]. The procedure of genetic algorithm consists of fives equentially process; encoding, evaluation, crossover, mutation, and decoding.

2. Research Objectives

These paper focuses on using genetic algorithm approach to formulate the problem of the selection of the shortest access road routes in wind farm to reduce time passed from wind turbine to another, and then minimize the overall project time.

3. Problem Formulation

3.1 Problem Description

In general this problem is defined as follow: There exists a set of wind turbines that arranged and interconnected by network of access road routes as shown in Fig.1, these wind turbines must be lifted and installed using a number of mobile cranes in a short period, which creates the importance of selection of shortest access road routes. The paper presents the problem description as follows:

- A set $C = \{c_1, c_2,...,c_n\}$ of wind turbines, each one with coordinates of (x, y).
- A special node d_0 refer to depot or warehouse of wind turbines parts.
- Distance between any pair of turbines with coordinates of (x_1, y_1) and (x_2, y_2) is defined as follow:

$$d = [(x_1-x_2)^2 + (y_1-y_2)^2] \wedge 0.5 \quad (1)$$

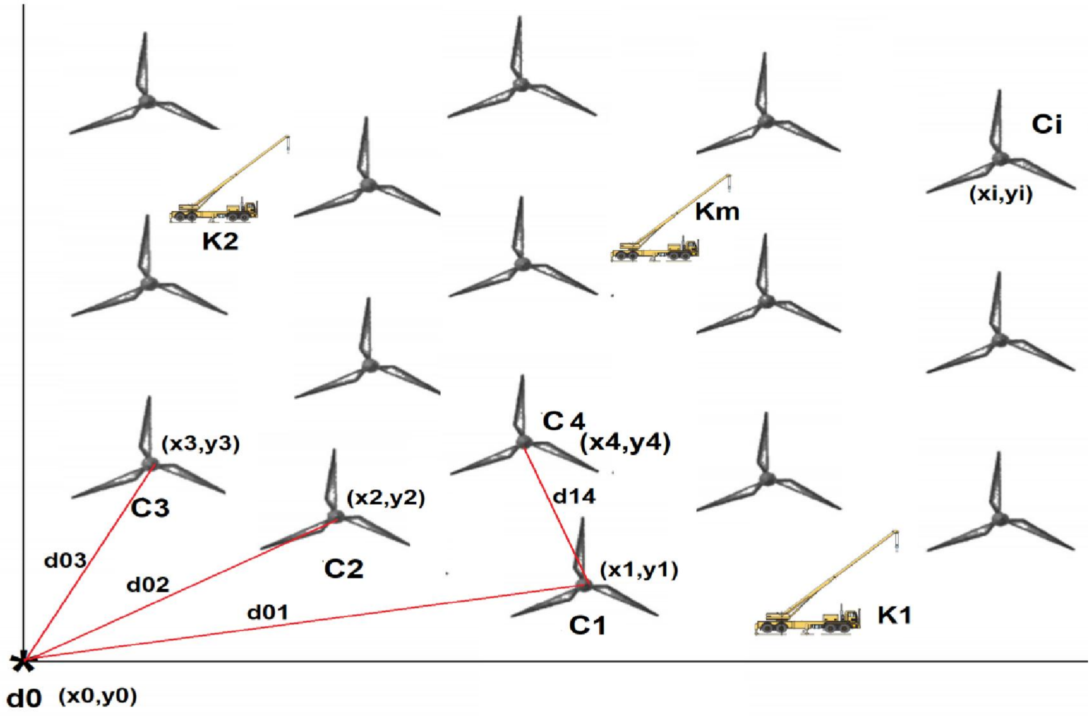

Fig. 1. Wind Turbines Layout

Initial population for this problem is randomly selected wind turbines taken as parent. Fitness function is evaluated by finding the minimum distance, for each transition between a pair of turbines the total distance is determined and likened to that of the fitness function [6]. cyclic crossover is implemented for the next generation over the parents. If the distance of the offspring is less than that of any parent, then the parent with longest distance is extracted from the population, and then added the offspring to the current population [7]. While, if the offspring distance greater than the distance of its parents then it is ignored.

3.2 Mathematical Model

The above problem is formulated to select routes in such a way that there should be minimum distances and minimum number of cranes, thus the fitness function $f\ (x)$ is formulated to minimize total distance and number of cranes as following:

$$\text{Minimize Min.} f\,(x) = \textstyle\sum^{n}_{i=1} \quad + \sum^{n}_{i=1} \sum^{n}_{i=1} \qquad (2)$$

This function subject to the next constraints:

- Crane capacity constraint

$\sum^{n}_{i=0} q_{ik} \leq V_k,\ K=1,\ldots\ldots,k$ (3)

- Transition time constraint

$\sum^{n}_{i=0}\sum^{n}_{j=0} y_{ik}\,(\,t_{ij}+f_i+w_i) \leq R_k,\ K=1,\ldots\ldots,k$ (4)

- Arrival time between two turbines constraint

$t_i\ +t_{ij}-(1-x_{ijk}\,)\leq t_j,\ K=1,\ldots\ldots,k.i,j=1,\ldots..,n$ (5)

-Earliest and latest time constraint

$f_i \leq t_i < L_i,\ i=1,\ldots\ldots,n$ (6)

-Logic constraint (time is positive)

$t_i \geq 0,\ i=1,\ldots..,n$ (7)

Variables:

Y_{ik}= {1, Turbine i is serviced by crane k
= {0, otherwise
X_{ijk} = {1, crane k moving from i to j directly
= {0, otherwise

3.3 Illustrative Example

The problem considered in this example to evaluate the algorithm is defined as a wind farm layout comprises a sixty turbine, Fig.2. Locations of these wind turbines are defined by coordinates. Mobile cranes move on different access roads to services all of these turbines in the wind farm by visiting each turbine only once. The problem deals with finding a shortest access road routes using as few cranes as possible, thence the total distance moved by mobile crane is minimum considering constraints mentioned in Eqs. (3-7).

Steps of the algorithm for solving this problem are mentioned in the following subsection:

1. Start.

2. Initialize randomly a population of chromosome of size N.

3. Calculate the fitness function for each chromosome.

4. Is the termination criteria satisfied?

5. If yes, then stop.

6. If not, then select a pair of chromosome for mating.

7. Create two offspring.

8. Change the values of gene in the tow offspring chromosomes randomly.

9. Generate a new population from the resulting chromosomes.

10. Go to step 3.

11. Is the optimization criteria satisfied?

If (not), another iteration, if optimization criteria satisfied, stop the process.

12. End

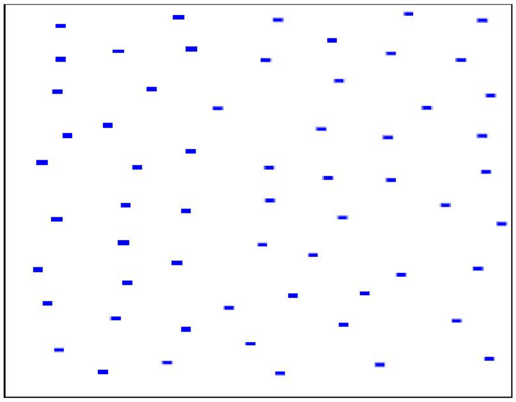
Fig.2. Layout of 60 Turbines

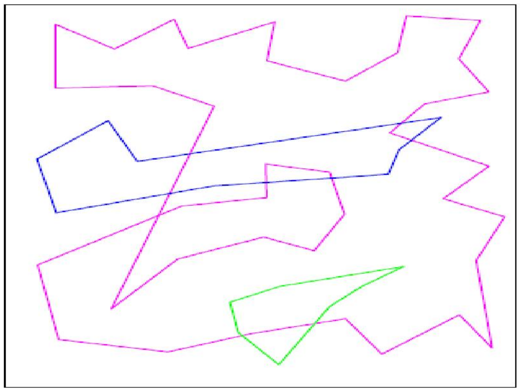
Fig.3. Initial Routes length4820.84 m

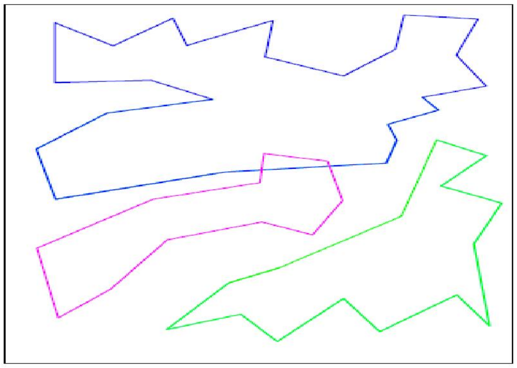
Fig.4. Routes length 3970.33 m

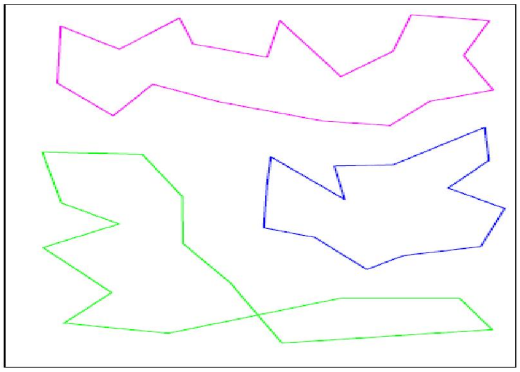
Fig.5. Routes length 372.346 m

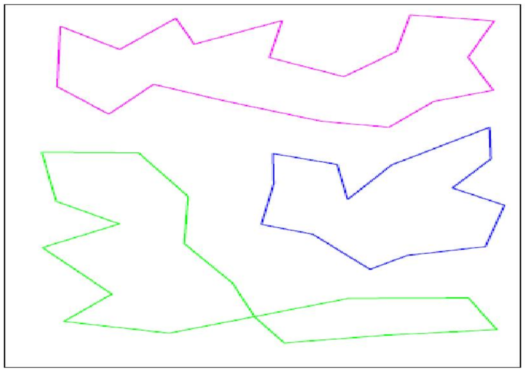
Fig.6. Routes length 369.205 m

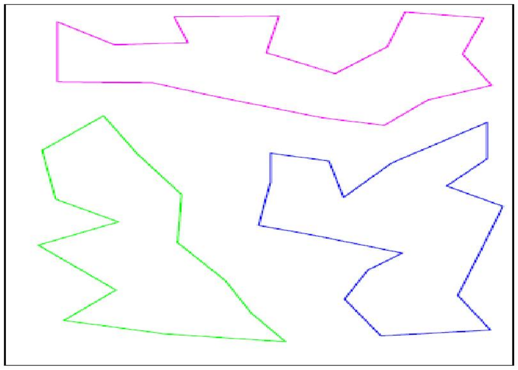
Fig.7. Minimal Routes distance 3640.172m

The algorithm has implemented in MATLAB, and results of the optimization with 60 turbines are illustrate in Figs. 3-7. Initially, the total distance of access road routes is 4820.84 m as shown in Fig.3, whoever the results of the intermediate iterations show that the total distance of access road routes is 3970.33m, 3720.346m, and3690.205m as shown in Fig.4, Fig.5, and Fig.6. respectively. The results of the final iteration illustrate the shortest access roads length is 3640.172 m, and the optimal number of mobile cranes are 3 cranes for this problem as shown in Fig.7.

4. Conclusion

In this study, we address the shortest crane routes problem, where the objective function is to minimize total distance using genetic algorithm technique. Genetic algorithm (GA) is preferred as an optimization technique. The proposed formulation and algorithm can achieve optimal solutions in an extremely short time with high efficiency output results.

Problem Variants

K= Number of cranes
N= Number of wind turbines
T = maximum time permitted for a crane
C_i = wind turbine i, d_0 = the start point (depot or warehouse)
D_k = total distance for a route k
R_k = total route time for a crane route k
t_{ij} = moving time between point i and j
V_k= maximum capacity of crane k
t_i = arrival time at wind turbine i
f_i = service time at wind turbine i
w_i = waiting time before servicing wind turbine i
L_i= latest time allowed for delivery to wind turbine i
q_{ik}= total demand of crane k until wind turbine i
R_{ik} = transition time of crane k until wind turbine i (service time and waiting time).

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