Differential Evolution Algorithm for House Size Determination in a Poultry Production

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Abstract

This study focuses on determining size (or capacity) and an appropriate number of hen houses for raising chicks in each week along the planning horizons. The chicks are raised in pullet farms until the age of 17 weeks. These pullets are then moved to hen houses and fed to a prescribed body weight to support egg production, and remain in the hen houses until they reach 75 weeks of age. Normally, the capacities of the pullet and hen houses are heterogeneous depending on the level of investment of contract farms. The complexity of poultry production that there are different sizes of pullet and hen houses then the different ages of hen could be mixed then the production cost get higher because hen will be slaughtered earlier than their ages. The problem is to determine how many hen houses to set up, new hen house to build and determine the capacity of them to cover changing trends in demand and/or cost. The purposed DE algorithm was developed to minimize the total cost including cost of open hen house, cost of ordering hen and cost of mix aged hen and also meet the demands over the planning horizons. Finally the metaheuristics using differential evolution (DE) was developed then the solutions compared to the lower bound. The results of DE algorithms have heuristics performance 87.28% to 92.73% and the average is 89.69%

Keywords: Differential Evolution, Heuristics Algorithm

1. Introduction

Egg production industries in Thailand are one of important agricultural product 95%-99% of egg production in Thailand was sold domestically and 1-5% exported. The egg production in Thailand have increasing

trend of demand during the years 2010-2014, the hen growth rate increased at 4.77 percent per year.⁽¹⁾

This research was motivated by the production firm in northeastern Thailand. The supply chain of the egg production starts from purchasing chicks from hatchery weekly. Then they transferred to the contract farm which different capacity of hen houses. Chicks stay until they are 17 weeks of age. After that they transferred to laying hen houses which different capacity for harvesting eggs, and remain in the hen house until the age of 75 weeks. After that they moved the hen to slaughter at slaughter house. The hen houses have to strip of all organic matter and sanitized before other hens enter. The eggs collection procedure is that eggs are collected and sent to the egg processing center. In order to washed, inspected, and then graded for packing and selling

We develop a model to minimize total costs which include open hen house cost, ordering of hen cost and loss cost from mixing hen with different ages. The goal is to select the number and capacities of the new hen house to open so that all hen demand is satisfied and also minimize total cost. We use metaheuristics Differential Evolution algorithms to solve the problem.

2. Literature Review

This research focuses to the allocation problem with the allocated hen into the Hen houses. Therefore review research that looks into the allocation problem or egg industries with similar solutions and applied Meta-heuristic on the allocation problem.

Demircan et al. (2010) studies the different capacity laying hen farms in Afyon province in Turkey. The study shown that the large farms had the highest egg yield and lower production cost and a better feed efficiency. It was

found that profit margin increased as the capacity of the farm increased ⁽¹⁾. Emam and Hassan (2010) studied poultry egg production in the open system in Khartoum State. They study the main factors production cost and compare between production costs, gross margins in different farm types and sizes. A Questionnaire used to collect the data. The highest gross profit was obtained in large farm sizes. The large size farm was more efficient than other sizes and type of the farms ⁽³⁾.

Helfand and Levine (2004) Levine study the relationship between farm size and efficiency. Data Envelopment Analysis (DEA) was used to analyze. They found that the relationship between farm size and efficiency is found to be non-linear. Technical efficiency of farms decreased at the beginning and then increased with the increasing farm size ⁽⁴⁾.

Sethanan et al.(2013) focused on determining the appropriate size of pullet and hen house by using neighborhood search and genetic algorithms to determine the number of pullet and hen houses ⁽⁵⁾. Sethanan et al. applied Whittin's algorithm to planning the chicks to allocate to pullet and hen houses ⁽⁶⁾. Boonmee et al. (2013) studied the decision making to fully utilize vehicle capacity in transporting eggs from contract farm to distribution center and from distribution center to the customers. The study shown cost reduction from the used fewer vehicles, shorter distances ⁽⁷⁾.

Amiri (2006) studied designing a distribution network in supply chain. Facility and demand allocation problems usually involve the cost of opening and operating cost and the transportation costs. As known capacitated warehouse location problem involves locating a given number of warehouses to satisfy customer demands. They developed mixed integer programming model and provide an efficient heuristic solution procedure for this supply chain system problem ⁽⁸⁾. In general the problems involve a set of distributed customers and a set of facilities that serve customer demand. Distances, times and costs are measures of the problem (Melo et al. ,2009) ⁽⁹⁾

The DE algorithm was first proposed by Storn and Price (1997) for continuous optimization ⁽¹⁰⁾. DE has been successfully applied in allocation problem fields, such as Worasan (2014) using differential evolution (DE) was developed to solve larger, more realistic problems on transportation problem with pickup and delivery with the objective to of minimize transportation costs and results obtained from this study show that the DE algorithm

provides better total cost values than that of the firm's current practice by 0.00 to 17.60% ⁽¹¹⁾. Saenkaeo (2015) developed differential evolution for minimize the total transportation cost in vehicle routing problem (VRP) ⁽¹²⁾.

Dechampai (2015) propose hybrid differential evolution algorithm for capacitated VRP with flexibility of mixing pickup and delivery services and the maximum duration of a route in poultry industry. The results obtained from this study show that the MESOMDE_G-Q-DVRP-FD algorithm provides lower total cost values than that of the firm's current practice by 7.59–31.28 and 0.84–13.15% etc ⁽¹³⁾.

Sethanan and Pitakaso (2016) presents DE algorithm to solve the generalized assignment problem (GAP) with the objective to minimize the assignment cost and applied three local search : shifting, exchange, and k-variable move algorithms for improve DE algorithm and competition performance with Bee algorithm (BEE) and Tabu search algorithm (TABU) ⁽¹⁴⁾

From the review of the literature, it was found that the available models could not be applied to the case. This study mainly finds the number of new hen houses to build and the capacity of them to minimize total cost. The differential evolution algorithm was used to solve the problem will be described in the next section.

3. Differential Evolution Algorithm

In this section, we developed model using Differential Evolution algorithm. The objective is to minimize total cost consisting three components: cost of open hen house, cost of ordering hen and cost of mix aged hen. The purposed method uses Differential Evolution with decode method by rank order value (ROV) to calculate the fitness value of DE vector used equation (1).

3.1 Objective Function:

Minimize $Z =$

$$\sum_{i=1}^I \sum_{t=1}^T ax_{it} + \sum_{j=1}^J \sum_{t=1}^T ax'_{jt} + \sum_{i=1}^I \sum_{t=1}^T b_i y_{it} + \sum_{j=1}^J \sum_{t=1}^T b'_j y'_{jt} + \sum_{i=1}^I \sum_{t=1}^T dq_{it+1} + \sum_{j=1}^J \sum_{t=1}^T dq'_{jt+1} \quad (1)$$

where;

Indices

i Old hen houses index; $i = 1, 2, 3, \dots, I$

j New hen houses index; $j = 1, 2, 3, \dots, J$

t	Period index; $t = 1, 2, 3, \dots T$
<u>Parameters</u>	
a	Cost order hens per unit (bath/hen)
b_i	Cost open of old hen houses i (baht)
b'_j	Cost open of new hen houses j (bath)
$capH_i$	Capacity of old hen houses i (hen)
$capNH_j$	Capacity of new hen houses j (hen)
d	Cost for mixed hen in period (bath)
D_t	Demand hen of period t (hen/week)

Decision variables

x_{it}	Number hens for allocating to old hen houses i on period t
x'_{it}	Number hens for allocating to new hen houses j on period t
q_{it+1}	Number hens for allocating to old hen houses i on period $t+1$
q'_{jt+1}	Number hens for allocating to new hen houses j on period $t+1$

Binary variables

y_{it}	= 1, if open old hen houses i on period t and 0 otherwise
y'_{jt}	= 1, if open new hen houses j on period t and 0 otherwise

3.2 Procedure: DE Algorithm

1. Begin
2. Define $D_t, capH_i, capNH_j, CR, NP$ and $Tmax$
3. Generate initial vector $x_{i,G}$ by random value between $[0, 1]$
4. While (not terminating condition) do
5. For $n=1$ to NP
6. Mutation operation: for the vectors $x_{i,G}$ randomly select three vectors $X_{r1,G}, X_{r2,G}$ and $X_{r3,G}$ then add the weighted difference of two vectors according to equation

$$Vx_{n,G+1} = X_{r1,G} + F(X_{r2,G} - X_{r3,G})$$

7. Recombination operation: the trial vectors $U_{xn,G+1}$ are developed from target vector and mutant vector according to the equation below.

$$U_{xn,G+1} = \begin{cases} V_{xn,G+1} & \text{if } (rand(j) < CR) \text{ or } j = rnbr(I) \\ X_{n,G} & \text{if } (randb(j) \geq CR) \text{ or } j \neq rnbr(I) \end{cases}$$

- $Rand(j)$ is a random number between $[0, 1]$. If $Rand(j) < CR$ use the mutant vectors as a trial vectors $U_{xn,G+1}$

8. The trial vectors $U_{xn,G+1}$ are normalized to value between $[0, 1]$ by equation below.

$$Ux^*_{n,G} = \frac{MaxTarget - MinTarget}{MaxU_n - MinU_n} \times (Ux_{n,G} - MinU_n)$$

9. Evaluate the fitness value: the decode method we used rank order value by ascending order of target vectors and trial vectors. The vectors $x_{i,G}$ were used to allocate the demand of hen D_t to the old hen house $capH_i$ and the new hen houses $capNH_j$. For example, there are demand of hens 5 periods and the old hen houses 7 houses. The demand of period to allocate is follow by 1-2-5-4-3 and allocated to the old hen houses follow by 6-1-2-4-5-7-3 as show in the Fig. 1. And the Fig. 2. show that how demand of hens allocated to the old hen houses on period =1, x_{it} was shown. Do until all demand period was satisfied. Then calculated objective function by equation (1)

Vector	Demand (t)					The old hen houses (i)						
	1	2	3	4	5	1	2	3	4	5	6	7
	0.01	0.07	0.70	0.67	0.18	0.89	0.03	0.18	0.75	0.76	0.96	0.18
ROV	1	2	5	4	3	6	1	2	4	5	7	3

Fig. 1. An example of decoding method by ROV

Period = 1							
D_t	$capH_i$						
	1	2	3	4	5	6	7
	5000	5000	10000	10000	20000	25000	50000
1	25000		5000	10000			10000

Fig. 2. An example hen allocated to hen house for period = 1

10. Selection operation: the target vectors $x_{i,G}$ is compared with the trial vectors $U_{x,G+1}$ and the one with the lowest cost is admitted to the next generation
11. Loop until $max_iteration$ or $Tmax$.

4. Numerical Experiments

The heuristics performance of the solution obtained by the purposed DE algorithm was compared to the lower bound. The value parameters of different data types we use to test the performance of heuristics were shown on Table 1. Eight types of data characteristics were generated and five test problems for each of them.

Table 1. Values of parameters of the different data types

Data type	number of periods	number of old hen houses	number of new hen houses
1	15	15	18
2	15	15	30
3	15	25	18
4	15	25	30
5	20	15	18

Table 1. Values of parameters of the different data types

Data type	number of periods	number of old hen houses	number of new hen houses
6	20	15	30
7	20	25	18
8	20	25	30

The purposed DE algorithm, was developed using Visual Basic programing on Intel® Core™ i5 processor(2.9-Ghz clock), with 16 GBytes of RAM. In order to test the model, the performance of the purposed DE algorithm measured by heuristic performance (HP) of the solution. The purposed DE algorithms was evaluated and presented below.

$$\text{Let } HP = \frac{sol_LB}{sol_heu} \times 100\%$$

Where; HP = heuristic performance
 sol_LB = the solution obtained from the lower bound
 sol_heu = the solution obtained from the purposed DE algorithm

For each data type, five different test problems were generated. The results of DE algorithm compared to lower bound are presented in Table 2. And computation times of them are shown on Table 3. That means the DE algorithm was good compared to the lower bound.

Table 2. Computational Result for all Data Types

Data Type	Total Cost (Million Bath)			HP (%)	
	Lower Bound	DE		DE	
		Best	Mean	Best	Mean
1	4.50	4.80	4.86	93.81	92.57
2	4.42	4.85	4.87	91.18	90.90
3	1.32	1.46	1.47	90.45	89.75
4	1.32	1.47	1.49	89.91	89.03
5	7.16	7.68	7.72	93.20	92.73
6	6.92	7.58	7.64	91.24	90.54
7	3.70	4.18	4.23	88.61	87.62
8	3.70	4.22	4.24	87.85	87.28

Table 3. Computational times for all Data Types

Data Type	Computation time(SEC)		
	lower bound	DE	
		Best	Mean
1	0.40	21.11	21.14
2	0.12	27.34	27.36
3	0.20	23.81	23.84
4	0.30	30.18	30.20
5	0.34	27.28	27.32
6	0.40	31.08	31.11
7	0.44	28.44	28.51
8	0.24	31.67	31.75

5. Conclusions

In this paper. We propose DE algorithm to solve a problem to find the capacity of old hen houses to set up and capacity of new hen houses to build. We use DE algorithm to allocate hen to old hen houses and new hen houses. The performance of algorithms was measured by heuristics performance (HP) by compared the total cost of them. The solutions compared to the lower bound. The results of DE algorithms have heuristics performance 87.28% to 92.73% and the average is 89.69% and the computation time is less than one minute.

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