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Research Paper

Optimization of integrated supply chain network problem using hybrid genetic algorithm approach

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Abstract

In this paper, an integrated supply chain network (ISCN) problem is designed. The ISCN problem is composed of forward and reverse logistics and represented by a nonlinear mixed integer programming (NMIP). The objective of the ISCN problem is to maximize the total profit which is consisted of total revenues and total costs resulting from its implementation. A hybrid genetic algorithm (HGA) approach proposed in this paper is applied to solve the NMIP. In numerical experiment, five scales of the ISCN problem are presented and they are solved using the proposed HGA approach and some conventional approaches. Experimental results show that the proposed HGA approach outperforms the others.

Keywords: *Integrated supply chain network problem, hybrid genetic algorithm, forward logistics, reverse logistics, nonlinear mixed integer programming.*

1. Introduction

Recent years have shown that many companies are focusing on the optimization of integrated supply chain network (ISCN) problem due to product life cycle, cost, and environmental regulations. In general, the ISCN problem is to consider an integration of forward logistics (FL) and reverse logistics (RL). To construct the ISCN problem, various facilities such as part supplier, manufacturer, distribution center, and retailer/customer in FL and collection center, recovery center (or remanufacturing center), secondary market and waste disposal center in RL are taken into consideration. Since the ISCN problem has larger complexity in its network structure than FL or RL problems alone, locating global optimal solution in the former is much more difficult than that in the latter.

Therefore, recent studies have shown a growing interest on the optimization of the ISCN problem to locate global optimal solution [1-5]. Geordiand is and Besiou[1] proposed an ISCN problem with the recycling activities of electrical equipment. In the proposed ISCN problem, the returned product from sale area in FL is collected at sorting area in RL and then classified into recoverable and unrecoverable materials. The quality of the recoverable material is recovered at recycling area and then sent to raw material area in FL, but the unrecoverable material is disposed at disposal area in RL. The proposed ISCN problem is applied to a real-world situation. Wang and Hsu[2] proposed an ISCN problem which are composed of supplier, manufacturer, distribution center, customer, recycler and landfill area. For constructing the ISCN problem, they divided the function of distribution center into two types. First type function is to send the product to customer and the second type one is to send the returned product to recycler. Especially, in the ISCN problem, recycler checks the returned product and then disassembles it into recoverable and unrecoverable materials. The recoverable material is sent to manufacturer in FL so that it is used for producing product. The unrecoverable material is sent to landfill area to be buried.

Similar to Wang and Hsu[2], Amin and Zhang [3-4]also considered an ISCN problem with various components such as supplier, manufacturer, distribution center, retailer, disassembling center, refurbishing center and disposal center in FL and RL. As an integrated concept, two types of part are used for producing product. First type part from supplier and second type one from refurbishing center are sent to manufacturer, respectively. Chen, et al [5] proposed an ISCN problem with various handling processes in RL. For the various handling processes, recycling center tests the returned products from customer and then classifies them into reusable and unusable products. The reusable products are sent to manufacturer in FL and the unusable products are disassembled into reusable and unusable materials. The reusable materials are sent to supplier in FL and the unusable materials are sent to waste disposal center in RL. The objective of the proposed ISCN problem is to minimize the total cost resulting from FL and RL processes. Wang and Hsu [2] proposed an ISCN problem with cyclic logistics network. For the cyclic logistics network, the returned product from customer is collected at recycler in RL through distribution center in FL. The recycler checks and classifies the returned product into recoverable and unrecoverable materials. The quality of the recoverable material is recovered at recycler and then sent to manufacturer in FL. The unrecoverable material is sent to landfill area in RL. The proposed ISCN problem is solved using genetic algorithm (GA) approach in order to minimize the total cost resulting from FL and RL processes.

As shown in the previous works mentioned above, most of researchers suggested various methodologies based on the ISCN problem. Unfortunately, however, they only used one or two integrated concepts in the ISCN problem, which can deteriorate the efficiency of the conventional problems. For example, Chen, et al [5] considered the reuse and disposal processes but did not considered secondary market for reselling recovered product. Also only reuse and resale processes are used for constructing the ISCN problem in Wang and Hsu [2].Resale, reuse, and wasted disposal concepts do not be used simultaneously in most of the previous works. Therefore, in this paper, a new ISCN problem is proposed to overcome the weakness of the previous works. The proposed ISCN problem has some characteristics as follows:

- The proposed ISCN problem considers a resale, reuse and waste disposal concepts simultaneously under considering various facilities such as part suppler, module manufacturer, product manufacturer, distribution center and retailer in FL and customer, collection center, recovery center, secondary market and waste disposal center in RL.
- In the proposed ISCN problem, location and allocation decisions of facility at each stage are also determined. For location and allocation decision, only one facility at each stage is opened and the others are closed. The facility opened at each stage sends various numbers of part, product, and returned products to the facility opened at the next stage.
- The objective of the proposed ISCN problem is to maximize the total profit which is consisted of total revenues and total costs resulting from its implementation process. For solving the ISCN problem, a new hybrid genetic algorithm (HGA) approach is developed, though GA has been used predominantly in the previous works [5].

Section 2 shows a conceptual structure of the ISCN problem. A mathematical formulation using nonlinear mixed integer programming (NMIP) is suggested for the ISCN problem in Section 3. The detailed implementation procedure of the proposed HGA approach is shown in Section 4. In numerical experiment of Section 5, the five scales of the ISCN problem are presented and the performance of the proposed HGA approach is compared with those of some conventional approaches under various measures of performance.

2. Proposed ISCN problem

Figure 1 shows a conceptual structure of the ISCN problem. As shown in Figure 1, various facilities at each stage are taken into consideration. For FL, part suppliers at areas 1 and 2 send two types of part (part types 1 and 2) to module manufacturer for assembling module. Also the remaining part suppliers at areas 3 and 4 send two types of part (part types 3 and 4) to product manufacturer for producing product. The product is then sent to retailer through distribution center. For RL, the returned product from customer is collected at collection center. Collection center checks and tests the returned product and then classifies it into recoverable and unrecoverable products. The recoverable product with α_1% is sent to recovery center and the unrecoverable product is disassembled into recoverable and unrecoverable part types 1, 2, 3, and 4. All recoverable part types with α_2%are sent back to part suppler in FL and all unrecoverable part types with α_3% are disposed at waste disposal center. The detailed function of the collection center is described in Figure 2. Recovery center recovers the quality of the recoverable product and then sent it to secondary market through redistribution center.

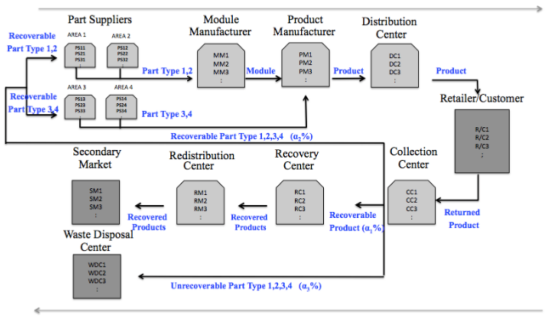

Figure 1: Conceptual structure of the ISCN problem

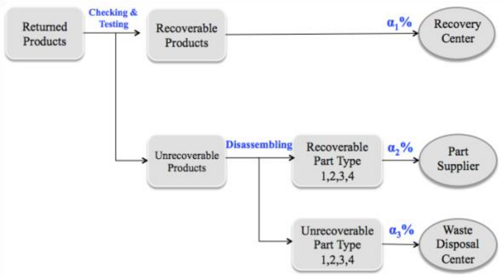

Figure 2: Functions of collection center

As shown in Figure 1, it can be seen that the resale activity using recovered product is done at secondary market in RL, the reuse activity using recovered parts is at part supplier, and the waste disposal activity is at waste disposal center. The objective of the ISCN problem is to optimally locate and allocate each facility at each stage and to effectively operate it so that the total profit should be maximized.

3. Mathematical formulation

As mentioned in Section 2, the objective of the ISCN problem is to maximize the profit which is consisted of total revenues and total costs resulting from its operation. Therefore, in this Section, a mathematical formulation is suggested for achieving the objective. First, some assumptions considered in the ISCN problem are as follows:

- The product of single item is considered.
- The numbers of facilities considered at part suppliers at each area, module manufacturer, product manufacturer, distribution center, retailer/customer, collection center, recovery center, redistribution center, secondary market, and waste disposal center are already known.
- All facilities considered at retailer/customer, secondary market and waste disposal center are always opened. However, only one facility at part suppliers of each area, module manufacturer, product manufacturer, distribution center, collection center, recovery center and redistribution center should be opened.
- Fixed costs for operating the facilities at each stage are different and already known.
- Unit handling costs considered at same stage are identical and already known.
- Unit transportation costs considered between the facilities are different and already known.
- All products from customer are returned to collection center.
- All recoverable parts from collection centers in RL have the same quality as the original parts from part supplier in FL.

Under considering the above assumptions, the mathematical formulation for the ISCN problem is suggested. The indexes, parameters and decision variables are as follows:

Index set

a : index of area of part supplier; $a \in A$
p : index of part supplier; $p \in P$
o : index of module manufacturer; $o \in O$
m : index of product manufacturer; $m \in M$
s : index of distribution center; $s \in S$
t : index of retailer/customer; $t \in T$
c : index of collection center; $c \in C$
e : index of recovery center; $e \in E$
r : index of redistribution center; $r \in R$
y : index of secondary market; $y \in Y$
q : index of waste disposal center; $q \in Q$

Parameters

VPS_{Pa}: fixed cost at part supplier *p* of area *a*
VMM_o : fixed cost at module manufacturer *o*
VPM_m : fixed cost at product manufacturer *m*
VDC_s : fixed cost at distribution center *s*
VCC_c : fixed cost at collection center *c*
VRC_e : fixed cost at recovery center *e*
VRM_r : fixed cost at redistribution center *r*
CPS_{pa} : unit handling cost at part supplier *p* of area *a*
CMM_o : unit handling cost at module manufacturer *o*
CPM_m : unit handling cost at product manufacturer *m*
CDC_s : unit handling cost at distribution centers
CCC_c : unit handling cost at collection center *c*
CRC_e : unit handling cost at recovery center *e*
CRM_r : unit handling cost at redistribution center *r*
$SPSMM_{pao}$: unit transportation cost from part supplier *p* of area *a* to module manufacturer *o*
$SMMPM_{om}$: unit transportation cost from module manufacturer *o* to product manufacturer *m*
$SPMDR_{ms}$: unit transportation cost from product manufacturer *m* to distribution centers
$SDRTC_{st}$: unit transportation cost from distribution centers to retailer/customer *t*
$STCCC_{tc}$: unit transportation cost from retailer/customer *t* to collection center *c*
$SCCMM_{cpa}$: unit transportation cost from collection center *c* to part supplier *p* of area *a*
$SCCRM_{ce}$: unit transportation cost from collection center *c* to recovery center *e*
$SCCWD_{cq}$: unit transportation cost from collection center *c* to waste disposal center *q*
$SRCRM_{er}$: unit transportation cost from recovery center *e* to redistribution center *r*
$SRMSM_{ry}$: unit transportation cost from redistribution center *r* to secondary market *y*
UP : unit price

Decision variables

Aps_{pa} : handling capacity at part supplier *p* of area *a*
Amm_o : handling capacity at module manufacturer *o*
Apm_m : handling capacity at product manufacturer *m*
Adc_s : handling capacity at distribution center *s*
Atc_t : handling capacity at retailer/customer *t*
Acc_c: handling capacity at collection center *c*
Arc_r : handling capacity at recovery center *r*
Arm_e : handling capacity at redistribution center *e*
Asm_y : handling capacity at secondary market *y*
Awd_q : handling capacity at waste disposal center *q*

$qps_{pa} = \begin{cases} 1, \text{when part supplier } p \text{ at area } a \text{ is opened} \\ 0, \text{otherwise} \end{cases}$

$qmm_o = \begin{cases} 1, \text{when module manufacturer} o \text{ is opened} \\ 0, \text{otherwise} \end{cases}$

$qpm_m = \begin{cases} 1, \text{when product manufacturer } m \text{ is opened} \\ 0, \text{otherwise} \end{cases}$

$qdc_s = \begin{cases} 1, \text{when distribution center } s \text{ is opened} \\ 0, \text{otherwise} \end{cases}$

$qcc_c = \begin{cases} 1, \text{when collection center } c \text{ is opened} \\ 0, \text{otherwise} \end{cases}$

$qrc_r = \begin{cases} 1, \text{when recovery center } r \text{ is opened} \\ 0, \text{otherwise} \end{cases}$

$qrm_e = \begin{cases} 1, \text{when redistribution center of } e \text{ is opened} \\ 0, \text{otherwise} \end{cases}$

For representing the ISCN problem, a mathematical formulation by the NMIP is proposed. The objective is to maximize total profit under satisfying various constraints such as opening and closing decision at each stage, etc. Therefore, the objective function is defined as the maximization of total profit (*TP*) and the *TP* is consisted of total revenue (*TR*) and total cost (*TC*), where the *TC* is the sum of total fixed cost (*TF*), total handling cost (*TH*) and total transportation cost (*TT*), and the *TR* is calculated as *TR = UP * (1+Rate of Return)*. The detailed mathematical formulation is as follows:

$$\text{Maximize } TP = TR - TC \quad (1)$$

$$TC = TF + TH + TT \quad (2)$$

$$TF = \sum_a \sum_p (VPS_{pa} \cdot qps_{pa}) + \sum_m (VPM_m \cdot qm_m) + \sum_o (VMM_o \cdot qmm_o) + \sum_s (VDC_s \cdot qdc_s) + \sum_c (VCC_c \cdot qcc_c) + \sum_r (VRC_r \cdot qrc_r) + \sum_e (VRM_e \cdot qrm_e) \quad (3)$$

$$TH = \sum_a \sum_p (CPS_{pa} \cdot Aps_{pa} \cdot qps_{pa}) + \sum_m (CPM_m \cdot Apm_m \cdot qpm_m) + \sum_o (CMM_o \cdot Amm_o \cdot qmm_o) + \sum_s (CDC_s \cdot Adc_s \cdot qdc_s) + \sum_c (CCC_c \cdot Acc_c \cdot qcc_c) + \sum_r (CRC_r \cdot Arc_r \cdot qrc_r) + \sum_e (CRM_e \cdot Arm_e \cdot qrm_e) \quad (4)$$

$$TT = \sum_a \sum_p \sum_o (SPM_{pa} \cdot Aps_{pa} \cdot qps_{pa} \cdot qmm_o) + \sum_o \sum_m (SMP_{om} \cdot Amm_o \cdot qmm_o \cdot qpm_m) + \sum_m \sum_s (SPD_{ms} \cdot Apm_m \cdot qpm_m \cdot qdr_s) + \sum_s \sum_t (SDC_{st} \cdot Adc_s \cdot qdr_s) + \sum_t \sum_c (SCC_{tc} \cdot Atc_t \cdot qcc_c) + \sum_c \sum_o (SCM_{co} \cdot Amm_c \cdot qcc_c) + \sum_c \sum_r (SCR_{cr} \cdot Arc_r \cdot qcc_c) + \sum_r \sum_e (SRC_{ce} \cdot Arm_e \cdot qrc_r) + \sum_e \sum_y (SRS_{ey} \cdot Asm_y \cdot xrm_e) + \sum_c \sum_q (SCW_{cq} \cdot Awd_q \cdot qcc_c) \quad (5)$$

Subject to

$$\sum_p qps_{pa} = 1, \quad \forall a \in A \quad (6)$$

$$\sum_o qmm_o = 1 \quad (7)$$

$$\sum_m qpm_m = 1 \quad (8)$$

$$\sum_s qdc_s = 1 \quad (9)$$

$$\sum_c qcc_c = 1 \quad (10)$$

$$\sum_r qrc_r = 1 \quad (11)$$

$$\sum_o (Amm_o \cdot qmm_o) - \sum_m (Apm_m \cdot qpm_m) = 0 \quad (12)$$

$$\sum_m (Apm_m \cdot qpm_m) - \sum_r (Adc_r \cdot qdc_r) = 0 \quad (13)$$

$$\sum_r (Adc_r \cdot qdc_r) - \sum_t Atc_t = 0 \quad (14)$$

$$\sum_t (Atc_t - \sum_c (Acc_c \cdot qcc_c) = 0 \quad (15)$$

$$\sum_r (Crc_r \cdot xrc_r) - \sum_y Csm_y = 0 \quad (16)$$

$$\sum_p (Aps_{pa} \cdot qps_{pa}) - \sum_o (Amm_o \cdot qmm_o) \geq 0, \forall a \in A \quad (17)$$

$$\sum_o (Amm_o \cdot qmm_o) - a_2\% \sum_c (Acc_c \cdot qcc_c) \geq 0 \quad (18)$$

$$\sum_q (Awd_q - a_3\% \sum_c (Acc_c \cdot qcc_c) \geq 0 \quad (19)$$

$$\sum_r (Crc_r \cdot qrc_r) - a_1\% \sum_c (Acc_c \cdot qcc_c) \geq 0 \quad (20)$$

$$\sum_r (Crc_r \cdot qrc_r) - \sum_e (Crm_e \cdot qrm_e) \geq 0 \quad (21)$$

$$qps_{pa} = \{0,1\}, \quad \forall p \in P, \forall a \in A \quad (22)$$

$$qmm_o = \{0,1\}, \forall o \in O \quad (23)$$

$$qpm_m = \{0,1\}, \forall m \in M \quad (24)$$

$$qdc_s = \{0,1\}, \quad \forall s \in S \quad (25)$$

$$qcc_c = \{0,1\}, \quad \forall c \in C \quad (26)$$

$qrc_r = \{0,1\}, \quad \forall r \in R$ (27)

$Aps_{pa}, Amm_o, Apm_m, Adc_s, Acc_c, Arc_r Asm_y, Awd_q \geq 0$

$\forall p \in P, \forall a \in A, \forall o \in O, \forall m \in M, \forall c \in C, \forall s \in S, \forall r \in R, \forall t \in T, \forall e \in E, \forall q \in Q, \forall y \in Y$ (28)

The objective function of equation (1) is to maximize the *TP* which is consisted of *TR* and *TC* in equations (2) to (5). Equations (6) to (11) indicate that only one facility should be opened at part suppliers of each area, module manufacturer, product manufacturer, distribution center, collection center, recovery center and redistribution center. Equation (12) implies that the sum of the handling capacity at module manufacturer is the same as that of product manufacturer. Equations (13) to (16) have the same meaning with equation (12). Equation (17) implies that the sum of the handling capacity at each supplier of areas 1, 2 is the same or greater than that of the module manufacturer. Equation (18) implies that the sum of the handling capacity at module manufacturer is the same or greater than that of the recoverable products witha_2%at collection center. Equations (19) to (21) have the same meaning with equations (17) and (18). Equations (22) to (27) restrict the variables to integers 0 and 1. Equation (28) means non-negativity.

4. Proposed HGA approach

GA is a probabilistic search method that mimics the evolutionary processes of organisms, natural selection and genetic rules. GA was first introduced by Holland [6].Many researchers have adapted various methodologies using GA [7-10]. However, GA sometimes fail to locate global search solution, since it has not local search scheme. To overcome this weakness, many hybrid approaches using GA with various local search schemes have been developed [11-16]. Of them, Kanagaraj et al. [16] proposed a HGA approach using GA with cuckoo search (CS). Its main scheme is to apply Levy flight scheme to an individual of the offspring resulting from GA operation. However, this HGA approach also has a weakness, that is, since Levy flight scheme is adapted to an individual of the offspring only one time, it may not find a better solution during its search process. Therefore, if all individuals of the offspring will be adapted by Levy flight, then this weakness can be improved. With this improved concept, we propose a new HGA approach in this Section. The detailed implementation procedure of the proposed HGA approach is as follows.

4.1. GA approach

1) Representation and initial populations

For effectively representing the ISCN problem in GA, a bit-sting representation scheme is used. The bit-string representation is to allocate the facility number which can be opened at each stage to each gene of GA. The opening decision of the facility number is determined by randomness. Figure 3 shows a result using the bit-sting representation scheme.

	XPS 1	XPS 2	XPS 3	XPS 4	XMM	XPM	XDC	XCC	XRC	XRD
V_1	5	2	7	8	10	7	9	1	3	11

Figure 3: A result using bit-sting representation scheme

As shown in Figure 3, the part supplier*(XPS)* numbers 5, 2, 7, 8 are opened at area 1, 2, 3, and 4, respectively. The remaining part supplier numbers in each area are closed. The same meanings are also shown at module manufacturer (*XMM*), product manufacturer (*XPM*), distribution center (*XDC*), collection center (*XCC*), recovery center (*XRC*) and redistribution center (*XRD*). Using the bit-sting representation scheme, if the population size is 5, then the initial population is randomly generated as shown in Figure 4.

	XPS 1	XPS 2	XPS 3	XPS 4	XMM	XPM	XDC	XCC	XRC	XRD
V_1	2	7	6	1	5	1	7	11	3	6
V_2	9	5	1	4	15	2	5	7	8	1
V_3	6	9	2	1	4	3	2	9	3	4
V_4	1	3	6	1	8	7	7	10	4	2
V_5	11	2	8	7	2	1	13	2	7	14

Figure 4: A initial population

2) Crossover and mutation

For crossover operation, one point crossover operator (1X) [8] is used. First, two individuals from pollution are randomly selected (V_1 and V_2 in Figure 5). Secondly, a point is randomly selected among all genes which means all facilities (*XMM* in Figure 5). Finally, the genes selected by the point are exchanged each other and then two new individuals are produced (V_1* and V_2* in Figure 5). This procedure is summarized in Figure 5.

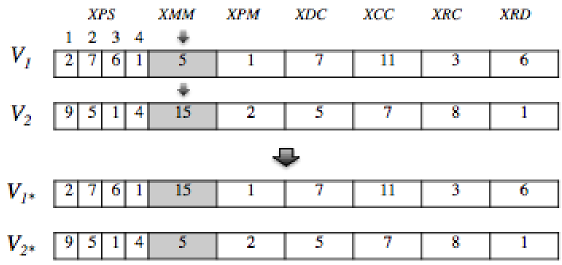

Figure 5: 1X

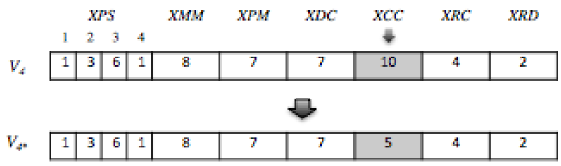

Figure 6: Random mutation operator

For mutation operation, random mutation operator [8] is used. First, an individual from pollution is randomly selected (V_4 in Figure 6). Secondly, a point is randomly selected among all genes (*XCC* in Figure 6). Finally, the gene selected by the point is randomly regenerated within all numbers of facilities (V_4* in Figure 6). This procedure is summarized in Figure 6.

3) Selection

For selection operator, the elitist strategy in enlarged sampling space proposed by Gen and Cheng [8] is used. First, all individuals of the initial population in Figure 4 and those of the offspring resulting from crossover and mutation operations are sorted using their fitness values. Secondly, a new population composed of the individuals with better fitness values is generated as many as the initial population.

4.2. Revised cuckoo search

As mentioned above, all individuals of the population should be adapted by Levy flight for revised Cuckoo search. First, the fitness values of all individuals are calculated ($F(X)$ in Figure 7). Secondly, Levy flight scheme is applied to all individuals. Finally, new individuals are generated as shown in Figure 8. Levy flight scheme is as follows:

$\boldsymbol{x}_i(t+1) = \boldsymbol{x}_I(t) + \alpha$ Levy (λ), Lévy (λ) $\simeq t^{-\lambda}$ $(1 < \lambda \le 3)$ (29)

Where α is the step size which should be related to the scales of the problem of interest. In most cases, we can use a = O(1). The product ⊕ means entry-wise multiplications. The Lévy flights essentially provide a random walk, while their random steps are drawn from a Levy distribution for large steps.

	XPS 1	2	3	4	XMM	XPM	XDC	XCC	XRC	XRD	F(X)
V_1	2	7	6	1	5	1	7	11	3	6	6120
V_2	9	5	1	4	15	2	5	7	8	1	10072
V_3	6	9	2	1	4	3	2	9	3	4	7894
V_4	1	3	6	1	8	7	7	10	4	2	9871
V_5	5	2	8	7	2	1	13	2	7	14	9130

Figure 7: Individuals before applying Levy flight

	XPS 1	2	3	4	XMM	XPM	XDC	XCC	XRC	XRD	F(X)
V_{1^*}	9	1	6	3	10	2	9	15	2	2	7820
V_2	9	5	1	4	15	2	5	7	8	1	10072
V_{3^*}	4	3	1	5	4	2	6	7	1	4	1103
V_4	1	3	6	1	8	7	7	10	4	2	9871
V_{5^*}	4	3	3	1	9	4	8	7	8	11	1130

Figure 8: Individuals after applying Levy flight

4.3 Detailed implementation procedure

The detailed implementation procedure of the proposed HGA approach using the GA in Section 4.1 and the revised Cuckoo search in Section 4.2 is summarized as follows:

Step 1: GA

Step 1.1: (Representation) 0-1 bit representation scheme is used.

Step 1.2: (Selection) elitist strategyin enlarged sampling space [8] is used.

Step 1.3: (Crossover)one-point crossover operator [8] is used

Step 1.4: (Mutation) random mutation operator [8] is used

Step 1.5: (Fitness evaluation) fitness evaluation by objective function under satisfying all constraints is used.

Step 2: Revised Cuckoo search

Step 2.1: (Applying Levy flight) Levy flight scheme [16] is applied to the individual randomly chosen from the GA population.

Step 2.2: (Evaluation) compare the fitness value of the individual applied by Levy flight with that of the individual randomly chosen by the population and store the best one among them.

Step 2.3: (Iteration)repeat Steps 2.1 and 2.2 for all individuals of population.

Step 3: Termination condition

If pre-determined iteration number is reached, then store current best solution and exit all steps, else go to Step 1.2.

5. Numerical experiments

To prove the efficiency of the proposed HGA approach, five scales of the ISCN problem are presented in numerical experiments. Table 1 shows the detailed information of the facility considered at each stage. For example, 5 part suppliers at each area 1, 2, 3, and 4 are considered.

Table 1: Five Scale of ISCN Problem

Scale	Part Supplier 1	2	3	4	Module Manufacturer	Product Manufacturer	Distribution Center	Retailers/ Customer	Collection Center	Recovery Center	Redistribution Center	Secondary Market	Waste Disposal Center
1	5	5	5	5	3	5	3	10	5	3	3	10	1
2	10	10	10	10	8	10	8	15	10	8	8	15	1
3	15	15	15	15	10	15	10	20	15	10	10	20	2
4	20	20	20	20	15	20	15	25	20	15	15	25	3
5	25	25	25	25	20	25	20	50	25	20	20	50	5

Table 2: Approaches for Experimental Comparison

Approach	Description
con-GA	Conventional GA [8]
con-HGA	Conventional HGA by Kanagaraj et al. [16]
HGA	HGA approach proposed in this paper
Lingo	Conventional optimization solver by Lindo Systems [17]

Table 3: Measures of Performance

Measure	Description
Best solution	Best value of the objective functions under satisfying all constraints.
Average solution	Averaged value of the objective functions under satisfying all constraints.
Average Time	Averaged value of the CPU times (Sec.) used for running each approach
Percentage Difference	Difference of the best solutionsat the con-GA, con-HGA and HGA when compared with that of Lingo

Table 4: Computation Results for Scale 1, 2, and 3

	Scale 1 con-GA	con-HGA	HGA	Lingo	Scale 2 con-GA	con-HGA	HGA	Lingo	Scale 3 con-GA	con-HGA	HGA	Lingo
Best sol.	53,262	55,262	55,688	11,775	45,190	48,844	53,191	9,537	40,873	42,897	58,789	7,383
Avg. sol.	43,735	45,740	49,717	-	41,144	41,447	47,200	-	35,690	36,195	53,372	-
Avg. Time	5.4	5.5	9.3	-	5.4	5.6	9.4	-	5.7	5.8	9.6	-
Per. Diff.	352.3%	369.3%	372.9%	0.0%	373.4%	412.5%	457.7%	0.0%	453.6%	481.0%	696.3%	0.0%

Table 5: Computation Results for Scale 4 and 5

	Scale 4				Scale 5			
	con-GA	con-HGA	HGA	Lingo	con-GA	con-HGA	HGA	Lingo
Best sol.	42,014	42,277	62,922	7,644	43,387	47,870	50,650	16,692
Avg. sol.	36,388	35,674	54,884	-	38,381	38,069	47,375	-
Avg. Time	5.6	6.1	10.0	-	6.5	6.7	12.0	-
Per. Diff.	449.6%	453.1%	723.2%	0.0%	159.9%	186.8%	203.4%	0.0%

For various comparisons, two conventional approaches (con-GA, con-HGA) and a benchmark approach (Lingo) are used and their performances are compared with that of the proposed HGA approach. Table 2 shows the description of all approaches used for experimental comparison. Each approach, except for the Lingo, uses the following parameters. Total iteration number is 1,000, population size 50, crossover rate 0.5 mutation rate 0.3, and selection rates at Cuckoo search and revised Cuckoo search 0.5. Total 30 trails are independently carried out to eliminate their randomness. All approaches are compare with each other using various measures of performance shown in Table 3.

All approaches ran on a same computation environment (IBM compatible PC 1.3 Ghz processor-Intel core I5-1600 CPU, 4GB RAM, and OS-X EI) and programmed by MATLAB version R2014a. Tables 4 and 5show the computation results by the con-GA, con-HGA, HGA approaches and Lingo using five scales of the ISCN problem.

In scale 1 of Table 4, the performances of the con-GA, con-HGA and proposed HGA approaches are significantly superior to that of Lingo in terms of the best solution and percentage difference. In the detailed comparison, the proposed HGA approach is 3.6% (= 372.9% - 369.3%) and 20.6% (= 372.9% - 352.3%) advantageous than the con-HGA and con-GA approaches. Also, in terms of the average solution, the proposed HGA approach is 8.0% (= 1 - (45,740/49,717)) and 12.0% (= 1 – (43,735/49,717)) advantageous than the con-HGA and con-GA approaches. However, in terms of the average time, the proposed HGA approach is about two times slower than the con-GA and con-HGA approaches. In scale 2, the performances of the HGA approach is greater than those of the con-GA and con-HGA in terms of the best solution and percentage difference. In the detailed comparison, the performance of the proposed HGA approach is 45.2% (= 457.7% - 412.5%) and 84.3% (= 457.7% - 373.4%) advantageous than the con-HGA and con-GA approaches. Also, in terms of the average solution, the proposed HGA approach is 12.8% (= 1 - (41,447/47,200)) and 12.8% (= 1 – (41,144/47,200)) advantageous than the con-HGA and con-GA approaches. However, in terms of the average time, the search speed of the proposed HGA approach is significantly slower than those of the con-GA and con-HGA approaches. In scale 3, the proposed HGA approach has 215.3% (= 696.3% - 481.0%) and 242.7% (= 696.3% - 453.6%) better performance in terms of the percentage difference and 32.2% (= 1 – (36,195/53,372)) and 33.1% (= 1–(35,690/53,372)) better performance in terms of the average solution than the con-HGA and con-GA, respectively. However, the search speed of the proposed HGA approach is about two times slower than those of the con-HGA and con-GA.

Similar computation results are also shown in the scales 4 and 5 of Table 5. The proposed HGA approach shows to be significantly better performances in terms of the best solution, percentage difference and average solution than the con-GA and con-HGA approaches. However, in terms of the average time, the proposed HGA approach is the worst performer.

Figures 9 and 10 show the convergence processes of the con-GA, con-HGA and proposed HGA approaches until the generation number is reached to 1,000. All approaches show rapid and various convergence processes during initial generations. In scale 4, the con-GA and con-HGA approaches do not show any better convergence processes after about 550 and 350 generations, respectively. However, the proposed HGA approach shows a better performance than the con-GA and con-HGA approaches during all generations. In scale 5, all approaches do not show any better convergence process after about 600 generations. However, in all generations, the convergence process of the proposed HGA approach is more efficient than those of the con-GA and con-HGA approaches.

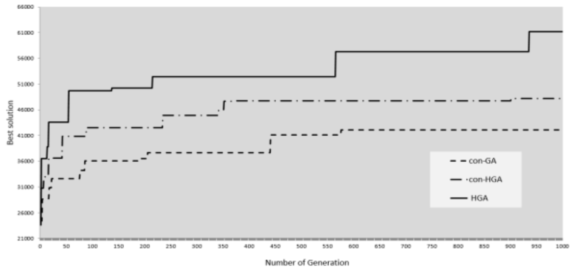

Figure 9: Convergence process in scale 4

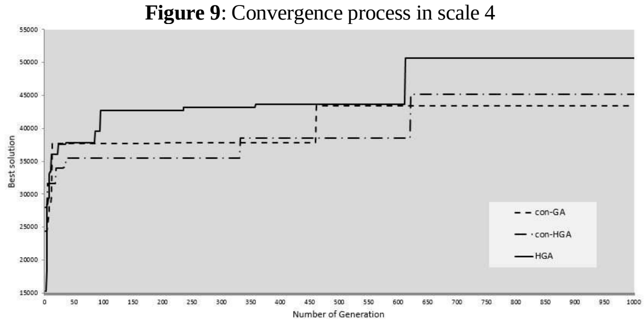

Figure 10: Convergence process in scale 5

Figure 11 shows the detailed material flows and the opening/ closing decision of facility in the proposed HGA approach for scale 5 under the situation that 3,000 product are produced and returned in FL and RL. For the opening/closing decision of facility, the opened facility number at each stageare displayed as white-coloured boxes. Therefore, the remaining facility numbers at each stage are all closed.For material flows, part suppliers at areas 1 and 2 produce 3,000 part types 1 and 2 (= 2,100 new part types 1 and 2 + 900 recoverable part types 1 and 2 from collection center) and then send them to module manufacturer. Part suppliers at areas 3 and 4 produce and send 3,000 part types 3 and 4 to product manufacturer. Module manufacturer assembles 3,000 modules using 3,000 part types 1 and 2 from part suppler at areas 1 and 2. Product manufacturer produces 3,000 products using 3,000 modules from module manufacturer and 3,000 part types 3 and 4 from part suppler at areas 3 and 4. 3,000 products are sent to retailer/customer through distribution center. Collection center collects 3,000 returned product from customer and then classifies them into 1,800 (= 3,000 product * 60%) recoverable products, 900 (= 3,000 product * 30%) recoverable part types 1, 2, 3, and 4 and 300 (= 3,000 product * 10%) unrecoverable part types 1, 2, 3, and 4. 1,800 recoverable products are sent to recovery center and its quality is recovered. 1,800 recovered products are resold at secondary market through redistribution center. 300 unrecoverable part types 1, 2, 3, and 4 are sent to waste disposal center to be disposed.

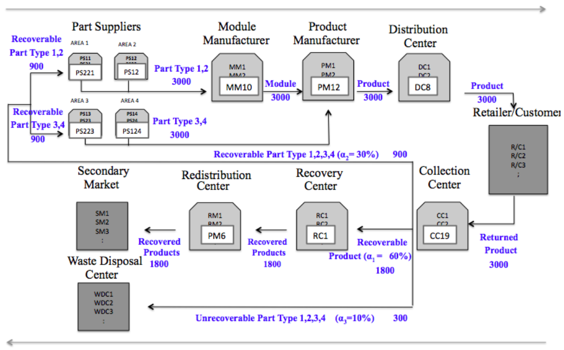

Figure 11: Opening or closing decision at each stage in scale 5

Based on the computation results using Tables 4 and 5 and Figures 3 and 4, the following can be summarized.

- The proposed HGA approach shows to be better performances in terms of the best solution, percentage difference and average solution than the con-GA and con-HGA approaches. Especially, in the comparison between the proposed HGA and con-HGA approaches, the search scheme used in the former is more efficient than that used in the latter, since the former applies Levy flight scheme to all individuals of offspring, but the latter applies it to only one individual of offspring, though both have a hybrid search scheme using GA and Cuckoo search,
- By the convergence processes in scales 4 and 5, the proposed HGA approach shows to be more various and better performances than the con-HGA approaches, which means that the search scheme using revised Cuckoo search in the proposed HGA approach outperforms the search scheme using conventional Cuckoo search in the con-HGA approach. Especially, in the comparison between the con-GA and con-HGA approaches, the former shows to be better performances in terms of the average solution of scales 3 and 4 than the latter, which implies that the search scheme using conventional Cuckoo search in the latter does not show any advantage than the search scheme without Cuckoo search in the former.

6. Conclusion

In this paper, we have proposed an integrated supply chain network (ISCN) problem. For designing the ISCN problem, various facilities such as part supplier, module manufacturer, product manufacturer, distribution center, retailer/costumer, collection center, recovery center, redistribution center, secondary market, and waste disposal center which can be considered in forward logistics (FL) and reverse logistics (RL) have been used. For the various handling processes, collection center in RL has multiple functions. First, collection center checks the returned product from customer and then classifies it into recoverable and unrecoverable products. The recoverable product is sent to recovery center and the unrecoverable product is disassembled into recoverable and unrecoverable parts. The recoverable parts are sent back to part supplier in FL and then reused for assembling module at module manufacturer. The unrecoverable parts are sent to waste disposal center to be land filled or burned. The recovered product from recovery center is sent to secondary market through redistribution center and then resold to customer. This reuse, resale and waste disposal concepts have not been considered simultaneously in the conventional works.

The ISCN problem has been represented by a nonlinear mixed integer programming (NMIP) in mathematical formulation. The NMIP is to maximize total profit which is consisted of total revenues and total costs resulting from the implementation of the ISCN problem. The hybrid genetic algorithm (HGA) approach, a revised version of the conventional HGA by Kanagaraj et al. [16], has been proposed to implement the NMIP. The main difference between the proposed HGA and conventional HGA approaches is that the former applies Levy flight scheme to all individuals of offspring, but the latter applies it to only one individual of offspring. In numerical experiments, five scales of the ISCN problem have been presented and they have used to compare the performance of the proposed HGA approach with those of the conventional approaches (conventional GA and HGA by Kanagaraj et al. [16]). Experimental results have shown that the proposed HGA approach is more efficient in most of measures of performance than the other competing approaches. However, since we have used small size scales of the ISCN problem, larger size scales will be used for proving its efficiency more precisely. Another effort to reduce the search speed in the proposed HGA approach will be also required since it has shown to be significantly slower search speed than the others.

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References

[1] Georgiadis P & Besiou M, “Sustainability in electrical and electronic equipment closed-loop supply chains: A System Dynamics approach”, *Journal of Cleaner Production*, Vol.16, pp.1665-1678, (2008).

[2] Wang HF & Hsu HW, “A closed-loop logistic model with a spanning-tree based genetic algorithm”, *Computers & Operations Research*, Vol.37, pp.376-389, (2010).

[3] Amin SH & Zhang G, “An integrated model for closed-loop supply chain configuration and supplier selection: Multi-objective approach”, *Expert Systems with Applications*, Vol.39, pp.6782-6791, (2012).

[4] Amin SH & Zhang G, “A multi-objective facility location model for closed-loop supply chain network under uncertain demand and return”, *Applied Mathematical Modelling*, Vol.37, pp.4165-4176, (2013).

[5] Chen TT, Chan FTS & Chung SH, “An integrated closed-loop supply chain model with location allocation problem and product recycling decisions”, *International Journal of Production Research*, Vol.53, No.10, pp.3120–3140, (2015).

[6] Holland JH, *Adaptation in natural and artificial systems: an introductory analysis with applications to biology, control, and artificial intelligence*, MIT Press, (1992).

[7] Cheong F and Lai R, “Constraining the optimization of a fuzzy logic controller using an enhanced genetic algorithm”, *IEEE Transaction Systems, Man, and Cybernetics-Part B: Cybernetics*, Vol.30, No.1, pp.31-46, (2000).

[8] Gen M & Cheng R, *Genetic algorithms and engineering design*, John Wiley & Son, New York, (1997).

[9] Gen M & Cheng R, *Genetic algorithms and engineering optimization*, John-Wiley & Sons, New York, (2000).

[10] Mak KL, Wong YS & Wang XX, “An adaptive genetic algorithm for manufacturing cell formation”, *International Journal of Manufacturing Technology*, Vol.16, pp.491-497, (2000).

[11] Holden NP & Freitas AA, “A hybrid PSO/ACO algorithm for classification”, *Proceedings of the 9th Annual Conference on* Genetic and Evolutionary Computation (GECCO), (2007).

[12] Surendar, A., Rani, N.U.”High speed data searching algorithms for DNA searching”,(2016) International Journal of Pharma and Bio Sciences, 2016 (Special Issue), pp. 73-77.

[13] Settles M & Soule T, “Breeding swarms:a GA/PSO hybrid”, Proceedings of the 7th Annual Conference on Genetic and Evolutionary Computation (GECCO), (2005).

[14] Yun YS, “Genetic algorithm with fuzzy logic controller for preemptive and non-preemptive job shop scheduling problems”, Computers & Industrial Engineering, Vol.43, No.3, pp.623-644, (2002).

[15] Shi XH, Liang YC, Lee HP, Lu C & Wang LM, “An improved GA and a novel PSO-GA-based hybrid algorithm”, Information Processing Letters, Vol.93, pp. 255-261, (2005).

[16] Kanagaraj G, Ponnambalam SG & Jawahar N, “A Hybrid cuckoo

search and genetic algorithm for reliability-redundancy allocation problems", Computers & Industrial Engineering, Vol.66, No.4, pp.1115-1125, (2013).

[17] Surendar, A., Arun, M."Efficient DNA sequence analysis for reduced gene selection using frequency analysis", (2016) Journal of Chemical and Pharmaceutical Sciences, 9 (4), pp. 3367-3373.

[18] Surendar, A., George, A."A real-time searching and sequencing assembly platform based on an FPGA implementation for Bioinformatics applications",(2016) International Journal of Pharma and Bio Sciences, 7 (4), pp. B642-B647.