Utilization of Genetic Algorithm in Allocating Goods to Shop Shelves Under an Application to Cup Noodles

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Received: April 3, 2019 Accepted: April 25, 2019 Online Published: April 29, 2019

doi:10.5430/ijba.v10n3p104 URL: https://doi.org/10.5430/ijba.v10n3p104

Abstract

How to allocate goods in shop shelves makes great influence to sales amount. Searching best fit allocation of goods to shelves is a kind of combinatorial problem. This becomes a problem of integer programming and utilizing genetic algorithm may be an effective method. Reviewing past researches, there are few researches made on this. Formerly, we have presented papers concerning optimization in allocating goods to shop shelves utilizing genetic algorithm. In those papers, the problem that goods were not allowed to allocate in multiple shelves and the problem that goods were allowed to allocate in multiple shelves were pursued. In this paper, we examine the problem that does not allow goods to be allocated in multiple shelves and introduce the concept of sales profits and sales probabilities. Expansion of shelf is executed. Optimization in allocating goods to shop shelves is investigated. An application to the convenience store with POS sales data of cup noodles is executed. Utilizing genetic algorithm, optimum solution is pursued and verified by a numerical example. Comparison with other past papers was executed. Various patterns of problems must be examined hereafter.

Keywords: display, genetic algorithm, optimization, shelf

1. Introduction

Displaying method in the shop makes influence to sales amount, therefore various ideas are devised. What kind of items should be placed where in the shop, how to guide customers to what aisle in the shop are the big issues to be discussed. Searching best fit allocation of goods to shelves is also an important issue to be solved. In this paper, we seek how to optimize in allocating goods to shop shelves.

As for allocating good to shop shelves, following items are well known (Nagashima, 2005). Shelf height is classified as follows.

- Shelf of 135cm height: Customers can see the whole space of the shop. Specialty stores often use this type.
- Shelf of 150cm height: Female customers may feel pressure to the shelf height. This height may be the upper limit to look over the shop.
- Shelf of 180cm height: It becomes hard to look over the shop. Therefore it should not be used for island display (display at the center or inside the shop).

Next, we show the following three functions of shelf for display.

1. Exhibition of goods function
2. Stock function
3. Display function

Effective range for exhibition is generally said to be 45cm-150cm. The range of 75cm-135cm is called golden zone especially. For the lower part under 45cm, goods are stocked as well as displaying.

Reviewing past papers, there are many papers concerning lay out problem. As for the problem of the distribution of equipment, we can see B. Korte *et al.* (2005), M. Gen *et al.* (1997) for the general research book. There are many researches made on this. Yamada *et al*. (2004) handles the lay out problem considering the aisle structure and intra-department material flow. Y. Wu *et al.* (2002) and Yamada *et al.* (2004) handle this problem considering aisle structure. Ito *et al.* (2006) considers multi-floor facility problem.

Although there are many researches on corresponding theme as stated above, we can hardly find researches on the problem of optimization in allocating goods to shop shelves.

Formerly, we have presented a paper concerning optimization in allocating goods to shop shelves utilizing genetic algorithm (Takeyasu *et al.*,2008) and many applications of them were presented (Shitara et al., 2015, Suzuki et al., 2015, Higuchi et al., 2016, Takeyasu et.al., 2016, Higuchi et al., 2017). In some of those papers, the problem that goods were not allowed to allocate in multiple shelves and the problem that goods were allowed to allocate in multiple shelves were pursued. In this paper, we examine the problem that does not allow goods to be allocated in multiple shelves and introduce the concept of sales profits and sales probabilities. Expansion of shelf is executed. Optimization in allocating goods to shop shelves is investigated. An application to the convenience store with POS sales data of cup noodles is executed. Utilizing genetic algorithm, optimum solution is pursued and verified by a numerical example. Comparison with other past papers was executed.

The rest of the paper is organized as follows. Problem description is stated in section 2. Genetic Algorithm is developed in section 3. Numerical example is exhibited in section 4 which is followed by the remarks of section 5. Section 6 is a summary.

2. Problem Description

Shelf model is constructed as Figure 1. There are five shelf positions. Shelf position 1 is mainly to put big and heavy goods including stock function. Shelf position 3, 4 at the height of the range 75cm to 135cm are the space of golden zone. Thus, we can use shelves properly by assuming these shelves. In numerical example, we examine using these five shelves. First of all, we make problem description in the case there is only one shelf (case 1). Then we expand to the case there are multiple shelves (case 2).

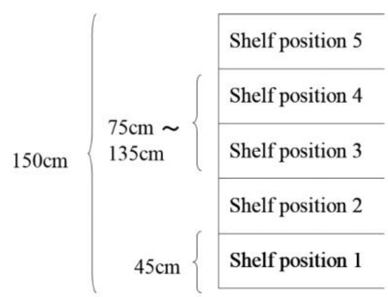

Figure 1. Shelf model

2.1 Case 1: The Case That There Is Only One Shelf

Although there are few cases that there is only one shelf, it makes the foundation for multiple shelves case. Therefore we pick it up as a fundamental one. Suppose shelf position k is from 1 to L (Figure 2).

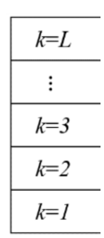

Figure 2. Shelf position

Suppose there are N amount of goods $(i = 1, \cdots, N)$. Set sales profit of goods i as H^i. Table 1 shows the sales probabilities when each goods is placed at each shelf position. The values in this table are written for example.

Table 1. Sales probability for each goods

Day of the Week	Time Zone(t)	Shelf $j=1$			Shelf $j=2$			…	Shelf $j=m$		
		Shelf Position			Shelf Position			…	Shelf Position		
		$k=1$	…	$k=L_1$	$k=1$	…	$k=L_2$	…	$k=1$	…	$k=L_m$
(Mon.)	0-1($t=1$)	0.01	…								
	1-2($t=2$)	0.02									
	…										
	23-24($t=24$)	0.03									
(Tue.)	0-1($t=25$)	0.02									
	1-2($t=26$)	0.02									
	…										
	23-24 $t=48$ ()	0.03									
…	…	…	…	…	…	…	…	…	…	…	…
(Sun.)	0-1($t=145$)	0.02									
	1-2($t=146$)	0.03									
	…										
	23-24($t=168$)	0.04									

Suppose goods are sold in the period from t_1 to t_n. In addition, a new goods i is replenished when goods i is sold out.

Set the accumulated sales probability of goods i in time zone t, shelf j, and shelf position k in the table as $HK^i_{t,j,k}$.

Then, the sales probability $K^{i,j,k}_{t_1/t_n}$ of goods i in the period will be described as follows.

$$K^{i,j,k}_{t_1/t_n} = \sum_{t=1}^{n} HK^i_{t,k,j}$$

This can take the value more than 1. For example, the value 2 means that 2 amount of goods were sold during the period. Set Benefit in the sales period from t_1 to t_n as $P^{i,j,k}_{t_1/t_n}$ $(i=1,\cdots,N)(j=1,\cdots,m)(k=1,\cdots,L)$ when goods i is placed at shelf j and shelf position k. Where Benefit means:

$$Benefit = SalesProbability \times SalesProfit$$

Therefore, this equation is represented as follows.

$$P^{i,j,k}_{t_1/t_n} = K^{i,j,k}_{t_1/t_n} \cdot H^i \tag{1}$$

where $j=1$ because one shelf case is considered here.

Set $x_{i,k}$ as:

$x_{i,k}=1$: Goods i is placed at shelf position k

$x_{i,k}=0$: Else

Suppose only one goods can be placed at one shelf position and also suppose that goods is not placed for more than 2 shelf positions and is not placed in multiple shelves. Then constraints are described as follows.

$$x_{i,k} = 1,0 (i=1,\cdots,N)(k=1,\cdots L) \tag{1}$$

$$\sum_{i=1}^{N} x_{i,k} = 1(k = 1, \cdots L) \tag{2}$$

$$\sum_{k=1}^{N} x_{i,k} \leq 1(i = 1, \cdots N) \tag{3}$$

Under these constraints,

$$Maximize\ J = \sum_{k=1}^{L} \sum_{i=1}^{N} P_{t_1/t_n}^{i,j,k} x_{i,k} \tag{4}$$

2.2 Case 2: The Case That There Are m *Shelves*

Suppose there are m shelves (Figure 3). Set Benefit as $P_{t_1/t_n}^{i,j,k}$ $(i = 1, \cdots, N)(j = 1, \cdots, m)\left(k = 1, \cdots, L_j\right)$where goods i is placed at shelf position k of shelf j. The sales period is the same with above stated (1).

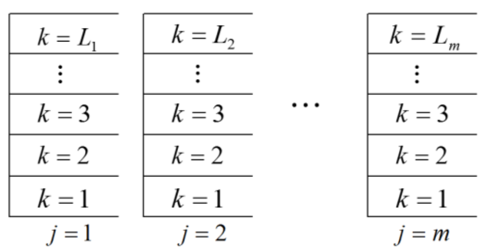

Figure 3. Shelf position under multiple shelves

Set $x_{i,j,k}$ as:

$x_{i,j,k} = 1$: Goods i is placed at shelf position k of shelf j

$x_{i,j,k} = 0$: Else

Suppose only one goods can be placed at one shelf position and also suppose that goods is not allowed to allocate in multiple shelf positions. Then constraints are described as follows. The sales period is the same with before.

$$x_{i,j,k} = 1,0(i = 1, \cdots, N)(j = 1, \cdots, m)\left(k = 1, \cdots, L_j\right) \tag{1}$$

$$\sum_{i=1}^{N} x_{i,j,k} = 1(j = 1, \cdots, m)\left(k = 1, \cdots, L_j\right) \tag{2}$$

$$\sum_{j=1}^{m} \sum_{k=1}^{L_j} x_{i,k,j} \leq 1(i = 1, \cdots, N) \tag{3}$$

Under these constraints,

$$Maximize\ J = \sum_{i=1}^{N} \sum_{j=1}^{m} \sum_{k=1}^{L_j} P_{t_1/t_n}^{i,j,k} x_{i,j,k} \tag{4}$$

3. Algorithm

We can make problem description as stated above, although these are somewhat under restricted cases. As far as only these are considered as they are, there is little difference between these and the conventional optimization problems. However, as soon as the number of involved shelves becomes larger, the number of variables dramatically grows greater, to which the application of Genetic Algorithm solution and Neural Network solutions may be appropriate. There are various means to solve this problem. When that variable takes the value of 0 or 1, the application of genetic algorithm would be a good method. As is well known, the calculation volume reaches numerous or even infinite amounts in these problems when the number of variables increases. It is reported that GA is effective for these problems (Gen et al. (1995), Lin et al. (2005), Zhang et al. (2005)).

A. The Variables

Suppose the number of goods, shelf position, and shelf are 60, 2, 9 respectively. In this paper, shelf is expanded from 2 to 9. Then the number of variables becomes 1080.

$$x_{i,j,k} = 1,0(i = 1,\cdots,60),(j = 1,\cdots,9),(k = 1,2)$$

Therefore, set chromosome as follows.

$$\begin{aligned} X = \big(&x_{1,1,1}, x_{2,1,1}, x_{3,1,1}, \cdots, x_{60,1,1}, \\ &x_{1,1,2}, x_{2,1,2}, x_{3,1,2}, \cdots, x_{60,1,2}, \\ &\vdots \\ &x_{1,2,1}, x_{2,2,1}, x_{3,2,1}, \cdots, x_{60,2,1}, \\ &x_{1,2,2}, x_{2,2,2}, x_{3,2,2}, \cdots, x_{60,2,2}, \\ &\vdots \\ &x_{1,9,1}, x_{2,9,1}, x_{3,9,1}, \cdots, x_{60,9,1}, \\ &x_{1,9,2}, x_{2,9,2}, x_{3,9,2}, \cdots, x_{60,9,2}\big) \end{aligned} \tag{1}$$

B. Initialize population

Initialization of population is executed. The number of initial population is M. Here set $M = 100$. Set gene at random and choose individual which satisfies constraints.

C. Selection

In this paper, we take elitism while selecting. Choose P individuals in the order which take maximum score of objective function. Here, set $P = 20$.

D. Crossover

Here, we take uniform crossover. Set crossover rate as:

$$P_c = 0.7 \tag{2}$$

E. Mutation

Set mutation rate as:

$$P_m = 0.01 \tag{3}$$

Algorithm of GA is exhibited at Table 2.

Table 2. Algorithm of multi-step tournament selection method

tep 1: Set maximum No. as g_{max}, population size as P, crossover rate as P_c, mutation rate as P_m.
Step 2: Set $t = 1$ for generation No. and generate initial solution matrix $x_p(t) = \left(x_{ikj}^{p}\right)$ $(p = 1,\cdots,M)$.
Step 3: Calculate Objective function $J\left(x_p(t)\right)$ for all solution matrix $x_p(t)$ $(p = 1,\cdots,P)$ in generation t.
Step 4: Set $t = t + 1$ until $t > g_{max}$.
Step 5: Crossover
Generate new individual by crossover utilizing the method of above stated *D*.
Step 6: Mutation

Reproduce by mutation utilizing the method of above stated *E*.

Step 7: Calculate objective function for reproduction of generation t.

Step 8: Selection

Next generation is selected by elitism.

Go to Step 4.

Introducing the variable y_s such that:

$$y_s = i \tag{4}$$

where

$$s = k + (j - 1) \cdot 2 \tag{5}$$

When

$$x_{i,j,k} = 1$$

then (10) is expressed as:

$$Y = (y_1, y_2, \cdots, y_{18}) \tag{6}$$

4. Numerical Example

Now, we execute numerical example using POS sales data. Numerical example is executed in "Case 2" of 2 (2). Suppose the sales period is 5 days for Monday through Saturday. Table 3 shows the unit sales profit H^i of each goods.

Table 3. Unit sales price and sales profit of each goods

Lot i	Sales Price	H^i
1		
2		
3		
4		
5		For Women
6		
7		
8		
9		
10		
11		
12		
13		For Men
14		
15		
16		
17		
18		
19		For Kids
20		

Supposing a general daytime retail store, we set opening time to be 9 through 18 o'clock. Table 4 shows the sales probabilities of lot *i* as an example.

Table 5 shows the sales probability by shelf for each shelf position. Table 6 shows the value in which Table 4 and Table 5 are multiplied. Table 7 shows the benefit Table in which accumulated probability of Table 6 and Sales Profit of Table 3 are multiplied.

Table 4. Sales probability of lot *i* (time zone)

Day of the Week	Time Zone(t)	Sales Probability	Day of the Week	Time Zone(t)	Sales Probability
(Mon.)	9-10		(Thu.)	9-10	
	10-11			10-11	
	11-12			11-12	
	12-13			12-13	
	13-14			13-14	
	14-15			14-15	
	15-16			15-16	
	16-17			16-17	
	17-18			17-18	
(Tue.)	9-10		(Fri.)	9-10	
	10-11			10-11	
	11-12			11-12	
	12-13			12-13	
	13-14			13-14	
	14-15			14-15	
	15-16			15-16	
	16-17			16-17	
	17-18			17-18	
(Wed.)	9-10		(Sat.)	9-10	
	10-11			10-11	
	11-12			11-12	
	12-13			12-13	
	13-14			13-14	
	14-15			14-15	
	15-16			15-16	
	16-17			16-17	
	17-18			17-18	

Table 5. Sales probability of lot i (shelf position)

Shelf $j = 1$		Shelf $j = 2$		Shelf $j = 3$		Shelf $j = 4$		Shelf $j = 5$		Shelf $j = 6$	
Shelf Position		Shelf Position		Shelf Position		Shelf Position		Shelf Position		Shelf Position	
k=1	k=2	k=1	k=2	k=1	k=2	k=1	k=2	k=1	k=2	k=1	k=2
1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2

Shelf $j = 7$		Shelf $j = 8$		Shelf $j = 9$	
Shelf Position		Shelf Position		Shelf Position	
k=1	k=2	k=1	k=2	k=1	k=2
1.1	1.1	1.0	1.0	0.9	0.9

In Table 5, shelf $j = 5$ is located near the entrance therefore the table value reflects this condition.

Table 6. Sales probability of lot i

Day of the Week	Time Zone(t)	Sales Probability										
		Shelf $j = 1$		Shelf $j = 2$		Shelf $j = 3$		…	Shelf $j = 8$		Shelf $j = 9$	
		k=1	k=2	k=1	k=2	k=1	k=2	….	k=1	k=2	k=1	k=2
(Mon.)	9-10							....				
	10-11							….				
	11-12							…				
	12-13							....				
	13-14							….				
	14-15							….				
	15-16							….				
	16-17							….				
	17-18							….				
(Tue.)	9-10							….				
	10-11							….				
	11-12							….				
	12-13							….				
	13-14							….				
	14-15							….				
	15-16							….				
	16-17							….				
	17-18							….				
						⋮						
(Sat.)	9-10							….				
	10-11							….				
	11-12							….				
	12-13							….				
	13-14							….				
	14-15							….				
	15-16							….				
	16-17							….				
	17-18							….				

Table 7 shows the benefit when each goods is placed at each shelf position of each shelf.

Table 7. Benefit table

	Shelf 1		Shelf 2		Shelf 3		Shelf 4		Shelf 5	
	Shelf Position		Shelf Position		Shelf Position		Shelf Position		Shelf Position	
Lot i	1	2	1	2	1	2	1	2	1	2
1	500	800	510	810	510	810	630	1270	550	1010
2	540	924	520	900	450	850	450	850	450	850
3	820	390	820	390	820	390	912	500	800	360
4	400	841	400	841	400	841	419	859	400	841

5	836	401	820	390	820	390	820	390	800	360
6	410	840	410	840	420	860	410	840	410	840
7	820	390	835	400	820	390	820	390	800	380
8	670	290	670	290	670	290	670	290	670	290
9	820	390	820	390	913	501	820	390	790	350
10	500	900	500	900	400	800	400	800	500	1000
11	500	900	539	923	450	850	450	850	450	850
12	560	900	560	900	400	850	400	850	630	1140
13	670	290	670	290	670	290	670	290	670	290
14	800	380	800	380	800	380	800	380	815	403
15	821	395	821	395	822	396	822	396	801	401
16	370	840	370	840	370	840	400	900	400	900
17	500	800	520	800	520	800	520	800	610	1100
18	680	295	680	295	680	295	680	295	680	295
19	790	310	790	310	790	310	790	310	790	310
20	390	900	390	900	380	830	460	990	460	990
21	475	767	478	783	483	777	600	1244	522	976
22	513	895	494	868	424	823	422	822	422	820
23	789	361	785	356	786	362	884	470	769	333
24	372	806	372	808	366	810	386	831	366	809
25	804	368	786	361	794	361	793	362	769	332
26	376	813	384	815	391	828	384	812	378	810
27	788	359	802	365	790	362	788	360	770	346
28	635	257	643	263	640	258	638	263	636	260
29	788	361	795	361	880	475	788	358	765	325
30	469	867	468	873	367	766	366	767	471	970
31	465	875	509	888	423	823	423	824	424	819
32	529	867	528	868	369	823	366	823	602	1114
33	642	265	643	264	642	264	640	262	641	259
34	771	352	775	350	774	354	768	345	781	368
35	786	361	787	362	792	367	795	369	774	370
36	339	815	340	815	335	813	368	871	374	868
37	466	770	488	775	491	770	490	775	579	1073
38	653	269	651	265	653	264	648	265	654	262
39	755	284	758	275	761	283	762	285	764	284
40	359	874	360	874	347	796	434	957	432	957
41	436	736	445	754	454	748	565	1213	492	948
42	479	866	464	840	391	785	390	788	393	787
43	765	330	756	334	763	325	851	437	737	304
44	337	780	338	781	342	779	361	801	341	780
45	774	343	756	335	755	330	757	332	735	301
46	347	782	348	782	358	804	349	783	347	782
47	764	329	772	338	755	335	758	331	744	323
48	611	233	614	226	609	227	605	232	605	228
49	760	334	760	328	848	441	759	330	726	294

50	442	840	445	838	338	736	344	735	444	940
51	437	840	482	868	391	794	392	788	387	792
52	500	836	505	839	340	787	338	785	568	1079
53	612	230	606	227	605	230	612	232	612	226
54	740	319	744	315	739	322	742	319	760	340
55	765	332	756	332	761	337	763	337	744	343
56	307	776	307	784	308	783	342	840	337	842
57	436	743	465	739	460	744	455	736	553	1038
58	616	231	619	238	620	231	624	239	617	235
59	727	254	729	249	735	247	734	253	734	245
60	335	839	326	843	316	769	403	926	405	926

	Shelf 6		Shelf 7		Shelf 8		Shelf 9	
	Shelf Position		Shelf Position		Shelf Position		Shelf Position	
Lot i	1	2	1	2	1	2	1	2
1	540	1010	550	1100	560	1100	560	1010
2	450	850	450	850	450	850	450	850
3	800	360	670	300	670	300	670	300
4	400	841	400	841	400	841	400	841
5	800	360	670	300	670	300	670	300
6	410	840	410	840	410	840	410	840
7	800	380	670	310	670	310	670	310
8	670	290	680	300	680	300	689	301
9	790	350	660	280	660	280	660	280
10	500	1000	500	1000	614	1272	500	1000
11	450	850	450	850	450	850	450	850
12	550	1000	550	1000	550	1000	550	1000
13	670	290	688	300	690	302	688	300
14	800	380	680	300	680	300	680	300
15	801	400	681	295	681	296	911	500
16	629	1139	460	990	460	990	460	990
17	615	1100	615	1273	600	1200	600	1100
18	680	295	691	303	685	300	685	300
19	814	402	680	290	680	290	680	290
20	460	990	460	990	460	990	605	1191
21	505	979	525	1074	531	1071	527	982
22	416	822	418	817	424	817	421	818
23	771	329	635	274	638	265	638	275
24	366	811	371	814	372	808	365	810
25	771	332	636	273	637	266	642	271
26	379	814	383	808	375	810	378	809
27	770	355	637	282	643	280	636	281
28	637	262	645	274	647	268	657	269
29	763	319	628	252	629	253	633	251
30	465	973	468	974	587	1238	475	966
31	424	825	417	818	416	817	424	815

32	517	974	521	965	519	965	523	966
33	638	262	654	274	665	277	662	266
34	766	354	654	265	653	275	654	272
35	767	366	652	264	656	264	879	465
36	598	1107	434	964	427	965	427	964
37	589	1072	581	1246	567	1175	575	1074
38	646	265	661	276	656	272	660	269
39	779	377	653	260	651	261	651	259
40	429	962	430	959	425	962	575	1157
41	479	946	490	1044	499	1036	504	949
42	385	787	391	789	391	793	395	789
43	738	303	612	241	612	244	605	244
44	342	784	335	786	343	785	342	780
45	738	304	615	242	605	236	610	243
46	350	785	347	775	351	781	352	778
47	743	315	614	252	615	249	606	246
48	613	231	621	244	625	243	633	237
49	732	295	601	224	600	220	595	217
50	442	939	435	937	549	1217	439	942
51	387	788	386	793	390	795	394	785
52	492	936	492	943	485	945	490	939
53	607	235	629	241	629	240	628	240
54	740	320	621	240	615	245	617	239
55	745	336	622	230	618	235	856	435
56	573	1081	396	935	398	931	395	926
57	550	1039	556	1217	543	1143	538	1045
58	618	236	627	244	629	240	630	243
59	751	340	615	233	622	233	621	228
60	395	930	395	934	399	926	550	1129

Experimental results are as follows. The expression Eq. (10) is complicated. Therefore, we use expression by Eq. (15). A sample set of initial population is exhibited in Table 8.

Table 8. A sample set of initial population

Y_1 =	(	50,	26,	16,	49,	13,	12,	43,	8,	40,	36,	21,	53,	35,	60,	7,	31,	39,	22	)
Y_2 =	(	15,	30,	22,	3,	32,	9,	5,	8,	55,	27,	13,	1,	45,	49,	43,	53,	14,	58	)
Y_3 =	(	1,	13,	3,	42,	2,	33,	15,	21,	36,	45,	20,	5,	58,	48,	50,	18,	43,	32	)
										⋮										
Y_{98} =	(	37,	58,	60,	7,	47,	44,	56,	27,	29,	50,	53,	4,	31,	21,	38,	9,	25,	23	)
Y_{99} =	(	33,	31,	2,	21,	18,	25,	8,	56,	4,	48,	13,	17,	30,	14,	54,	26,	5,	15	)
Y_{100} =	(	15,	13,	11,	32,	53,	10,	57,	35,	55,	42,	37,	1,	36,	23,	31,	56,	21,	14	)

Convergence process is exhibited in Figure 4.

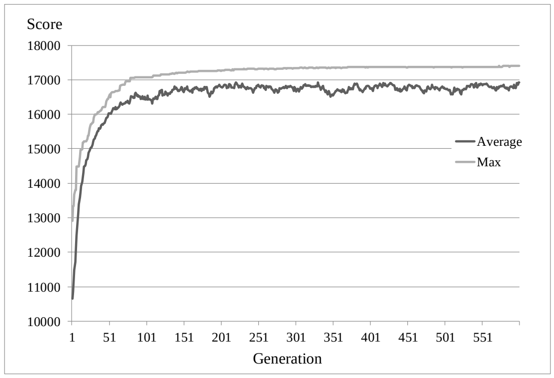

Figure 4. Convergence process of Case 2

The problem is simple, so combination of genotype for crossover saturates in the 578th generation. Genotype in which objective function becomes maximum is as follows.

$$Y = (5,2,7,11,9,6,3,1,14,12,19,16,18,17,13,10,15,20)$$

This coincides with the result of optimal solution by the calculation of all considerable cases, therefore it coincides with a theoretical optimal solution. We take up simple problem and we can confirm the effectiveness of GA approach. Further study for complex problems should be examined hereafter.

5. Remarks

As there are few papers made on this theme, we constructed prototype version before (Takeyasu et al.,2008). In this paper, we examined the problem that did not allow goods to be allocated in multiple shelves and introduced the concept of sales profits and sales probabilities. An application to the shop with POS sales data was executed. We can see that genetic algorithm is effective for this problem.

In practice, following themes occur.

1. Sales probabilities should be arranged correctly.
2. There are various types of shelves corresponding to goods characteristics (For example, cold storage goods).
3. Furthermore, genotype must be devised in construction when there are huge number of goods and shelves.

For these issues, expanded version of the paper will be built hereafter consecutively. As for 1, constraints are relaxed than those of this paper. As for 2, expansion is easy to make. As for 3, constructing genotype from the shelf side would bear much more simple expression.

We have examined various patterns on this problem type where the number of shelf position and those of shelf are different. They also include the different pattern that “Goods are allowed to allocate in multiple shelves” and “Goods are not allowed to allocate in multiple shelves”.

These are arranged by the viewpoint of variable number (The number of shelf position and those of shelf are involved), lot number, presence of the permission of allocating goods in multiple shelves. Then the convergence number will be different accordingly.

We summarize here and compare them. There are 9 papers. Comparison is exhibited in Table 9.

In the table, the notation means:

32: Number of convergence

(20): Lot Number

[15]: Reference Number

Table 9. Comparison with other cases

Variables	12	15	16	18	20
Goods are allowed to allocate in multiple shelves	63	170	489	125	

	(20)	(20)	(40)	(20)	
	[6]	[4]	[7]	[5]	
				184	
				(25)	
				[2]	
Goods are not allowed to allocate in multiple shelves		408		321	43
		(60)		(40)	(20)
		[8]		[3]	[1]

Note. number of references in Table 9 are as follows:

[1] Takeyasu, K., Higuchi, Y. (2011). Optimization in Allocating Goods to Shop Shelves, International Journal of Information Systems for Logistics and Management, Vol.6, No.2, pp.1-6.

[2] Takeyasu, K., Higuchi, Y. (2013). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm - An Application to the Shop Shelves for Yogurt Sales data-, Journal of Communication and Computer, Vol. 10, No.3, pp.416-424.

[3] Takeyasu, K., Higuchi, Y. (2013). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm for Yogurt Sales data, Chinese Business ReviewUSA-China Business Review, Vol.12, No.7, pp.497-508.

[4] Shitara, A., Higuchi, Y., Takeyasu, D., Takeyasu, K. (2015). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm Under the Introduction of Sales Probabilities, Journal of Communication and Computer, Vol12, No.4, pp.155-163.

[5] Suzuki, K., Higuchi, Y., Takeyasu, K. (2015). Optimization in Allocating Goods to Shop Shelves for Cup Noodles, Journal of Computations & Modelling, Vol.5, No.4, pp.1-25.

[6] Higuchi, K., Takeyasu, K. (2016). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm under Expanded Shelf Position Case, Journal of Computations & Modelling, Vol.6, No.2, pp.15-31.

[7] Takeyasu, K., Higuchi, Y. (2016). Utilization of Genetic Algorithm in Allocating Goods to Shop Shelves, Business and Management Research, Vol.5. No.4, pp.1-13.

[8] Higuchi, K., Takeyasu, K. (2017). Utilization of Genetic Algorithm in Allocating Goods to Shop Shelves Under the Introduction of Sales Probabilities, Bulletin of Kagawa Junior College, Vol.45, pp.29-41.

We can observe the following points.

- Generally, the convergence number is greater in the case “Goods are not allowed to allocate in multiple shelves” than the case “Goods are allowed to allocate in multiple shelves”.
- Generally, the convergence number is greater for the case of greater lot number.

If the variable number is greater such that 200, 2000 or 20000, then the convergence number would be greater. Such confirmation is our future works to be investigated.

6. Conclusion

How to allocate goods in shop shelves makes great influence to sales amount. Searching best fit allocation of goods to shelves is a kind of combinatorial problem. This becomes a problem of integer programming and utilizing genetic algorithm may be an effective method. Reviewing past researches, there were few researches made on this. Formerly, we had presented papers concerning optimization in allocating goods to shop shelves utilizing genetic algorithm. In those papers, the problem that goods were not allowed to allocate in multiple shelves and the problem that goods were allowed to allocate in multiple shelves were pursued. In this paper, we examined the problem that did not allow goods to be allocated in multiple shelves and introduced the concept of sales profits and sales probabilities. Expansion of shelf was executed. Optimization in allocating goods to shop shelves was investigated. An application to the convenience store with POS sales data of cup noodles was executed. Utilizing genetic algorithm, optimum solution was pursued and verified by a numerical example.

Comparison with other past papers was executed. We could observe the following points.

- Generally, the convergence number is greater in the case “Goods are not allowed to allocate in multiple shelves” than the case “Goods are allowed to allocate in multiple shelves”.

- Generally, the convergence number is greater for the case of greater lot number.

If the variable number is greater such that 200, 2000 or 20000, then the convergence number would be greater. Such confirmation is our future works to be investigated.

Various patterns of problems should be examined hereafter.

References

Arial, M., & Masui, Y. (2006). Optimization of maritime container-transportation network through the use of genetic algorithm. *Japan Ship-Marine Engineering Society*, *4*, 55-61.

Atsumi, S. (2008). *Shop Lay Out (in Japanese).* Jitsumu-Kyoiku-Press.

Gen, M., & Cheng, R. (1997). *Genetic Algorithms & Engineering Design*. John Wiley & Sons, Inc.

Gen, M., Ida, K., & Li, Y. (1995). Solving multi objective solid transportation problem by genetic algorithm. *JIMA*, *46*(5), 445-454.

Higuchi, K., & Takeyasu, K. (2016). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm under Expanded Shelf Position Case. *Journal of Computations & Modelling*, *6*(2), 15-31.

Higuchi, K., & Takeyasu, K. (2017). Utilization of Genetic Algorithm in Allocating Goods to Shop Shelves Under the Introduction of Sales Probabilities. *Bulletin of Kagawa Junior College, 45*, 29-41.

Ito, T., & Irohara, T. (2006). Multi-floor Facility Layout Technique Including Determination of Detailed I/O Location. *JIMA*, *57*(5), 395-403.

Kohno, H. (2006). *Making Charming Shop (in Japanese)*. Paru-Press.

Korte, B., & Vygeu, J. (2005). *Combinatorial Optimization.* Springer.

Michalewicz, Z. (1999) .*Genetic Algorithms + Data Structures = Evolution Programs*. Springer.

Nagashima, Y. (2005). *Shop Arrangement and Displaying (in Japanese)*. Nihon-Jitsugyo-Press.

Shitara, A., Higuchi, Y., Takeyasu, D., & Takeyasu, K. (2015). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm Under the Introduction of Sales Probabilities. *Journal of Communication and Computer, 12*(4), 155-163.

Suzuki, K., Higuchi, Y., & Takeyasu, K. (2015). Optimization in Allocating Goods to Shop Shelves for Cup Noodles. *Journal of Computations & Modelling, 5*(4), 1-25.

Takeyasu, K., & Higuchi, Y. (2011). Optimization in Allocating Goods to Shop Shelves. *International Journal of Information Systems for Logistics and Management, 6*(2), 1-6.

Takeyasu, K., & Higuchi, Y. (2013). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm - An Application to the Shop Shelves for Yogurt Sales data. *Journal of Communication and Computer, 10*(3), 416-424.

Takeyasu, K., & Higuchi, Y. (2013). Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm for Yogurt Sales data. *Chinese Business Review*, *12*(7), 497-508.

Takeyasu, K., & Higuchi, Y. (2016). Utilization of Genetic Algorithm in Allocating Goods to Shop Shelves. *Business and Management Research, 5*(4), 1-13.

Toyama, H., Ida, K., & Teramatsu, C. (2006). A proposal of a genetic algorithm for fixed-charge transportation problem and related numerical experiments. *JIMA*, *57*(3), 227-230.

Wu, Y., & Appleton, E. (2002). The optimization of block layout and aisle structure by a genetic algorithm. *Computers & Industrial Engineering, 41*, 371-382.

Yamada, T., & Irohara, T. (2006). Detailed Layout Design Methodology using Mixed Integer Programming and Simulated Annealing. *JIMA*, *57*(1), 39-50.

Yamada, T., Irohara, T., & Fujikawa, H. (2004). Design methodology for the Facility Layout Problem to Consider the Aisle Structure and Intra-Department Material Flow. *JIMA*, *55*(3), 111-120.