

# A Hybrid Meta heuristic Algorithm for the Balanced Line Production under Uncertainty

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**Abstract.** This study proposes a hybrid Golden Ball Algorithm for solving a balanced line production for a garment firm in Thailand. At present, production lines are those in which the timing of the job movement between stations is coordinated in such a way that all of the jobs are indexed simultaneously via some heuristic sequencing or dispatching rules. This research studies the balanced line production problem with some stochastic patterns, and develops a Golden Ball Algorithm or GBA and its variants to solve the problem. To assess the effectiveness of the proposed hybrid algorithm, a computational study is conducted for both deterministic and stochastic patterns of the problem. The comparisons are made for two different levels of processing times and due date. It can be concluded that the variant HGBA2 of the algorithm by adjusting answers of the successor function on both custom training and successor phases, is slightly more effective than the other hybrid approaches in terms of quality of solutions under uncertainty.

## 1 Introduction

Generally, the job shop deals with a work location in which a number of general purposed work stations exist and are used to perform a variety of jobs. There are some special characteristics when compared to traditional machine shop [1]. The factors describing the job shop consist of an arrival pattern (static or dynamic), number of machines or work stations, work sequence (fixed or random sequence) and performance evaluation criterion (make span, average time of jobs in shop, lateness, average number of jobs in shop, utilization of machines or workers). The job shop can be described via a Gantt chart. It is simple to display graphically results and schedule evaluating results. However, it is not suitable for complex situations.

For the problem with  $N$  Jobs and  $M$  Machines, the number of possible schedules is extremely large  $(N!)^M$ . Heuristics can be practically solve this problems based on sequencing or dispatching rules [2-4]. The conventional ones include a random pick with equal probability (RANDOM), first come first serve with earliest release date (FCFS), shortest processing time (SPT), earliest due date (EDD), critical ratio of processing time and time until due (CR), slack time (ST) and slack time per remaining operation (ST/O).

Recently, production lines have become the primary mechanism of productive industrial systems. Although there are various problems relative to the line production in the reality, the literature on this issue has been

focusing on a few specific problems [5-6]. Many new production lines have been focusing on the Just In Time (JIT) production principle. In this article, the Golden Ball Algorithm has been presented, an effective metaheuristic approach, to seek optimal solutions for the balanced line production problem. Moreover, there is an introduction of a robust optimisation approaches to balanced line production with the input data uncertainty of task times and due date changes. The objective of this research is to apply new hybrid methods based on the Golden Ball Algorithm for the job arrangement in order to balance workload in three production sections. Workload has impact on overtime cost, due date and employees' opinion. The remainder of this article is organised as follows. The background of the problem definition and the proposed algorithm with its hybridisations are reviewed in Sections 2 and 3, respectively. The problem and computational results are described in Section 4. Finally, present areas for future research are concluded in Section 5.

## 2 Balanced line production

A firm for this study is one of the small and medium enterprises or SMEs garment manufacturer of cleanroom apparels. It develops, produces and distributes a wide range of other cleanroom components. Production is done in a main assembly building and completed in 4-5 assembly stations that vary from apparel to apparel. The

steps of the cleanroom apparel production can be summarized as follows. The production of the apparel starts at the cutting and pattern department. The cut and patterned parts that require sawing are taken to the sawing sub-assembly shop. After the completion of sawing the parts are stored in an after sawing area. Then these parts are taken to the final assembly line according to the scheduling. When the assembly is done in the production department then the final part is packed and stored in the warehouse for shipping. Lean and just In Time (JIT) principles drive the firm as an assembling technology.

The company is currently developing a new cleanroom apparel line production. The current status of this project is that a design of the line production is in the final phase and the process engineers are working on the possible assembling methods under uncertainty on some important information. This is the background why the company now asks for a thorough analysis of the cleanroom apparel line production and an assembly line with shortest and balanced line production system. Balancing an production line is a strategy in which tasks are distributed evenly to each assembly line so that each line has the same amount of the work. The significant thing is to balance the workload of the operator at every line or stations, reducing the operator idle time over the takt time which means the decrease of unused idle station capacity. The objective is then to balance line production which gives various advantages in reducing wastes, idle workers, and operator changing, faulty product and stocks.

### 3 Hybrid golden ball algorithm (HGBA)

Golden ball algorithm (GBA), introduced by Osaba, Diaz & Onieva [7], is a method first used in solving the close-open mixed vehicle routing problem. The GBA algorithmic procedures are based on the principle of football competition as shown in Figure 1[8]. This method is similar to the league football competition. The league consists of a number of football clubs whose members are football players. Once a football team of a specified number of members is formed, the playing season starts. Every team will be matched up together in a form of league. A team with good football players will have a good chance to win as team strength depends on the quality of team members. Before each competition, every football player will have a chance to practice enhancing their capability while each player can move to other teams through trading. Details of the Golden ball algorithm presented in each step are as follows:

Step 1: Build a football team from a standard prototype problem. In this step, n football teams will be built randomly, and each team will create m football players.

Step 2: Calculate the objective function which will be the value of the team's power.

Step 3: The competition is to develop an answer or Competition Phase dividing into two stages.

The first step involves the answer adjustment process using the principle of a self-practicing athlete in order to increase their individual capability, or the custom training

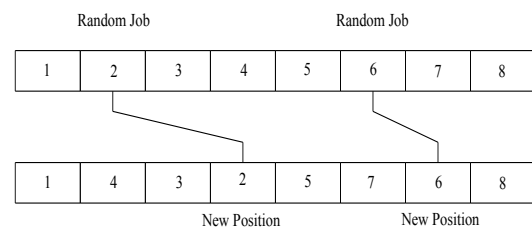
function. The second step is to build a new answer using the principle of practicing the team's plan where football players are generated, practice the training plan among team members to enhance the overall team's capability using the successor function created from the answer's neighbourhood. This new answer will be compared with the previous one. If it is better, it will be kept. If it is not better, then the existing answer will be used for further development in the next round.

Step 4: Transfer period is referred to as the trading period of football players. When the competing season ends, a football team with higher scores will have a chance to exchange high performance football players with a team with lower scores to increase the team's strength. There are two cases, i.e. exchanging between teams and generating answers by randomly inputting new values which is similar to trading football players from other sources.

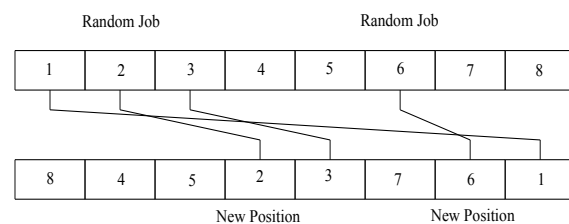
Step 5: Repeat the competition. After finishing each match, the team with better answers will be a winner with three points and the losing team will get 0 point. For the case of a tie score, each team will get 1 point. In each season, the competition will end only if all teams compete together. Competition will continue until completing the specified number or the termination criterion.

In this paper, three methods were generated to modify answers. The first and the second methods were represented the answer improvements in the custom training function. The third were used to adjust answers of the successor function.

Method 1: Randomize two jobs from all jobs and randomly swap positions.



Method 2: Randomize four jobs from all jobs and randomly swap positions.



Method 3: Randomize six jobs from all jobs and randomly swap positions.

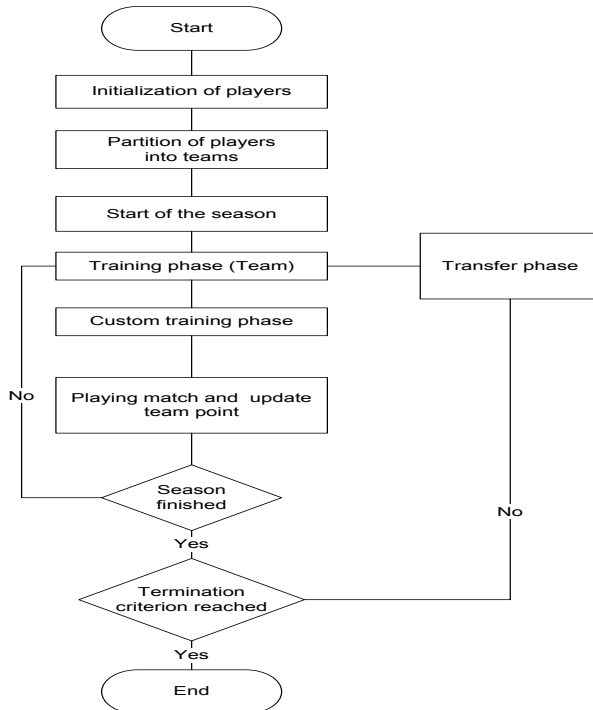
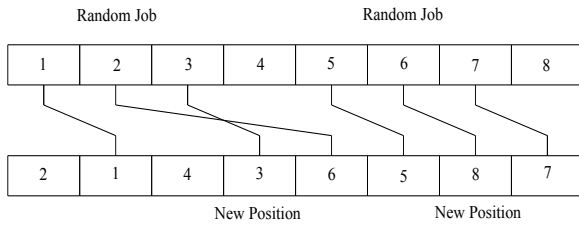


Fig. 1. Process flow of the GBA

Hybrid method type 1 (HGBA1) was calculated by the first and third methods for a custom training and successor phase. Hybrid method type 2 (HGBA2) was analysed by the second and third methods for a custom training and successor phase. Hybrid method type 3 (HGBA3) was applied by the third method on both custom training and successor phases.

#### 4 Computational results and analyses

The case study of balanced load schedule problem is based on real data from a cleanroom apparel company in Thailand. We test our methods on the orders of a three-month timeframe. The company's quantity demand is currently over its production capacity. In the SMEs case study, the main processes are cutting and pattern process, sawing sub-assembly, final assembly and packaging. There are eight regular working hours per day and three overtime hours per days. Based on the information, Table 1 shows the ordered items for processing processes. It

contains 30 jobs including order arrival, with different amount of quantities, set up time, production processes, cycle times, and due date. The average cycle time is 50 units per day. The operation units as described above can be categorized as three sets of OP1, OP2 and OP3. The production problems were missing due date time data, high over time cost and unbalanced load in three operation units. Thus, the objective of this research was to balance load in three operation units [9]. If balance load of all operation units are equal, overtime cost will decrease and can make product already in due date time.

In this work, the computational procedure described above was implemented as a computer simulation program in a Visual C#2008 computer program. A Desktop computer with CPU AMD FX6300 Series was used for computational experiments. A comparison of the new method procedures of HGBA1, HGBA2 and HGBA3 results are obtained in this section. GBA algorithm has its own influential parameters that affect its performance in terms of solution quality and process time. In each algorithm, the parameter setting values were based on previous literatures. For all optimization problems presented in this paper, the parameter levels were applied throughout. For parameter setting, the initial population was set at 48 players, 8 teams and 6 players per team.

All algorithms were applied 1000 evaluation points. There were fifteen trial runs in each problem. The performance of the different algorithms was compared based on criteria which comprise of balancing work load in each operation and minimizing an average of the total difference values. Table 2 shows the work load of each operation units of new three hybrid methods compared with original heuristic scheduling methods such as the first come first serve (FCFS), the longest processing time (LPT), the shortest processing time (SPT) and early due date (EDD). Sum of difference value (SDV) was calculated from an absolute difference in time among OP1, OP2 and OP3. The SDV value of unbalanced workload of HGBA3 was lower than any other methods.

In real business industries, the due date and production processing time are uncertain so we created two patterns of noise uncertainty in this study. The first pattern, production process time was randomly ranged between [-1, 1] via the uniform distribution add to average process time. The second pattern, the due date could be changed by customer. The random value ranged between [-5, 5] via the uniform distribution which was designed for adjusting the due date before balancing workload in each operation unit. From tables 3 and 4, performance of HGBA2 was better than other methods in minimizing SDV when the process was uncertain.

**TABLE 1.** Data from company

Clean room Apparel								
No of job	Start	S	M	L	XL	Total	Lead time	Due date
1	1/3/2017	1	110	153		264	17	1/20/2017
2	1/4/2017		192	100	19	311	11	1/15/2017
3	1/6/2017	81	50	26	63	220	13	1/19/2017
4	1/7/2017		58	48	12	118	18	1/25/2017
5	1/8/2017		40		25	65	21	1/29/2017
6	1/9/2017	3	1			4	18	1/27/2017
7	1/10/2017	5	110	25	35	175	14	1/24/2017
8	1/14/2017		105	20	63	188	19	2/2/2017
9	1/16/2017		15	15		30	20	2/5/2017
10	1/20/2017		1	9	10	20	16	2/5/2017
11	1/21/2017		66	2	2	70	21	2/11/2017
12	1/22/2017	5		40	20	65	12	2/3/2017
13	1/23/2017		55	100	40	195	10	2/2/2017
14	1/25/2017		148		30	178	16	2/10/2017
15	1/27/2017		115			115	12	2/8/2017
16	1/29/2017	174				174	20	2/18/2017
17	1/30/2017	12	15	15	4	46	20	2/19/2017
18	1/31/2017			108	47	155	15	2/15/2017
19	2/3/2017				38	38	16	2/19/2017
20	2/4/2017	320				320	17	2/21/2017
21	2/5/2017			170		170	20	2/25/2017
22	2/7/2017		112	91	4	207	19	2/26/2017
23	2/8/2017		100			100	19	2/27/2017
24	2/9/2017	2	24	29	13	68	18	2/27/2017
25	2/11/2017	40	21	9	5	75	15	2/26/2017
26	2/12/2017	8	6	6	1	21	17	2/29/2017
27	2/13/2017	2	5	71	15	93	15	2/28/2017
28	2/14/2017		130	20	67	217	15	2/29/2017
29	2/15/2017			98	33	131	13	2/28/2017
30	2/17/2017		14			14	19	3/7/2017

**TABLE 2.** Summary workload (day) for each operation unit from the nominal demand

Operation Unit	OP1	OP2	OP3	SDV
HGBA1	24.42	26.54	25.98	4.24
HGBA2	25.7	25.72	25.52	0.4
HGBA3	25.72	25.64	25.58	0.28
FCFS	26.84	24.34	25.76	5
SPT	25.28	25.82	25.84	1.12
LPT	22.22	27.52	27.2	10.6
EDD	24.24	27.52	25.18	6.56

**TABLE 3.** Summary workload (day) for each operation unit from the first uncertain pattern (Adjust process time)

Operation Unit	SPT	HGBA1	HGBA2	HGBA3
OP1	24.47	25.377	26.785	25.049
OP2	26.366	27.568	26.366	26.505

OP3	29.124	27.014	26.809	28.405
SDV	9.31	4.38	0.89	6.71

**TABLE 4.** Summary workload (day) for each operation unit from the second uncertain pattern (adjust due date time)

Operation Unit	SPT	HGBA1	HGBA2	HGBA3
OP1	32.46	25.18	25.52	25.18
OP2	23.42	25.88	25.86	25.88
OP3	21.06	25.88	25.56	25.88
SDV	22.80	1.40	0.68	1.40

## 5 Conclusions

This study proposed the algorithmic procedures of the GBA to simulate the parameter of number of players, number of teams and number of players per team. Various hybridisations applied to assess performance and

created new possible solution methods. The hybrid techniques apply a random location swap of jobs for balancing workload. The new hybrid method called HGBA2 is a compromise tools for this target. The hybrid technology is a new way to increase the performance of original techniques to find better solution. To confirm the performance of our new method, it should apply to solve other combinatorial problems such as quadratic assignment problem and travelling sales man problem. Also, various types of production lines can be considered, such as mixed-model lines, parallel stations, U-shaped lines, etc. The algorithm parameters should be optimised by means of the design and analyses of experiments for finding suitable parameter levels when solving complex problems. Future studies should determine whether other proposed hybrid metaheuristic algorithms can be used for solving this problem as well as enhancing the speed of convergence. In addition, other rules of the custom training function seem challenging during searching the optimum.

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