Advances in Intelligent Systems and Computing 620

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Sara Rodríguez
Gabriel Villarrubia
Pedro Faria
Paweł Sitek
Javier Prieto *Editors*

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e-mail: kacprzyk@ibspan.waw.pl

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Preface

Nowadays, most computing systems from personal laptops/computers to cluster/grid/cloud computing systems are available for parallel and distributed computing. Distributed computing performs an increasingly important role in modern signal/data processing, information fusion and electronics engineering (e.g. electronic commerce, mobile communications and wireless devices). Particularly, applying artificial intelligence in distributed environments is becoming an element of high added value and economic potential. Research on Intelligent Distributed Systems has matured during the last decade and many effective applications are now deployed. The artificial intelligence is changing our society. Its application in distributed environments, such as the Internet, electronic commerce, mobile communications, wireless devices, distributed computing, and so on is increasing and is becoming an element of high added value and economic potential, both industrial and research. These technologies are changing constantly as a result of the large research and technical effort being undertaken in both universities and businesses.

The 14th International Symposium on Distributed Computing and Artificial Intelligence 2017 (DCAI 2017) is a forum to present applications of innovative techniques for solving complex problems in these areas. The exchange of ideas between scientists and technicians from both academic and business areas is essential to facilitate the development of systems that meet the demands of today's society. The technology transfer in this field is still a challenge and for that reason this type of contributions will be specially considered in this symposium. This conference is the forum in which to present application of innovative techniques to complex problems. This year's technical program will present both high quality and diversity, with contributions in well-established and evolving areas of research. Specifically, 58 papers were submitted from over 21 different countries (Angola, Austria, Belgium, Brazil, China, Colombia, Denmark, Ecuador, France, India, Ireland, Italy, Japan, Malaysia, Mexico, Poland, Portugal, Spain, Switzerland, Taiwan, Tunisia, USA), representing a truly "wide area network" of research activity. The DCAI'17 technical program has selected 41 papers and, as in past editions, it will be special issues in JCR-ranked journals such as Neurocomputing, and International Journal of Knowledge and Information Systems. These special issues will cover extended versions of the most highly regarded works. Moreover, DCAI'17 Special Sessions have been a very useful tool in order to complement the regular program with new or emerging topics of particular interest to the participating community. Special Sessions that emphasize on multi-disciplinary and transversal aspects, such as *AI-driven methods for Multimodal Networks and Processes Modeling* and *Intelligent and Secure Management towards Smart Buildings and Smart Grids* have been especially encouraged and welcome.

This symposium is organized by the Polytechnic of Porto, the Osaka Institute of Technology and the University of Salamanca. The present edition was held in Porto, Portugal, from 21–23rd June, 2017.

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Part I
AI–driven methods for Multimodal Networks and Processes Modeling

Optimization of urban freight distribution with different time constraints - a hybrid approach

Paweł Sitek, Jarosław Wikarek, Tadeusz Stefański

Department of Control and Management Systems, Kielce University of Technology, Poland
e-mail: {sitek, j.wikarek, t.stefanski}@tu.kielce.pl

Abstract. The efficient and timely distribution of freight is critical for supporting the demands of modern urban areas. Without optimal freight distribution, urban areas could not survive and develop. The paper presents the concepts of hybrid approach to optimization of urban freight distribution. This approach proposed combines the strengths of mathematical programming (MP) and constraint logic programming (CLP), which leads to a significant reduction in the search time necessary to find the optimal solution and allows solving larger problems. It also presents the formal model for optimization of urban freight distribution with different types of time constraints. The application of the hybrid approach to the optimization of urban freight distribution is the primary contribution of this paper. The proposed model was implemented using both the hybrid approach and pure mathematical programming for comparison. Several experiments were performed for both computational implementations in order to evaluate both approaches.

Keywords: Urban Freight Distribution, Hybrid methods, Constraint Logic Programming, Mathematical Programming, Optimization, Presolving.

1 Introduction

Urban Freight Distribution (UFD) is the system and set of processes by which consumer goods are collected, packed, transported, and distributed within urban environments [1]. In general, the urban freight system can include airports, seaports, manufacturing facilities, and distribution centers/warehouses that are connected by a network railroads, roadways, highways and pipelines, that enable goods to get to their destinations. The principal challenge of UFD is the efficient and timely distribution of freight for supporting the demands of modern urban areas and functions. UFD is essential to supporting and developing international and domestic trade as well as the daily needs of local businesses and consumers. In addition, it provides large number of jobs and other economic benefits [2]. The problem of urban freight distribution is characterized by a large number of different constraints. Constraints concern the resources, capacity, transportation, time and so on. Particularly important in this context are time constraints. They relate to on-time delivery, transport time, working time of drivers and so on [3]. The main contribution of this research is the hybrid approach to the modeling and optimization of urban freight distribution problem. The formal op-

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timization model of the UFD problem was presented along with computational experiments for this model using the hybrid approach [3,4] and mathematical programming [5]. The application of the hybrid approach to the optimization of urban freight distribution is the primary contribution of this paper. The approach proposed offers: (a) finding optimal solution in a substantially shorter time than that needed by mathematical programming, (b) solving larger size models and (c) modeling other e.g., nonlinear and logic constraints, in addition to linear constraints.

2 Problem description

There is a UFD system that consists of depots/distribution center d ($d \in D$, D–the set of all depots). These depots supply delivery points (retailers, shops, etc.) o ($o \in O$, O–the set of all delivery points) by sending them shipments s ($s \in S$, S–the set of all shipments). A shipment may be a pallet / a bin /a package containing a variety of products for the delivery point. The depot can send some shipments (due to e.g. the maximum size of pallet / bin / packages) to the delivery point. The delivery point can get shipments from several depots. These shipments are delivered by courier / driver k ($k \in K$, K–the set of all couriers / drivers). Couriers are assigned to a specific depot / distribution center (due to e.g. the specific nature of transported goods that must match the specifics of the vehicle, e.g. refrigerated truck, tank truck etc.). The courier can deliver the shipments to several delivery points in one run of the route.

Shipments have specific dimensions / sizes. The courier can only take the number of shipments such that it does not exceed the capacity of his vehicle. There are known travel times between depots and delivery points and the time it takes to unload shipment at the destination (delivery point). It is assumed that there is no possibility of reloading shipments. Specify how to realize delivery (i.e. which couriers and in which order) from the depots to the delivery points to minimize the total travel time. Parameters and decision variables for mathematical model of UFD system are presented in table 1.

There may be additional time constraints:

- working time of a courier / supplier is not greater than time T.
- some delivery to the selected delivery points must be within a certain time window.

The objective function (1) is the minimization of all traveling times. Arrival and departure from the point i are ensured by constraint (2). If no items are to be carried on the route, a courier does not travel that route (3). If a courier k does not travel along a route, no shipments are to be carried on that route (4). At no route segment, courier k carries more shipments s than the allowable courier's vehicle capacity (5). Shipping must be downloaded from the depot d (6). Constraint (7) ensures delivery of shipments to the delivery points. Each courier k picked up the shipments s from a depot d (8). Constraint (9) defines a set of shipments s for the courier k. The selected shipment is delivered by only one courier (10). Constraint (11) determines the time of arrival of the courier k to the delivery point o. Other constraints determine the binarity of decision variables.

Table 1. Parameters and decision variables for mathematical model

Symbol	Description
	Parameters
Vs_s	Shipment volume (volumetric weight) *s* ($s \in S$)
Vk_k	Courier's vehicle volume *k* ($k \in K$)
TS_o	Unloading time at delivery point *o* ($o \in O$)
$SDO_{s,d,o}$	If the shipment *s* ($s \in S$) is delivered from depot *d* to the delivery point *o* then $SDO_{s,d,o}=1$ otherwise $SDO_{s,d,o}=0$
$DK_{d,k}$	If the courier *k* operates from the depot *d* than $DK_{d,k}=1$ otherwise $DK_{d,k}=0$
$TT_{i,j}$	Travelling time from the point *i* ($i \in D \cup O$) to the point *j* ($j \in D \cup O$)
WX	A large number quantity
	Decision variables
$X_{k,i,j}$	If courier *k* travels from point *i* to point *j* than $X_{k,i,j}=1$, otherwise $X_{k,i,j}=0$, ($k \in K$, $i \in O \cup D$, $j \in O \cup D$)
$Y_{k,i,j,s}$	If courier *k* travels from point *i* to point *j* carrying shipment *s* than $Y_{k,i,j,s}=1$, otherwise $Y_{k,i,j,s}=0$, ($k \in K$, $i \in O \cup D$, $j \in O$, $s \in S$)
$FX_{k,s}$	If shipment *s* is delivered by courier *k* then $FX_{k,s}=1$, otherwise $FX_{k,s}=0$ ($k \in K$, $s \in S$)
$TX_{k,i}$	A moment of time in which courier *k* arrives to the delivery point/depot *i* ($k \in K$, $i \in O \cup D$)

$$\sum_{k\in K}\sum_{i\in O\cup D}\sum_{j\in O\cup D} X_{k,i,j}\cdot TT_{i,j} \tag{1}$$

$$\sum_{j\in O\cup D} X_{k,i,j} = \sum_{j\in O\cup D} X_{k,j,i} \quad \forall\ k\in K, i\in O\cup D : DK_{d,k}=1 \tag{2}$$

$$X_{k,i,j} \le \sum_{s\in S} Y_{k,i,j,s} \quad \forall\ k\in K, i\in O\cup D, j\in O \tag{3}$$

$$Y_{k,i,j,s} \le X_{k,i,j} \quad \forall\ k\in K, i\in O\cup D, j\in O\cup D, s\in S \tag{4}$$

$$\sum_{s\in S} Vs_s\cdot Y_{k,i,j,s} \le Vk_k\cdot X_{k,i,j} \quad \forall\ k\in K, i\in O\cup D, j\in O\cup D \tag{5}$$

$$\sum_{k\in K}\sum_{j\in D} Y_{k,d,j,s} = 1 \quad \forall\ s\in S, d\in D, o\in O : SDO_{s,d,o}=1 \tag{6}$$

$$\sum_{k\in K}\sum_{j\in O\cup D} Y_{k,d,j,s} - \sum_{k\in O}\sum_{j\in O} Y_{k,o,j,s} = SDO_{s,d,o} \quad \forall\ s\in S, d\in D, o\in O \tag{7}$$

$$\sum_{k\in K}\sum_{i\in O} Y_{k,d,i,s,g} = SDO_{s,d,o} \quad \forall\ s\in S, d\in D, o\in O \tag{8}$$

$$\sum_{i\in O\cup D}\sum_{j\in O\cup D} Y_{k,d,i,s} \le WX\cdot FX_{s,k} \quad \forall\ s\in S, k\in K \tag{9}$$

$$\sum_{k\in K} FX_{s,k} = 1 \quad \forall\ s\in S \tag{10}$$

$$TX_{k,i} - WX\cdot(1 - X_{k,i,j}) + TT_{i,j}\cdot X_{k,i,j} \le TX_{k,j} \quad \forall\ k\in K, i\in O\cup D, j\in O \tag{11}$$

$$Y_{k,i,j,s} = \{0,1\} \;\forall\; k \in k, i \in O \cup D, j \in O \cup D, s \in S \tag{12}$$

$$X_{k,i,j} = \{0,1\} \;\forall\; k \in k, i \in O \cup D, j \in O \cup D \tag{13}$$

$$FX_{s,k} = \{0,1\} \;\forall\; s \in S, k \in K \tag{14}$$

3 Methodology – a hybrid approach

Numerous studies and our previous experience show that the constraint-based environment [6,7] offers a very good environment for representing the knowledge, information and methods needed for modeling and solving complex problems such as UFD. The constraint logic programming (CLP) is a particularly interesting option in this context. The CLP is a form of constraint programming (CP) in which logic programming is extended to include concepts from constraint satisfaction [6]. A constraint logic program contains constraints in the body of clauses (predicates). Effective search for the solution in the CLP depends considerably on the effective constraint propagation, which makes it a key method of the constraint-based approach. Constraint propagation embeds any reasoning that consists in explicitly forbidding values or combinations of values for some variables of a problem because a given subset of its constraints cannot be satisfied otherwise [7].

Based on [6-8] and our previous work [4,9,10], we observed some advantages and disadvantages of MP and CLP environments. An integrated approach of CLP and MP (mathematical programming) can help to solve optimization problems that are intractable with either of the two methods alone [11,12].

Both the MP and the finite domain CLP involve variables and constraints. However, the types of the variables and constraints that are used, and the ways the constraints are solved are different in the two approaches [5,12,13]. Both in MP and in CLP, there is a group of constraints that can be solved with ease and a group of constraints that are difficult to solve. The easily solved constraints in the MP methods are linear equations and inequalities over rational numbers. Integrity constraints are difficult to solve using mathematical programming methods and often the real problems of the MIP make them NP-hard. In the CP/CLP, domain constraints with integers and equations between variables are easy to solve. The system of such constraints can be solved over integer variables in polynomial time. The inequalities between variables, general linear constraints, and symbolic constraints are difficult to solve in the CP/CLP (NP-hard). This type of constraints reduces the strength of constraint propagation. The MP approach focuses mainly on the methods of solving and, to a lesser degree, on the structure of the problem. The data, however, is completely outside the model. The same model without any changes can be solved for multiple instances of data. In the CLP approach, due to its declarative nature, the methods are already in place. The data and structure of the problem are used for its modeling.

These observations and the knowledge of the properties of CLP and MP systems enforce the integration. Our approach differs from the known integration of CLP/MP

[12-14]. This approach, called hybridization, consists of the combination of both environments and the transformation of the model.

The transformation is seen as a presolving method. In general, it involves elimination from the model solutions space of those points which are unacceptable. It is determined on the basis of data instances and model constraints. For example, in UFD, based on analysis of instances of data stored in the form of facts, you can specify that shipments cannot be prepared by the given depots, which delivery points placed orders, etc. The general concept of the hybrid approach is shown in Figure 1.

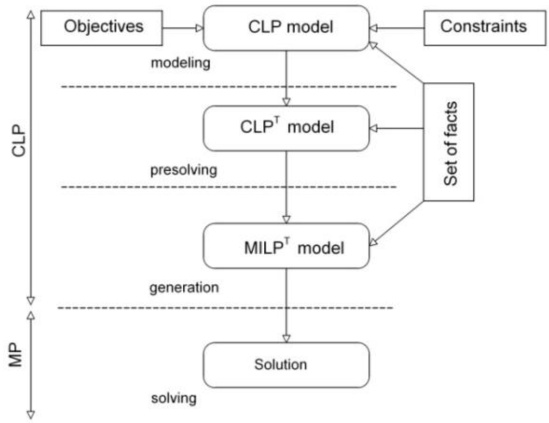

Fig. 1. The concept of the hybrid approach.

Figure 1 presents the general concept of the hybrid approach. This approach comprises several phases: modeling, presolving, generation phase and solving. It has two inputs and uses the set of facts. Inputs are the set of objectives and the set of constraints to the model of a given problem. Based on them, the primary model of the problem is generated as a CLP model, which is then presolved. The built-in CLP method (constraint propagation [7]) and the method of problem transformation designed by the authors [4,9] are used for this purpose. Presolving procedure results on the transformed model CLPT. This model is the basis for the automatic generation of the MILP (Mixed Integer Linear Programming) model, which is solved in MP (with the use of an external solver or as a library of CLP).

4 Computational experiments

All the experiments relate to the UFD with four depots (*d=1..4*), eight delivery points (*o=1..8*), eight couriers (*k=1..8*), and three sets of orders (*E(10), E(18), E(28)*). Computational experiments were carried out for the model (Section 2) implemented using mathematical programming and the hybrid approach. Experiments were made for different sets of orders and the introduction of various combination of additional time constraints *C1* (delivery by courier cannot exceed delivery time T=190 (15)) and *C2* (time window are taken into account (16)). The results are shown in Table 3 and Figure 2a, 2b. Analysis of the results clearly shows the superiority of the hybrid approach for use with UFD problems. The parameters for additional time constraints are presented in Table 2.

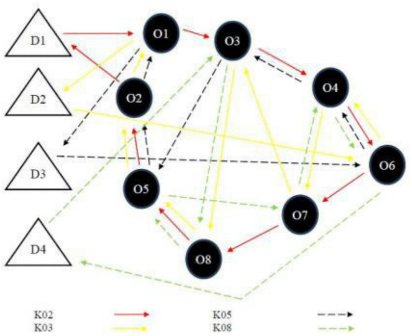

Fig. 2a. Optimal delivery network for *E9*

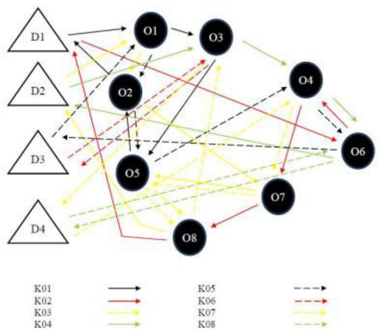

Fig. 2b. Optimal delivery network for *E12*

Table 2. Parameters for time constraints *C1* and *C2*

Symbol	Description
T	The time at which delivery must be carried out
$t1_{d,o}$	The beginning of the time window for delivery from the depot *d* to the delivery point *o*
$t2_{d,o}$	The end of the time window for delivery from the depot *d* to the delivery point *o*

$$TX_{k,i} \le T \; \forall k \in K, i \in D \tag{15}$$

$$Time\_delivery(d, o, t1_{d,o}, t2_{d,o}) \tag{16}$$

Table 3. Results of computational examples

E	Number of orders	Additional Constrains	MP				Hybrid approach			
			Fc	T	V_{int}	C	Fc	T	V	C
E1	10	---	195	341	12712	31461	195	21	1891	554
E2	10	*C1*	297	548	12712	31462	297	41	1891	555
E3	10	*C2*	195	359	12712	31469	195	22	1891	562
E4	10	*C1+C2*	302	378	12712	31470	302	48	1891	563
E5	18	---	340	541	22056	50168	340	30	2952	929
E6	18	*C1*	410	849	22056	50169	410	53	2952	930
E7	18	*C2*	349	573	22056	50176	349	33	2952	937
E8	18	*C1+C2*	425	604	22056	50177	425	36	2952	938
E9	28	---	508	755	33520	73430	508	42	4272	1416
E10	28	*C1*	659*	900**	33520	73431	659	63	4272	1417
E11	28	*C2*	509	734	33520	73438	509	48	4272	1424
E12	28	*C1+C2*	683*	900**	33520	73439	683	73	4272	1425

T Time of finding solution (in seconds) Fc Objective function
V_{int} The number of integer decision variables C The number of constrains
* Feasible solution (not found optimality) E Example
** Interrupt the process of finding a solution after a given time 1500 s

Compared with the MP method, the hybrid approach substantially reduced the size of the problem solved. The number of variables was reduced up to 8 times and constraints up to 56 times. And most importantly solution time was reduced up to 18 times. Moreover, for some examples you did not get the optimal solution using the MP in an acceptable time.

A detailed analysis of the results allows determining optimal delivery times, the effect of time constraints C1(15) and C2(16) on the optimal solution, and optimal delivery networks (routes, number of couriers, etc.) (Figure 2a and Figure 2b).

5 Conclusion

This paper provides a robust and effective hybrid approach to modeling and optimization of the UFD problem. The hybrid approach incorporates two environments (i) mathematical programming and (ii) constraint logic programming. The use of the hybrid approach allows the optimization of larger size problems within a shorter time compared to mathematical programming (Table 3). It also makes it easy to model all types of constraints and store data in the form of a set of facts. The data storage in the form of a set of facts allows easy integration of the proposed hybrid approach with database systems, data warehouses, and even flat files, e.g. XML, which provides high flexibility to the hybrid approach.

In the versions to follow, implementation is planned of other additional constraints (e.g. two couriers cannot be at a given delivery point at the same time, different categories of delivery points are introduced, etc). Additionally, the hybrid approach is planned to be complemented with fuzzy logic [15] and to be applied to project management [16] and complex systems [17].

The integration of CLP with metaheuristics such as GA (Genetic Algorithms) and ACO (Ant Colony Optimization) within the hybrid approach is also planned to enable solving problems of industrial size, which would be difficult to solve using the CLP/MP hybrid approach. It is also considering development of models to take account product demand interdependencies [18]. In the future it is planned to integrate proposed model with ERP and APS systems [19] and as a cloud internet application [20].

6 Reference

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Artificial bee colony algorithms for two-sided assembly line worker assignment and balancing problem

Mukund Nilakantan Janardhanan [1*], Zixiang Li[2], Peter Nielsen[1], Qiuhua Tang[2]

[1]Department of Mechanical and Manufacturing Engineering, Aalborg University, Denmark

Email: {mnj, peter}@m-tech.aau.dk

[2]Industrial Engineering Department, Wuhan University of Science and Technology, Wuhan 430081, Hubei, China

Email: zixiangli@126.com, tangqiuhua@wust.edu.cn

Abstract. Worker assignment is a new type of problem in assembly line balancing problems, which typically occurs in sheltered work centers for the disabled. However, only a few contributions consider worker assignment in a two-sided assembly line. This research presents three variants of artificial bee colony algorithm to solve worker assignment and line balancing in two-sided assembly lines. The utilization of meta-heuristics is motivated by the NP-hard nature of the problem and the chosen methods utilize different operators for onlooker phase and scout phase. The proposed algorithms are tested on 156 cases generated from benchmark problems. A comparative study is conducted on the results obtained from the three proposed variants and other well-known metaheuristic algorithms, such as simulated annealing, particle swarm optimization and genetic algorithm. The computational study demonstrates that the proposed variants produce more promising results and are able to solve this new problem effectively in an acceptable computational time.

Keywords: Assembly line balancing; two-sided assembly line; worker assignment; artificial bee colony; metaheuristics

1. Introduction

Extensively industry is using assembly lines to assemble different types of products, where a set of tasks is allocated to workstations and each workstation is assigned with one or several workers. In any real application, the problem of worker assignment requires consideration due to the different skills of the workers. This situation has been studied for sheltered work centers for the disabled [1, 2], where disabled workers might need more times to operate certain tasks or even are incapable of operating some tasks. The current state of task allocation mechanisms followed in assembly line balancing problems presently ignores this situation. Worker assignment and task allocation results in a new integrated assembly line worker assignment and balancing problem, which contains two interacted sub-problems. The worker assignment problem determines the

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assignment of the workers on workstations and the assembly line balancing problem allocates tasks to workstations while satisfying different constraints.

Two-sided assembly lines are widely applied in automobile industries to assemble large-size high-volume products. In this type of line, workers operate tasks on two-faced workstations, referred to as mated-stations, in parallel [3, 4]. In this research worker assignment and balancing of a two-sided assembly line are taken into account simultaneously, a new integrated two-sided assembly line worker assignment and balancing problem (TALWABP) is proposed.

Even though there are plenty of contributions regarding two-sided assembly line balancing problems (TALBP) or worker assignment in one-sided assembly line, to the author's best knowledge there is no reported research on TALWABP where cycle time minimization is considered. Hence, this paper presents a first approach to solve the TALWABP with the objective of minimizing the cycle time. As a common objective function, the cycle time minimization criterion has great applications for the reconfiguration of the installed assembly lines[5]. A simple balancing problem in an assembly line is classified as NP-hard[4]; the considered problem also falls under this category due to the additional complexity incorporated. Hence, there is a need to use optimization techniques such as constraint programming and metaheuristics to solve large problem instances [1, 6, 7]. In this paper, several variants of the artificial bee colony (ABC) algorithm are developed to tackle the problem. A set of benchmarks are generated based on the benchmarks available in [8]. A comparative study on the proposed algorithms and three other well-known metaheuristics is presented and discussed in detail to demonstrate the performance of the proposed algorithms.

The reminder of the paper is organized as follows. Section 2 presents the problem description. Section 3 presents the details of the proposed algorithms. The comparative study and the statistical analysis are presented in Section 4. Finally, Section 5 concludes this research and suggests several future directions.

2. Problem definition

To scope the problem, we consider a set of assumptions as follows:

1) Workers have different skills and the operation times of tasks depend on the assigned workers.

2) All workstation is assigned a worker and the worker number is equal to the workstation number.

3) Some workers are incapable of operating some tasks and the corresponding operation times are set to a very large number when this situation happens.

In TALWABP, there is a special constraint on the preferred directions of tasks, referred to as direction constraint. Direction constraints can be grouped into three general types: L-type tasks, R-type tasks and E-type tasks. L-type tasks are allocated to the left side, R-type tasks are allocated to the right side and E-type tasks can be allocated to the left or right side[9]. In addition, there is a special condition for tasks on a mated-station, which is the existence of sequence-depended idle time[5]. Sequence-depended idle time is due to the precedence constraint and utilization of two sides, and can be reduced by optimizing the task sequence on each workstation. Taking the sequence-depended idle time into account, our solution to the TALWABP optimizes not only the worker assignment and task allocation to workstations, but also the task sequence on each workstation. An example of worker assignment and task allocation on two-sided assembly line is depicted in Fig.1. In this figure, two facing workstations on the left side and right side comprise a mated-station. For instance, workstation (1, 1) and workstation (1, 2) comprise mated-station 1. Each workstation is assigned a worker and there are four workers on the four workstations. Two workers on a mated-station operate the allocated tasks simultaneously. Two-sided assembly line balancing determines the detailed allocation of tasks on each mated-station while worker assignment assigns the best-fit worker to each workstation.

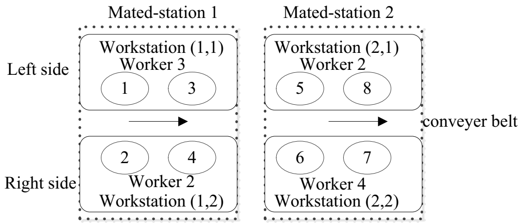

Fig.1 Worker assignment and task allocation on a two-sided assembly line

3. Proposed Methodology

Artificial Bee Colony (ABC) is one of the recently developed metaheuristic algorithm which has shown promising results for solving two sided assembly line balancing problem[5, 10] due to the faster convergence rate and there are only few parameters to be fine-tuned. This section first describes the procedure of the basic ABC algorithm, subsequently describes the proposed encoding and decoding policies along with the details of several variants of ABC algorithm.

3.1 ABC procedure

When solving optimization problems utilizing ABC algorithms, each solution is regarded as a food source and the fitness of an individual is referred to as the nectar amount. A pseudocode example of the ABC algorithm is presented in Fig. 2. Three groups of bees in the swarm search for the best food source, namely employed bees, onlookers and scouts. Employed bees exploit the nectar sources and provide the food sources' information to onlookers. Onlooker select food sources to exploit which emphasize intensification. The scout carries a random search to achieve a new food source to emphasize exploration. The procedure of the ABC algorithm is clarified in the following, where PS is the number of employed bees or onlookers. It should be noted that the number of employed bee is equal to onlookers and an onlooker becomes a scout.