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Modified artificial bee colony algorithm for scheduling optimization for printed circuit board production

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ABSTRACT

The production scheduling of placement machines strongly influences the efficiency of printed circuit board (PCB) production. This study focuses on the scheduling optimization for PCB production, that is, on maximizing throughput and minimizing total assembly time and head moving distance. Three problems—the automatic nozzle changer (ANC) assignment problem, the nozzle assignment problem, and the component pick-and-place sequence problem—are investigated using a modified artificial bee colony algorithm (MABCA) to enhance the production efficiency of placement machines.

The proposed scheduling optimization algorithm comprises three phases. First, the proportional distribution method is applied to optimize ANC assignment. Second, considering the component height as well as the pick, simultaneous pickup, and component shape restrictions, the MABCA generates the nozzle assignment. Third, under the constraints of place restriction and the predetermined nozzle assignment, the MABCA and the 2-opt algorithm generates the place sequence with the minimal PCB assembly time. Finally, the proposed algorithm is experimentally demonstrated. The average number of pickups in the solutions generated by the proposed method, the onsite engineer, and two related studies are 159.3, 167.2, 208.6, and 210.6, respectively. The proposed approach yields the least PCB assembly time. The average total assembly time (T_{total}) improved between on-site engineer and the proposed MABCA is 4.08%.

1. Introduction

Rapid technological advances have spurred the electronics industry and in turn the electronic parts manufacturing–related industries, placing them among the most active industries worldwide. Enhancing the efficiency of printed circuit board (PCB) production, in which the critical constraint is the scheduling of placement machines, has become a crucial issue in the electronics industry. Scheduling optimization for placement machines, which usually entails solving the feeder assignment problem, the nozzle assignment problem, and the component pick-and-place sequence problem, has been widely investigated. Neammanee et al. [1] applied a memetic algorithm (MA) for optimizing the scheduling of a single placement machine. Compared with commonly used distribution rules, MAs present more effective solutions but involve high computational costs. Tiemei et al. [2] combined improved shuffled frog-leaping algorithm and tabu search to significantly enhance production efficiency and to obtain an optimal place sequence. Sun et al. [3] used genetic algorithms (GAs) and greedy algorithms to optimize pick sequence; they maximized the number of simultaneous pickups and mutation and selection operations and evaluated the performance of each scheduling solution in terms of total assembly time. Du et al. [4] proposed hybrid GAs (HGAs), a combination of heuristic algorithms and GAs, to optimize the efficiency of PCB assembly and evaluated the total moving distance for each feasible solution. The aforementioned studies have focused on the feeder assignment and component pick-and-place sequence problems.

Ashayeri et al. [5] and Chen and Shen [6] applied linear programming and heuristic algorithms to reduce the number of nozzle exchanges, the nozzle work load, and the moving distance as well as to maximize the moving speed. Jiang et al. [7] investigated the component place sequence problem in multihead placement machines as a traveling salesman problem (TSP) [8] by using an improved

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Table 1
Summary of studied problems of related references.

Authors	Methods	Pick and place sequence	component height	simultaneous pickup	component shape
Neammanee et al. [1]	memetic algorithm	√			
Tiemei et al. [2]	shuffled frog-leaping algorithm and tabu search	√			
Sun et al. [3]	genetic algorithms and greedy algorithms	√		√	
Du et al. [4]	heuristic algorithms and genetic algorithm	√			
Ashayeri et al. [5]	linear programming heuristic algorithms	√			
Chen and Shen [6]					
Jiang et al. [7]	ant colony algorithm	√			
Lin et al. [9]	genetic algorithms	√			
Zhu et al. [10]	differential evolution algorithm				
Jiang et al. [11]	MAX–MIN Ant System	√			
Chen et al. [12]	diversification perturbation operator mutation operator modified tabu search	√			
Loh et al. [13]	genetic algorithm	√			
Our study		√	√	√	√

ant colony algorithm. Lin et al. [9] used GAs to solve the TSP and evaluated the solutions in terms of total assembly time. Zhu et al. [10] employed a differential evolution algorithm to improve total assembly time. By using a MAX–MIN Ant System, Jiang et al. [11] proposed a novel optimization method to resolve the TSP and the component place sequence problem in order to enhance component placement speed. Chen et al. [12] analyzed the component place sequence problem by using diversification perturbation operator and mutation operator as well as a modified tabu search and successfully reduced placement speed. Loh et al. [13] simultaneously solved feeder assignment and component sequencing problems by GA. The aforementioned studies have focused on the nozzle assignment and the component pick-and-place sequence problems and have approached the place sequence problem as a TSP. To decrease complexity, most studies have ignored such restrictions as component height, pick-and-place, simultaneous pickup, and component shape restrictions as well as time costs of nozzle change. Table 1 displays the discussed problems of related studies.

Kechadi et al. focused specifically on modeling a cyclic job shop problem and developed an efficient neural network approach to minimize the cycle time of a schedule [14]. An artificial immune system (AIS) was proposed to minimize the total completion time for a two-stage multi-machine assembly scheduling problem [15]. Except the field of scheduling optimization, some of the importance of optimization and optimized values in other fields are listed below. Valipour [16] has studied the variations of land use and irrigation for next decades under different scenarios to establish a link for more important parameters in agricultural water management. The evolution of the major achievements in water lifting devices on the modern technologies was discussed [17]. A forecasting model of monthly rainfall was created by studying the effect of the length of the recorded data. Determining the proper length of rainfall month in each climate condition for agriculture schedule is recommended [18]. A study developed and compared several models on a spatial and temporal estimation of potential evapotranspiration according to the peak and low events and climate change alarm [19]. The annual precipitation was forecast by a non-linear autoregressive neural network (NARNN), non-linear input–output (NIO) and NARNN with exogenous input (NARNNX) [20].

This study considers the following hardware restrictions: (1) component height restrictions, (2) time costs of nozzle change, (3) pick restrictions, (4) place restrictions, (5) simultaneous pickup restrictions, and (6) component shape restrictions. A modified arti-

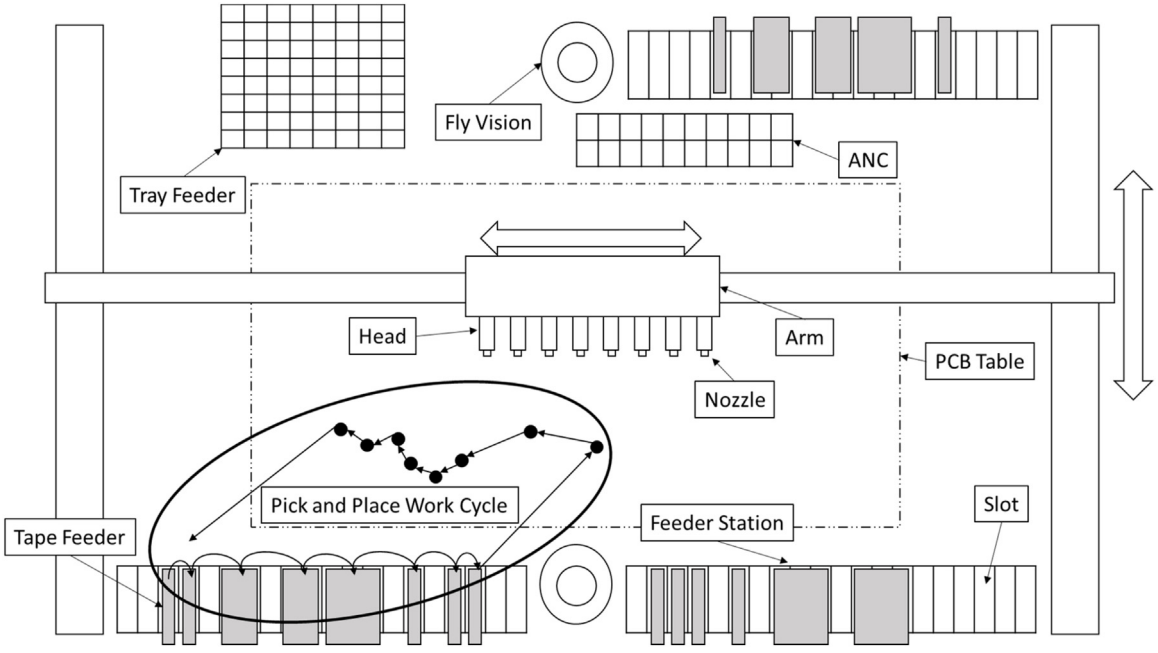

Fig. 1. Machine architecture.