Response Letter

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Manuscript Details
Title: A Scan-based Hierarchical Heuristic Optimization Algorithm for PCB Assembly Process
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Authors' Response

We sincerely appreciate the Editor-in-Chief, the Associated Editor and all Reviewers for their thorough reading and insightful advice that helped us improve the manuscript's quality. The major change of this submission is to reformulate the mathematical model of the PCB assembly process, refine the relevant algorithm description, and supplement the comparison experiments with the optimal solution of the reformulated model. Additionally, we have modified some figures and improved the English expressions in the manuscript. We have listed the reviewers' comments below in *italicized font* with orange text and numbered the specific concerns. Our response is given in normal font, and the changes/additions to the manuscript are given in the blue text (The excerpts from the manuscript are underlined). We sincerely hope this revised version is considered for publication in *IEEE Transactions on Industrial Informatics*. The following is a detailed description of how we address the reviewers' concerns.

Content

Response to the Associate Editor

Dear Associate Editor,

Thank you very much for the prompt and efficient handling of our manuscript. We greatly appreciated the constructive comments and valuable advice from you and all the Reviewers. These comments have helped us to further revise the manuscript and refine the details. Reviewers #1, #2, and #3 have made numerous valuable suggestions for this manuscript from different perspectives that help us improve the technicality, presentation, and precision of our work. We are especially grateful to Reviewer #3 for pointing out the problems of mathematical model that have promoted further research. Point-by-point responses to these comments can be found on the following pages.

The research on the optimization of the PCB assembly process is a challenging subject, and we believe that what is proposed in the manuscript is of great application. The results described in this manuscript are more innovative than the existing studies in terms of mathematical models and algorithm design. The newly proposed mixed-integer linear model considers the factors affecting the assembly efficiency more completely, and its optimal solution could be a benchmark for the algorithm design. The hierarchical scan-based heuristic algorithm proposed in this paper outperforms previous studies in terms of both the solution's quality and the consideration of practical application scenarios. We sincerely hope that the editor and the reviewers will take your valuable time to review the manuscript again, and we hope that our humble work will have the opportunity to be viewed by potential readers that helps to further research in this field. Thank you once more for your time and effort!

Best wishes,

Authors of the manuscript

Response to the Reviewer 1#

1. *A more thorough description of where the scan-based notion is mirrored should be provided, as the work described in this research is a hierarchical scan-based heuristic algorithm design.*

Response: Thanks for your advice. The first two algorithms proposed in this paper are both related to the scanning process, which is primarily reflected in the scanning of the feederbase pick-up process by the heads, and the heuristic refers to the strategy employed for feeder arrangement and component pick-up during the scanning process. To emphasize the scan-based idea, we have revised the relevant paragraphs of the algorithm description. This has been described in the manuscript, which includes but is not limited to:

(a) The first paragraph of Section III-B, "… The basic idea of feeder allocation heuristic described in Algorithm 1 is assigning the feeders while scanning the feederbase under the constraint of the nozzle pattern.".

(b) The first paragraph of Section III-C "… Similar to feeder allocation produces, each head aligns to a slot starting from different pick-up slots.".

In the description of Algorithm 1 and Algorithm 2, the framework of the algorithm is to place the head to complete the scanning process from left to right. The description of heuristic scanning in the manuscript has been adequate.

2. *The description of the PCB assembly process is oversimplified. The essential assembly operations and its impact on the assembly efficiency should be discussed.*

Response: Thanks for your advice. We have revised the description of the PCB assembly process in the third paragraph of Introduction Section-I as follows:

As shown in Fig. 2, the surface mount process consists of six different types of operations, and the dashed-line framed portion includes a PAP cycle, which is its fundamental unit. The nozzle change, component pick-up, and component placement processes in a PAP cycle take substantial time, and the algorithm can optimize the first two processes. More specifically, by combining multiple head motions, the pick-up operation could be more effective, and the nozzle changes are connected to the sequence of component pick-up. The dumping operations caused by image processing errors are exceptions and are not considered in this paper.

We believe that a combination of Fig. 2 and the explanation can adequately describe the PCB assembly process, and the impact of the assembly operations on productivity is described in Section II-B:

The surface mount process is accomplished by a complex series of motions that work together. The target of minimizing the assembly time depends on the gantry traveling distance, simultaneous pick-ups, and nozzle changes, which are the sub-objectives. The coupling of sub-objectives is reflected in improving the number of simultaneous pick-ups, which may bring additional nozzle change. The distance of the gantry traveling relies on the pick-up and nozzle changes operations.

3. *There is no instance support for the algorithm's flexibility about the specialized requirements for*

operators of contribution 3 mentioned in the Introduction.

Response: Thanks for your comment. We have provided the instance support that the proposed algorithms support the specialized requirements of pre-assigning feeders (Algorithm 1), assigning nozzle to heads (Algorithm 2), and prohibiting feeder slots (Algorithm 3) in Section III-E.

4. *Constraint (14) mentions that "simultaneous pickup happens in slot"; however, this statement is unclear. The constraint's definition should be clarified.*

Response: Thanks for your comment. The mathematical model proposed in this paper has been reformulated, and the mathematical expression about pick-up is given in Constraint (14)

$$e_{sk} \leq \sum_{i \in I} \sum_{h \in H} x_{i[s+(h-1)\cdot\tau]kh} \leq M \cdot e_{sk} \quad \forall s \in S, k \in K$$

We convert the pick-up slot equivalent to the slot where the left-most head is aligned, and binary variable e_{sk} (= 0 or 1) to count whether the equivalent slots s in cycle k have heads for pick-up operations and evaluate the assembly efficiency by the total number of pick-ups rather than the number of simultaneous pick-ups. Please refer to clauses 13 and 14 for a detailed description of the model and its decision variables.

5. *It is recommended that the criteria of the component assignment should be combined with the procedure in the algorithm flow for illustration.*

Response: Thanks for your advice. To facilitate the understanding of the connection between the criterion and the algorithm design, we provide the following additional explanation in the second paragraph of Section III-C: "Algorithm 2 describes the implementation of the component assignment. Each round determines the type of component assigned to heads with unpicked placement point and the related cycle groups. A "cycle group" is a set of consecutive PAP cycles with the same component assignments. It should be mentioned that the scanning-based pick-up procedure tries to maximize the number of simultaneous pick-ups while minimizing the expense of nozzle changes. The component assignment heuristic is forward-looking, which means that the single-head component assignment prejudges its impact on subsequent assignments. This is principally reflected in the following two aspects: the first is to assign just those components that improve the overall objective, and the second is the long-short term objectives. As for long-short term objectives implemented in Algorithm 3, the long-term objective is simultaneously picking up components from all aligned slots until one is empty. The short-term goal is greedily picking up all components from the aligned slots. The current component assignment result is the short-term objective, and its effect on pick-up efficiency as a whole is the long-term objective. The long-short term objective is the weighted sum of these two."

6. *A flow chart of the PAP sequence heuristic method is advised to be added.*

Response: Thanks for your advice. We are grateful to the reviewer for this suggestion and reorganized the content of the explanation of the PAP sequence heuristic method as 'The pick and placement routes schedule make up the PAP route schedule problem. In the case of the feeder allocation and component assignment are determined, the pick-up procedure calls for picking up components from each preset slot in a single direction on the feederbase. Algorithm 4 shows the process of beam search, which is utilized to solve the placement route schedule problem by retaining multiple potentially optimal solutions based on greedy search. The placement process can be thought of as a constrained vehicle route schedule problem with capacity constraints and candidate placement points constraints imposed by the component assignment. The dynamic programming is employed to determine the placement sequence in each cycle, which is efficient with a limited number of placement points.'. We have adopted a more straightforward way to explain the PAP sequence heuristic as follows.

Algorithm 1: PAP Sequence Heuristic

Input : PCB data with coordinate (X_p, Y_p) of point p, component assignment $\mathcal{C}$ and $\mathcal{K}$
Output: PAP sequence $\mathcal{P}$

Initialize $B = \{1, 2, \cdots, \beta\}$ as the beam set where β is the beam width ;
Initialize $\mathcal{P}, \mathcal{P}_b$ as empty matrix and $\mathcal{T}_b$ as $1 \times |H|$ matrix, $\forall b \in B$;
for $\mathcal{H}^{CP} \in \mathcal{C},\ k \in \mathcal{K}$ **do**
  while $k \neq 0$ **do**
    Initialize $\beta \times 2$ matrix $\mathcal{W}$ as the coordinates of the β leftmost unplaced points ;
    for $h \in H$ **do**
      Select β points which nearest to $\mathcal{W}(b)$, $\forall b \in B$ with component type $\mathcal{H}^{CP}(h)$;
      Select β points among β^2 candidates with minimal Chebyshev distance as $p_1, \cdots, p_b$;
    end
    $k \leftarrow k - 1, \mathcal{W}_b \leftarrow [X_{p_b}, Y_{p_b} - (h-1) \cdot \rho]$, $\mathcal{T}_b(h) \leftarrow p_b, \forall b \in B$;
    PAP sequence schedule for $\mathcal{T}_b$ using dynamic programming and attach $\mathcal{T}_b$ to $\mathcal{P}_b$ with column direction, $\forall b \in B$;
  end
end
$\mathcal{P} \leftarrow \mathcal{P}_b$ with minimal Chebyshev distance $\forall b \in B$

The above has been supplemented in the manuscript.

7. *The extension of the suggested algorithm is described in Section III-E. There should be more explanation to show how the algorithm is preferable in terms of extensionality.*

Response: Thanks for your advice. The extension of the algorithm proposed in this paper is mainly reflected in the following aspects:

(a) The proposed algorithm in this paper is applied to various feeder allocation scenarios, including feeder pre-allocation prior to optimizing, feeder re-allocation, and allocation of different feeder types.
(b) The algorithm proposed in this paper can be applied to various types of machines with linearly arranged machine heads.
(c) In practice, nozzle change and pick-up efficiency can be balanced by adjusting weight parameters.
(d) The proposed algorithm can meet various customization needs, as described in clause 3.

All the above are reflected in the newly revised manuscript.

Response to the Reviewer 2#

8. *The proposed approach reveals good results when compared to other methods. The reviewer didn't find any evidence of the computation time of the algorithms which could be important as an overall processing time.*

Response: Thanks for your comments. The computation time is determined by the algorithm complexity, PCB data, and experimental platform, which has been provided in the manuscript. In practice, in the case of low-volume orders and frequent data adjustments, operators often want to obtain an optimized result with a small cost of time-consuming.

9. *Minor English revision is advised.*

Response: Thanks for your advice. We have proofread the entire manuscript and revised the presentation of the content, including the literature review, PCB assembly process description, and algorithm explanation.

The minor English revision is listed below:

(a) Rewrite Paragraph 4~6 in Section I with respect to the problem description and literature review.

(b) Rewrite the part of B, C and D of Section IV with respect to the algorithm explanation, esp. the explanation of the component assignment heuristic.

(c) Revise "The design of the scan-based algorithms optimizes the significant sub-objective for feeder allocation and component assignment. The allocation heuristic arranges the feeders to slots as prerequisites of the component assignment. Then the feederbase scanning procedure adopts various criteria to determine the component assignment result. After solving the PAP sequence problem, the placement machine can finally complete the assembly process." to "<u>Then the component assignment heuristic determines the component type for each head with a variety of criteria and long-short term objective. Finally, the PAP sequence problem is solved using a modified beam search algorithm.</u>" (page 1, line 13 of Abstract).

(d) Revise "On our platform of placement machines, as shown in Fig. 4, algorithm verification is carried out. We transform the assembly time into the standard time-chip per hour (CPH) to provide a clearer comparison independent of the number of placement points." to "<u>Algorithm verification is done on our placement machine platform, which is shown in Fig. 4. We convert the assembly time into the standard time-chip per hour (CPH) to provide a clearer comparison independent of the number of placement points.</u>" (page 8 of Section IV).

Response to the Reviewer 3#

10. It is unclear why the model is non-linear. They are already using a large number of binary variable and "Big-M", so it is quite possible that the model can be linearized.

Response: Thanks for your comment. Since mathematical modeling is not the main topic of this study, our analysis of the previous model is incomplete. We apologize for drawing the hasty inference that the model is non-linear. In fact, in the previous model, the non-linear term is reflected in the calculation regarding the assembly time. We re-selected the decision variables associated with the model to build a linear model with the decomposition technique. After decomposition, both the pick-up model and the placement model are linear forms that can be solved using the optimizer Gourbi.

11. The heuristic has been implemented in Python on a simple Intel i7 computer; it is hard to believe that it is best compute environment to support operations of a considerably capital-intensive machine.

Response: Thanks for your comment. In most cases, the proposed optimization algorithm for PCB assembly processes is executed on the production site. The industrial computer used to operate the placement machine has a limited computing performance because of the stability requirements of the industrial application areas. In terms of computational performance, the industrial computer processor does not outperform the commercial and personal PC. As a result, the experimental setup employed in this work is appropriate. The computational time comparison findings show that the proposed algorithm has a superior search efficiency on the Intel i7 computer. This result applies to PCs with different processors as well.

12. Today optimization software like Gurobi can handle quadratic constraints and there are other MINLP solvers that can be applied. It is hard to trust a sweeping statement that the model can simply not be solved.

Response: Thanks for your comment. We apologize for the severe problem of the statement that the model cannot be solved. The relatively large number of decision variables involved in the PCB assembly process, as well as the mathematical model including the NP-hard problem of assignment problems and MTSP problem (the description of the new model is explained in Clause 14), both carry out difficulties for the solution of the problem. A more accurate statement would be that complex models cannot be solved in a reasonable amount of time, even with efficient solvers. The optimizer Gurobi is also used to solve the proposed model to further validate this statement.

13. The mixed integer model is not developed in a principled way. There is excess use of binary variables, when it can be reformulated with a lot fewer and in simpler terms.

Response: Thanks for your advice. We have reformulated the mathematical model and eliminated the redundant variables. The new decision variables in the model are listed below.

Variables	Description

g_k	binary var. =1 iff at least one point is picked and placed in cycle k
u_k	integer var. the number of slots that the gantry crosses over in cycle k
d_h	integer var. the number of nozzle change of head h
e_{sk}	binary var. = 1 iff component is picked up from equality slot s in cycle k
f_{si}	binary var. = 1 iff comp. type i is assigned to slot s
x_{iskh}	binary var. = 1 iff head h picks up comp. type i from slot s with head h
w_{pqka}	binary var. = 1 iff point q is placed after point p along with arc a in cycle k
y_{pkh}	binary var. = 1 iff point p is the first point placed with head h in cycle k
z_{pkh}	binary var. = 1 iff point p is the last point placed with head h in cycle k

Since the overall framework of the model has been changed, we have added some new decision variables. The variables used in the model have been adequately simplified. Here is a further explanation of the arc set A, each element of which is a tuple (h, l), indicating that the head l is placed after the head h. The arc set is used to determine the placement sequence.

14. The authors should revisit this paper in terms of an efficient math programming model. Use it to solve modest-sized problem instances, even if it cannot handle industrial-sized problems. This can also benchmark their heuristics and develop confidence that their method can be applied in industrial use. Alternatively, the authors can develop math programming decomposition models that will accompany optimality gap. At the current time there are significant contribution gaps.

Response: Thanks for your advice. We have reformulated the mathematical model of the PCB assembly process. Due to the intricacy of the surface mount process, it still takes a long time to solve moderately sized problems. Existing research on the modeling theory of the PCB assembly process either solves only subproblems, lacks careful consideration, or only applies to small-scale data. As a result, we propose an efficient decomposed mixed-integer linear model, which incorporates a pick-up model and a placement model. The index and set explanation are listed below.

Notation	Description
$i \in I$	Index of component type, $I = \{1,2, \dots \dots\}$
$j \in J$	Index of nozzle type, $J = \{1,2, \dots \dots\}$
$p, q \in P$	Index of (placement) point, $P = \{1,2, \dots \dots\}$
$h, l \in H, H_s$	Index of head, $H = \{1,2, \dots \dots\}$, H_s is the subset of H, which refers to the head set that can reach slot s
$a \in A$	Index of arc, $A = \{(h, l) \mid h \neq l, h \in H, l \in H\}$, $A_h = \{a \mid h \in a, a \in A\}$, $A_h^f = \{a \mid a(1) = h, a \in A\}$, $A_h^t = \{a \mid a(2) = h, a \in A\}$
$k \in K, K'$	Index of cycle, $K = \{1,2, \dots \dots\}$, $K' = \{1,2, \dots, \sum_{k \in K} g_k\}$, K is used to determine the number of cycles in the pick-up model, and K' is the cycle set of placement model.
$s, r \in S, S'$	Index of slot, $S = \{1,2, \dots \dots\}$, $S' = \{-\tau \cdot (H-1)+1, \dots, \lvert S \rvert\}$, S is the slot set, and S' is the equality slot set.

We will go over each equation of the newly proposed model in the manuscript below. The model descriptions can also be found in Section II of the manuscript.

(a) Pick-up Model

As for pick-up model with the objective

$$\min t_c \cdot \sum_{k\in K} g_k + t_n \cdot \sum_{h\in H} d_h + t_p \cdot \sum_{k\in K}\sum_{s\in S'} e_{sk} + t_m \cdot \sum_{k\in K} u_k$$

where t_c, t_n, t_p,and t_p are the average moving time for round trip, time for nozzle change operations, time for pick-up operations, and time for moving on the feederbase per-slot, respectively. The term of $\sum_{k\in K} g_k$ is used to calculate the number of cycles. To ensure the first few cycles of the surface mount process given top priory, there are

$$g_k \geq g_{k+1} \quad \forall k \in K\backslash\{|K|\}$$

$$\sum_{i\in I}\sum_{s\in S} x_{i[s+(h-1)\cdot\tau]kh} \leq g_k \quad \forall k \in K, h \in H$$

$$\sum_{s\in S}\sum_{h\in H}\sum_{k\in K} x_{iskh} = \psi_i \quad \forall i \in I$$

where ψ_i is the total number of placement point(s) of component type i, τ is the interval ratio of the adjacent heads and adjacent slots.

In terms of the consistency of the component's nozzle type and nozzle change calculations, there are

$$\sum_{i\in I}\sum_{h\in H}\sum_{s\in S} \mu_{ij} \cdot x_{i[s+(h-1)\cdot\tau]kh} \leq 1 \quad \forall k \in K, h \in H$$

$$d_h = \sum_{k\in K\backslash\{|K|\}} \left(\sum_{j\in J} \left| \sum_{i\in I}\sum_{s\in S} \mu_{ij} \cdot x_{iskh} - \sum_{i\in I}\sum_{s\in S} \mu_{ij} \cdot x_{is(k+1)h} \right| - 1 \right) \quad \forall h \in H$$

where μ_{ij}(= 0 or 1) represents the compatibility of component type i and nozzle type j.

When calculating the number of simultaneous pick-ups, there are

$$e_{sk} \leq \sum_{i\in I}\sum_{h\in H_s} x_{i[s+(h-1)\cdot\tau]kh} \leq M \cdot e_{sk} \quad \forall s \in S', k \in K.$$

When calculating the number of slots that the gantry crosses over, there are

$$u_k \geq s \cdot e_{sk} - r \cdot e_{rk} \quad \forall s, r \in S, k \in K.$$

In terms of the consistency of feeder allocation and component assignment, there are

$$f_{si} \leq \sum_{k\in K}\sum_{h\in H} x_{iskh} \leq M \cdot f_{si} \quad \forall s \in S, i \in I$$

where M is a sufficiently large number.

The limited capacity of feeder slots, the limited available number ζ_j of nozzle type j, and the limited available feeder number ϕ_i of component type i are reflected in

$$\sum_{i\in I} f_{si} \leq 1 \quad \forall s \in S$$

$$\sum_{i\in I}\sum_{h\in H}\sum_{s\in S} \mu_{ij} \cdot x_{iskh} \leq \zeta_j \quad \forall k \in K, j \in J$$

$$\sum_{s\in S} f_{si} \leq \phi_i \quad \forall i \in I.$$

(b) Placement Model

As for the placement model with the objective

$$min \sum_{k \in K'} \left\{ \sum_{p \in P} \sum_{h \in H} \lambda_{pkh}^{FW} \cdot y_{pkh} + \sum_{p \in P} \sum_{q \in P} \sum_{a \in A} \lambda_{pqa}^{PL} \cdot w_{pqka} + \sum_{p \in P} \sum_{h \in H} \lambda_{pkh}^{BW} \cdot y_{pkh} \right\}$$

where λ_{pkh}^{FW} is the moving time between the first point p and feederbase with head h in cycle c, λ_{pkh}^{BW} is the moving time between the feederbase and the last point p with head h in cycle c, and λ_{pqa}^{PL} is the moving time between the point p and point q along with arc a. The objective of the placement model is the total of the moving times except for the pick-up movement, which has been solved in the pick-up model.

In terms of the consistency of the pick-up model and placement model, there are

$$\sum_{q \in P} \sum_{a \in A_h} w_{pqka} = \sum_{i \in I} \sum_{s \in S} \eta_{ip} \cdot x_{iskh} \quad \forall k \in K', p \in P, h \in H.$$

where $\eta_{ip}(= 0$ or $1)$ represents the correspondence of component type i and placement point p.

Since each head is placed at most one point, there are

$$\sum_{p \in P} \sum_{q \in P} \sum_{a \in A_h} w_{pqka} \leq 2 \quad \forall k \in K', h \in H$$

$$\sum_{p \in P} \left(y_{pkh} + z_{pkh} \right) \leq 1 \quad \forall k \in K', h \in H.$$

In terms of the continuity of the placement task, i.e., the placement head is unique for each point, there are

$$\sum_{q \in P} \sum_{a \in A_h^t} w_{pqka} + y_{pkh} = \sum_{q \in P} \sum_{a \in A_h^f} w_{qpka} + z_{pkh} \quad \forall k \in K', p \in P, h \in H$$

$$y_{pkh} \leq \sum_{q \in P} \sum_{a \in A_h^f} w_{pqka} \quad \forall k \in K', p \in P, h \in H$$

$$z_{pkh} \leq \sum_{q \in P} \sum_{a \in A_h^t} w_{qpka} \quad \forall k \in K', p \in P, h \in H.$$

In terms of the uniqueness of the placement head to and from the feeder base and PCB path, there are

$$\sum_{p \in P} \sum_{h \in H} y_{pkh} = 1 \quad \forall k \in K'$$

$$\sum_{p \in P} \sum_{h \in H} z_{pkh} = 1 \quad \forall k \in K'.$$

In terms of the uniqueness of the entry edge and the leave edge of each point, there are

$$\sum_{k \in K'} \left(\sum_{h \in H} y_{pkh} + \sum_{q \in P} \sum_{a \in A} w_{pqka} \right) = 1 \quad \forall p \in P$$

$$\sum_{k \in K'} \left(\sum_{h \in H} z_{pkh} + \sum_{q \in P} \sum_{a \in A} w_{qpka} \right) = 1 \quad \forall p \in P.$$

To eliminate the subtour in each cycle, we introduce the intermediate continuous variables m_p, n_p

and v_{pq}, there are

$$m_p + \sum_{q \in P} v_{pq} - n_p - \sum_{q \in P} v_{qp} = 1 \quad \forall p \in P$$

$$v_{pq} \leq \sum_{k \in K'} \sum_{a \in A} (|P| - |K'| + 1) \cdot w_{pqka} \quad \forall p, q \in P$$

$$n_p \leq \sum_{k \in K'} \sum_{h \in H} (|P| - |K'| + 1) \cdot y_{pkh} \quad \forall p \in P$$

$$m_p \leq \sum_{k \in K'} \sum_{h \in H} (|P| - |K'| + 1) \cdot z_{pkh} \quad \forall p \in P.$$

All variables in the model of the manuscript are non-negative. The relevant section in the manuscript has been reorganized and revised based on the model above. The placement model is a variant of the classical multiple traveling salesman model with Gavish-Graves formulation but more decision variables. Therefore, we conclude the statement in clause 12: the complex models cannot be solved in a reasonable amount of time, even with efficient solvers.

We take several small-scale data as examples to benchmark the proposed heuristics, and the experimental results are as follows:

	Scale	Objective Value			Comput. time	
PCB	(*N*, *C*, *P*)	T_{scan}	T_{mip}	Gap	t_{scan}	t_{mip}
1-1	(1, 1, 14)	4.735	4.408	7.42%	0.29	323.60
1-2	(1, 1, 14)	4.314	3.833	12.55%	0.34	34.03
1-3	(1, 1, 14)	4.095	3.886	5.83%	0.20	984.10
1-4	(1, 1, 14)	4.720	4.165	13.33%	0.27	1117.84
1-5	(1, 1, 14)	5.793	5.170	12.05%	0.48	718.44
1-6	(1, 1, 14)	6.257	5.773	8.38%	0.59	5445.63
AVG				9.93%		

15. The abstract should be revised to be more impactful. The exact/quantitative measure of "better results" should be included to interest the reader.

Response: Thanks for your advice. We have revised the abstract with comparison of the mathematical model and mainstream study. That is, computational experiments show that the scan-based heuristic algorithm obtains near-optimal solutions with a gap of 9.93% averagely comparing with the proposed MIP model and provides efficiency improvement over the mainstream study.

16. The abstract font is not standard.

Response: Thanks for your comment. We have compared the font in the manuscript with the *IEEE template* and revised the font's color.

17. Page 2, column 1, line 38, etc should end with a period "etc.".

Response: Thanks for your comment. We have revised this item and double-checked the whole manuscript.

18. Page 2, column 2, lines 12 and 14, capitalize "section".

Response: Thanks for your comment. We have revised this item and double-checked the whole manuscript.

19. Avoid use of contractions (It's p. 4, col. 2, line 1; don't line 11, etc.)

Response: Thanks for the advice. We have checked all paragraphs in the manuscript with contractions and revised them.

20. Notations should be notation at almost every place in page 3.

Response: Thanks for your comment. We have double-checked all the notations used in the manuscript to ensure that their meanings have been explained.