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Original Article

Heuristic Solutions for Organized Ceramic Bowl Placement in Manufacturing Environments

Benchalak Maungmeesri[1], Yamin Thwe[2]

[1]*Department of Engineering Management, Suan Sunandha Rajabhat University, Bangkok, Thailand.*
[2]*Department of Mechatronics Engineering, Rajamangala University of Technology Thanyaburi, Thailand.*

[1]*Corresponding Author : benchalak.mu@ssru.ac.th*

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Abstract - *The challenge of the process involved in placing ceramic bowls during the firing process, a common occurrence in ceramic production, is addressed. Each ceramic item possesses a distinct shape and unique attributes. Given the dimensions of a shelf and a single ceramic piece, the objective is to determine the subset of items that maximize profit and can fit into the container while ensuring the items do not come into contact with each other. This research focuses on a ceramics company in Lampang, Thailand. One recurring problem in the planning and preparation of ceramics before the firing process involves a single shelf accommodating multiple items with varying dimensions. To address this intricate problem, a series of heuristics are employed successively, with each heuristic designed to solve a specific aspect of the problem. Large and small-sized ceramics are arranged in a specialized structure to ensure efficient use of the designated region of interest with a safe distance maintained during firing. The importance of algorithm performance is discussed and analyzed, and this approach is compared with several other algorithms currently in the literature. Comprehensive numerical trials demonstrate that the suggested heuristic technique is effective.*

Keywords - *Ceramic bowl, Optimization, Loading problem, Heuristic algorithm, Approximation algorithm.*

1. Introduction

The worldwide ceramic sector serves as evidence of the enduring attraction and adaptability of ceramic goods in various markets and cultures [1], [2]. Ceramics have reached an essential status in numerous facets of global artistic expression and daily life, finding use in intricate artwork as well as functional kitchenware [3], [4]. Thailand is a country that is well-known throughout the world for its rich cultural legacy, booming craft sector, and stunning natural resources, which bring in millions of tourists every year [5]. Of all the attractions in the nation, Lampang province uses its ceramic skills—especially in the production of plates and cups—to great use to entice visitors [6].

Lampang province emerged as a distinguished hub for ceramic production, where highly skilled artisans meticulously crafted a diverse array of pieces [7]. These range from intricately designed bowls to uniquely inspired artifacts, contributing to the province's reputation for excellence in ceramic artistry. The entire ceramic production process in Lampang operates with a keen emphasis on precision and expertise at every stage. Our study specifically zooms in on the initial phases leading up to the pivotal firing process [8], with a particular focus on geometric optimization techniques for arranging [9] ceramic bowls on flat shelves. The aim is to discern strategies that can significantly enhance workflow efficiency in this crucial aspect of ceramic production.

The creation of ceramic bowls involves a meticulous and multi-step process [10], with the final firing stage standing as a critical transformation from raw materials to finished, aesthetically pleasing products [11]. Before reaching this crucial point, workers in Lampang's ceramic factories encounter a significant challenge: arranging ceramics on refractory shelves [12], [13]**.** This step requires careful consideration to ensure that bowls of varying sizes and shapes are strategically positioned, preventing any unintended contact that could result in damage during subsequent production stages. Through the exploration of geometric optimization in this arrangement process, the goal is to streamline workflows, boost productivity, and maintain high quality [14], [15] associated with Thai ceramic craftsmanship. Automation with the use of artificial intelligence plays an important role in increasing efficiency in several fields, such as agriculture, disaster detection, healthcare, and also factories [16], [17], [18]. Efficiency in ceramic production is not solely an industrial concern but a vital element in meeting the demands of a dynamic market. Geometric optimization in the arrangement of ceramic bowls on flats emerges as a key factor influencing the overall workflow in Lampang's factories.

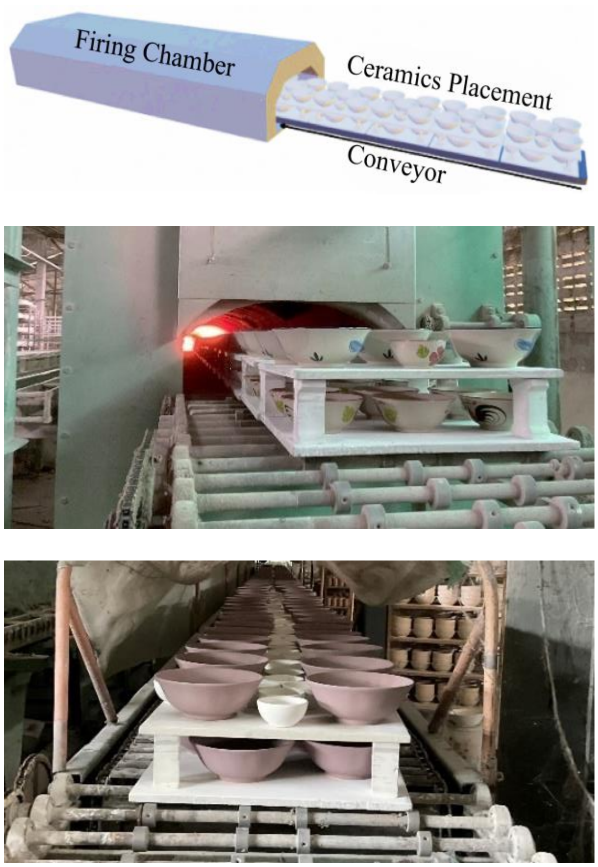

Fig. 1 Ceramics factory firing chamber

Numerous previous studies regarding object placement have been carried out, with researchers exploring various tree search methods, heuristic methods [20], [21], [22], and meta-heuristic methods [23], [24], [25]. Noteworthy contributions include [26] the introduction of the AND/OR-graph approach, [27] an algorithm for constructing homogeneous blocks of identically orientated items, and [28] an innovative tree-based search strategy employing a hill-climbing strategy. [29] proposed a novel wall-building-heuristic approach, while [30] derived a heuristic from the branch-and-bound approach. [31] suggested the block-building-hierarchical search approach, and [32] presented a multi-dimensional block-loading heuristic algorithm. [33] put a two-stage search algorithm [33], and Araya and Riff employed a beam search strategy, a variant of the branch-and-bound search [34]. Additionally, [35] proposed a combined heuristic algorithm with greedy and tree search modules, while [36] employed a branch-and-bound method with a layer-wise loading strategy.

In the realm of heuristic methods, conventional approaches such as greedy algorithms and local search algorithms have been presented by [37], [38], [39]. On the other hand, meta-heuristic methods have gained traction, with [40] introducing genetic, parallel genetic, and hybrid genetic algorithms. [25] have contributed to tabu search and parallel tabu search algorithms. [41] proposed simulated annealing and hybrid simulated annealing algorithms. [42], suggested a GRASP method for cargo loading optimization, while [19] presented a swarm optimization algorithm. Several researches only focused on placing cargo in containers, so it was deemed necessary to carry out research that focused on placing ceramics before the firing process. Our study aims to uncover optimal ceramics loading strategies that not only safeguard against potential damage but also enable personnel to work more quickly.

In the face of an expanding market for intricately designed ceramic products, the optimization of production processes becomes paramount for the sustainability and competitiveness of Lampang's ceramic industry. In this research, a heuristic algorithm was developed and implemented for the ceramic placement on the shelf. The modified algorithm, referred to as the "Heuristic Ceramic Placement Algorithm," aimed to optimize the arrangement of ceramics on the shelf, considering factors such as size and spatial constraints. The method involved the adaptation of traditional placement techniques to enhance efficiency. In the results, the heuristic algorithm demonstrated notable improvements in ceramic placement, showcasing space-saving advantages.

The discussion highlights the effectiveness of the proposed algorithm in optimizing shelf usage and its potential applications in practical settings, emphasizing the significance of heuristic approaches for efficient placement strategies in diverse contexts. These not only enhance workflow but also minimize the risk of damage during handling, thereby influencing the economic viability of the ceramic factories in Lampang.

2. Problem Description

The process of localizing ceramics in the firing chamber before the firing process is a crucial aspect of ceramic production, demanding meticulous planning and strategic considerations. This preparatory step is essential for ensuring the optimal outcome in terms of both product quality and operational efficiency. Ceramics, each possessing unique shapes and dimensions, necessitate careful arrangement within the firing chamber to maximize space utilization and, consequently, production efficiency. The placement of shaped and dried clay objects on shelves or within the firing chamber requires a thoughtful approach, as the firing process involves high temperatures that directly influence the final properties of the ceramics. The ceramics that have been arranged are then put into the firing chamber through a conveyor, as shown in Figure 1.

In this study, three innovative approaches were introduced to optimize the placement of bowls on a shelf. Firstly, recognizing that the bowls situated in the corner of the shelf do not need to be precisely aligned with the shelf's border, an equation was developed for bowls placed slightly outside the border while ensuring stability to prevent falls, as demonstrated in Equations (1) and (2). b signifies the radius of the base circle, and u stands for the radius of the upper circle. Additionally, r is defined as the distance from the arc of the base circle to the outer edge of the upper circle. The actual width of the bowl relative to the border is determined by the sum of half of r, the diameter of the base circle (c_b), and r. This flexibility in placement allows for more efficient use of the shelf's surface without compromising safety.

$$r = u - b \tag{1}$$

$$width = \frac{r}{2} + r + c_b \tag{2}$$

Our second focal point involved bowls characterized by diverse designs and sizes, specifically classifying them into larger and smaller categories based on the variation between their top and base diameters. To optimize placement efficiency, a strategic approach was devised wherein the smaller bowl is positioned to overlap between two larger bowls. This deliberate arrangement minimizes the spatial footprint, maximizing the utilization of the shelf surface for enhanced aesthetic and functional outcomes.

Notably effective, this approach demonstrates adaptability when accommodating a diverse array of bowl designs and sizes, offering a versatile solution for culinary presentation. As shown in Figure 2, it can be seen that the placement of the bowl can be done based on the size of the diameter of the small bowl (t_2) and large bowl diameter (t_1) at the height of a small bowl (h_2). The mathematical expression for determining the actual size (d) of the larger bowl in the context of bowl arrangement on the shelf is defined as Equation (3):

$$d = b_2 + \frac{h_1}{h_2} * (t_2 - b_2) \tag{3}$$

Thirdly, the study introduced the concept of a Region of Interest (RoI) for ceramic placement, consisting of two shelves of identical size arranged in two tiers. The RoI is characterized by Depth (DROI), Width (WROI), and Height (HROI). Notably, the RoI is divided into two parts by the presence of shelves, with the first part reduced by the space required for four supporting pillars. The second part of the RoI exhibits more available space, offering a nuanced understanding of the spatial dynamics involved in ceramic placement on the shelf. These three approaches collectively contribute to an advanced and comprehensive strategy for optimizing ceramic arrangement on shelves.

After the ceramics are arranged on both shelves, then the shelves will be stacked parallel, as presented in Figure 3. Shelf1, which has pillars, will be placed at the bottom, while Shelf2, without pillars, will be placed at the top. The bottom shelf1 will contain a smaller number of bowls due to cut space for pillars.

Figure 4 shows several parameters that are used to make variable declarations easier in Python programs. $p_1, p_2, p_3,$ and p_4 are the placement or location of the four pillars. Meanwhile, ph and pw represent the width and height of the four pillars, which are the same size. wp_1, wp_2, hp_1, and $hp_2,$ respectively, are variables used to store the width and height of each shelf.

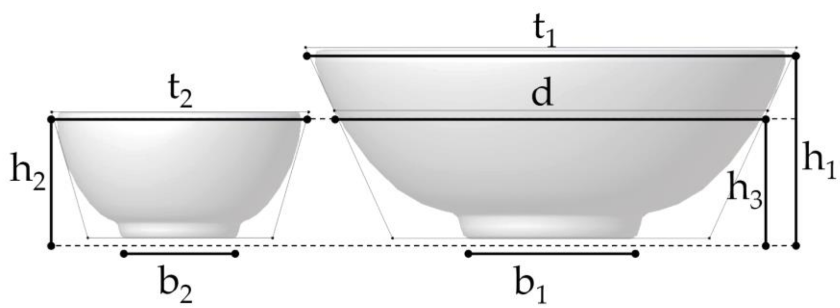

Fig. 2 Small and big bowl placement

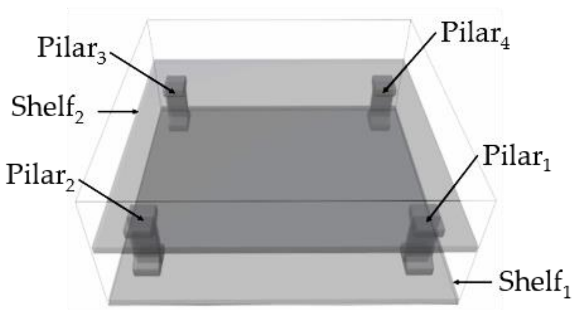

Fig. 3 Layer structure of shelves

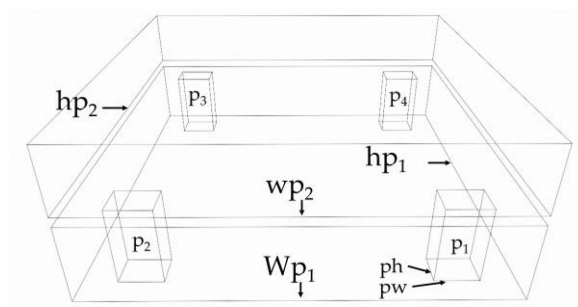

Fig. 4 Pillars placement on the shelf 1

3. Materials and Methods

As illustrated in Figure 5, the sequence of steps outlines the process of initializing parameters, sorting bowls, and systematically arranging them in alternating order while ensuring they fit within the container's dimensions based on defined algorithms.

Step 1: Begin by initializing the necessary parameters for the bowl arrangement process. Step 2: Create a structured pattern by sorting the bowls in an alternate order. Step 3: Evaluate whether the current layer is the base layer. Step 4: If the current layer is identified as the base layer in Step 3, position the bowls along the Y-axis using Algorithm I. Step 5: Repeat the assessment from Step 3 until the cumulative height of the bowls surpasses the container's height. Step 6: If the height limit is breached in Step 5, proceed to the next column with space. Step 7: If the height remains within acceptable bounds, continue placing the bowls along the Y-axis according to Algorithm I. Step 8: Examine whether the cumulative width of the bowls exceeds the container's width. Step 9: If the width limit is surpassed, make adjustments to the Y-axis positioning using Algorithm II. Step 10: Reassess if the cumulative height of the bowls exceeds the container's height. Step 11: If the height surpasses the limit in Step 10, move to the next column with sufficient space. Step 12: Conduct a final check to determine if the cumulative width of the bowls exceeds the container's width.

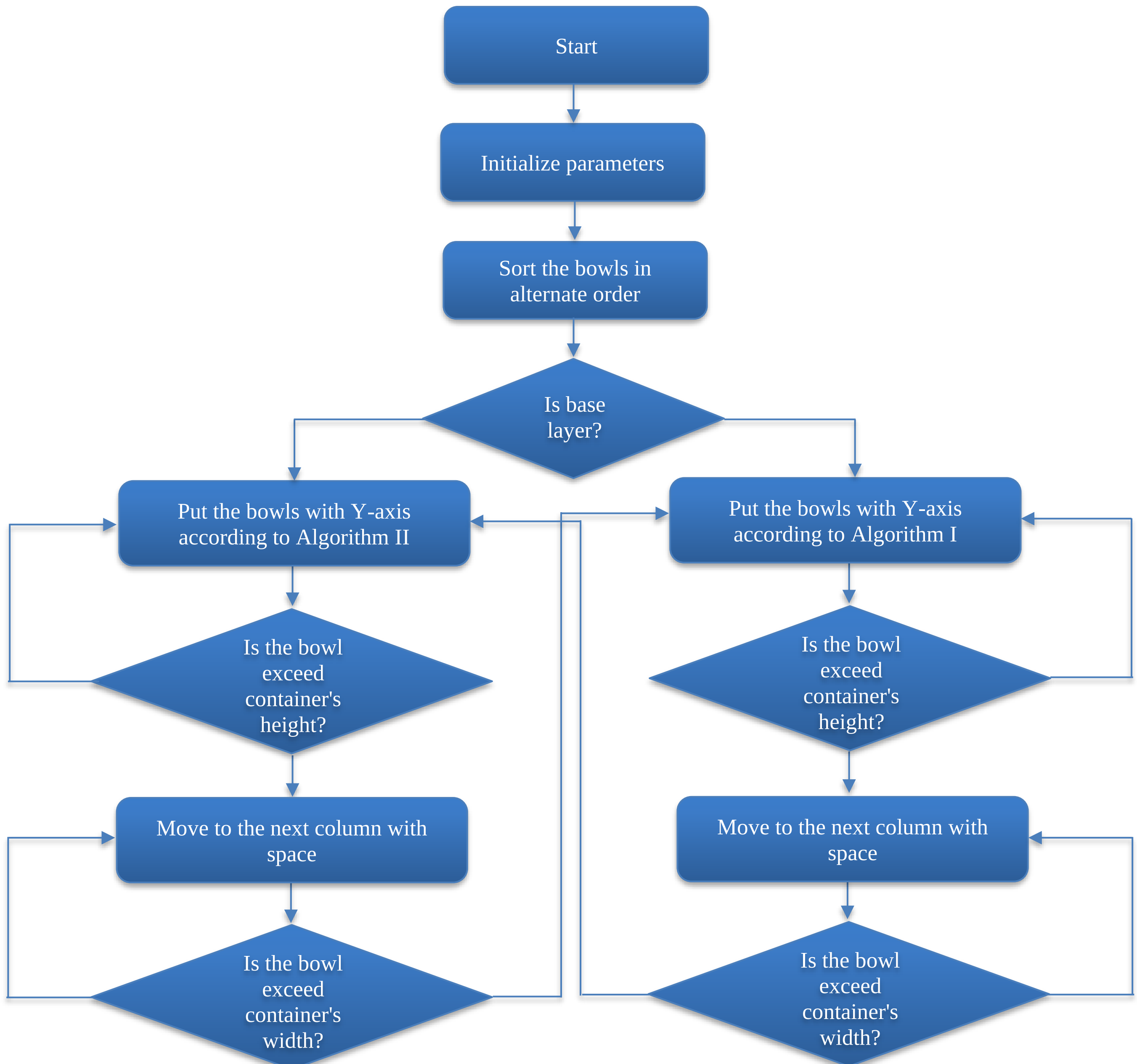

Fig. 5 Ceramics placement flowchart

Algorithm

Input:

R_b ← Radius of the big bowls
R_s ← Radius of the small bowls
N_b ← Total number of big bowls
N_s ← Total number of small bowls
$P_{w,h}$ ← Width and height of the ceramic placement

Output: Visualization of the arrangement of circles within the ceramic placement.

Procedure:

```
R ← alternate sorting array result for R_b and R_s
P_x,y ← starting point from x and y edge
w ← P_x
h ← P_y
x_position = P_x
y_position = P_y
total_circles = N_b + N_s
circles_placed = 0
prev_i = 0
circles = []
# Create rectangles for circles
circle_radii = R_b * N_b + R_s * N_s
sorted_circle_list = []
For i=0; length of circle_radii;
    IF i % 2 == 0:
        num = max(circle_radii)
        sorted_circle_list.append(num)
        circle_radii.remove(num)
    ELSE:
        num = min(circle_radii)
        sorted_circle_list.append(num)
        circle_radii.remove(num)
circle_radii = sorted_circle_list
# Place circles from the top-left corner with space
While circles_placed < total_circles:
     For i, r in enumerate(circle_radii):
        P_x = x_position + r
        P_y = y_position + r
# Check if the circle exceeds the container height
        If y_position + r - out > h:
            P_y = 0
            y_position = P_y   # Move to the next row
            x_position = prev_i + space
# Check if the circle exceeds the container width
        If x_position + r - out> w:
            P_x = x_position + r
            P_y = y_position + r
# Display the current circles in the terminal
            plot_solution(container, circles)
            circles = []  # Reset the circles
            y_position = 0  # Move to the next row
            x_position = 0  # Start from the left edge
        IF x_position == 0 or y_position == 0:
            IF P_x == r or P_y == r:
                x_position = x_position - out
                y_position = y_position - out
            IF P_y == 0:
                y_position = y_position - out
            prev_i = x_position + r
        circles.append((x_position + r / 2 , y_position + r / 2 , r / 2))
        circles_placed += 1
        Y_position += r+space
ENDIF
```

4. Results and Discussion

4.1. Algorithm Evaluation

As an initial test, the algorithm was given several bowls with different diameters. The complexity of the algorithm was then tested by providing several different bowl placement conditions on the shelf.

Some of these conditions include:
1) The bowl is placed only on one layer of shelf 2 and cannot cross the ROI boundary;
2) The bowl can pass through the ROI of shelf 2;
3) The large and small bowls can overlap each other and cross the ROI;
4) Large and small bowls can overlap each other, pass through the ROI, and be placed on shelves 1 and 2 (2 layers).

Several parameter values used in this test are presented in Table 1.

Table 1. Evaluation parameters setup (Scenario 1)

Parameters	Value	Parameters	Value
wp_1	45 cm	ph	3.3 cm
wp_2	45 cm	pw	4 cm
hp_1	45 cm	t_1	20.5 cm
hp_2	45 cm	t_2	11 cm

Table 2. Condition 1: The bowl is placed only on one layer of shelf 2 and cannot cross the ROI boundary

SB	BB	SB/shelf	BB/shelf	Total Required Shelves
10	10	9	4	4
20	20	9	4	7
30	30	9	4	11
40	40	9	4	14
50	50	9	4	18
60	60	9	4	22
70	70	9	4	25
80	80	9	4	29
90	90	9	4	33
100	100	9	4	36

Table 3. Condition 2: The bowl can pass through the ROI of shelf 2

SB	BB	SB/shelf	BB/shelf	Total Required Shelves
10	10	4	2	3
20	20	4	2	5
30	30	4	2	8
40	40	4	2	11
50	50	4	2	14
60	60	4	2	16
70	70	4	2	19
80	80	4	2	22
90	90	4	2	24
100	100	4	2	27

Table 4. Condition 3: the large and small bowls can overlap each other and cross the ROI

SB	BB	SB/shelf	BB/shelf	Total Required Shelves
10	10	4	5	3
20	20	4	5	5
30	30	4	5	7
40	40	4	5	9
50	50	4	5	11
60	60	4	5	13
70	70	4	5	16
80	80	4	5	18
90	90	4	5	20
100	100	4	5	22

Table 2-4 presents the test results from conditions 1 to 3 sequentially, where the results of placing the bowl are efficient based on the number of shelfs used. Small Bowl (SB) and Big Bowl (BB) are the number of bowls that will be placed on the shelf. Condition 4 is the most complex test where conditions 1 to 3 are combined, and placement is applied to two layers (1^{st} and 2^{nd} shelves).

Overall, the test results show satisfactory results where the efficiency of bowl placement can be generated automatically. As an illustration of bowl placement in ideal conditions, in the next sub-topic the ideal conditions and the application of this algorithm are visualized.

Table 5. Condition 4: large and small bowls can overlap each other, pass through the ROI, and be placed on shelves 1 and 2 (2 layers)

SB	BB	SB (1^{st})	BB (1^{st})	SB (2^{nd})	BB (2^{nd})	1set shelf (1^{st} and 2^{nd})	Extra 1^{st} layer shelf
10	10	4	5	4	3	1	1
20	20	4	5	4	3	2	1
30	30	4	5	4	3	3	1
40	40	4	5	4	3	4	1
50	50	4	5	4	3	5	1
60	60	4	5	4	3	6	1
70	70	4	5	4	3	7	1
80	80	4	5	4	3	8	1
90	90	4	5	4	3	10	1
100	100	4	5	4	3	11	1

Table 6. Evaluation parameters setup (Scenario 2)

Parameters	Value	Parameters	Value
wp_1	30 cm	p_1 (x, y)	(25.2, 3.2)
wp_2	30 cm	p_2 (x, y)	(4.8, 3.2)
hp_1	30 cm	p_3 (x, y)	(4.8, 26.8)
hp_2	30 cm	p_4 (x, y)	(25.2, 26.8)
ph	3,3 cm	d	12 cm
pw	4 cm	t_2	6 cm

Table 7. Evaluation scenario

Scenario	Object Type	Shelf	Count
S1	Big Bowl	1	20 pcs
	Small Bowl	1	16 pcs
S2	Big Bowl	2	16 pcs
	Small Bowl	2	12 pcs

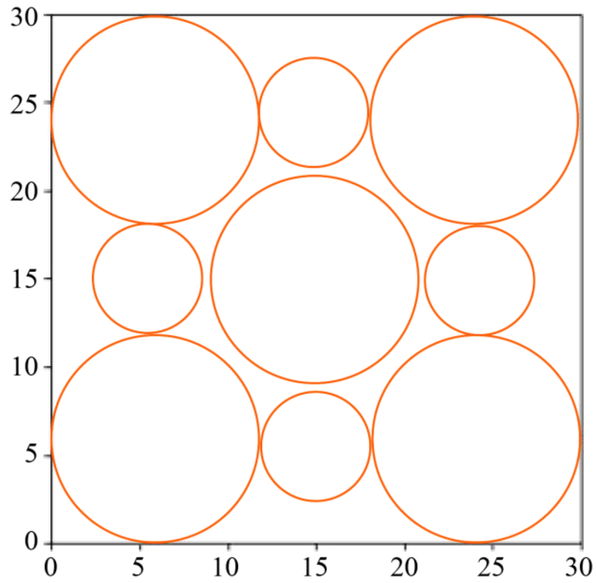

Fig. 6 Placement Results for Shelf 2

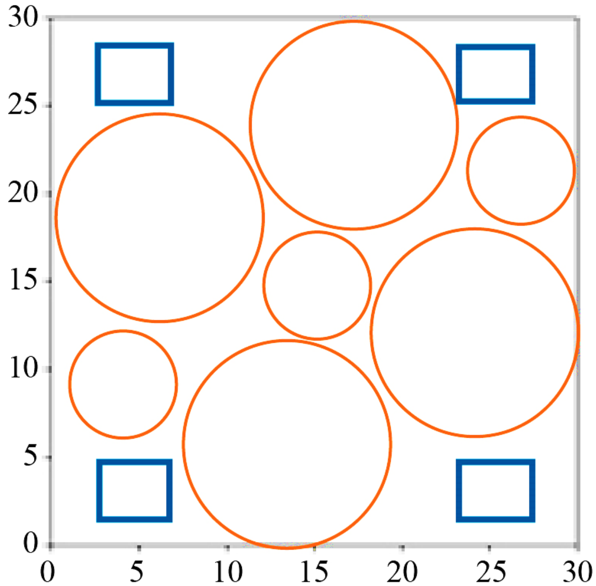

Fig. 7 Placement Results for Shelf 1

4.2. Illustration of Bowl Placement in Ideal Conditions

The test was carried out using two types of bowls of different sizes (large and small). Several test parameters are set before the program is run, namely the width height of the shelf (wp_1, wp_2, hp_1, and hp_2), the width height of the pillars (ph and pw), and the coordinates of the pillars p_1, p_2, p_3, and p_4, the diameter of the large bowl (*d*), small bowl (t_2). The parameter setup can be seen in Table 6.

4.3. Placement Results

When the program is executed, the placement of the ceramic bowl will follow the specified parameter settings. The program on shelves 1 and 2 is run separately with the input parameters for the number of objects (ceramics) to be arranged, which are presented in Table 7. The results of generating the bowl placement locations are then plotted in the form of graphs and images.

In scenario 1, four shelves are needed to arrange the bowl so that its placement is efficient, this is shown in Figures 6 and 7. Meanwhile, in scenario 2, four shelves are also needed to accommodate the placement of all objects. The test results using these two scenarios show efficiency in planning the arrangement of ceramic objects before entering the firing chamber.

4.4. Illustrated Placement Results

If illustrated manually in three-dimensional form, the shelf placement looks like in Figure 8, where shelf 1 will be at the bottom as a base. Shelf 2 is placed directly above Shelf 1, which rests on four pillars. Figure 9 shows an illustration of the placement of several shelves arranged in parallel.

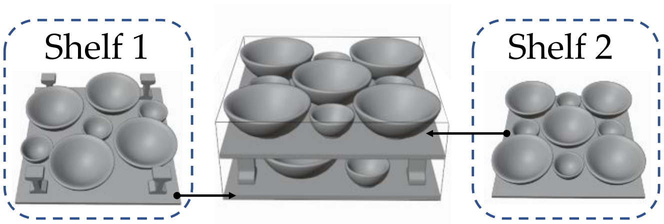

Fig. 8 Shelf 1 and 2 illustrations

Fig. 9 Parallel arrangement of refractory shelf

Based on the results of the arrangement and illustrations of the arrangement of ceramics, it can be seen that the algorithm can run well. The available space for each shelf can be filled optimally. So, it can save workers time in determining the pattern for arranging ceramics. There were several shortcomings found in this research, including that this algorithm was limited to only being able to arrange two types of ceramic bowls. This provides an opening for further research in developing algorithms with more flexible and dynamic parameters, not limited to bowl shapes only.

5. Conclusion

In conclusion, this paper presents a methodical process for effectively setting up ceramic bowls in a certain area. The suggested algorithm shows its efficacy in bowl placement optimisation by using alternating sorting and careful consideration of container dimensions. The evaluation results, which are based on scenario-based testing, demonstrate how the algorithm may be used to strategically arrange large and small bowls on different shelves, maximising space and enabling more efficient manufacturing procedures. Visual representations, which show well-organized placements on several shelves, further demonstrate the algorithm's effectiveness. Although the study recognises the limitations of the current algorithm, which is tailored for two specific types of ceramic bowls, it also offers opportunities for future research to expand its adaptability to a wider range of ceramic shapes and configurations. Overall, this paper advances the discipline by offering a workable solution for ceramic arrangement, opening the door to increased productivity in industrial settings.

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References

[1] P.N. Alkali, T.E. Olatunji, and A.D. Morakinyo, "The Economics of Planned Obsolescence of Manufactured Goods: A Case Study of Ceramics and Leather Products," *NIU Journal of Humanities*, vol. 8, no. 4, pp. 123-130, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[2] Van Dai Nguyen et al., "Counter-Institutional Identities and Product Innovation: "Core-Satellite" as a Response to Competing Logics Shaping Artisan Businesses," *Sage Open*, vol. 13, no. 3, pp. 1-23, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[3] Liliana Morais, "Material and Spiritual Entanglements with Ceramics. Looking at the Case of Contemporary Western Prac-Titioners in Japan," *Artis Observatio*, vol. 2, no. 1, pp. 52-91, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[4] Carmen Cipriano-Crespo, Elena Freire-Paz, and F. Xavier Medina, "The Cultural Revalorisation of the Ceramics of Talavera: From Folk Culture to Haute Cuisine," *International Journal of Gastronomy and Food Science*, vol. 32, pp. 1-7, 2023, [CrossRef] [Google Scholar] [Publisher Link]

[5] Md. Hasanur Rahman et al., "Corporate Social Responsibility and Green Financing Behavior in Bangladesh: Towards Sustainable Tourism," *Innovation and Green Development*, vol. 3, no. 3, pp. 1-14, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[6] W. Panthuwat et al., "The Effect of Natural Fiber Ratio on Mechanical Properties of Kaolin/Fly-Ash at Low Temperature Ceramics," *Journal of Physics: Conference Series*, vol. 2431, pp. 1-6, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[7] Weeranan Kamnungwut, and Frederick Guy, "Knowledge in the Air and Cooperation among Firms: Traditions of Secrecy and the Reluctant Emergence of Specialization in the Ceramic Manufacturing District of Lampang, Thailand, Thailand," *Environment and Planning A: Economy and Space*, vol. 44, no. 7, pp. 1679-1695, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[8] Elisabetta Gliozzo, "Ceramic Technology. How to Reconstruct the Firing Process," *Archaeological and Anthropological Sciences*, vol. 12, no. 11, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[9] Erick Gomez-Nieto et al., "Dealing with Multiple Requirements in Geometric Arrangements," *IEEE Transactions on Visualization and Computer Graphics*, vol. 22, no. 3, pp. 1223-1235, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[10] Bin Li et al., "A Single-Sensor Multi-Scale Quality Monitoring Methodology for Laser-Directed Energy Deposition: Example with Height Instability and Porosity Monitoring in Additive Manufacturing of Ceramic Thin-Walled Parts," *Additive Manufacturing*, vol. 79, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[11] Xiaobing Hu et al., "Research on the Application of Polymer Materials in Contemporary Ceramic Art Creation," *Polymers*, vol. 14, no. 3, pp. 1-12, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[12] Haowen Jiao, Bing Chen, and Shichun Li, "Removal Mechanism of 2.5-Dimensional Carbon Fiber Reinforced Ceramic Matrix Composites Processed by Nanosecond Laser," *The International Journal of Advanced Manufacturing Technology*, vol. 112, pp. 3017-3028, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[13] David Menzi et al., "Novel iGSE-C Loss Modeling of X7R Ceramic Capacitors," *IEEE Transactions on Power Electronics*, vol. 35, no. 12, pp. 13367-13383, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[14] Y.G. Stoyan, and S.V. Yakovlev, "Theory and Methods of Euclidian Combinatorial Optimization: Current Status and Prospects," *Cybernetics and Systems Analysis*, vol. 56, no. 3, pp. 366-379, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[15] Feifei Chen, and Michael Yu Wang, "Design Optimization of Soft Robots: A Review of the State of the Art," *IEEE Robotics & Automation Magazine*, vol. 27, no. 4. pp. 27-43, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[16] Padma Nyoman Crisnapati, and Dechrit Maneetham, "Two-Dimensional Path Planning Platform for Autonomous Walk behind Hand Tractor," *Agriculture*, vol. 12, no. 12, pp. 1-15, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[17] Padma Nyoman Crisnapati et al., "Earthquake Damage Intensity Scaling System Based on Raspberry Pi and Arduino Uno," *2018 6th International Conference on Cyber and IT Service Management*, Parapat, Indonesia, pp. 1-4, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[18] Singhanart Ketsayom, Dechrit Maneetham, and Padma Nyoman Crisnapati, "AGV Maneuverability Simulation and Design Based on Pure Pursuit Algorithm with Obstacle Avoidance," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 34, no. 2, pp. 835-847, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[19] Dang Cong Hop, Nguyen Van Hop, and Truong Tran Mai Anh, "Adaptive Particle Swarm Optimization for Integrated Quay Crane and Yard Truck Scheduling Problem," *Computers & Industrial Engineering*, vol. 153, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[20] Ennio Torre et al., "A Dynamic Evolutionary Multi-Objective Virtual Machine Placement Heuristic for Cloud Data Centers," *Information and Software Technology*, vol. 128, pp. 1-12, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[21] Sara Ali et al., "On-Line Three-Dimensional Packing Problems: A Review of Off-Line and On-Line Solution Approaches," *Computers & Industrial Engineering*, vol. 168, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[22] Teodor Gabriel Crainic, Franklin Djeumou Fomeni, and Walter Rei, "Multi-Period Bin Packing Model and Effective Constructive Heuristics for Corridor-Based Logistics Capacity Planning," *Computers & Operations Research*, vol. 132, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[23] Avita Katal, Tanupriya Choudhury, and Susheela Dahiya, "Energy Optimized Container Placement for Cloud Data Centers: A Meta-Heuristic Approach," *The Journal of Supercomputing*, vol. 80, no. 1, pp. 98-140, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[24] Ufuk Dereci, and Muhammed Erkan Karabekmez, "The Applications of Multiple Route Optimization Heuristics and Meta-Heuristic Algorithms to Solid Waste Transportation: A Case Study in Turkey," *Decision Analytics Journal*, vol. 4, pp. 1-13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[25] Ying Li, Mingzhou Chen, and Jiazhen Huo, "A Hybrid Adaptive Large Neighborhood Search Algorithm for the Large-Scale Heterogeneous Container Loading Problem," *Expert Systems with Applications*, vol. 189, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[26] Reinaldo Morabito, and Marcos Arenales, "An AND/OR-Graph Approach to the Container Loading Problem," *International Transactions in Operational Research*, vol. 1, no. 1, pp. 59-73, 1994. [CrossRef] [Google Scholar] [Publisher Link]

[27] Michael Eley, "Solving Container Loading Problems by Block Arrangement," *European Journal of Operational Research*, vol. 141, no. 2, pp. 393-409, 2002, [CrossRef] [Google Scholar] [Publisher Link]

[28] Mhand Hifi, and Labib Yousef, "A Global Dichotomous Search-Based Heuristic for the Three-Dimensional Sphere Packing Problem," *International Journal of Operational Research*, vol. 33, no. 2, pp. 139-160, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[29] David Pisinger, "Heuristics for the Container Loading Problem," *European Journal of Operational Research*, vol. 141, no. 2, pp. 382-392, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[30] Andreas Bortfeldt, and Daniel Mack, "A Heuristic for the Three-Dimensional Strip Packing Problem," *European Journal of Operational Research*, vol. 183, no. 3, pp. 1267-1279, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[31] Merve Aydemir, and Tuncay Yigit, "A Review of the Solutions for the Container Loading Problem, and the Use of Heuristics," *Proceedings of the International Conference on Artificial Intelligence and Applied Mathematics in Engineering*, pp. 690-700, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[32] Tian Tian et al., "A Two-Phase Constructive Algorithm for the Single Container Mix-Loading Problem," *Annals of Operations Research*, vol. 332, no. 1, pp. 253-275, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[33] Huiling Zhu, Mingjun Ji, and Wenwen Guo, "Two-Stage Search Algorithm for the Inbound Container Unloading and Stacking Problem," *Applied Mathematical Modelling*, vol. 77, pp. 1000-1024, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[34] Ignacio Araya, Mauricio Moyano, and Cristobal Sanchez, "A Beam Search Algorithm for the Biobjective Container Loading Problem," *European Journal of Operational Research*, vol. 286, no. 2, pp. 417-431, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[35] Sven F. Falkenberg, Stefan Spinler, and Arne K. Strauss, "An Algorithm for Flexible Transshipments with Perfect Synchronization," *European Journal of Operational Research*, vol. 315, no. 3, pp. 913-925, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[36] Batin Latif Aylak et al., "Application of Machine Learning Methods for Pallet Loading Problem," *Applied Sciences*, vol. 11, no. 18, pp. 1-22, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[37] ZiYan Zhao, MengChu Zhou, and ShiXin Liu, "Iterated Greedy Algorithms for Flow-Shop Scheduling Problems: A Tutorial," *IEEE Transactions on Automation Science and Engineering*, vol. 19, no. 3, pp. 1941-1959, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[38] Tao Zhang, Qin Zeng, and Xin Zhao, "Optimal Local Dimming Based on an Improved Greedy Algorithm," *Applied Intelligence*, vol. 50, no. 12, pp. 4162-4175, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[39] Xing Wang et al., "An Effective Iterated Greedy Algorithm for Online Route Planning Problem," *2020 IEEE Congress on Evolutionary Computation*, Glasgow, UK, pp. 1-8, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[40] Tuğrul Bayraktar, Filiz Ersöz, and Cemalettin Kubat, "Effects of Memory and Genetic Operators on Artificial Bee Colony Algorithm for Single Container Loading Problem," *Applied Soft Computing*, vol. 108, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[41] Mohamed ElWakil, Mohamed Gheith, and Amr Eltawil, "A New Hybrid Salp Swarm-Simulated Annealing Algorithm for the Container Stacking Problem," *Proceedings of the 9th International Conference on Operations Research and Enterprise Systems*, Valletta, Malta, pp. 89-99, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[42] M.T. Alonso, R. Alvarez-Valdes, and F. Parreño, "A GRASP Algorithm for Multi Container Loading Problems with Practical Constraints," *4OR*, vol. 18, pp. 49-72, 2020. [CrossRef] [Google Scholar] [Publisher Link]