HYBRID MULTI-PATTERNS WITH MONTE CARLO SEARCH APPROACH FOR THE PUZZLE GAME SOLVER

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ABSTRACT
Much current research in the game AI community has been more explored and better understood. It is interesting to quest what this could mean for games as we stumble towards human-level intelligence in different kind of applications. The popular Puzzle Games, Light Up and Sudoku, provided the wide leisure market in magazines and application software. Light Up is a single-player puzzle game from Nikoli in Japan. The game rules are simple, easy to get started but difficult to master. The design and implementation of logic strategy for solving Light Up is contributed to promote the inference ability for players. The main purposes of this paper are to conduct the pattern matching concept to improve the drawback of elimination search, and to propose the hybrid Multi-Patterns with Monte-Carlo Search (MPMCS) approach to enhance the performance of the searching ability for the Light Up problem. Several Light Up problems with various sizes are considered to compare the proposed MPMCS algorithm. Experimental results show that the MPMCS is efficiently to solve for the Light Up. In addition, the development of MPMCS approach can be guided in the dynamic simulation and can be useful for auxiliary education purposes.

Keywords: AI Community, Puzzle Game, Light Up, Multi-Patterns with Monte-Carlo Search (MPMCS).

1. Introduction
Nowadays machine learning and Artificial Intelligence (AI) have been attracted much attention in many fields such as image recognition [1], speech recognition [2] and automated game design [3]. Much current research in the game AI community pioneered the design and modeling of games that combine strategy and dexterity to play effectively. It is interesting to quest what this could mean for games as we stumble towards human-level intelligence in different kind of applications [4]. Light Up [5] is a single-player puzzle game from Nikoli in Japan. The game rules are simple, but difficult to master and has been proved to be NP-complete [6].

The Light Up puzzle [5-7] is a binary-determination logic game, and played on a rectangular N M grid of white and black cells. The example of a Light Up problem (N=10, M=10) is in Figure 1-1. The objective is to place light bulbs on the grid so that every white square is illuminated, and the corresponding puzzle solution as shown in Figure 1-2. A square is considered to be placed by a light bulb if they are in the same row or column. No light bulb may illuminate another light bulb. Some of the black cells have numbers in them. The number in a black cell indicates how many light bulbs share an edge with that cell. For example, the black cell number

ISSN: 2456-3676

is 2, then there are 2 Lights on the edge of that cell. Otherwise left click a square to place a light bulb. When every white square is illuminated, the puzzle game is solved.

The main purposes of this paper are to conduct the pattern matching concept to improve the drawback of Elimination Search [8], and propose the hybrid Multi-Patterns with Monte-Carlo Search (MPMCS) framework to enhance the performance of the searching ability for the Light Up problem. The Monte-Carlo Search algorithm [9] rely on random simulations to evaluate the states of remaining unknown pattern matching region of the puzzle. Several Light Up problems with various sizes are considered to compare the proposed MPMCS algorithm. Experimental results show that the MPMCS is efficiently to solve for the Light Up puzzle game. The rest of the paper is organized as follows. Section 2 described the proposed methods including multi-patterns matching [8] and the proposed hybrid MPMCS framework. Experiment results are provided in section 3. Finally, conclusion is made in section 4.

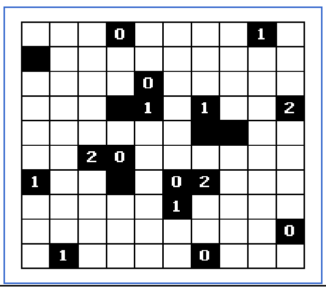

Figure 1-1. The example of a Light Up problem.

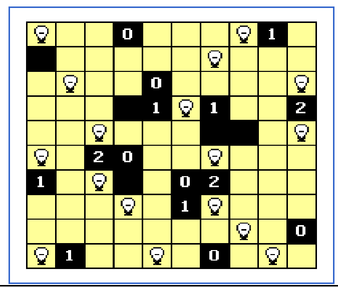

Figure 1-2. The corresponding Light Up solution.

2. Methods

2.1 Multi-Patterns matching

Example of size 7x7 is shown in Figure 2-1, and the multi-patterns matching procedure is illustrated in Figure 2-2 to Figure 2-17.

Multi-Patterns matching procedure:

Step 1: The number in a black cell is 0, and these bulbs cannot be placed on squares. As is shown in Figure 2-2.
Step 2: A bulb should be placed as that light source. As is shown in Figure 2-3.
Step 3: No light bulb may illuminate another light bulb. As is shown in Figure 2-4.
Step 4: Refer the number in a black cell and bulbs cannot be placed on squares. As is shown in Figure 2-5.
Step 5: The number in a black cell is 1 and the bulbs are placed at all white squares. As is shown in Figure 2-6.
Step 6: The bulbs cannot be placed at the same row or column position. As is shown in Figure 2-7.
Step 7: The number in a black cell is 2 and the bulbs cannot be placed. As is shown in Figure 2-8.

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Step 8: The Monte-Carlo Search algorithm is used to evaluate the unknown pattern matching region. As is shown in Figure 2-9.
Step 9: The number in a black cell is 1 and the bulbs are placed at all white squares. As is shown in Figure 2-10.
Step 10: No light bulb may illuminate another light bulb. As is shown in Figure 2-11.
Step 11: The Monte-Carlo Search algorithm is used to evaluate the unknown pattern matching region. As is shown in Figure 2-12.
Step 12: No light bulb may illuminate another light bulb. As is shown in Figure 2-13.
Step 13: Refer the number in a black cell and no light bulb can be placed. As is shown in Figure 2-14.
Step 14: Refer the number in a black cell and surround marked with light bulb. As is shown in Figure 2-15.
Step 15: No light bulb may illuminate another light bulb. As is shown in Figure 2-16.
Step 16: Refer the number in a black cell and surround marked with light bulb. As is shown in Figure 2-17.

First, the six types of pattern are matched to solve parts of the puzzle is summarized as follows. Then, the Monte-Carlo Search algorithm is used to evaluate the states of remaining unknown pattern matching region of the puzzle.

Six patterns summary:
Pattern 1: Bulbs cannot be placed on squares marked with, as shown in Step 1, Step 13.
Pattern 2: The bulbs are placed at all white squares, as shown in Step 2, Step 14, Step 16.
Pattern 3: No light bulb may illuminate another light bulb, as shown in Step 3, Step 6, Step 10, Step 12, Step 15.
Pattern 4: The bulbs cannot be placed at the same row or column position, as shown in Step 4, Step 7.
Pattern 5: Refer the number in a black cell and surround marked with, as shown in Step 5.
Pattern 6: Refer the number in a black cell and surround marked with light bulb, as shown in Step 9.

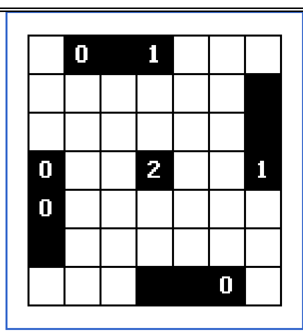

Figure 2-1. Example of size 7x7.

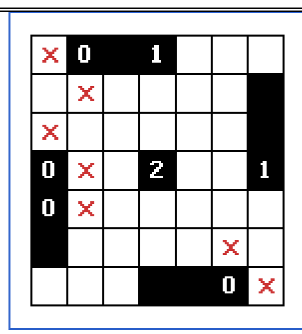

Figure 2-2. Step 1 procedure.

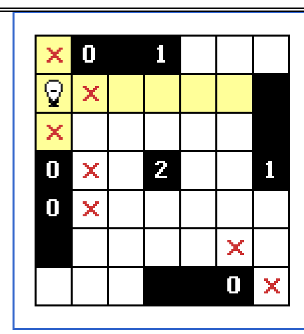

Figure 2-3. Step 2 procedure.

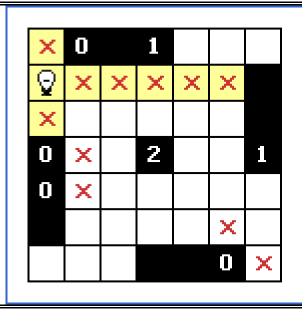

Figure 2-4. Step 3 procedure.

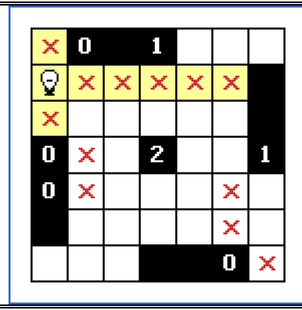

Figure 2-5. Step 4 procedure.

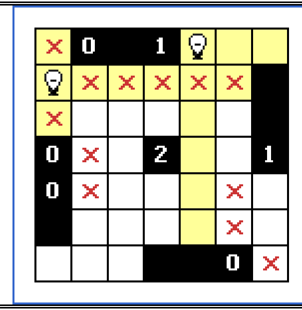

Figure 2-6. Step 5 procedure.

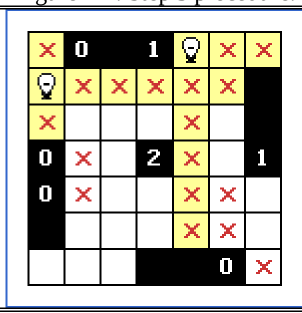

Figure 2-7. Step 6 procedure.

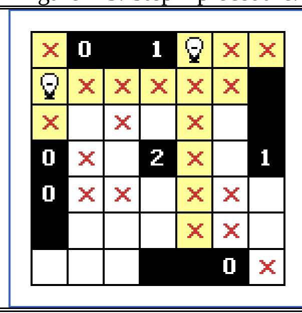

Figure 2-8. Step 7 procedure.

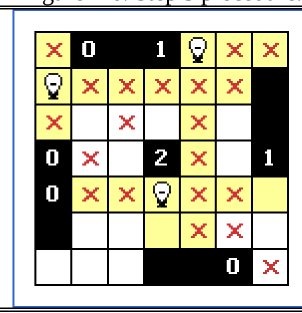

Figure 2-9. Step 8 procedure.

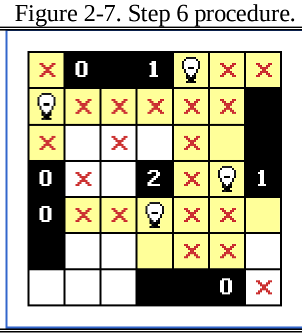

Figure 2-10. Step 9 procedure.

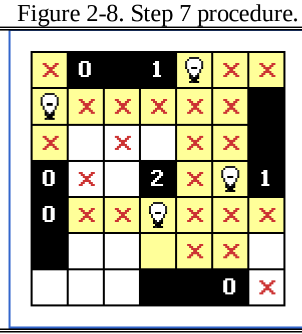

Figure 2-11. Step 10 procedure.

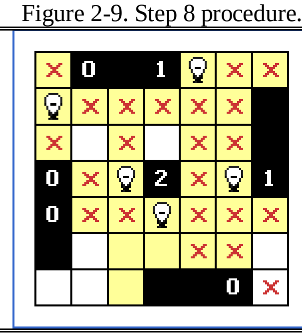

Figure 2-12. Step 11 procedure.

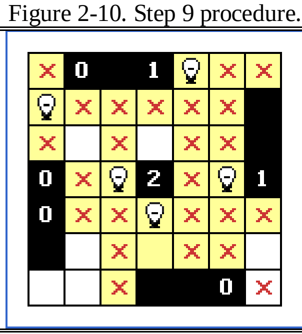

Figure 2-13. Step 12 procedure.

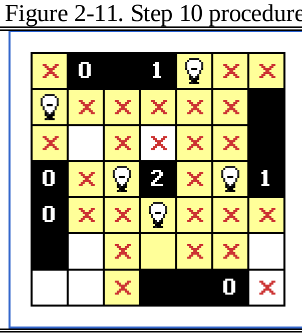

Figure 2-14. Step 13 procedure.

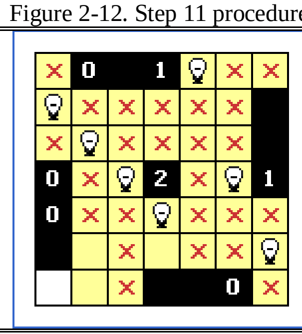

Figure 2-15. Step 14 procedure.

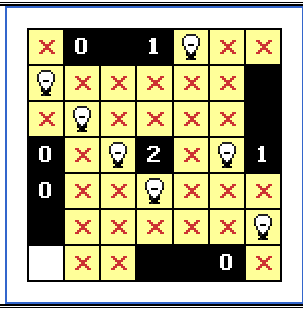	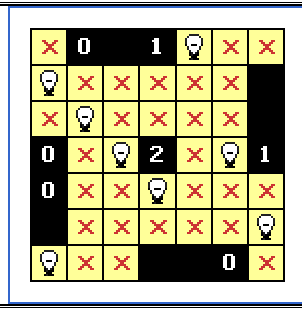
Figure 2-16. Step 15 procedure.	Figure 2-17. Step 16 procedure.

2.2 Hybrid Multi-Patterns with Monte-Carlo Search (MPMCS) framework

Figure 3 shows the system architecture of our proposed hybrid MPMCS framework for Light Up puzzle. In this work, the Monte-Carlo Search algorithm based on random simulations to evaluate the states of remaining unknown pattern matching region of the puzzle, and the proposed hybrid Multi-Patterns with Monte-Carlo Search (MPMCS) framework to enhance the performance of the searching ability for the Light Up problem is presented as follows.

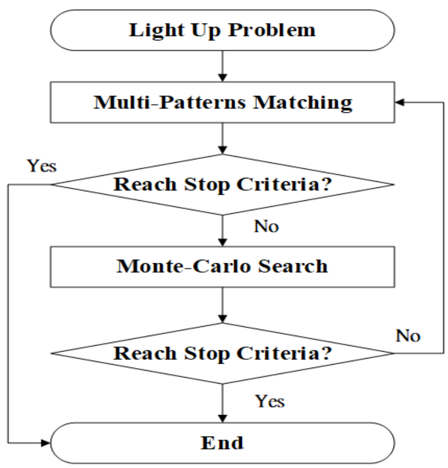

Figure 3: The system architecture of hybrid MPMCS framework for Light Up problem.

3. Experimental results

In order to show the performance of the proposed algorithm for the Light Up puzzle, the medium-large size 14x14 and the large size 25x25 of Light Up problems are adopted, and the level of problems all are hard. Experimental results show that the MPMCS is efficiently to solve for the Light Up. In addition, the development of MPMCS approach can be guided in the dynamic simulation and auxiliary tuition platform for game players.

3.1 The simulation result of medium-large size 14x14 for Light Up puzzle

The problem of medium-large size 14x14 is shown in Figure 4-1, and the results are illustrated in Figure 4-2 to Figure 4-17.

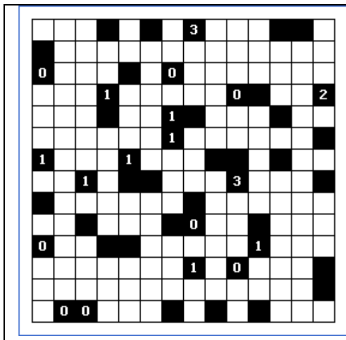

Figure 4-1. Example of size 14x14.

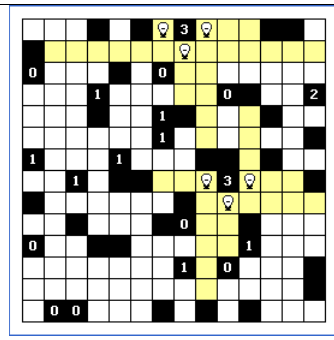

Figure 4-2. Step 1 procedure.

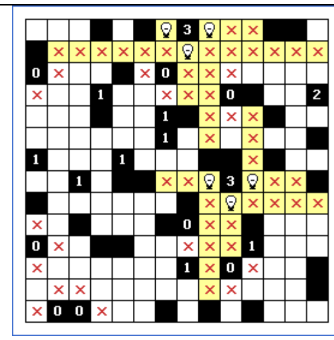

Figure 4-3. Step 2 procedure.

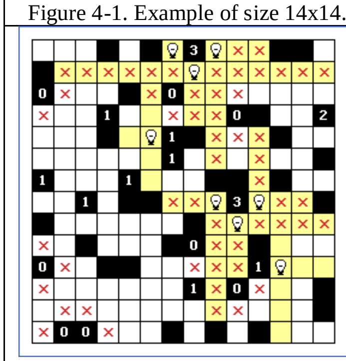

Figure 4-4. Step 3 procedure.

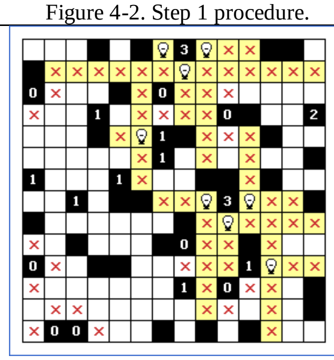

Figure 4-5. Step 4 procedure.

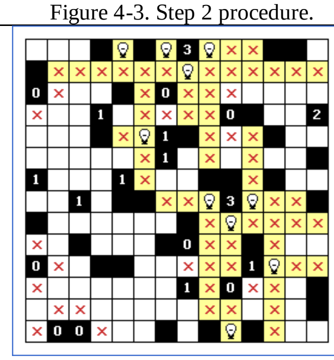

Figure 4-6. Step 5 procedure.

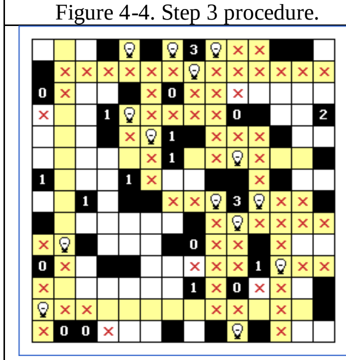

Figure 4-7. Step 6 procedure.

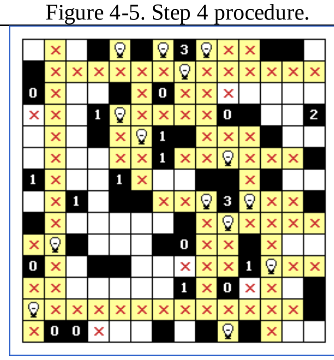

Figure 4-8. Step 7 procedure.

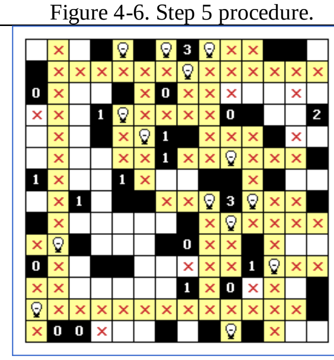

Figure 4-9. Step 8 procedure.

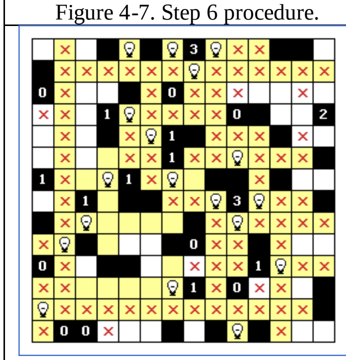

Figure 4-10. Step 9 procedure.

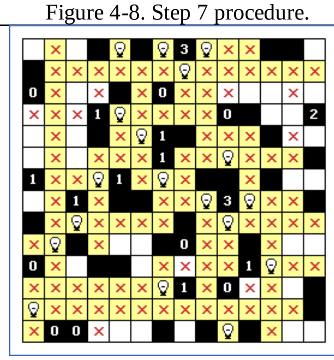

Figure 4-11. Step 10 procedure.

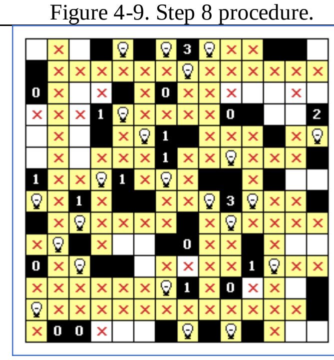

Figure 4-12. Step 11 procedure.

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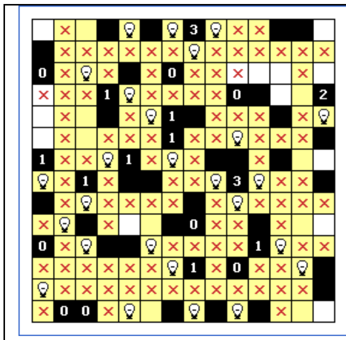


Figure 4-13. Step 12 procedure.

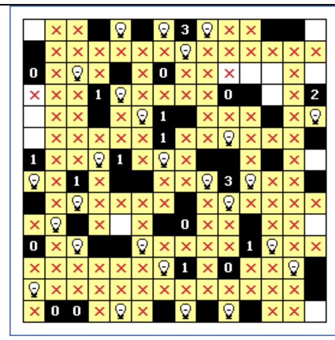


Figure 4-14. Step 13 procedure.

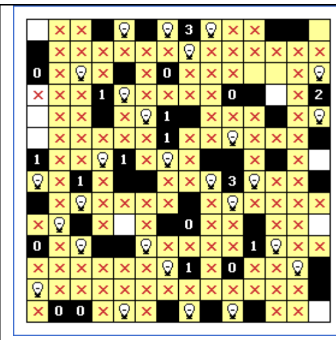


Figure 4-15. Step 14 procedure.

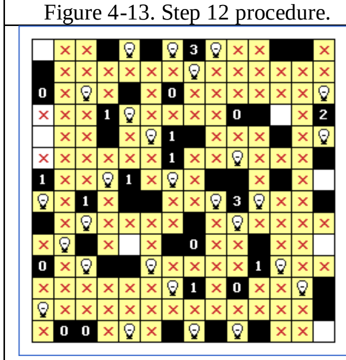


Figure 4-16. Step 15 procedure.

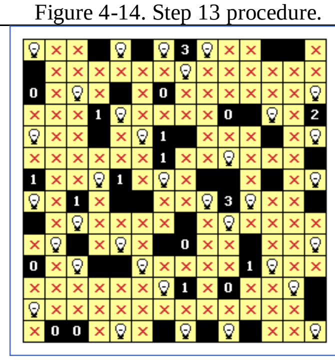


Figure 4-17. Step 16 procedure.

3.2 The simulation result of large size 25x25 for Light Up puzzle

The problem of large size 25x25 is shown in Figure 5-1, and the results are illustrated in Figure 5-2 to Figure 5-30.

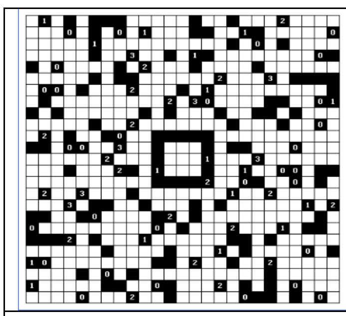


Figure 5-1. Example of size 25x25.

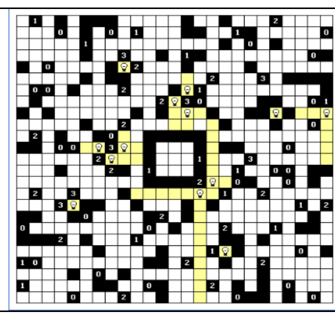


Figure 5-2. Step 1 procedure.

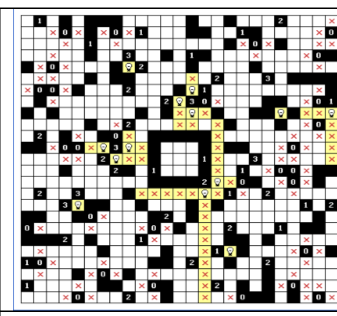
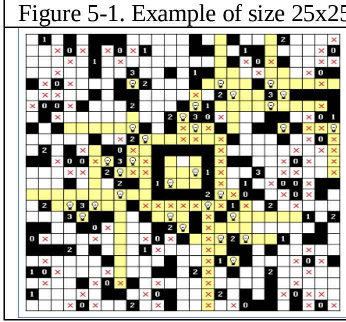
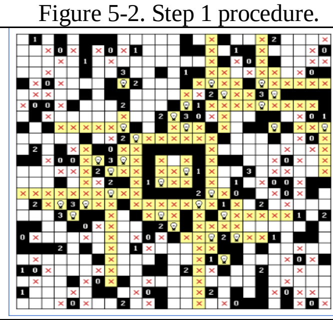


Figure 5-3. Step 2 procedure.





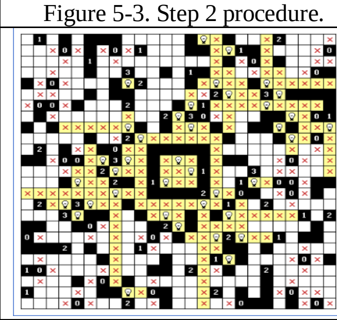


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Figure 5-4. Step 3 procedure.	Figure 5-5. Step 4 procedure.	Figure 5-6. Step 5 procedure.

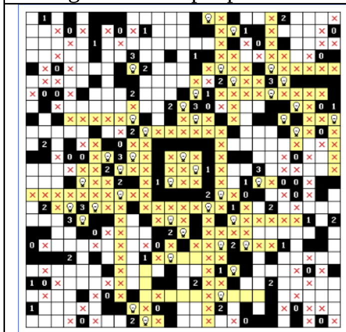
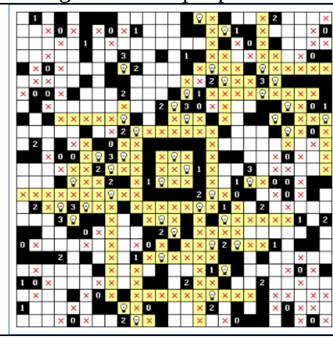
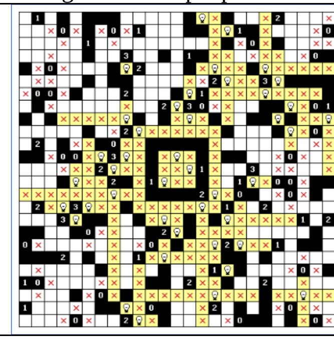

		

Figure 5-7. Step 6 procedure.	Figure 5-8. Step 7 procedure.	Figure 5-9. Step 8 procedure.

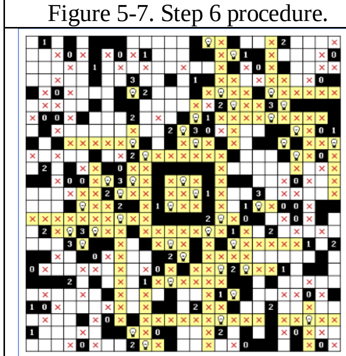
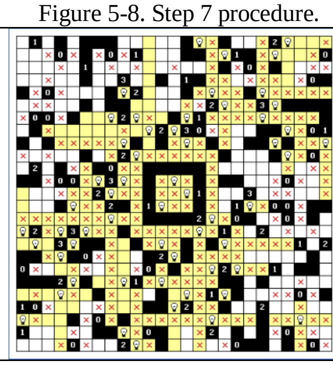
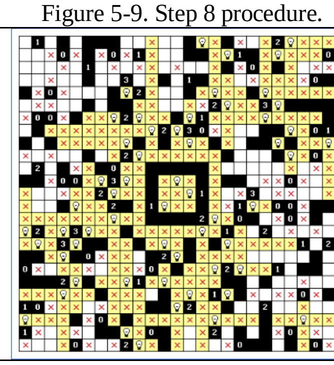

		

Figure 5-10. Step 9 procedure.	Figure 5-11. Step 10 procedure.	Figure 5-12. Step 11 procedure.

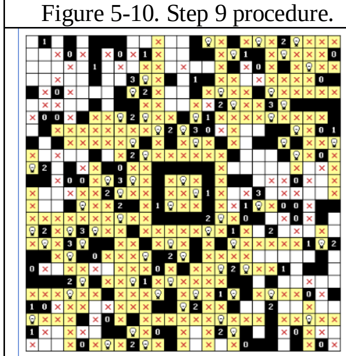
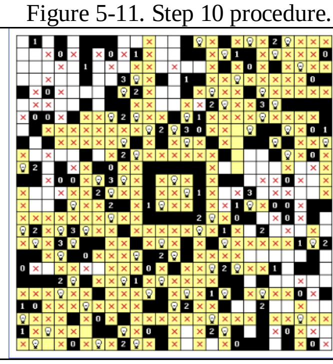
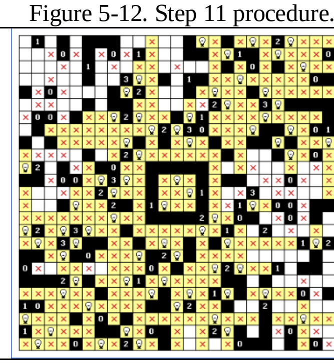

		

Figure 5-13. Step 12 procedure.	Figure 5-14. Step 13 procedure.	Figure 5-15. Step 14 procedure.

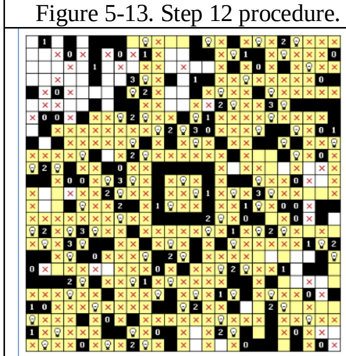
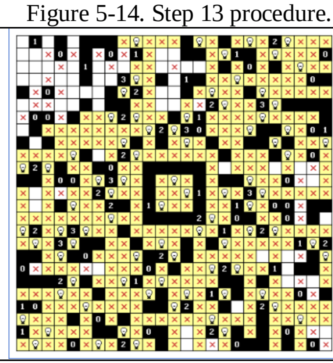
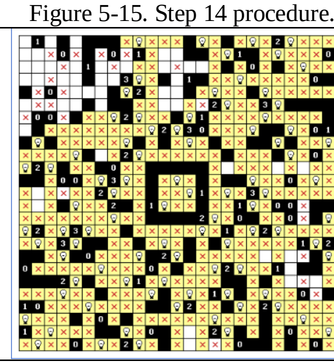

		

Figure 5-16. Step 15 procedure.	Figure 5-17. Step 16 procedure.	Figure 5-18. Step 17 procedure.

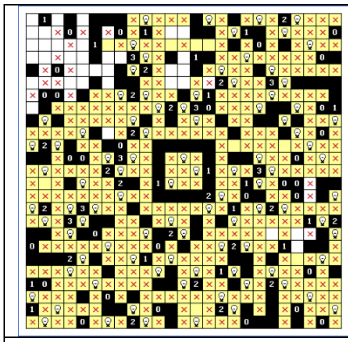
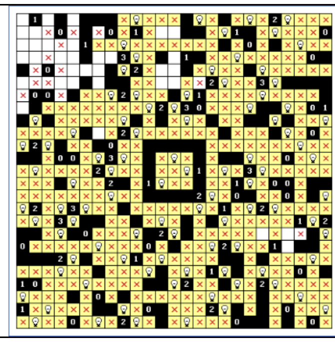


Figure 5-19. Step 18 procedure.



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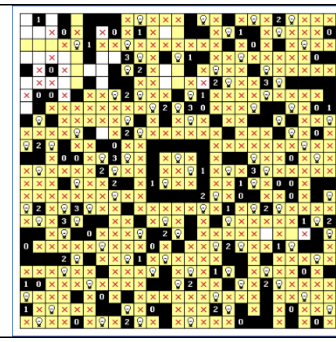

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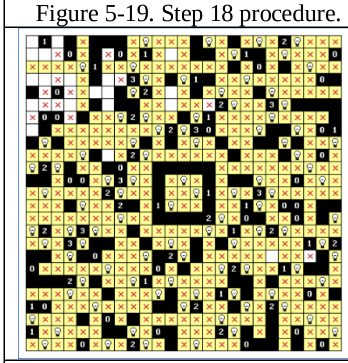

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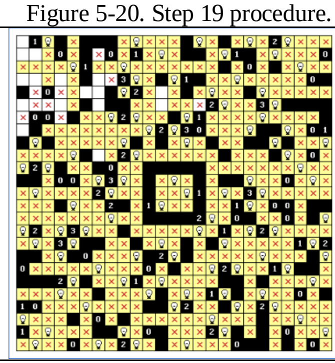
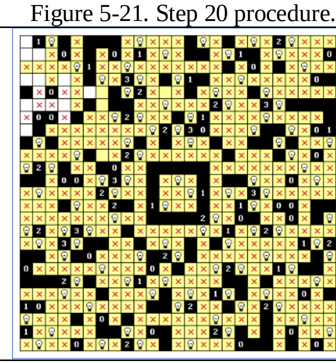


Figure 5-23. Step 22 procedure.



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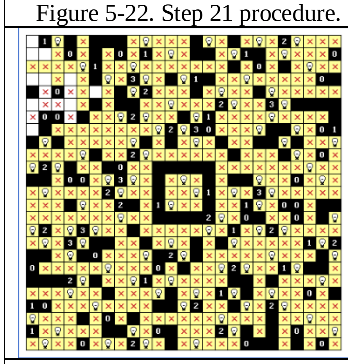

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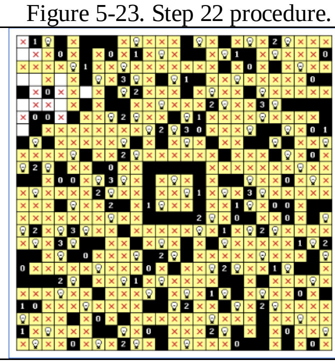

Figure 5-26. Step 25 procedure.

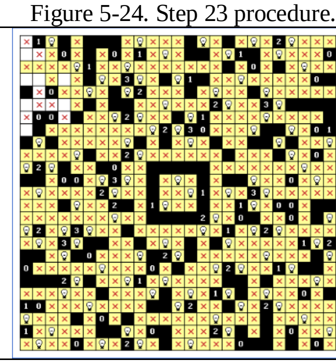

Figure 5-27. Step 26 procedure.

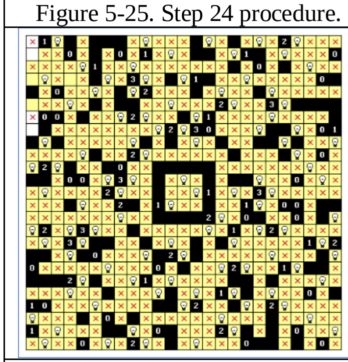

Figure 5-28. Step 27 procedure.

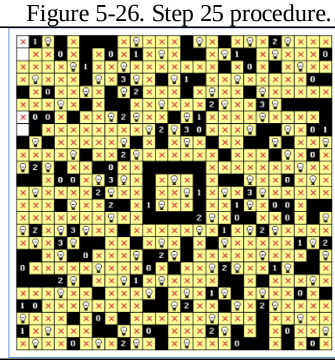

Figure 5-29. Step 28 procedure.

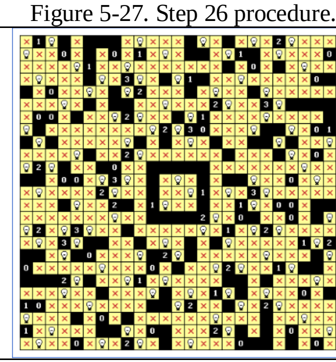

Figure 5-30. Step 29 procedure.

4. Conclusion

In this paper, the effectively hybrid MPMCS algorithm is proposed to solve for the Light Up puzzle. The algorithm is based on hybrid Multi-Patterns matching with Monte-Carlo Search to obtain feasible solutions in terms of the hard constraints of the puzzle. Experiments carried out in different size of puzzle instances have shown that our approach can achieve better performance to solve these problems. The development of MPMCS approach can be guided in the dynamic simulation and can be useful for education purposes. The study of novel techniques for reducing the search space in evolutionary computation may be interesting future work.

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