**Implementation Details:**

**GameState Class:**

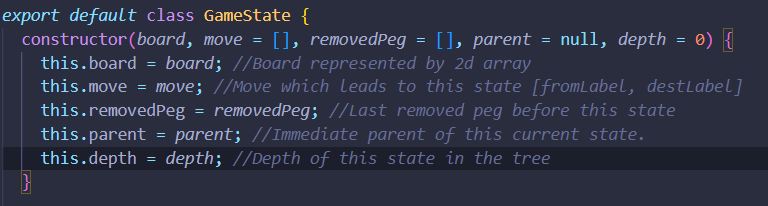
We have a GameState class which holds the current board represented by a 2-D array with 0 for empty slots, 1 for non-empty slots and -1 for invalid slots (slots at the corners).

It has a parent variable which is a reference to another GameState instance. The reason we have parents in our data structure is that when we find a final node, we will be able to iterate all the way up to print all states until the solutions.

Also, we store the depth of each GameState variable to use in Iterative Deepening Search.

Another variable is Move, it is a 2X1 array which holds the labels from and destination. For example, if our move is 14 -> 16 removing the peg 15. Then the array is [14, 16]. We use this variable for visualization only.

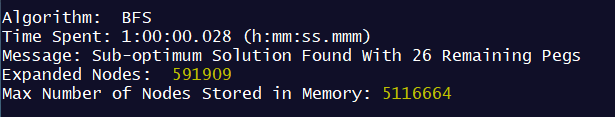
We also have a variable for removedPeg. It holds the slot label of the removed peg. It is necessary because we choose the least numbered removed peg in BFS DFS and Iterative Deepening Search.



**Algorithms:**

We have different functions for each algorithm specified in the assignment. And each one of these functions,

**a)Breadth-first Search**

****

=== Board States Until the Solution. ===

Move #1: 29 => 17

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 0 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #2: 10 => 24

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1 0 1 1 1

1 0 1

1 1 1

Move #3: 19 => 17

1 1 1

1 1 1

1 1 1 0 1 1 1

1 1 1 0 1 1 1

1 1 1 1 1 1 1

1 0 1

1 1 1

Move #4: 16 => 18

1 1 1

1 1 1

1 1 1 0 1 1 1

1 1 1 1 0 0 1

1 1 1 1 1 1 1

1 0 1

1 1 1

Move #5: 14 => 16

1 1 1

1 1 1

1 1 1 0 1 1 1

1 1 0 0 1 0 1

1 1 1 1 1 1 1

1 0 1

1 1 1

Move #6: 2 => 10

1 1 1

1 1 1

1 1 1 0 1 1 1

0 0 1 0 1 0 1

1 1 1 1 1 1 1

1 0 1

1 1 1

1 0 1

1 0 1

1 1 1 1 1 1 1

0 0 1 0 1 0 1

1 1 1 1 1 1 1

1 0 1

1 1 1

**b) Depth-First Search**

**Text

Description automatically generated**

=== Board States Until the Solution. ===

Move #1: 5 => 17

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 0 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #2: 8 => 10

1 1 1

1 0 1

1 1 1 0 1 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #3: 1 => 9

1 1 1

1 0 1

1 0 0 1 1 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #4: 3 => 1

0 1 1

0 0 1

1 0 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #5: 11 => 3

1 0 0

0 0 1

1 0 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #6: 16 => 4

1 0 1

0 0 0

1 0 1 1 0 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #7: 1 => 9

1 0 1

1 0 0

1 0 0 1 0 1 1

1 1 0 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #8: 10 => 8

0 0 1

0 0 0

1 0 1 1 0 1 1

1 1 0 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #9: 7 => 9

0 0 1

0 0 0

1 1 0 0 0 1 1

1 1 0 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #10: 13 => 11

0 0 1

0 0 0

0 0 1 0 0 1 1

1 1 0 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #11: 18 => 6

0 0 1

0 0 0

0 0 1 0 1 0 0

1 1 0 1 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #12: 3 => 11

0 0 1

0 0 1

0 0 1 0 0 0 0

1 1 0 1 0 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #13: 21 => 7

0 0 0

0 0 0

0 0 1 0 1 0 0

1 1 0 1 0 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #14: 22 => 8

0 0 0

0 0 0

1 0 1 0 1 0 0

0 1 0 1 0 1 1

0 1 1 1 1 1 1

1 1 1

1 1 1

Move #15: 8 => 10

0 0 0

0 0 0

1 1 1 0 1 0 0

0 0 0 1 0 1 1

0 0 1 1 1 1 1

1 1 1

1 1 1

Move #16: 24 => 22

0 0 0

0 0 0

1 0 0 1 1 0 0

0 0 0 1 0 1 1

0 0 1 1 1 1 1

1 1 1

1 1 1

Move #17: 11 => 9

0 0 0

0 0 0

1 0 0 1 1 0 0

0 0 0 1 0 1 1

0 1 0 0 1 1 1

1 1 1

1 1 1

Move #18: 31 => 23

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 0 1 0 1 1

0 1 0 0 1 1 1

1 1 1

1 1 1

Move #19: 30 => 18

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 0 1 0 1 1

0 1 1 0 1 1 1

0 1 1

0 1 1

Move #20: 22 => 24

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 0 1 1 1 1

0 1 1 0 0 1 1

0 1 0

0 1 1

Move #21: 18 => 16

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 0 1 1 1 1

0 0 0 1 0 1 1

0 1 0

0 1 1

Move #22: 33 => 31

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 0 1 1

0 0 0 1 0 1 1

0 1 0

0 1 1

Move #23: 27 => 25

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 0 1 1

0 0 0 1 0 1 1

0 1 0

1 0 0

Move #24: 20 => 18

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 0 1 1

0 0 0 1 1 0 0

0 1 0

1 0 0

Move #25: 18 => 30

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 1 0 0

0 0 0 1 1 0 0

0 1 0

1 0 0

Move #26: 30 => 28

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 0 0 0

0 0 0 1 0 0 0

0 1 1

1 0 0

Move #27: 31 => 23

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 0 0 0

0 0 0 1 0 0 0

1 0 0

1 0 0

Move #28: 24 => 22

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 0 0 0

0 0 1 1 0 0 0

0 0 0

0 0 0

Move #29: 9 => 23

0 0 0

0 0 0

1 0 1 0 0 0 0

0 0 1 0 0 0 0

0 1 0 0 0 0 0

0 0 0

0 0 0

Move #30: 22 => 24

0 0 0

0 0 0

1 0 0 0 0 0 0

0 0 0 0 0 0 0

0 1 1 0 0 0 0

0 0 0

0 0 0

0 0 0

0 0 0

1 0 0 0 0 0 0

0 0 0 0 0 0 0

0 0 0 1 0 0 0

0 0 0

0 0 0

**d) Depth-First Search with Random Selection**

**Text

Description automatically generated**

=== Board States Until the Solution. ===

Move #1: 19 => 17

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 0 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #2: 6 => 18

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #3: 25 => 11

1 1 1

1 1 0

1 1 1 1 0 1 1

1 1 1 1 1 0 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #4: 33 => 25

1 1 1

1 1 0

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 1 1 1 0 1 1

1 1 1

1 1 1

Move #5: 31 => 33

1 1 1

1 1 0

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 1 1 1 1 1 1

1 1 0

1 1 0

Move #6: 4 => 6

1 1 1

1 1 0

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 1 1 1 1 1 1

1 1 0

0 0 1

Move #7: 24 => 32

1 1 1

0 0 1

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 1 1 1 1 1 1

1 1 0

0 0 1

Move #8: 23 => 31

1 1 1

0 0 1

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 1 1 0 1 1 1

1 0 0

0 1 1

Move #9: 21 => 23

1 1 1

0 0 1

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 1 0 0 1 1 1

0 0 0

1 1 1

Move #10: 17 => 5

1 1 1

0 0 1

1 1 1 1 1 1 1

1 1 1 1 0 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #11: 2 => 10

1 1 1

0 1 1

1 1 1 0 1 1 1

1 1 1 0 0 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #12: 16 => 4

1 0 1

0 0 1

1 1 1 1 1 1 1

1 1 1 0 0 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #13: 7 => 9

1 0 1

1 0 1

1 1 0 1 1 1 1

1 1 0 0 0 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #14: 6 => 18

1 0 1

1 0 1

0 0 1 1 1 1 1

1 1 0 0 0 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #15: 13 => 11

1 0 1

1 0 0

0 0 1 1 0 1 1

1 1 0 0 1 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #16: 10 => 8

1 0 1

1 0 0

0 0 1 1 1 0 0

1 1 0 0 1 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #17: 14 => 16

1 0 1

1 0 0

0 1 0 0 1 0 0

1 1 0 0 1 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #18: 26 => 24

1 0 1

1 0 0

0 1 0 0 1 0 0

0 0 1 0 1 0 1

0 0 1 0 1 1 1

0 0 0

1 1 1

Move #19: 18 => 6

1 0 1

1 0 0

0 1 0 0 1 0 0

0 0 1 0 1 0 1

0 0 1 1 0 0 1

0 0 0

1 1 1

Move #20: 3 => 11

1 0 1

1 0 1

0 1 0 0 0 0 0

0 0 1 0 0 0 1

0 0 1 1 0 0 1

0 0 0

1 1 1

Move #21: 1 => 9

1 0 0

1 0 0

0 1 0 0 1 0 0

0 0 1 0 0 0 1

0 0 1 1 0 0 1

0 0 0

1 1 1

Move #22: 8 => 10

0 0 0

0 0 0

0 1 1 0 1 0 0

0 0 1 0 0 0 1

0 0 1 1 0 0 1

0 0 0

1 1 1

Move #23: 16 => 28

0 0 0

0 0 0

0 0 0 1 1 0 0

0 0 1 0 0 0 1

0 0 1 1 0 0 1

0 0 0

1 1 1

Move #24: 10 => 12

0 0 0

0 0 0

0 0 0 1 1 0 0

0 0 0 0 0 0 1

0 0 0 1 0 0 1

1 0 0

1 1 1

Move #25: 27 => 13

0 0 0

0 0 0

0 0 0 0 0 1 0

0 0 0 0 0 0 1

0 0 0 1 0 0 1

1 0 0

1 1 1

Move #26: 13 => 11

0 0 0

0 0 0

0 0 0 0 0 1 1

0 0 0 0 0 0 0

0 0 0 1 0 0 0

1 0 0

1 1 1

Move #27: 31 => 23

0 0 0

0 0 0

0 0 0 0 1 0 0

0 0 0 0 0 0 0

0 0 0 1 0 0 0

1 0 0

1 1 1

Move #28: 23 => 25

0 0 0

0 0 0

0 0 0 0 1 0 0

0 0 0 0 0 0 0

0 0 1 1 0 0 0

0 0 0

0 1 1

Move #29: 33 => 31

0 0 0

0 0 0

0 0 0 0 1 0 0

0 0 0 0 0 0 0

0 0 0 0 1 0 0

0 0 0

0 1 1

0 0 0

0 0 0

0 0 0 0 1 0 0

0 0 0 0 0 0 0

0 0 0 0 1 0 0

0 0 0

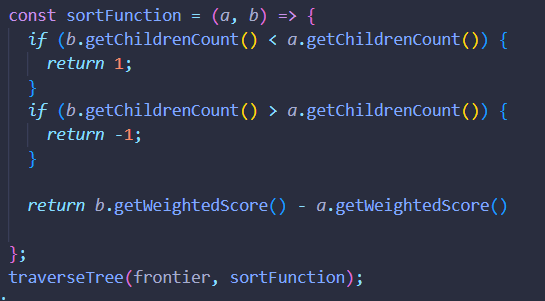
1 0 0

**e) Depth-First Search With a Node Selection Heuristic**

**Heuristic Function:**

In our heuristic function, we first choose the node which yields more children states. And if they are equal, we choose the node which has the least weighted score.

Weighted score is the sum of all the Euclidean distances from each peg and center for each non-empty slot. In this way, we get an optimal Solution in less than 1 second by expanding 19057 nodes and storing maximum of 298 nodes in the memory.

****

Text

Description automatically generated

=== Board States Until the Solution. ===

Move #1: 29 => 17

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 0 1 1 1

1 1 1 1 1 1 1

1 1 1

1 1 1

Move #2: 26 => 24

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1 0 1 1 1

1 0 1

1 1 1

Move #3: 11 => 25

1 1 1

1 1 1

1 1 1 1 1 1 1

1 1 1 1 1 1 1

1 1 1 1 0 0 1

1 0 1

1 1 1

Move #4: 9 => 11

1 1 1

1 1 1

1 1 1 1 0 1 1

1 1 1 1 0 1 1

1 1 1 1 1 0 1

1 0 1

1 1 1

Move #5: 23 => 9

1 1 1

1 1 1

1 1 0 0 1 1 1

1 1 1 1 0 1 1

1 1 1 1 1 0 1

1 0 1

1 1 1

Move #6: 14 => 16

1 1 1

1 1 1

1 1 1 0 1 1 1

1 1 0 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 1 1

Move #7: 31 => 23

1 1 1

1 1 1

1 1 1 0 1 1 1

0 0 1 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 1 1

Move #8: 33 => 31

1 1 1

1 1 1

1 1 1 0 1 1 1

0 0 1 1 0 1 1

1 1 1 1 1 0 1

0 0 1

0 1 1

Move #9: 16 => 28

1 1 1

1 1 1

1 1 1 0 1 1 1

0 0 1 1 0 1 1

1 1 1 1 1 0 1

0 0 1

1 0 0

Move #10: 4 => 16

1 1 1

1 1 1

1 1 1 0 1 1 1

0 0 0 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #11: 7 => 9

1 1 1

0 1 1

1 1 0 0 1 1 1

0 0 1 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #12: 2 => 10

1 1 1

0 1 1

0 0 1 0 1 1 1

0 0 1 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #13: 6 => 18

1 0 1

0 0 1

0 0 1 1 1 1 1

0 0 1 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #14: 13 => 11

1 0 1

0 0 0

0 0 1 1 0 1 1

0 0 1 1 1 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #15: 18 => 6

1 0 1

0 0 0

0 0 1 1 1 0 0

0 0 1 1 1 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #16: 3 => 11

1 0 1

0 0 1

0 0 1 1 0 0 0

0 0 1 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #17: 10 => 12

1 0 0

0 0 0

0 0 1 1 1 0 0

0 0 1 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #18: 27 => 13

1 0 0

0 0 0

0 0 1 0 0 1 0

0 0 1 1 0 1 1

1 1 0 1 1 0 1

1 0 1

1 0 0

Move #19: 13 => 11

1 0 0

0 0 0

0 0 1 0 0 1 1

0 0 1 1 0 1 0

1 1 0 1 1 0 0

1 0 1

1 0 0

Move #20: 30 => 18

1 0 0

0 0 0

0 0 1 0 1 0 0

0 0 1 1 0 1 0

1 1 0 1 1 0 0

1 0 1

1 0 0

Move #21: 24 => 10

1 0 0

0 0 0

0 0 1 0 1 0 0

0 0 1 1 1 1 0

1 1 0 1 0 0 0

1 0 0

1 0 0

Move #22: 31 => 23

1 0 0

0 0 0

0 0 1 1 1 0 0

0 0 1 0 1 1 0

1 1 0 0 0 0 0

1 0 0

1 0 0

Move #23: 16 => 28

1 0 0

0 0 0

0 0 1 1 1 0 0

0 0 1 0 1 1 0

1 1 1 0 0 0 0

0 0 0

0 0 0

Move #24: 21 => 23

1 0 0

0 0 0

0 0 1 1 1 0 0

0 0 0 0 1 1 0

1 1 0 0 0 0 0

1 0 0

0 0 0

Move #25: 28 => 16

1 0 0

0 0 0

0 0 1 1 1 0 0

0 0 0 0 1 1 0

0 0 1 0 0 0 0

1 0 0

0 0 0

Move #26: 16 => 4

1 0 0

0 0 0

0 0 1 1 1 0 0

0 0 1 0 1 1 0

0 0 0 0 0 0 0

0 0 0

0 0 0

Move #27: 1 => 9

1 0 0

1 0 0

0 0 0 1 1 0 0

0 0 0 0 1 1 0

0 0 0 0 0 0 0

0 0 0

0 0 0

Move #28: 18 => 6

0 0 0

0 0 0

0 0 1 1 1 0 0

0 0 0 0 1 1 0

0 0 0 0 0 0 0

0 0 0

0 0 0

Move #29: 9 => 11

0 0 0

0 0 1

0 0 1 1 0 0 0

0 0 0 0 0 1 0

0 0 0 0 0 0 0

0 0 0

0 0 0

Move #30: 6 => 18

0 0 0

0 0 1

0 0 0 0 1 0 0

0 0 0 0 0 1 0

0 0 0 0 0 0 0

0 0 0

0 0 0

Move #31: 19 => 17

0 0 0

0 0 0

0 0 0 0 0 0 0

0 0 0 0 1 1 0

0 0 0 0 0 0 0

0 0 0

0 0 0

0 0 0

0 0 0

0 0 0 0 0 0 0

0 0 0 1 0 0 0

0 0 0 0 0 0 0

0 0 0

0 0 0

**Note:** If you want to run this program, you need to have Node.js installed in your computer. To run the program after you install node.js go to the project directory and run first **“npm install”** and after you install the dependencies run **“node src/index.js”.**