Heuristic Function

The heuristic function is the sum of the path length of individual tiles from current location to the goal location.

The path length is calculated using following conditions: -

1. Tile is in 0-180: -
    a. Goal State is in 90-270: - Distance is the number of moves to reach (0,0) or (180,180) location on axis as they are the intersection points and also the number of moves from there to reach the goal coordinate on 90-270.
        i. E.g. Tile = (30,0) and Goal = (30,90)
        Distance from (30,0) to (0,0) = 1
        Distance from (0,0) to (30,90) = 1
        Total Distance = 2
    b. Goal State is in equator: - Distance is the number of moves to reach (90,0) or (90,180) location on axis as they are the intersection points and also the number of moves from there to reach the goal coordinate on equator.
        i. E.g. Tile = (30,0) and Goal = (90,60)
        Distance from (30,0) to (0,0) = 1
        Distance from (0,0) to (90,60) = 2
        Total Distance = 3
    c. Goal state is in 0-180 itself: - Distance is the number of move to reach there.
        i. E.g. Tile = (150,0) and Goal = (180,180)
        Distance = 1

2. Tile is in 90-270: -
    a. Goal State is in 0-180: - Distance is the number of moves to reach (0,0) or (180,180) location on axis as they are the intersection points and also the number of moves from there to reach the goal coordinate on 0-180.
        i. E.g. Tile = (30,90) and Goal = (30,0)
        Distance from (30,90) to (0,0) = 1
        Distance from (0,0) to (30,0) = 1
        Total Distance = 2
    b. Goal State is in equator: - Distance is the number of moves to reach (90,90) or (90,270) location on axis as they are the intersection points and also the number of moves from there to reach the goal coordinate on equator.
        i. E.g. Tile = (30,90) and Goal = (90,60)
        Distance from (30,90) to (90,90) = 2
        Distance from (90,90) to (90,60) = 1
        Total Distance = 3
    c. Goal state is in 90-270 itself: - Distance is the number of move to reach there.
        i. E.g. Tile = (150,90) and Goal = (150,270)

Distance = 2

3. Tile is in equator: -
    a. Goal State is in 0-180: - Distance is the number of moves to reach (90,0) or (90,180) location on axis as they are the intersection points and also the number of moves from there to reach the goal coordinate on 0-180.
        i. E.g. Tile = (90,60) and Goal = (30,0)
        Distance from (90,60) to (0,0) = 1
        Distance from (0,0) to (30,0) = 1
        Total Distance = 2
    b. Goal State is in equator: - Distance is the number of moves to reach (90,90) or (90,270) location on axis as they are the intersection points and also the number of moves from there to reach the goal coordinate on 90-270.
        i. E.g. Tile = (90,60) and Goal = (30,90)
        Distance from (90,60) to (90,90) = 1
        Distance from (90,90) to (30,90) = 2
        Total Distance = 3
    c. Goal state is in equator itself: - Distance is the number of move to reach there.
        i. E.g. Tile = (90,90) and Goal = (90,270)
        Distance = 6

So the heuristic cost is given by above conditions and total cost is given by

$$g(x) = f(x) + h(x)$$

Where g(x) is total cost,
h(x) is the heuristic cost,
f(x) is the path cost given by height of node * 12

This heuristic gives good results because we are calculating the path required to transfer from one tile position to another keeping in mind, we don't disrupt the other tiles which is practically possible using certain moves. Over overall aim is to do that only so if we calculate the heuristic cost for each tile and sum it up, then we can say that which move will take minimal steps to reach the goal. The constant '12' is derived from the total number of tiles which move when we rotate any axis by 30° which is equal to 1 state change for this search.

Also, we can consider that

$$\forall n: h(n) \leq c\,(n, a, n') + h(n')$$

is true because,

We can consider a state at level n and another state at level n'. Our goal state is c. Then the cost we calculate is based on the movement of tiles. So after each level 12 of our tiles are moved.

Suppose $h(n)$ is the cost to go from level n to n',
Then the cost $h(n')$,

$h(n) + 0 \leq h(n') \leq h(n) + 24$

Considering left bound which can be achieved if we reach goal state and on the other hand upper bound can be achieved when we disrupt each and every tile in the axis and the path required to reach the goal increases by 2 moves for each of the 12 tiles.

Now we know that $c(n, a, n')$ is 12 because transition from one level to another takes 12 cost as defined earlier.

So,

$h(n) \leq h(n'), \forall n$

$\therefore\ h(n) \leq h(n') + c(n, a, n'), \forall n$

Hence the heuristic is admissible.

Analysis

Summary Report For A*

States Expanded:
- Min = 31,
- Max = 2985832,
- Average = 285285

Max Queue:
- Min = 126,
- Max = 11594420,
- Average = 1107336.5

The Hardest Puzzle For A* is “Puzzle2-10” because it expands the maximum number of states i.e. 2985832.

Summary Report For RBFS

States Expanded:
- Min = 25,
- Max = 542964,
- Average = 71427.923

Max Queue:
- Min = 150,
- Max = 3257784,
- Average = 428567.538

The Hardest Puzzle for RBFS is “Puzzle2-1” because it expands the maximum number of states i.e. 542964.

Summary Report For BFS

Only Puzzle2-3 completed the goal which was achieved at level 8. Other all were terminated after 1800 seconds.

States Expanded:
- Min = 389693,
- Max = 6^{16},
- Average = Unbound

Max Queue:
- Min = 1529823,
- Max = Unbound,
- Average = Unbound

The Hardest Puzzle for BFS is “Puzzle2-10” because it will go till level 16 and for BFS the deeper the level hard is the goal to achieve.

Best Algorithm for This Problem

By doing analysis on all the algorithms, '**A*'** works best for this problem because though RBFS is faster than A* theoretically but for this problem it goes into loops sometimes which increases time required to execute as well as it doesn't guarantee an optimal path when RBFS is used whereas when A* is used we will always get optimal path. Apart from these 2, BFS is also optimal but it will discover all the states which will increase the time complexity exponentially compared to A* and RBFS so BFS is also not suitable for this problem.

Detailed Results

Detailed Results for Each Puzzle using A*

1. Puzzle2-0
    a. States Expanded: 197765
    b. Maximum Queue: 777112
    c. Path Length: 13
    d. Path:
        i decrease_90-270
        ii increase_Equator
        iii decrease_0-180
        iv decrease_Equator
        v decrease_Equator
        vi increase_0-180
        vii increase_90-270
        viii increase_0-180
        ix increase_90-270
        x increase_0-180
        xi increase_90-270
        xii increase_Equator
        xiii increase_0-180
    e. Time Taken: 98.67

2. Puzzle2-1
    a. States Expanded: 82472
    b. Maximum Queue: 328390
    c. Path Length: 14
    d. Path:
        i increase_0-180
        ii increase_0-180
        iii increase_90-270
        iv decrease_0-180
        v increase_90-270
        vi increase_Equator
        vii increase_0-180
        viii increase_Equator
        ix increase_0-180
        x increase_0-180
        xi increase_Equator
        xii decrease_90-270
        xiii increase_Equator
        xiv decrease_90-270
    e. Time Taken: 39.74

3. Puzzle2-2
    a. States Expanded: 31
    b. Maximum Queue: 126
    c. Path Length: 9
    d. Path:
        i decrease_90-270
        ii decrease_90-270
        iii increase_Equator
        iv increase_Equator
        v increase_Equator
        vi decrease_90-270
        vii increase_Equator
        viii increase_90-270
        ix decrease_0-180
    e. Time Taken: 0.02

4. Puzzle2-3
    a. States Expanded: 753
    b. Maximum Queue: 3001
    c. Path Length: 8
    d. Path:
        i increase_Equator
        ii increase_0-180
        iii decrease_90-270
        iv decrease_Equator
        v increase_90-270
        vi increase_90-270
        vii decrease_Equator
        viii increase_0-180
    e. Time Taken: 0.35

5. Puzzle2-4
    a. States Expanded: 4012
    b. Maximum Queue: 15875
    c. Path Length: 11
    d. Path:
        i increase_0-180
        ii increase_90-270
        iii increase_Equator
        iv decrease_90-270
        v increase_Equator
        vi increase_0-180
        vii increase_90-270
        viii decrease_0-180

ix increase_Equator
x decrease_0-180
xi decrease_0-180

e. Time Taken: 1.82

6. Puzzle2-5
   a. States Expanded: 1204
   b. Maximum Queue: 4817
   c. Path Length: 12
   d. Path:
      i decrease_90-270
      ii decrease_90-270
      iii decrease_Equator
      iv increase_90-270
      v decrease_Equator
      vi decrease_Equator
      vii increase_0-180
      viii increase_0-180
      ix increase_Equator
      x increase_0-180
      xi increase_0-180
      xii increase_0-180
   e. Time Taken: 0.55

7. Puzzle2-6
   a. States Expanded: 34755
   b. Maximum Queue: 138781
   c. Path Length: 16
   d. Path:
      i increase_90-270
      ii increase_Equator
      iii increase_Equator
      iv decrease_90-270
      v decrease_90-270
      vi decrease_90-270
      vii decrease_90-270
      viii increase_Equator
      ix increase_Equator
      x increase_0-180
      xi increase_Equator
      xii increase_0-180
      xiii decrease_90-270
      xiv decrease_Equator
      xv decrease_90-270

xvi decrease_90-270

e. Time Taken: 18.32

8. Puzzle2-7
    a. States Expanded: 317182
    b. Maximum Queue: 1243840
    c. Path Length: 16
    d. Path:
        i increase_0-180
        ii decrease_Equator
        iii increase_0-180
        iv decrease_90-270
        v increase_Equator
        vi increase_0-180
        vii decrease_90-270
        viii increase_0-180
        ix increase_0-180
        x increase_0-180
        xi increase_0-180
        xii increase_90-270
        xiii increase_Equator
        xiv increase_0-180
        xv decrease_Equator
        xvi increase_0-180
    e. Time Taken: 179.12

9. Puzzle2-8
    a. States Expanded: 439
    b. Maximum Queue: 1740
    c. Path Length: 7
    d. Path:
        i decrease_Equator
        ii decrease_0-180
        iii decrease_0-180
        iv decrease_90-270
        v increase_0-180
        vi increase_90-270
        vii increase_0-180
    e. Time Taken: 0.19

10. Puzzle2-9
    a. States Expanded: 1159
    b. Maximum Queue: 4633
    c. Path Length: 10

d. Path:
    i increase_0-180
    ii increase_90-270
    iii increase_90-270
    iv increase_Equator
    v increase_0-180
    vi decrease_Equator
    vii decrease_Equator
    viii increase_90-270
    ix increase_0-180
    x increase_0-180
e. Time Taken: 0.59

11. Puzzle2-10
    a. States Expanded: 2985832
    b. Maximum Queue: 11594420
    c. Path Length: 16
    d. Path:
        i increase_Equator
        ii decrease_90-270
        iii increase_0-180
        iv increase_90-270
        v increase_Equator
        vi decrease_90-270
        vii increase_0-180
        viii decrease_90-270
        ix decrease_90-270
        x increase_0-180
        xi increase_90-270
        xii increase_Equator
        xiii increase_90-270
        xiv increase_90-270
        xv increase_0-180
        xvi decrease_Equator
    e. Time Taken: 3658.54

12. Puzzle2-11
    a. States Expanded: 63
    b. Maximum Queue: 254
    c. Path Length: 7
    d. Path:
        i decrease_Equator
        ii decrease_Equator
        iii decrease_90-270

iv decrease_Equator
v increase_90-270
vi decrease_0-180
vii increase_90-270

e. Time Taken: 0.03

13. Puzzle2-12
    a. States Expanded: 84
    b. Maximum Queue: 338
    c. Path Length: 7
    d. Path:
        i decrease_0-180
        ii decrease_90-270
        iii increase_Equator
        iv increase_Equator
        v increase_0-180
        vi decrease_Equator
        vii decrease_90-270
    e. Time Taken: 0.04

14. Puzzle2-13
    a. States Expanded: 79307
    b. Maximum Queue: 307474
    c. Path Length: 13
    d. Path:
        i decrease_0-180
        ii decrease_Equator
        iii decrease_90-270
        iv decrease_0-180
        v increase_Equator
        vi increase_Equator
        vii increase_0-180
        viii increase_90-270
        ix decrease_Equator
        x decrease_Equator
        xi increase_0-180
        xii increase_90-270
        xiii decrease_0-180
    e. Time Taken: 44.92

15. Puzzle2-14
    a. States Expanded: 9144
    b. Maximum Queue: 36423
    c. Path Length: 12

d. Path:
    i decrease_90-270
    ii increase_0-180
    iii increase_0-180
    iv decrease_Equator
    v increase_0-180
    vi increase_0-180
    vii decrease_90-270
    viii decrease_90-270
    ix decrease_Equator
    x decrease_0-180
    xi decrease_0-180
    xii decrease_90-270
e. Time Taken: 4.87

16. Puzzle2-15
    a. States Expanded: 9713
    b. Maximum Queue: 37795
    c. Path Length: 10
    d. Path:
        i increase_0-180
        ii decrease_Equator
        iii decrease_0-180
        iv decrease_0-180
        v increase_90-270
        vi increase_Equator
        vii decrease_90-270
        viii increase_0-180
        ix decrease_Equator
        x decrease_90-270
    e. Time Taken: 5.32

17. Puzzle2-16
    a. States Expanded: 590
    b. Maximum Queue: 2361
    c. Path Length: 8
    d. Path:
        i increase_0-180
        ii decrease_90-270
        iii increase_Equator
        iv decrease_0-180
        v decrease_0-180
        vi increase_Equator
        vii decrease_0-180

viii increase_90-270

e. Time Taken: 0.3

18. Puzzle2-17

a. States Expanded: 1769900

b. Maximum Queue: 6834217

c. Path Length: 15

d. Path:

i increase_Equator
ii increase_Equator
iii decrease_0-180
iv increase_90-270
v increase_Equator
vi decrease_90-270
vii decrease_0-180
viii decrease_90-270
ix decrease_Equator
x decrease_Equator
xi increase_0-180
xii increase_0-180
xiii increase_0-180
xiv increase_90-270
xv increase_Equator

e. Time Taken: 1598.15

19. Puzzle2-18

a. States Expanded: 4573

b. Maximum Queue: 18107

c. Path Length: 12

d. Path:

i increase_Equator
ii increase_90-270
iii increase_Equator
iv increase_Equator
v increase_Equator
vi decrease_90-270
vii decrease_90-270
viii increase_0-180
ix decrease_Equator
x increase_90-270
xi increase_90-270
xii decrease_0-180

e. Time Taken: 2.39

20. Puzzle2-19
    a. States Expanded: 206722
    b. Maximum Queue: 797026
    c. Path Length: 13
    d. Path:
        i increase_Equator
        ii decrease_0-180
        iii decrease_90-270
        iv increase_0-180
        v decrease_Equator
        vi increase_90-270
        vii decrease_Equator
        viii increase_0-180
        ix increase_0-180
        x increase_90-270
        xi increase_Equator
        xii decrease_90-270
        xiii increase_Equator
    e. Time Taken: 117.75

Detailed Results for Each Puzzle using RBFS

1. Puzzle2-0

   Terminated after 40 Mins. Following are the variables when terminated

   a. States Expanded: 578932

   b. Maximum Queue: 3473592

   e. Time Taken: 2405.31

2. Puzzle2-1

   a. States Expanded: 542964

   b. Maximum Queue: 3257784

   c. Path Length: 16

   d. Path:

i	increase_0-180
ii	increase_0-180
iii	increase_90-270
iv	decrease_0-180
v	increase_90-270
vi	increase_Equator
vii	increase_0-180
viii	increase_Equator
ix	increase_0-180
x	increase_0-180
xi	increase_Equator
xii	decrease_90-270
xiii	increase_Equator
xiv	decrease_0-180
xv	increase_0-180
xvi	decrease_90-270

   e. Time Taken: 348.58

3. Puzzle2-2

   a. States Expanded: 25

   b. Maximum Queue: 150

   c. Path Length: 9

   d. Path:

i	decrease_90-270
ii	decrease_90-270
iii	increase_Equator
iv	increase_Equator
v	increase_Equator
vi	decrease_90-270
vii	increase_Equator
viii	increase_90-270
ix	decrease_0-180

e. Time Taken: 0.04

4. Puzzle2-3
    a. States Expanded: 7982
    b. Maximum Queue: 47892
    c. Path Length: 8
    d. Path:
        i increase_Equator
        ii increase_0-180
        iii decrease_90-270
        iv decrease_Equator
        v increase_90-270
        vi increase_90-270
        vii decrease_Equator
        viii increase_0-180
    e. Time Taken: 4.31

5. Puzzle2-4
    a. States Expanded: 70981
    b. Maximum Queue: 425886
    c. Path Length: 11
    d. Path:
        i increase_0-180
        ii increase_90-270
        iii increase_Equator
        iv decrease_90-270
        v increase_Equator
        vi increase_0-180
        vii increase_90-270
        viii decrease_0-180
        ix increase_Equator
        x decrease_0-180
        xi decrease_0-180
    e. Time Taken: 44.09

6. Puzzle2-5
    a. States Expanded: 11670
    b. Maximum Queue: 70020
    c. Path Length: 12
    d. Path:
        i decrease_90-270
        ii decrease_90-270
        iii decrease_Equator
        iv increase_90-270

v decrease_Equator
vi decrease_Equator
vii increase_0-180
viii increase_0-180
ix increase_Equator
x increase_0-180
xi increase_0-180
xii increase_0-180

e. Time Taken: 7.59

7. Puzzle2-6
   a. States Expanded: 168450
   b. Maximum Queue: 1010700
   c. Path Length: 16
   d. Path:
      i increase_90-270
      ii increase_Equator
      iii increase_Equator
      iv decrease_90-270
      v decrease_90-270
      vi decrease_90-270
      vii decrease_90-270
      viii increase_Equator
      ix increase_Equator
      x increase_0-180
      xi increase_Equator
      xii increase_0-180
      xiii decrease_90-270
      xiv decrease_Equator
      xv decrease_90-270
      xvi decrease_90-270
   e. Time Taken: 97.22

8. Puzzle2-7
   Terminated after 40 Mins. Following are the variables when terminated
   a. States Expanded: 4135725
   b. Maximum Queue: 24814350
   e. Time Taken: 2400.04

9. Puzzle2-8
   a. States Expanded: 14731
   b. Maximum Queue: 88386
   c. Path Length: 7
   d. Path:

i decrease_Equator
ii decrease_0-180
iii decrease_0-180
iv decrease_90-270
v increase_0-180
vi increase_90-270
vii increase_0-180

e. Time Taken: 7.94

10. Puzzle2-9
    a. States Expanded: 5725
    b. Maximum Queue: 34350
    c. Path Length: 10
    d. Path:
        i increase_0-180
        ii increase_90-270
        iii increase_90-270
        iv increase_Equator
        v increase_0-180
        vi decrease_Equator
        vii decrease_Equator
        viii increase_90-270
        ix increase_0-180
        x increase_0-180
    e. Time Taken: 3.33

11. Puzzle2-10
    Terminated after 40 Mins. Following are the variables when terminated
    a. States Expanded: 6944828
    b. Maximum Queue: 41668968
    e. Time Taken: 2400.04

12. Puzzle2-11
    a. States Expanded: 167
    b. Maximum Queue: 1002
    c. Path Length: 7
    d. Path:
        i decrease_Equator
        ii decrease_Equator
        iii decrease_90-270
        iv decrease_Equator
        v increase_90-270
        vi decrease_0-180
        vii increase_90-270

e. Time Taken: 0.12

13. Puzzle2-12
    a. States Expanded: 199
    b. Maximum Queue: 1194
    c. Path Length: 7
    d. Path:
        i decrease_0-180
        ii decrease_90-270
        iii increase_Equator
        iv increase_Equator
        v increase_0-180
        vi decrease_Equator
        vii decrease_90-270
    e. Time Taken: 0.15

14. Puzzle2-13
    a. States Expanded: 5553135
    b. Maximum Queue: 33318810
    c. Path Length: 13
    d. Path:
        i decrease_0-180
        ii decrease_Equator
        iii decrease_90-270
        iv decrease_0-180
        v increase_Equator
        vi increase_Equator
        vii increase_0-180
        viii increase_90-270
        ix decrease_Equator
        x decrease_Equator
        xi increase_0-180
        xii increase_90-270
        xiii decrease_0-180
    e. Time Taken: 6321.23

15. Puzzle2-14
    a. States Expanded: 52784
    b. Maximum Queue: 316704
    c. Path Length: 14
    d. Path:
        i decrease_90-270
        ii increase_0-180
        iii increase_0-180

iv decrease_Equator
v increase_0-180
vi increase_0-180
vii decrease_90-270
viii decrease_90-270
ix decrease_Equator
x decrease_0-180
xi decrease_0-180
xii decrease_0-180
xiii increase_0-180
xiv decrease_90-270

e. Time Taken: 26.66

16. Puzzle2-15
    a. States Expanded: 950247
    b. Maximum Queue: 5701482
    c. Path Length: 10
    d. Path:
        i increase_0-180
        ii decrease_Equator
        iii decrease_0-180
        iv increase_90-270
        v decrease_0-180
        vi increase_Equator
        vii increase_0-180
        viii decrease_90-270
        ix decrease_Equator
        x decrease_90-270
    e. Time Taken: 394.25

17. Puzzle2-16
    a. States Expanded: 2613
    b. Maximum Queue: 15678
    c. Path Length: 10
    d. Path:
        i increase_0-180
        ii decrease_90-270
        iii increase_Equator
        iv decrease_0-180
        v decrease_0-180
        vi increase_Equator
        vii decrease_0-180
        viii decrease_0-180
        ix increase_0-180

x increase_90-270

e. Time Taken: 1.41

18. Puzzle2-17

Terminated after 40 Mins. Following are the variables when terminated

a. States Expanded: 10189223

b. Maximum Queue: 61135338

e. Time Taken: 2402.83

19. Puzzle2-18

a. States Expanded: 50272

b. Maximum Queue: 301632

c. Path Length: 12

d. Path:

i increase_Equator
ii increase_90-270
iii increase_Equator
iv increase_Equator
v increase_Equator
vi decrease_90-270
vii decrease_90-270
viii increase_0-180
ix decrease_Equator
x increase_90-270
xi increase_90-270
xii decrease_0-180

e. Time Taken: 32.43

20. Puzzle2-19

Terminated after 40 Mins.Following are the variables when terminated.

a. States Expanded: 11963978

b. Maximum Queue: 71783868

e. Time Taken: 2427.8

Detailed Results for Each Puzzle using BFS

1. Puzzle2-0

   Terminated after 30 Mins. Following are the variables when terminated

   a. States Expanded: 869769

   b. Maximum Queue: 3408406

   e. Time Taken: 1822.98

2. Puzzle2-1

   Terminated after 30 Mins. Following are the variables when terminated

   a. States Expanded: 393175

   b. Maximum Queue: 1543489

   e. Time Taken: 1861.81

3. Puzzle2-2

   Terminated after 30 Mins. Following are the variables when terminated

   a. States Expanded: 419151

   b. Maximum Queue: 1645452

   e. Time Taken: 1801.91

4. Puzzle2-3

   a. States Expanded: 389693

   b. Maximum Queue: 1529823

   c. Path Length: 8

   d. Path:

i	increase_Equator
ii	increase_0-180
iii	decrease_90-270
iv	decrease_Equator
v	increase_90-270
vi	increase_90-270
vii	decrease_Equator
viii	increase_0-180

   e. Time Taken: 182.62

5. Puzzle2-4

   Terminated after 30 Mins.Following are the variables when terminated

   a. States Expanded: 1004588

   b. Maximum Queue: 3934964

   e. Time Taken: 1804.93

6. Puzzle2-5

   Terminated after 30 Mins.Following are the variables when terminated

   a. States Expanded: 1012817

   b. Maximum Queue: 3967183

e. Time Taken: 1804.27

7. Puzzle2-6
   Terminated after 30 Mins.Following are the variables when terminated
   a. States Expanded: 1005369
   b. Maximum Queue: 3938035
   e. Time Taken: 1804.54

8. Puzzle2-7
   Terminated after 30 Mins.Following are the variables when terminated
   a. States Expanded: 837481
   b. Maximum Queue: 3282000
   e. Time Taken: 1832.59

9. Puzzle2-8
   Terminated after 30 Mins.Following are the variables when terminated
   a. States Expanded: 321787
   b. Maximum Queue: 1263279
   e. Time Taken: 1813.44

10. Puzzle2-9
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 361265
    b. Maximum Queue: 1418200
    e. Time Taken: 1806.62

11. Puzzle2-10
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 823059
    b. Maximum Queue: 3225517
    e. Time Taken: 1890.56

12. Puzzle2-11
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 938713
    b. Maximum Queue: 3677601
    e. Time Taken: 1859.18

13. Puzzle2-12
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 899424
    b. Maximum Queue: 3524423
    e. Time Taken: 1805.06

14. Puzzle2-13
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 952217
    b. Maximum Queue: 3730524
    e. Time Taken: 1806.13

15. Puzzle2-14
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 892337
    b. Maximum Queue: 3496642
    e. Time Taken: 1805.27

16. Puzzle2-15
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 488376
    b. Maximum Queue: 1917248
    e. Time Taken: 1899.7

17. Puzzle2-16
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 114138
    b. Maximum Queue: 448786
    e. Time Taken: 1862.91

18. Puzzle2-17
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 942193
    b. Maximum Queue: 3691264
    e. Time Taken: 1806.37

19. Puzzle2-18
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 922921
    b. Maximum Queue: 3616231
    e. Time Taken: 1811.23

20. Puzzle2-19
    Terminated after 30 Mins.Following are the variables when terminated
    a. States Expanded: 876597
    b. Maximum Queue: 3435157
    e. Time Taken: 1814.0