Path Puzzles Interactive Park 1.0
User Manual

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1 Introduction

1.1 Path Puzzles Overview

Path Puzzle is a single-player logic puzzle introduced by Roderick Kimball in 2013. This puzzle was proven NP-complete in 2020. The puzzle is played on a rectangular grid of cells with two openings on the edge and constraint numbers on some rows and columns. The objective is to find a solution by creating a single continuous line, or path, that connects the two openings while satisfying the given constraints. Each cell in the grid can only be passed through at most once, and the number of cells passing through a specific row or column must equal the constraint numbers.

1.2 Application Overview

The “Path Puzzles Interactive Park 1.0” is an online tool designed to assist the users in exploring Path Puzzles. The application simplifies constructing and solving these puzzles by providing a user-friendly interface and useful features. This user manual guides the users through the application process, covering everything from puzzle construction to challenging anyone to solve the puzzles independently. The layout of the main interface is depicted in Figure 1.

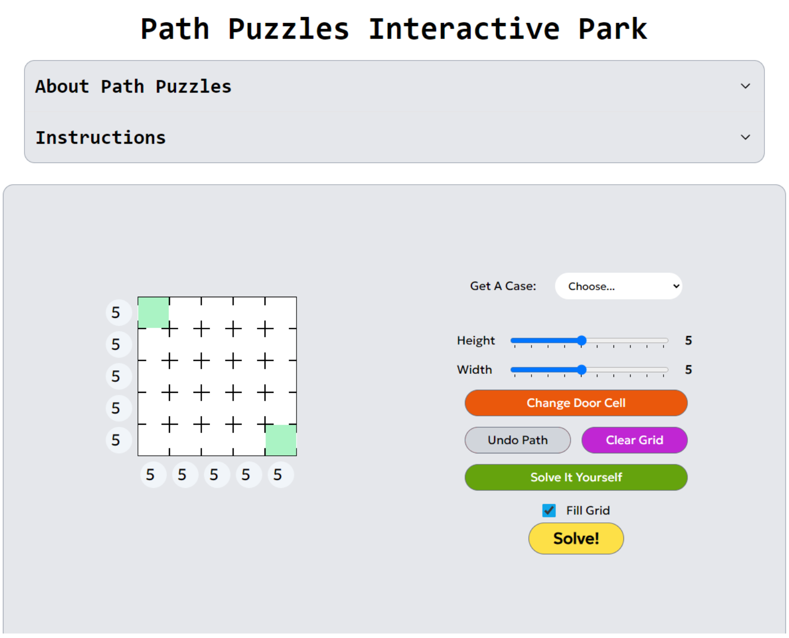


Figure 1: The main layout of “Path Puzzles Interactive Park 1.0”.

1.3 Source Code

The application is built using the Django framework. The puzzle solver in the application is implemented in Python using the PySAT library, while the puzzle solution verifier is implemented in Javascript. The source code for the project can be found on `https://github.com/joshuagatizz/path-puzzles-interactive-park`.

2 Functionalities

2.1 Overview

The upper section of the page contains information about Path Puzzles and provides instructions for utilizing the application. The users can expand the sections if they wish to read the details. The application has two primary functionalities: puzzle creation and puzzle solving. The middle of the page has the puzzle grid and various inputs. The users have the flexibility to create Path Puzzles using the diverse inputs provided. When solving the puzzles, the users can utilize our implemented solver or challenge themselves to solve the puzzle independently—the choice is theirs. The puzzles available for solving can be selected from the prepared cases, or if the users prefer, they can create their own Path Puzzles from scratch.

2.2 Getting A Case

If the users are up for a challenge or interested in testing the difficulty of Path Puzzles, they can select a case from the "Get A Case" dropdown menu, as shown in Figure 2. This will automatically map the chosen case onto the grid for the users. Most of these cases are taken from the font-pathpuzzles GitHub repository created by Erik Demaine. The cases are conveniently divided into three categories based on their difficulty: easy, medium, and hard. The designer of this puzzle, Joshua E. Sakti, has curated this leveling. The difficulty level is determined by how 'complete' the grid information is, which refers to the number of rows and columns with clue numbers in the grid. In many cases, the more complete the grid, the more restrictions there are in solving the puzzle, making it more challenging. The users are free to choose the category that suits their preferences.

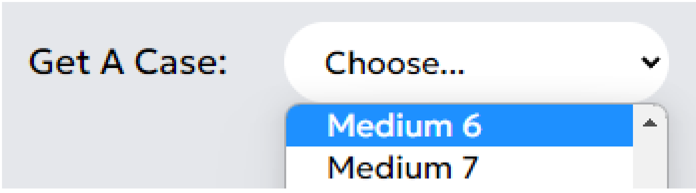


Figure 2: The “Get A Case” dropdown.

2.3 Adjusting the Puzzle Grid

The players can use the “Width” and “Height” sliders as in Figure 3 to increase or decrease the grid size according to the players’ preferences. The minimum dimension for both width and height is 1 while the maximum is 10. Note that the 1×1 grid is invalid since one of the puzzle’s rules is that the door cells must be distinct, which is impossible in a 1×1 grid.

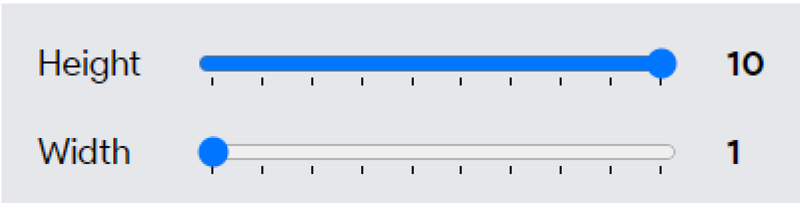
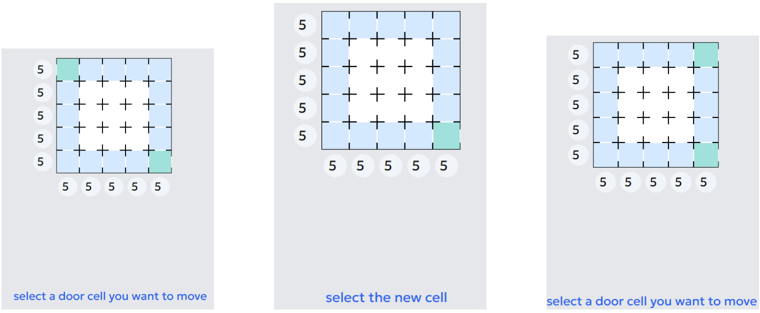


Figure 3: The “Width” and “Height” sliders.

2.4 Changing Door Cells

The door cells are the starting and ending points of the path in the puzzle grid. They are marked with a green color. The players can press the “Change Door Cell” button to move the door cells to different cells on the grid. After pressing the button, the edge cells of the grid will change color to blue as in Figure 4, highlighting the possible cells to be a door cell. When the players have done moving the door cells, they must press the button again to confirm.



(a) “Change Door Cell” button clicked. (b) A door cell is chosen. (c) The new cell is chosen.

Figure 4: The process of moving a door cell.

2.5 Modifying Clue Numbers

Each row and column in the puzzle grid may have clue numbers on the sides, as in Figure 5, indicating the number of cells that must be passed through that row or column. To modify the clue numbers, the players can directly change their values. They can enter specific numbers or leave the value empty if they want no restrictions on a row or column.

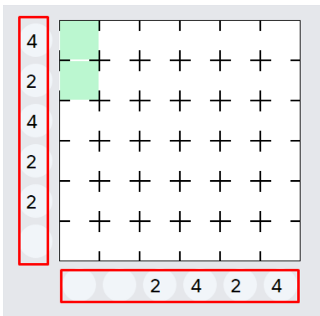
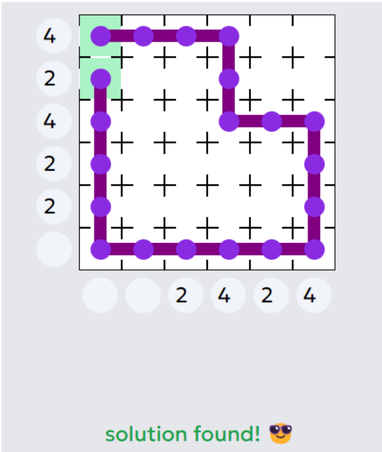


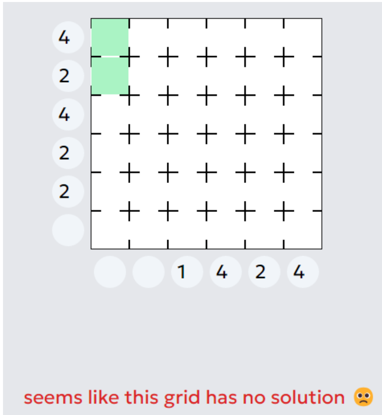
Figure 5: The clue numbers for each row and column.

2.6 Solving the Puzzle Automatically

To solve the puzzle automatically, the players can press the “Solve!” button to instruct the solver to find the solution for the puzzle. If a solution exists, it will be drawn on the grid. The solver will create a path connecting the two door cells, ensuring each cell is passed at most once. It will also satisfy the clue numbers for each row and column. If no solution is found, the players may need to adjust the clue numbers or door cell positions to make the puzzle solvable. The output from the “Solve!” button is depicted in Figure 6.



(a) A solution exists.

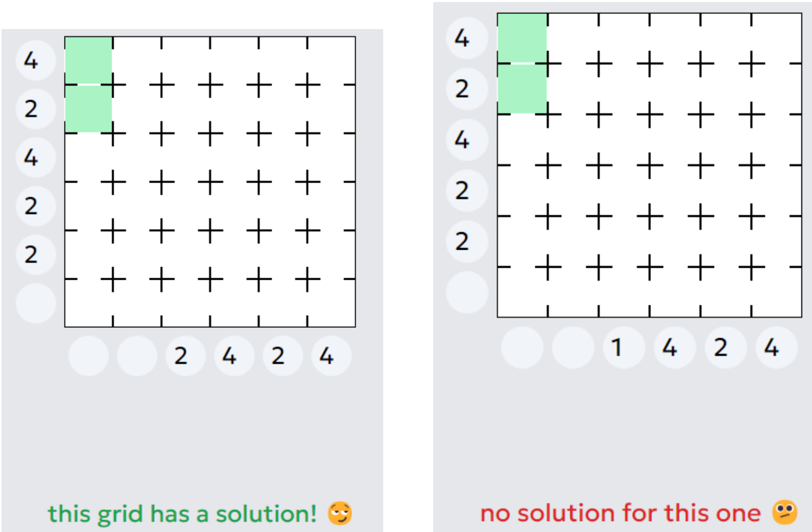


(b) There is no solution.

Figure 6: The output from pressing the “Solve!” button.

Furthermore, the users can uncheck the “Fill Grid” checkbox, which will transform the “Solve!” button into a “Check!” button. Despite the name change, the button serves the same purpose of finding the solution. However, the solver will not draw the grid with the solution this time. Instead, it will only give the players a verdict indicating whether a solution exists.

This feature proves particularly useful when the players prefer to solve a grid on their own but remain uncertain about the presence of a valid solution. By using the “Check!” button, the players can determine the existence of a solution without being directly provided with the solution itself. The output from the “Check!” button is depicted in Figure 7.

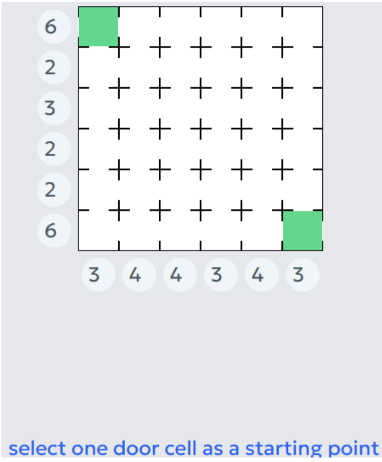


(a) A solution exists. (b) There is no solution.

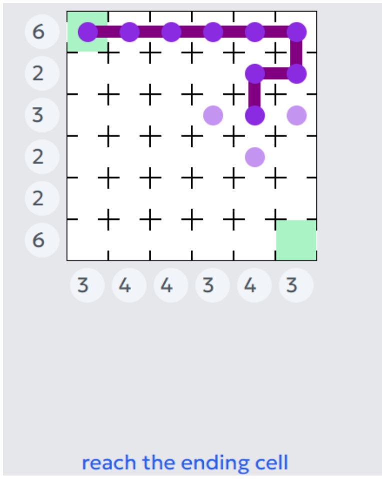
Figure 7: The output from pressing the “Check!” button.

2.7 Solving the Puzzle by The Players

The players can try to solve the puzzle themselves by pressing the “Solve It Yourself” button. To begin solving the puzzle, they click on one of the door cells marked with a green color. Then, they continue to one of its valid adjacent cells marked by semi-opaque purple circles, following the rules of the Path puzzle. The process is depicted in Figure 8.



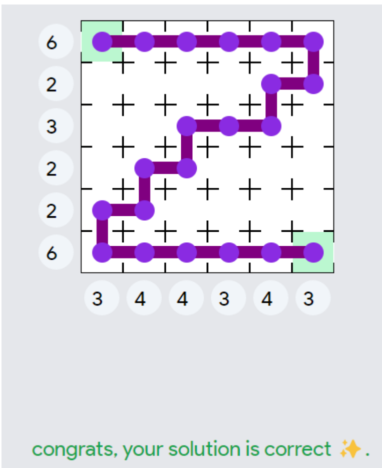
(a) Choosing the starting cell.



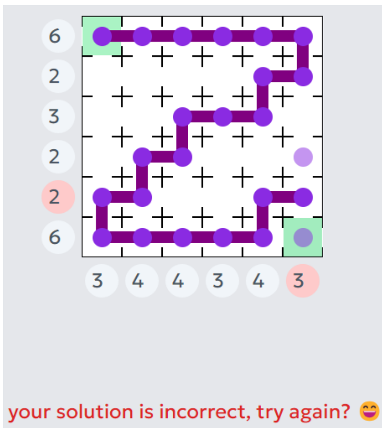
(b) Constructing the path to the ending cell.

Figure 8: The traversal process in creating the solution for a Path puzzle.

Once the players reach the other door cell, they will receive a verdict indicating whether their solution is correct, as depicted in Figure 9. If the solution is incorrect, particular clue numbers will be highlighted with a blinking red effect. This visual indication highlights the unsatisfied clue numbers, allowing the players to pinpoint the mistake in their current solution more easily.



(a) The solution is correct.



(b) The solution is incorrect.

Figure 9: The verdict when the two door cells are connected.

2.8 Undo and Clear

If the players make a mistake while constructing the path, they can backtrack one cell by pressing the “Undo Path” button. This feature will remove the last cell they traversed, allowing them to correct their solution seamlessly. To restart from scratch, they press the “Clear Grid” button. It will clear the entire grid and allow them to start over.

It’s worth noting that the “Clear Grid” button also serves another purpose. If the players use the “Solve!” button to generate a solution and wish to remove it, a single press on the “Clear Grid” button will erase the solver’s solution from the grid.

A SAT-based Solver Source Code

```python
import itertools
from pysat.solvers import MinisatGH

# Path instance
m, n = -1, -1
start_x, start_y, finish_x, finish_y = -1, -1, -1, -1
cr, cc = [], []

# Helpers
dirs = ['d', 'l', 'r', 'u']
move = { 'd': (1,0), 'l': (0,-1), 'r': (0,1), 'u': (-1,0) }
max_lit = 0

def is_valid(i, j):
  return 0 <= i < m and 0 <= j < n
def get_adjacents(i, j):
  return [(i+dx, j+dy) for dx, dy in move.values()
          if is_valid(i+dx, j+dy)]

# Cardinality constraints
def atMost(lits, bound):
  combinations = list(
                   map(list, itertools.combinations(lits, bound+1)))
  return [[-v for v in comb] for comb in combinations]
def equals(lits, bound):
  return atMost(lits, bound)
       + atMost([-v for v in lits], len(lits)-bound)

def solve_puzzle(cfg):
  global m, n
  global start_x, start_y, finish_x, finish_y
  global cr, cc
  global max_lit

  m = cfg.get('m')
  n = cfg.get('n')
  start_x = cfg.get('start_x')
  start_y = cfg.get('start_y')
  finish_x = cfg.get('finish_x')
  finish_y = cfg.get('finish_y')
  cr = cfg.get('cr')
  cc = cfg.get('cc')
```

```python

    lower_bound_row = sum([val for val in cr if val != -1])
    upper_bound_row = sum([(val if val != -1 else n) for val in cr])
    lower_bound_col = sum([val for val in cc if val != -1])
    upper_bound_col = sum([(val if val != -1 else m) for val in cc])
    ds = abs(finish_y - start_y) + abs(finish_x - start_x)
    lb = max(lower_bound_col, lower_bound_row, ds+1)
    ub = min(upper_bound_col, upper_bound_row)

    found = False
    for path_len in range(lb, ub + 1):
      solver = MinisatGH()

      # A bijective function that maps V(i,j,t) to a unique integer
      def V(i: int, j: int, t: int) -> int:
        return t + j*path_len + i*path_len*n + 1

      max_lit = V(m-1, n-1, path_len-1)

      # Configure start and finish cells
      solver.add_clause([V(start_x, start_y, 0)])
      solver.add_clause([V(finish_x, finish_y, path_len-1)])

      # Configure rule: if true for some cell (i,j), then one of its
      # adjacent cells must be true
      for t in range(path_len - 1):
        for i in range(m):
          for j in range(n):
            adj = get_adjacents(i,j)
            if len(adj) != 0:
              solver.add_clause([-V(i,j,t)]
                  + [V(ni,nj,t+1) for ni,nj in adj])

      # Configure rule: at time t, only one cell must be true
      for t in range(path_len):
        solver.add_clause([V(i,j,t) for i in range(m) for j in range(n)])
        AC = [V(i,j,t) for i in range(m) for j in range(n)]
        for a in range(m*n-1):
          for b in range(a+1, m*n):
            solver.add_clause([-AC[a], -AC[b]])

      # Configure rule: at each cell (i,j), it can be true
      # for at most one time t
      for i in range(m):
```

```
    for j in range(n):
      for t1 in range(path_len-1):
        for t2 in range(t1+1, path_len):
          solver.add_clause([-V(i,j,t1), -V(i,j,t2)])

  # Contraint number setup
  memo = {}
  def C(i: int, j: int):
    global max_lit
    if (i,j) in memo: return memo[(i,j)]
    max_lit += 1
    memo[(i,j)] = max_lit
    return memo[(i,j)]

  for i in range(m):
    for j in range(n):
      cur_cell = [V(i,j,t) for t in range(path_len)]
      solver.add_clause([-C(i,j), *cur_cell])
      solver.append_formula([[C(i,j), -x] for x in cur_cell])

  # Configure constraint row
  for i in range(m):
    if cr[i] != -1:
      row_vars = [C(i,j) for j in range(n)]
      constraint_row = equals(lits=row_vars, bound=cr[i])
      solver.append_formula(constraint_row)

  # Configure constraint col
  for j in range(n):
    if cc[j] != -1:
      col_vars = [C(i,j) for i in range(m)]
      constraint_col = equals(lits=col_vars, bound=cc[j])
      solver.append_formula(constraint_col)

  # Running the SAT solver
  sat = solver.solve()

  if sat:
    solution = solver.get_model()
    def var_is_true(x):
      l, r = 0, len(solution) - 1
      while l <= r:
        mid = (l+r)//2
        if abs(solution[mid]) == x:
```

```
            return solution[mid] > 0
          elif abs(solution[mid]) > x:
            r = mid - 1
          else:
            l = mid + 1
        assert(False)
      # Get path
      path = []
      for t in range(path_len):
        for i, j in itertools.product(range(m), range(n)):
          if var_is_true(V(i,j,t)):
            path.append((i,j))
            break
      # Draw grid
      grid = [['.' for _ in range(n)] for _ in range(m)]
      grid[finish_x][finish_y] = 'u'
      for i in range(len(path) - 1):
        for d, delta in move.items():
          adj_x, adj_y = path[i][0]+delta[0], path[i][1] + delta[1]
          if path[i+1] == (adj_x,adj_y):
            grid[path[i][0]][path[i][1]] = d
      # Return
      found = True;
      return {'found': found, 'grid': grid}
      break

  if not found:
    return {'found': found, 'grid': []}
```

B Verifier Source Code

```
function verify() {
    let invalid = []
    let isIncompliant = false
    updateConstraints()
    for (let idx = 0; idx < path.length; idx++) {
        if (cr[path[idx][0]] - 1 == -1) {
            cr[path[idx][0]] = 999
        } else if (cc[path[idx][1]] - 1 == -1) {
            cc[path[idx][1]] = 999
        }
        if (cr[path[idx][0]] != -1)
            cr[path[idx][0]] = cr[path[idx][0]] -1
        if (cc[path[idx][1]] != -1)
            cc[path[idx][1]] = cc[path[idx][1]] -1
    }
    for (let i = 0; i < m; i++) {
        if (cr[i] > 0)  {
            invalid.push(`cr-${i+1}`)
            isIncompliant = true
        }
    }
    for (let j = 0; j < n; j++) {
        if(cc[j] > 0) {
            invalid.push(`cc-${j+1}`)
            isIncompliant = true
        }
    }
    updateConstraints()
    return [!isIncompliant, invalid]
}
```