HILL CLIMBING

In [1]:
```
import numpy as np
```

Função Estado Inicial

- Gerando matriz de dimensão NxN onde N é o número de rainhas e atribuindo uma posição para cada rainha.

In [2]:
```
def estadoInicial(numRainhas):

    tabuleiro = np.zeros((numRainhas, numRainhas),
                         dtype=np.int)

    for i in range(numRainhas):
        posicaoAleatoria = np.random.randint(numRainhas)
        tabuleiro[posicaoAleatoria, i] = 1

    return tabuleiro
```

Função Diagonal

- Função para percorrer diagonais da matriz do tabuleiro

In [3]:
```
def funcaoDiagonal(dimensao, valor, tipo='P'):

    linhas = []; colunas = []
    sinal  = 1 if tipo == 'P' else -1

    for i in range(dimensao):
        for j in range(dimensao):
            if i + j*sinal == valor:
                linhas.append(i)
                colunas.append(j)

    return linhas, colunas
```

Função Ataque Linhas

- Função para calcular o número total de ataques nas linhas do tabuleiro

In [4]:
```
def ataqueLinha(tabuleiro, dimensao, ataques=0):

    for linha in range(dimensao):
        numRainhas = np.count_nonzero(tabuleiro[linha, :])
        ataques += numRainhas - 1 if numRainhas > 1 else 0

    return ataques
```

Função Ataque Diagonal Primária

- Sabendo que LINHA + COLUNA resultam em constantes para uma determinada diagonal primária teremos:
- 1 a 2N -3, onde N é parte da dimensão NxN da matriz (tabuleiro)

In [5]:
```
def ataqueDiagonalPrimaria(tabuleiro, dimensao, ataques=0):

    for valorDiagonal in range(1, 2*dimensao-3):
        linhas, colunas = funcaoDiagonal(dimensao, valorDiagonal)
        numRainhas = np.count_nonzero(tabuleiro[linhas, colunas])
        ataques += numRainhas - 1 if numRainhas > 1 else 0

    return ataques
```

Ataque Diagonal Secundária

- Sabendo que LINHA - COLUNA resultam em constantes para uma determinada diagonal secundária teremos:
- -N+2 a N-1, onde N é parte da dimensão NxN da matriz (tabuleiro)

In [6]:
```
def ataqueDiagonalSecundaria(tabuleiro, dimensao, ataques=0):

    for valorDiagonal in range(-dimensao+2, dimensao-1):
        linhas, colunas = funcaoDiagonal(dimensao, valorDiagonal, tipo='S')
        numRainhas = np.count_nonzero(tabuleiro[linhas, colunas])
        ataques += numRainhas - 1 if numRainhas > 1 else 0

    return ataques
```

Função Custo

- Função para calcular o número total de pares de damas em ataque com base nas funções de ataque acima

In [7]:
```
def funcaoCusto(tabuleiro):

    dimensao = tabuleiro.shape[0]

    ataques  = ataqueLinha(tabuleiro, dimensao)
    ataques += ataqueDiagonalPrimaria(tabuleiro, dimensao)
    ataques += ataqueDiagonalSecundaria(tabuleiro, dimensao)

    return ataques
```

Função Matriz de Custo

- Utilizando a função anterior, é possível chegar na matriz de custo. Ou seja, calcularmos os custos para todos os movimentos possíveis das rainhas em suas colunas do tabuleiro.

In [8]:
```
def gerarmatrizCusto(tabuleiro):

    dimensao = tabuleiro.shape[0]
    custos   = []

    for coluna in range(dimensao):
        posicaoInicialRainha = tabuleiro[:, coluna].argmax()
        tabuleiro[:, coluna] = 0

        for linha in range(dimensao):
            tabuleiro[linha, coluna] = 1
            custos.append(funcaoCusto(tabuleiro))
            tabuleiro[linha, coluna] = 0
```

```
        tabuleiro[posicaoInicialRainha, coluna] = 1

    return np.array(custos).reshape((dimensao, dimensao)).T
```

Funções de Mutação (Melhor Vizinho)

- Funções para tentativa de alcançar a função ótima, utilizando a lógica de "melhor vizinho"

In [9]:

```
# POSIÇÕES DAS RAINHAS
def gerarPosicaoRainhas(tabuleiro):

    linhas, colunas = np.where(tabuleiro == 1)
    return set(zip(linhas, colunas))
```

In [10]:

```
# POSIÇÕES SEM RAINHAS
def gerarPosicaoAleatoria(tabuleiro):

    linhas, colunas = np.where(tabuleiro == 0)
    return list(zip(linhas, colunas))
```

In [11]:

```
# POSSÍVEIS MOVIMENTOS NO TABULEIRO
def gerarMovimentos(matrizCusto):

    linhas, colunas = np.where(matrizCusto == np.min(matrizCusto))
    return set(zip(linhas, colunas))
```

In [12]:

```
# ITERAÇÕES DE MUDANÇA DE ESTADO NO TABULEIRO
def mudarDeEstado(tabuleiro):

    dimensao = tabuleiro.shape[0]

    posicaoRainhas = gerarPosicaoRainhas(tabuleiro)
    matrizCusto  = gerarmatrizCusto(tabuleiro)
    possibilidades = gerarMovimentos(matrizCusto)

    if (possibilidades - posicaoRainhas) == set():
        print('\nSHOW! Temos um Mínimo Local!\n')
        movimentos = gerarPosicaoAleatoria(tabuleiro)

    else:
        movimentos = list(possibilidades - posicaoRainhas)

    aleatorio  = np.random.randint(len(movimentos))
    movimento  = movimentos[aleatorio]

    tabuleiro[:, movimento[1]] = 0
    tabuleiro[movimento]       = 1

    print('\nMatriz de Custo')
    print(matrizCusto.view())

    return tabuleiro
```

Algoritmo de Hill Clumbing

In [13]:

```
def hillClimbing(numRainhas):
```

```
    tabuleiro = estadoInicial(numRainhas)

    print('\nEstado Inicial')
    print(tabuleiro.view())

    movimentos = 0
    while(funcaoCusto(tabuleiro)):
        tabuleiro = mudarDeEstado(tabuleiro)
        movimentos += 1

        print('\nMelhor Vizinho # %d' % movimentos)
        print(tabuleiro.view())


    print('\nCusto:', funcaoCusto(tabuleiro))
    print('Total Movimentos: %d\n' % movimentos)
```

In [18]:
```
%time hillClimbing(numRainhas=15)
```

```
Estado Inicial
[[0 0 0 0 0 0 0 0 0 0 0 1 0 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 0]
 [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 1 0 0 1 0 0 0 0 0 0]
 [0 0 0 0 0 0 0 1 0 0 0 0 0 0 1]
 [0 0 0 1 0 0 0 0 0 0 0 0 0 0 0]
 [0 1 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 0 0 0]
 [1 0 0 0 0 0 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 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 1 1 0 0 0 0]
 [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[16 18 17 16 16 17 15 16 17 19 16 17 17 17 16]
 [15 16 16 16 14 16 15 16 16 16 17 16 17 16 17]
 [15 16 15 16 15 15 16 17 15 17 16 17 15 18 15]
 [16 16 15 15 15 17 15 16 17 17 16 15 17 16 16]
 [17 18 16 16 16 17 16 17 17 19 16 17 16 18 16]
 [16 18 17 17 16 16 17 17 17 18 18 16 16 17 17]
 [17 17 18 17 15 17 16 18 17 18 17 17 16 18 16]
 [16 17 17 17 17 17 16 16 18 18 16 17 17 17 16]
 [16 17 16 16 16 17 14 16 15 17 16 16 16 17 16]
 [17 17 17 18 16 17 17 16 16 17 18 17 16 19 18]
 [15 18 16 16 15 16 15 16 15 17 15 16 17 17 16]
 [17 17 17 15 15 16 14 16 17 16 15 16 17 17 15]
 [16 18 15 17 14 15 15 16 16 17 16 16 15 17 16]
 [17 17 17 16 16 16 16 17 16 17 17 16 16 17 17]
 [15 17 15 16 14 17 14 15 17 17 16 16 15 16 15]]

Melhor Vizinho # 1
[[0 0 0 0 0 0 0 0 0 0 0 1 0 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 0]
 [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 1 0 0 1 0 0 0 0 0 0]
 [0 0 0 0 0 0 0 1 0 0 0 0 0 0 1]
 [0 0 0 1 0 0 0 0 0 0 0 0 0 0 0]
 [0 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 0 0 0 0 0]
 [1 0 0 0 0 0 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 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 1 1 0 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[13 15 14 13 16 14 12 13 14 16 13 14 14 14 13]
 [12 13 13 13 14 13 12 13 13 13 14 14 14 13 14]
 [12 13 12 13 15 12 13 14 12 14 13 15 12 15 12]
 [13 13 12 12 15 14 12 13 14 14 13 13 14 13 13]
 [14 15 13 13 16 14 13 14 14 16 13 15 13 15 14]
 [13 15 14 14 16 13 14 14 14 15 15 14 13 15 14]
 [14 14 15 14 15 14 13 15 14 15 14 15 14 15 13]
 [13 14 14 14 17 14 13 13 15 15 13 16 14 14 13]
 [13 14 13 13 16 14 11 13 12 14 14 14 13 14 13]
 [14 14 14 15 16 14 14 13 13 15 15 15 13 16 15]
 [13 15 13 13 15 13 12 13 13 14 12 14 14 14 13]
 [14 15 14 12 15 13 11 14 14 13 12 14 14 14 12]
 [13 15 13 14 14 12 13 13 13 14 13 14 12 14 13]
 [14 14 14 14 16 14 13 14 13 14 14 14 13 14 14]
 [13 15 13 14 14 15 12 13 15 15 14 15 13 14 13]]

Melhor Vizinho # 2
[[0 0 0 0 0 0 0 0 0 0 0 0 1 0 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 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 1 0 0 0 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 0 0 0 0 0 0 0 0 0 0]
 [0 1 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 0 0]
 [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 0]
 [0 0 0 0 0 0 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 1 0 0 0 0 0 0 1 1 0 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[11 12 12 10 13 11 12 10 11 13 10 11 11 11 10]
 [10 10 11 10 11 10 12 10 10 10 11 11 11 10 11]
 [10 10 10 10 12  9 13 11  9 11 10 12  9 12  9]
 [11 10 10  9 12 11 12 10 11 11 10 10 11 10 11]
 [12 12 11 10 13 11 13 11 11 13 10 12 10 13 11]
 [12 12 12 11 13 10 14 11 11 12 12 11 11 12 11]
 [12 12 13 11 12 11 13 12 11 12 11 13 11 12 10]
 [11 11 13 11 14 11 13 10 12 12 11 13 11 11 10]
 [11 11 11 11 13 11 11 10  9 12 11 11 10 11 10]
 [11 11 12 12 14 11 14 10 11 12 12 12 10 13 12]
 [11 12 11 10 12 11 12 11 10 11  9 11 11 11 10]
 [13 13 13 10 13 11 11 12 12 11 10 12 12 12 10]
 [11 12 11 11 11 10 13 11 10 11 10 11  9 11 10]
 [12 11 11 11 14 11 13 11 11 11 11 11 10 11 11]
 [11 12 11 12 11 12 12 10 12 13 11 12 10 11 10]]

Melhor Vizinho # 3
[[0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 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 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 1 0 0 0 0 0 0 1]
 [0 0 0 1 0 0 0 0 0 0 0 0 0 0 0]
 [0 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 0 0 0 0]
 [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 0 0 0 0 0 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 1 0 0 0 0 0 0 1 1 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[ 9  9 10  9 11 11 10  9 10 11  8  9  9  9  8]
 [ 8  8  8  8 10 10 11  8  9  8  9  9  9  8  9]
 [ 9  9  9  8 11  9 12 10  9 10  9 11  8 11  8]
 [ 9  8  8  7 10 11 11  8 10  9  8  8  9  8  9]
 [10 10  9  9 11 11 11 10  9 11  8 10  8 11  9]
 [10 10 11  9 11 10 11  9 11 10 10  9  9 10  9]
 [10 11 11  9 10 11 11  9 10 11  9 11  9 10  8]
 [10  9 11  9 12 11 11  8 10 10 10 11  9  9  8]
 [ 9  9  9  9 11 11  9  8  8  9  9 10  8  9  8]
 [ 9  9 10 10 12 11 12  8 10 10  9 10  9 11 10]
 [ 9 10  9  8 10 11 10  9  9  9  7  8  9 10  8]
 [11 11 11  8 11 11  9 10 11  9  8 10  9 10  9]
 [ 9 10  9  9  9 10 11  9  9  9  8  9  7  8  8]
 [10  9  9  9 12 11 11  9 10  9  9  9  8  9  8]
 [ 9 10  9 10  9 12 10  8 11 11  9 10  8  9  8]]

Melhor Vizinho # 4
[[0 0 0 0 0 0 0 0 0 0 0 1 0 1 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 1 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 1 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 0 1 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 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 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 1 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[ 9  7  8  9  9  9  9  7  8  9  7  7  7  7  6]
 [ 7  7  6  8  8  9  9  6  7  6  8  7  7  6  7]
 [ 8  7  8  8 10  7 10  8  7  8  8  9  6  9  6]
 [ 9  7  7  7  9 10 10  7  9  8  8  7  8  7  8]
 [ 9  8  8  9 10  9  9  8  7  9  7  8  6  9  7]
 [ 9  9  9  9  9  9  9  7  9  8  9  7  7  8  7]
 [ 9  8  8  9  7  8  9  6  7  8  7  8  6  7  5]
 [ 9  7  9  9 10  9  9  7  8  8  9  9  7  7  6]
 [ 8  7  7  9  9  9  7  6  7  7  8  8  6  7  6]
 [ 7  7  8 10 10  9 10  6  8  9  8  8  7  9  8]
 [ 8  8  7  8  8  9  8  7  7  7  7  6  7  8  6]
 [10  9  9  8  9  9  7  8  9  7  7  9  7  8  7]
 [ 8  8  7  9  7  8  9  7  7  7  7  7  6  6  6]
 [ 9  7  7  9 10  9  9  7  8  7  7  7  6  8  6]
 [ 8  8  7 10  7 10  8  6  9  9  8  8  6  7  7]]

Melhor Vizinho # 5
[[0 0 0 0 0 0 0 0 0 0 0 1 0 1 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 1 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 1 0 0 0 0 0 0 0]
 [0 0 0 0 0 0 0 0 0 0 0 0 0 0 1]
 [0 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 0 0 0 0]
 [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 0 0 0 0 0 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 1 0 0 0 0 0 0 1 1 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[7 5 6 7 7 7 7 6 7 6 5 5 6 5 6]
 [5 5 4 6 6 7 7 5 5 5 5 5 6 4 7]
 [6 5 6 6 8 5 8 7 5 6 7 6 5 7 6]
 [7 5 5 5 7 8 8 6 7 6 6 6 6 5 8]
 [7 6 6 7 8 7 7 7 5 7 5 6 6 6 7]
 [7 7 7 7 7 7 7 5 7 6 7 5 6 7 7]
 [8 7 7 8 6 7 8 6 6 7 6 7 6 6 5]
 [7 5 7 7 8 7 7 6 6 6 7 7 5 6 6]
 [6 5 5 7 7 7 5 5 5 5 6 6 6 5 6]
 [5 5 6 8 8 7 8 5 6 7 6 7 6 7 8]
 [6 6 5 6 6 7 6 6 5 5 6 4 6 6 6]
 [8 7 7 6 7 7 5 7 7 6 5 7 6 6 7]
 [6 6 5 7 5 6 7 6 6 5 5 5 5 4 6]
 [7 5 5 7 8 7 7 7 6 5 5 5 5 6 6]
 [6 6 5 8 5 8 7 5 7 7 6 6 5 5 7]]

Melhor Vizinho # 6
[[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 0 0]
 [0 0 0 0 0 1 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 0 0 0 1 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 0 0 0 0 0 1]
 [0 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 0 0 0 0]
 [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 0 0 0 0 0 1 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 1 0 0 0 0 0 0 1 1 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[6 5 5 6 6 6 6 5 6 5 4 4 5 5 5]
 [4 4 4 5 5 6 6 4 4 4 4 5 4 4 5]
 [5 4 5 6 7 4 7 6 4 5 6 5 4 7 5]
 [6 4 4 4 7 7 7 5 6 5 4 6 5 5 7]
 [6 5 5 6 7 7 6 6 4 5 4 6 5 6 6]
 [6 6 6 6 6 6 7 4 5 5 6 5 5 7 6]
 [7 6 6 7 5 6 7 5 5 6 5 7 5 6 4]
 [6 4 6 6 7 6 5 5 6 5 6 7 4 6 5]
 [5 4 4 6 6 5 4 4 4 5 5 6 5 5 5]
 [4 4 5 7 6 6 7 4 5 6 6 7 5 7 7]
 [5 5 4 4 5 6 5 5 4 4 5 5 5 6 5]
 [7 6 5 5 6 6 4 6 6 5 4 7 6 6 7]
 [6 5 5 7 5 6 7 6 6 5 5 6 5 4 6]
 [5 4 4 6 7 6 6 6 5 4 4 5 5 6 6]
 [5 5 4 7 4 7 6 4 6 6 5 7 4 5 6]]
```

```
Melhor Vizinho # 7
[[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 0 0]
 [0 0 0 0 0 1 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 0 0 0 1 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 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 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 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 0 0 0 0 0 1 0]
 [0 0 1 0 0 0 0 0 0 1 1 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[5 5 5 6 6 6 6 5 5 5 4 4 6 5 5]
 [3 4 4 5 5 6 6 3 4 4 4 5 5 4 5]
 [4 4 5 6 7 4 6 6 4 5 6 5 5 7 5]
 [5 4 4 4 7 6 7 5 6 5 4 6 6 5 7]
 [5 5 5 6 6 7 6 6 4 5 4 6 6 6 6]
 [5 6 6 5 6 6 7 4 5 5 6 5 6 7 6]
 [5 6 5 7 5 6 7 5 5 6 5 7 6 6 4]
 [6 4 6 6 7 6 5 5 6 5 6 7 4 6 5]
 [4 4 4 7 7 6 5 5 5 6 6 7 7 6 6]
 [4 4 6 6 6 6 7 4 5 6 6 7 6 7 7]
 [4 5 4 5 4 6 5 5 4 4 5 5 6 6 5]
 [6 6 5 5 7 5 4 6 6 5 4 7 7 6 7]
 [5 5 5 7 5 7 6 6 6 5 5 6 6 4 6]
 [4 4 4 6 7 6 7 5 5 4 4 5 6 6 6]
 [4 5 4 7 4 7 6 5 5 6 5 7 5 5 6]]

Melhor Vizinho # 8
[[0 0 0 0 0 0 0 0 0 0 0 1 0 0 0]
 [1 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 1 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 1 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 1 0 0]
 [0 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 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 0 0 0 0 0 1 0]
 [0 0 1 0 0 0 0 0 0 1 1 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[5 6 4 5 5 5 5 4 4 4 3 3 5 4 4]
 [3 5 4 5 5 6 6 3 4 4 4 5 5 4 5]
 [4 5 4 5 6 3 5 5 3 4 5 4 4 6 4]
 [5 4 4 3 6 5 6 4 5 4 3 5 5 4 6]
 [5 5 4 6 5 6 5 5 3 4 3 5 5 5 5]
 [5 6 5 4 6 5 6 3 4 4 5 4 5 6 5]
 [5 6 4 6 4 6 6 4 4 5 4 6 5 5 3]
 [6 4 5 5 6 5 5 4 5 4 5 6 3 5 4]
 [4 3 3 6 6 5 4 5 4 5 5 6 6 5 5]
 [4 3 4 4 4 4 5 2 4 4 4 5 4 5 5]
 [4 4 3 4 3 5 4 4 3 4 4 4 5 5 4]
 [6 6 3 4 6 4 3 5 5 4 4 6 6 5 6]
 [5 5 4 5 4 6 5 5 5 4 4 6 5 3 5]
```

```
 [4 4 3 5 5 5 6 4 4 3 3 4 6 5 5]
 [4 5 3 6 3 5 5 4 4 5 4 6 4 5 5]]

Melhor Vizinho # 9
[[0 0 0 0 0 0 0 0 0 0 0 1 0 0 0]
 [1 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 1 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 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 1 0 0]
 [0 1 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 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 0 0 0 0 0 1 0]
 [0 0 1 0 0 0 0 0 0 1 1 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]]

Matriz de Custo
[[4 5 2 4 4 4 4 4 4 3 2 2 4 3 3]
 [2 4 3 3 4 5 5 3 4 3 3 4 4 3 4]
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Melhor Vizinho # 10
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Matriz de Custo
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Melhor Vizinho # 11
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Matriz de Custo
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Melhor Vizinho # 12
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Matriz de Custo
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Melhor Vizinho # 13
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Matriz de Custo
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Melhor Vizinho # 14
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Matriz de Custo
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Melhor Vizinho # 15
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Matriz de Custo
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Melhor Vizinho # 16
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Matriz de Custo
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Melhor Vizinho # 17
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Matriz de Custo
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Melhor Vizinho # 18
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Matriz de Custo
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Melhor Vizinho # 20
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Matriz de Custo
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Melhor Vizinho # 21
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Matriz de Custo
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Melhor Vizinho # 22
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Matriz de Custo
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Melhor Vizinho # 23
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Matriz de Custo
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Melhor Vizinho # 24
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Matriz de Custo
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Melhor Vizinho # 25
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Matriz de Custo
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Melhor Vizinho # 26
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Matriz de Custo
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Melhor Vizinho # 27
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Matriz de Custo
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Melhor Vizinho # 28
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Matriz de Custo
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Melhor Vizinho # 29
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Matriz de Custo
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Melhor Vizinho # 30
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Matriz de Custo
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Melhor Vizinho # 31
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Matriz de Custo
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Melhor Vizinho # 32
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Matriz de Custo
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Melhor Vizinho # 33
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Matriz de Custo
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Melhor Vizinho # 34
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Matriz de Custo
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Melhor Vizinho # 35
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Matriz de Custo
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Melhor Vizinho # 36
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Matriz de Custo
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Melhor Vizinho # 37
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Matriz de Custo
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Melhor Vizinho # 38
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 [0 0 0 0 1 0 0 0 0 0 0 0 0 0 0]]

Custo: 0
Total Movimentos: 38

CPU times: user 30.1 s, sys: 152 ms, total: 30.2 s
Wall time: 33.1 s
```

In [ ]: