Introducción

Para llevar a cabo esta simulación, se hicieron dos clases de agentes distintos: el agente de roomba, que es el encargado en llevar a cabo la tarea de moverse alrededor del grid; y el agente de basura, que representa la basura estática y fija en el grid.

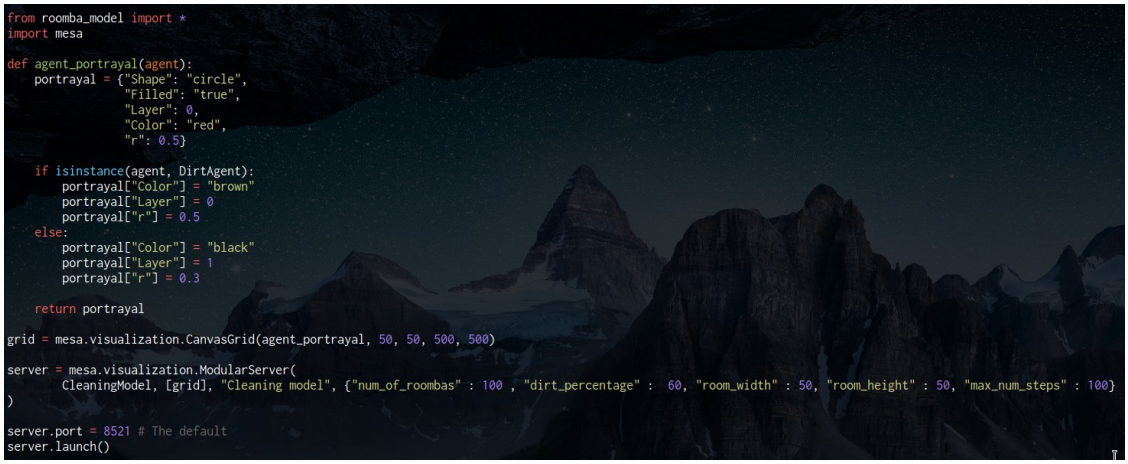
Una vez hecho esto, se establecieron ciertas reglas para los agentes:

- Los agentes de roomba se moverán en alguna dirección aleatoria si no encuentran a su alrededor basura que limpiar
- Los agentes de roomba no tienen permitido interactuar entre sí, pues no pueden ocupar el mismo espacio físico
- Los agentes de basura son estáticos y no pueden aparecer en la misma casilla a la vez

Además, la simulación funciona en un espacio físico no toroide, en cuyo caso significa que los bordes no están conectados los unos con los otros. Por tanto, todos los agentes de la simulación están confinados a un espacio en 2D, como si un tablero de ajedrez se tratese. Una vez explicado esto, procederé a mostrar los resultados de la simulación para una cantidad grande de agentes a través de imágenes. Una vez vista el funcionamiento y los resultados esperados, se procederá a realizar por lotes los análisis estadísticos para encontrar el tiempo en promedio de limpieza, la cantidad promedio de movimientos de cada agente y como la cantidad de agentes afecta en su medida al tiempo de solución.

Simulación

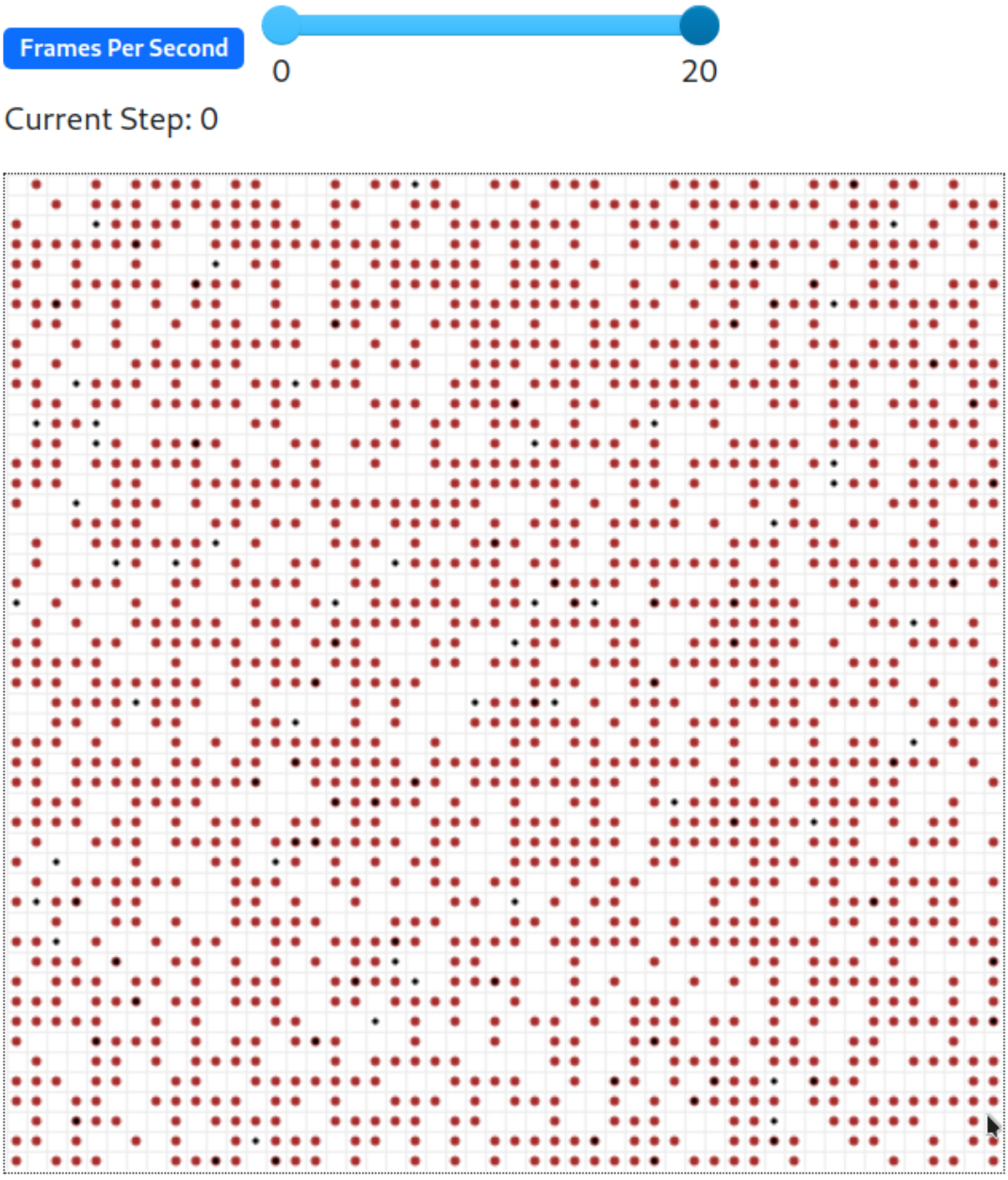
La simulación probada consta de lo siguiente:



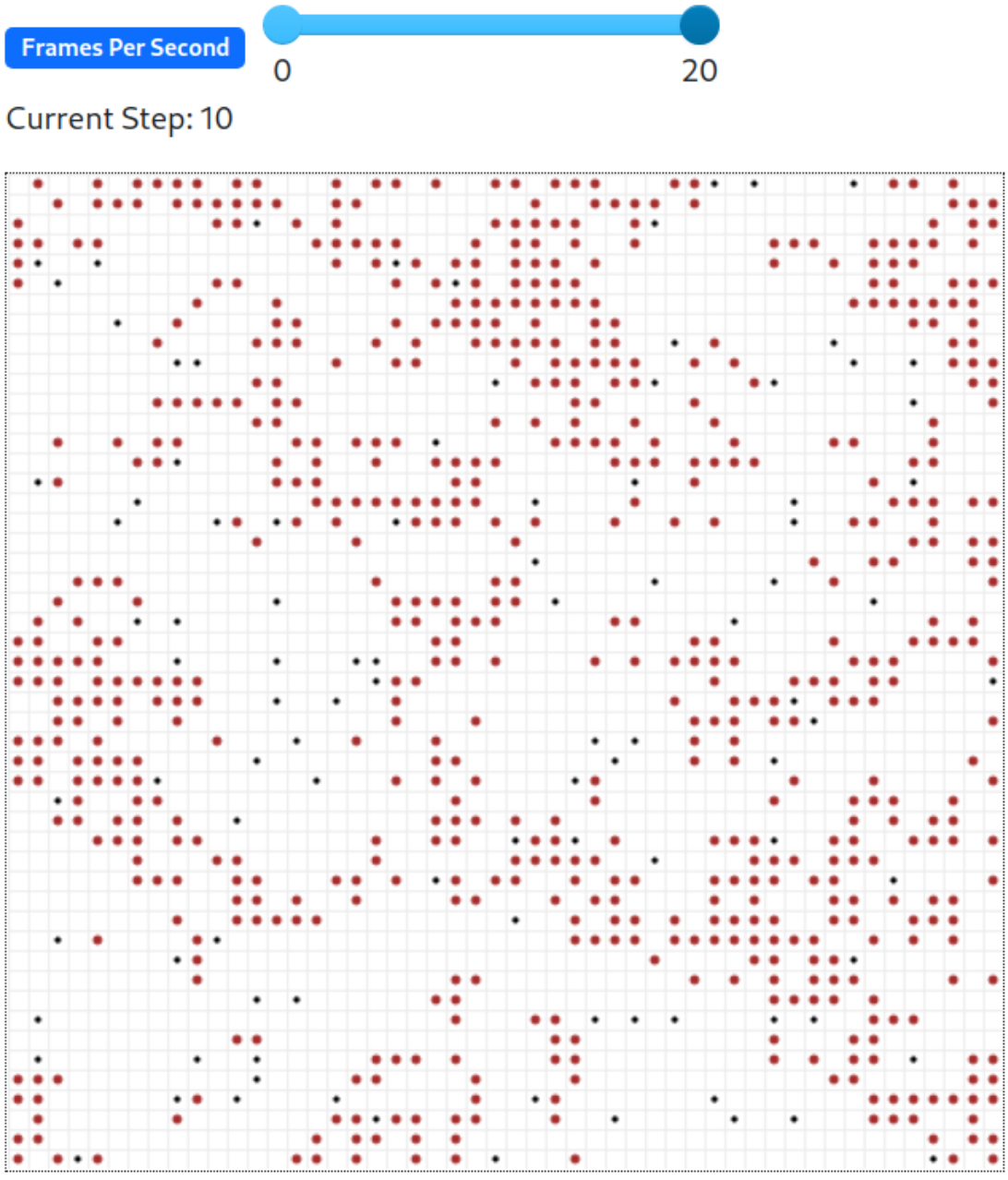
```
from roomba_model import *
import mesa

def agent_portrayal(agent):
    portrayal = {"Shape": "circle",
                 "Filled": "true",
                 "Layer": 0,
                 "Color": "red",
                 "r": 0.5}

    if isinstance(agent, DirtAgent):
        portrayal["Color"] = "brown"
        portrayal["Layer"] = 0
        portrayal["r"] = 0.5
    else:
        portrayal["Color"] = "black"
        portrayal["Layer"] = 1
        portrayal["r"] = 0.3

    return portrayal

grid = mesa.visualization.CanvasGrid(agent_portrayal, 50, 50, 500, 500)

server = mesa.visualization.ModularServer(
        CleaningModel, [grid], "Cleaning model", {"num_of_roombas" : 100 , "dirt_percentage" :  60, "room_width" : 50, "room_height" : 50, "max_num_steps" : 100}
)

server.port = 8521 # The default
server.launch()
```

Tal como muestra la imagen, se uso una cantidad de 100 roombas para la simulación, en un espacio de 50x50 celdas con un porcentaje de suciedad del 60%. Además, se estableció como máximo número de pasos 100. Los resultados son como a continuación:

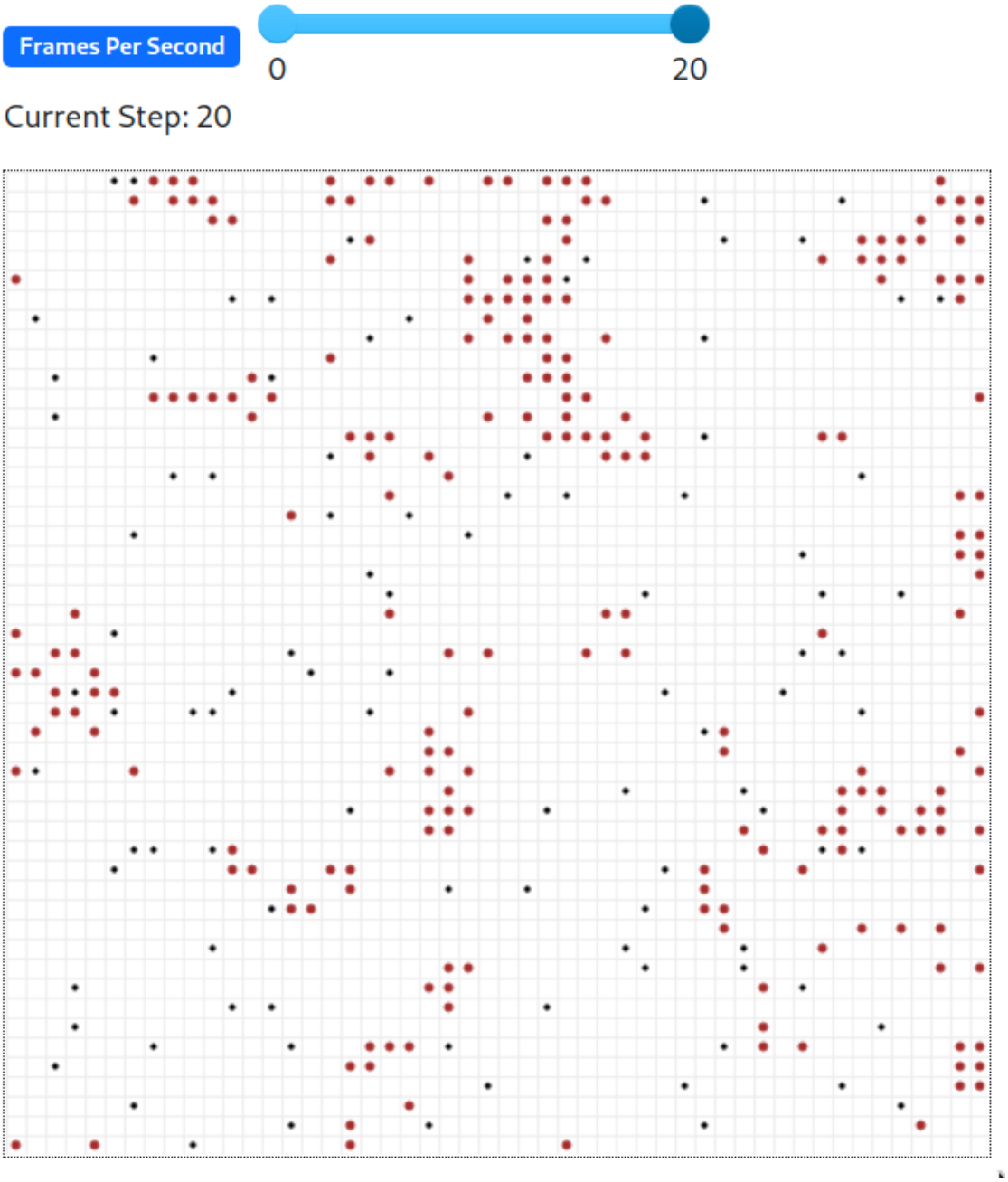
En el paso 0:



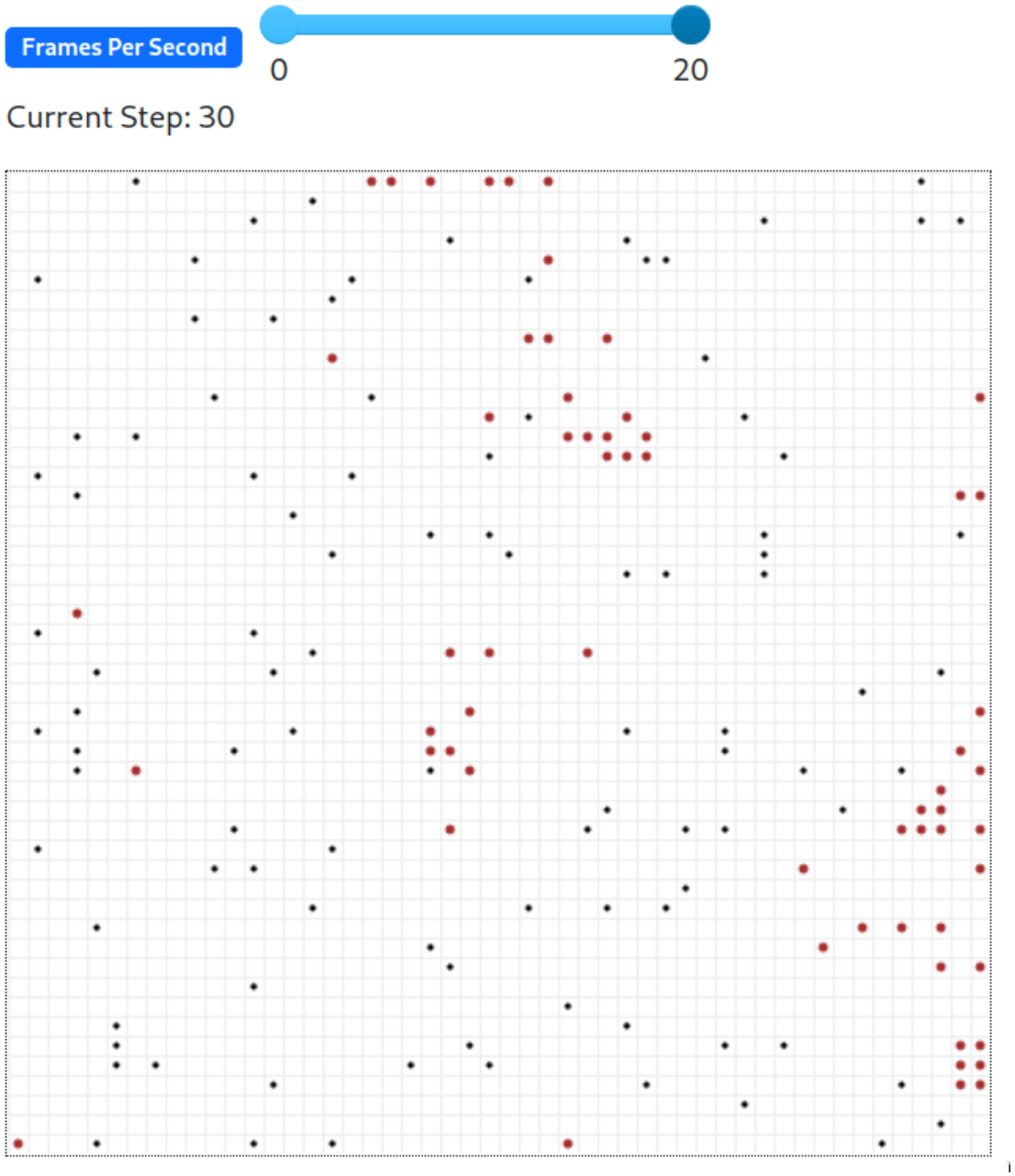
En el paso 10:



En el paso 20:

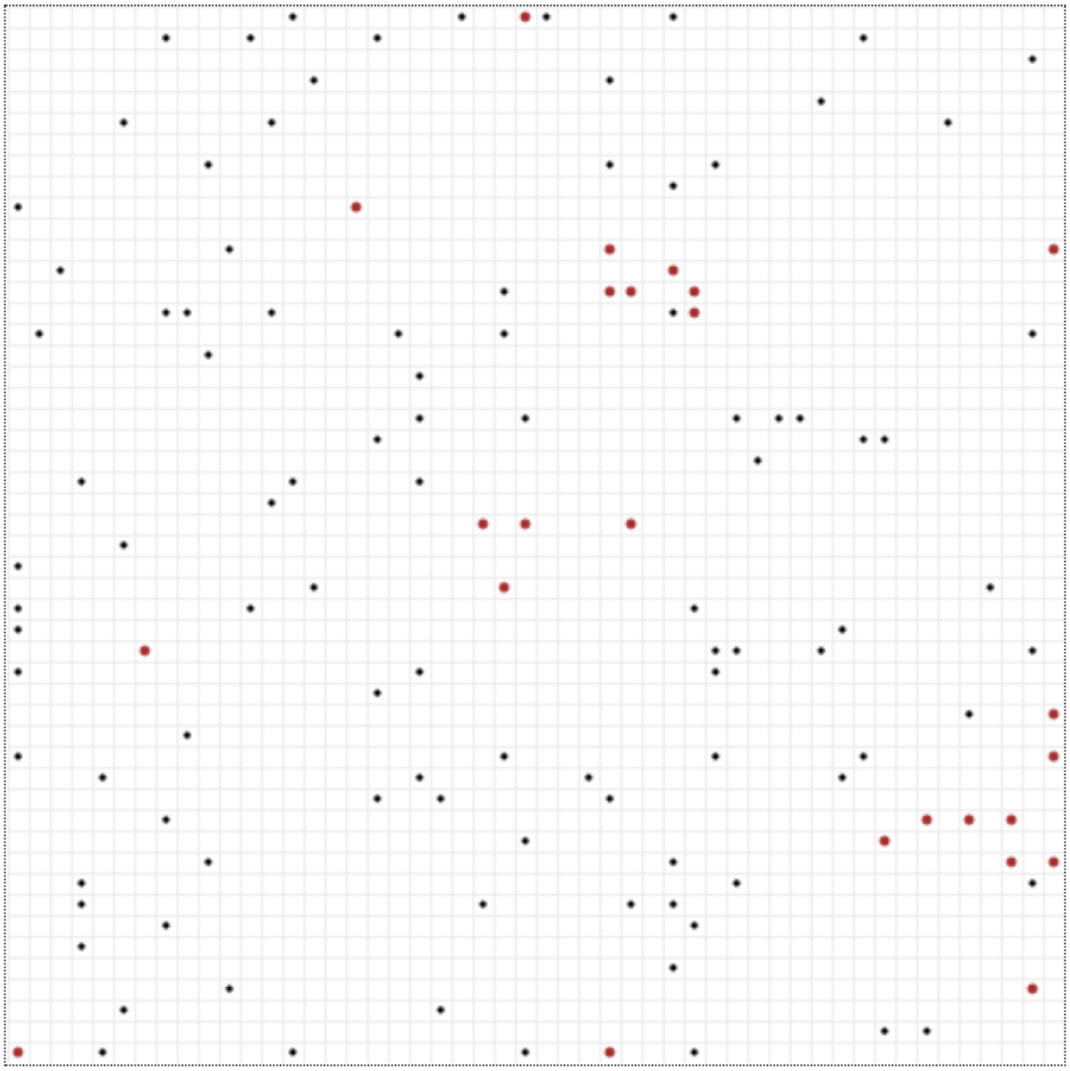


En el paso 30:

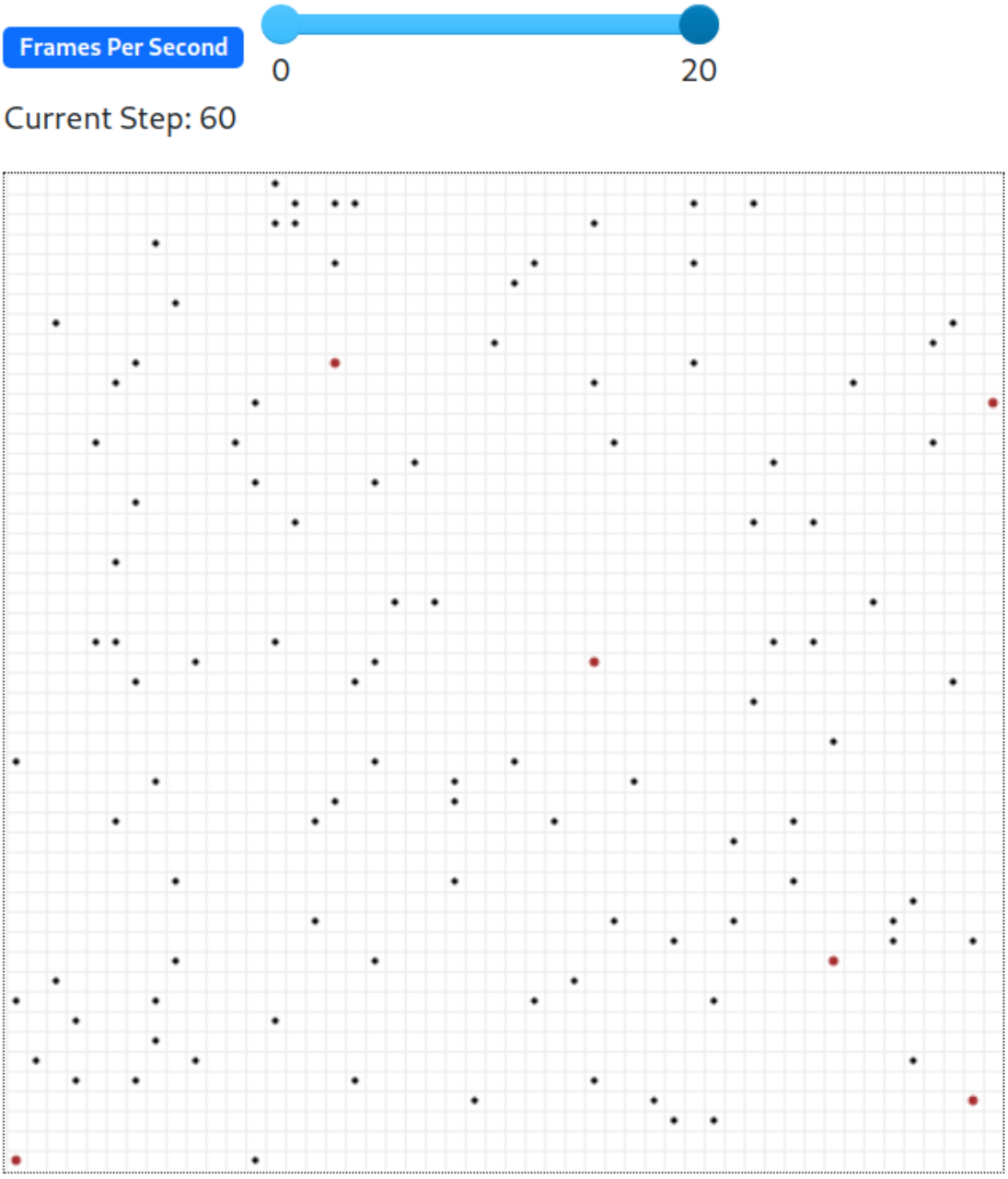


En el paso 40:

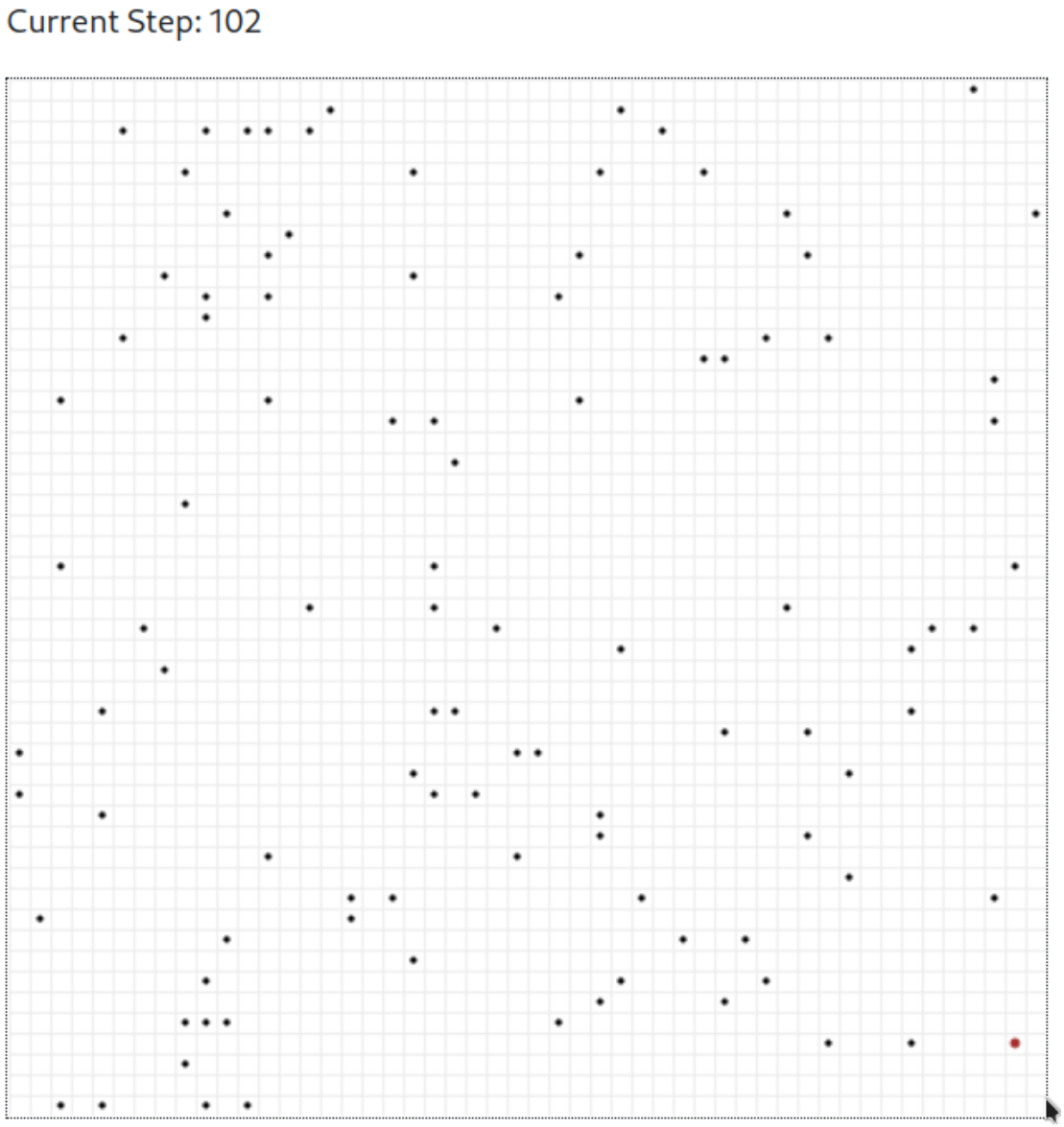
Current Step: 40



En el paso 60:



En el último paso:



En este caso en particular, la simulación no completo en su totalidad la limpieza del lugar. De hecho, se quedo a un 99% de completarse, pues abajo a la derecha se puede apreciar una mancha roja de suciedad.

Por la forma en la que están modelados los agentes, resulta fácil para ellos recorrer y limpiar una larga cantidad de suciedad que este agrupada en contra de buscar pequeños espacios de basura. La razón es simple: una vez que se encuentra una basura, los agentes de roomba buscarán la basura inmediatamente pegada a su ubicación. Pero, al ir poco a poco disminuyendo la basura, los agentes no tendrán cómo buscar la siguiente y estarán moviendose aleatoriamente hasta encontrar más basura. Esa es la razón por la que en un inicio empieza rápida la limpieza pero después toma muchísimos pasos encontrar basura y limpiar más.

```
from roomba_model import *

def run_batch(num_batches, num_of_roombas, dirt_percentage,
room_width, room_height, max_num_steps):
    print(f"Running batch {num_batches} time(s)")
    time = []
    max_time = []
    movements_batches = []
    area_cleaned = []
    not_cleaned = 0

    for i in range(num_batches):
        print(f"\nIteration {i+1}")

        model = CleaningModel(num_of_roombas, dirt_percentage,
room_width, room_height, max_num_steps)
        for j in range(max_num_steps+1):
            ended = model.step()
            if ended is True:
                time.append(model.curr_steps)
                break
            elif ended is False:
                max_time.append(model.max_steps)
                continue

        agent_num = [agent.num_mov for agent in model.schedule.agents
if isinstance(agent, RoombaAgent)]

        dirt_num = [agent for agent in model.schedule.agents if
isinstance(agent, DirtAgent)]
        movements_batches.append(sum(agent_num) / len(agent_num))

        # Check if whole area cleaned
        if dirt_num != []:
            print(f"Did not cleaned the whole area. Missing
{len(dirt_num)} cells out of {model.total_cells}, which is the
{len(dirt_num)*100/model.total_cells}%")
            print(f"Roomba average movements is {round(sum(agent_num)
/ len(agent_num), 2)}")
            not_cleaned += 1
        else:
            print(f"Cleaned the whole area with a roomba average
movements of {round(sum(agent_num) / len(agent_num), 2)}")


    # For a jupyter notebook add the following line:
    #%matplotlib inline

    # The below is needed for both notebooks and scripts
    #import matplotlib.pyplot as plt
```

```
    print("\n::- Batch results::-")
    print(f"Roomba average movements per batch is
{round(sum(movements_batches) / len(movements_batches), 2)}")

    if time == []:
        print(f"Did not cleaned the whole area {not_cleaned} of
{num_batches} times")
        if max_time != []:
            print(f"Roomba reached max time {len(max_time)} out of
{len(max_time) + len(time)} times")
        else:
            print(f"Roomba never reached max time")
        pass
    elif time != []:
        if max_time != []:
            print(f"Roomba reached max time {len(max_time)} out of
{len(max_time) + len(time)} times")
        else:
            print(f"Roomba never reached max time")

        print(f"Roomba time per batch not including max time reached
is {round(sum(time) / len(time), 2)}")
```

A continuación, se procederá a correr múltiples pruebas con tal de obtener una aseveración.

```
run_batch(10, 90, 60, 50, 50, 100)
```

```
Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 7 cells out of 2500, which is
the 0.28%
Roomba average movements is 99.39

Iteration 2
Cleaned the whole area with a roomba average movements of 90.42

Iteration 3
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.41

Iteration 4
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.39

Iteration 5
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
```

```
the 0.04%
Roomba average movements is 99.34

Iteration 6
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.3

Iteration 7
Cleaned the whole area with a roomba average movements of 76.38

Iteration 8
Did not cleaned the whole area. Missing 6 cells out of 2500, which is
the 0.24%
Roomba average movements is 99.38

Iteration 9
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.38

Iteration 10
Did not cleaned the whole area. Missing 3 cells out of 2500, which is
the 0.12%
Roomba average movements is 99.4

::- Batch results::-
Roomba average movements per batch is 96.18
Roomba reached max time 8 out of 10 times
Roomba time per batch not including max time reached is 84.0

run_batch(10, 50, 60, 50, 50, 100)

Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 12 cells out of 2500, which is
the 0.48%
Roomba average movements is 99.52

Iteration 2
Did not cleaned the whole area. Missing 38 cells out of 2500, which is
the 1.52%
Roomba average movements is 99.36

Iteration 3
Did not cleaned the whole area. Missing 28 cells out of 2500, which is
the 1.12%
Roomba average movements is 99.54
```

```
Iteration 4
Did not cleaned the whole area. Missing 36 cells out of 2500, which is
the 1.44%
Roomba average movements is 99.38

Iteration 5
Did not cleaned the whole area. Missing 55 cells out of 2500, which is
the 2.2%
Roomba average movements is 99.36

Iteration 6
Did not cleaned the whole area. Missing 30 cells out of 2500, which is
the 1.2%
Roomba average movements is 99.38

Iteration 7
Did not cleaned the whole area. Missing 32 cells out of 2500, which is
the 1.28%
Roomba average movements is 99.48

Iteration 8
Did not cleaned the whole area. Missing 48 cells out of 2500, which is
the 1.92%
Roomba average movements is 99.38

Iteration 9
Did not cleaned the whole area. Missing 32 cells out of 2500, which is
the 1.28%
Roomba average movements is 99.38

Iteration 10
Did not cleaned the whole area. Missing 23 cells out of 2500, which is
the 0.92%
Roomba average movements is 99.4

::- Batch results::-
Roomba average movements per batch is 99.42
Did not cleaned the whole area 10 of 10 times
Roomba reached max time 10 out of 10 times

run_batch(10, 70, 60, 50, 50, 100)

Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.49

Iteration 2
```

```
Did not cleaned the whole area. Missing 7 cells out of 2500, which is
the 0.28%
Roomba average movements is 99.41

Iteration 3
Did not cleaned the whole area. Missing 13 cells out of 2500, which is
the 0.52%
Roomba average movements is 99.43

Iteration 4
Did not cleaned the whole area. Missing 14 cells out of 2500, which is
the 0.56%
Roomba average movements is 99.39

Iteration 5
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
the 0.32%
Roomba average movements is 99.49

Iteration 6
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
the 0.32%
Roomba average movements is 99.44

Iteration 7
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.34

Iteration 8
Did not cleaned the whole area. Missing 34 cells out of 2500, which is
the 1.36%
Roomba average movements is 99.44

Iteration 9
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.31

Iteration 10
Did not cleaned the whole area. Missing 7 cells out of 2500, which is
the 0.28%
Roomba average movements is 99.41

::- Batch results::-
Roomba average movements per batch is 99.42
Did not cleaned the whole area 10 of 10 times
Roomba reached max time 10 out of 10 times
```

```
run_batch(10, 80, 60, 50, 50, 100)

Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.34

Iteration 2
Cleaned the whole area with a roomba average movements of 73.44

Iteration 3
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.34

Iteration 4
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
the 0.32%
Roomba average movements is 99.34

Iteration 5
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.46

Iteration 6
Cleaned the whole area with a roomba average movements of 90.44

Iteration 7
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
the 0.32%
Roomba average movements is 99.41

Iteration 8
Cleaned the whole area with a roomba average movements of 76.38

Iteration 9
Did not cleaned the whole area. Missing 7 cells out of 2500, which is
the 0.28%
Roomba average movements is 99.41

Iteration 10
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.39

::- Batch results::-
```

```
Roomba average movements per batch is 93.59
Roomba reached max time 7 out of 10 times
Roomba time per batch not including max time reached is 80.67
```

Al correr estos batches, podemos apreciar que entre más roombas hay es más fácil limpiar en su totalidad el espacio, lo cual tiene sentido. En promedio, el tiempo que se tarda en limpiar las habitaciones cuando se logra es mucho menor que el tiempo cuando no se logra limpiar las habitaciones, y este tiempo corresponde a cuando hay más roombas vs cuando hay menos:

```
run_batch(10, 50, 60, 50, 50, 100)
run_batch(10, 60, 60, 50, 50, 100)
run_batch(10, 70, 60, 50, 50, 100)
run_batch(10, 80, 60, 50, 50, 100)
run_batch(10, 90, 60, 50, 50, 100)
run_batch(10, 100, 60, 50, 50, 100)
```

```
Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 30 cells out of 2500, which is
the 1.2%
Roomba average movements is 99.5

Iteration 2
Did not cleaned the whole area. Missing 34 cells out of 2500, which is
the 1.36%
Roomba average movements is 99.36

Iteration 3
Did not cleaned the whole area. Missing 17 cells out of 2500, which is
the 0.68%
Roomba average movements is 99.4

Iteration 4
Did not cleaned the whole area. Missing 29 cells out of 2500, which is
the 1.16%
Roomba average movements is 99.44

Iteration 5
Did not cleaned the whole area. Missing 23 cells out of 2500, which is
the 0.92%
Roomba average movements is 99.3

Iteration 6
Did not cleaned the whole area. Missing 28 cells out of 2500, which is
the 1.12%
Roomba average movements is 99.34

Iteration 7
```

```
Did not cleaned the whole area. Missing 22 cells out of 2500, which is
the 0.88%
Roomba average movements is 99.42

Iteration 8
Did not cleaned the whole area. Missing 16 cells out of 2500, which is
the 0.64%
Roomba average movements is 99.44

Iteration 9
Did not cleaned the whole area. Missing 21 cells out of 2500, which is
the 0.84%
Roomba average movements is 99.34

Iteration 10
Did not cleaned the whole area. Missing 33 cells out of 2500, which is
the 1.32%
Roomba average movements is 99.46

::- Batch results::-
Roomba average movements per batch is 99.4
Did not cleaned the whole area 10 of 10 times
Roomba reached max time 10 out of 10 times
Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 16 cells out of 2500, which is
the 0.64%
Roomba average movements is 99.45

Iteration 2
Did not cleaned the whole area. Missing 44 cells out of 2500, which is
the 1.76%
Roomba average movements is 99.47

Iteration 3
Did not cleaned the whole area. Missing 24 cells out of 2500, which is
the 0.96%
Roomba average movements is 99.4

Iteration 4
Did not cleaned the whole area. Missing 7 cells out of 2500, which is
the 0.28%
Roomba average movements is 99.38

Iteration 5
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.47
```

```
Iteration 6
Did not cleaned the whole area. Missing 18 cells out of 2500, which is
the 0.72%
Roomba average movements is 99.37

Iteration 7
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
the 0.32%
Roomba average movements is 99.4

Iteration 8
Did not cleaned the whole area. Missing 17 cells out of 2500, which is
the 0.68%
Roomba average movements is 99.32

Iteration 9
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
the 0.32%
Roomba average movements is 99.48

Iteration 10
Did not cleaned the whole area. Missing 10 cells out of 2500, which is
the 0.4%
Roomba average movements is 99.45

::- Batch results::-
Roomba average movements per batch is 99.42
Did not cleaned the whole area 10 of 10 times
Roomba reached max time 10 out of 10 times
Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 19 cells out of 2500, which is
the 0.76%
Roomba average movements is 99.43

Iteration 2
Did not cleaned the whole area. Missing 3 cells out of 2500, which is
the 0.12%
Roomba average movements is 99.4

Iteration 3
Did not cleaned the whole area. Missing 11 cells out of 2500, which is
the 0.44%
Roomba average movements is 99.4

Iteration 4
Did not cleaned the whole area. Missing 13 cells out of 2500, which is
```

```
the 0.52%
Roomba average movements is 99.46

Iteration 5
Did not cleaned the whole area. Missing 17 cells out of 2500, which is
the 0.68%
Roomba average movements is 99.43

Iteration 6
Did not cleaned the whole area. Missing 14 cells out of 2500, which is
the 0.56%
Roomba average movements is 99.53

Iteration 7
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
the 0.32%
Roomba average movements is 99.43

Iteration 8
Did not cleaned the whole area. Missing 5 cells out of 2500, which is
the 0.2%
Roomba average movements is 99.37

Iteration 9
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.43

Iteration 10
Did not cleaned the whole area. Missing 32 cells out of 2500, which is
the 1.28%
Roomba average movements is 99.4

::- Batch results::-
Roomba average movements per batch is 99.43
Did not cleaned the whole area 10 of 10 times
Roomba reached max time 10 out of 10 times
Running batch 10 time(s)

Iteration 1
Cleaned the whole area with a roomba average movements of 79.29

Iteration 2
Did not cleaned the whole area. Missing 32 cells out of 2500, which is
the 1.28%
Roomba average movements is 99.4

Iteration 3
Did not cleaned the whole area. Missing 8 cells out of 2500, which is
```

```
the 0.32%
Roomba average movements is 99.41

Iteration 4
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.39

Iteration 5
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.33

Iteration 6
Did not cleaned the whole area. Missing 3 cells out of 2500, which is
the 0.12%
Roomba average movements is 99.5

Iteration 7
Did not cleaned the whole area. Missing 6 cells out of 2500, which is
the 0.24%
Roomba average movements is 99.38

Iteration 8
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.34

Iteration 9
Did not cleaned the whole area. Missing 3 cells out of 2500, which is
the 0.12%
Roomba average movements is 99.44

Iteration 10
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.44

::- Batch results::-
Roomba average movements per batch is 97.39
Roomba reached max time 9 out of 10 times
Roomba time per batch not including max time reached is 80.0
Running batch 10 time(s)

Iteration 1
Did not cleaned the whole area. Missing 3 cells out of 2500, which is
the 0.12%
Roomba average movements is 99.4
```

```
Iteration 2
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.34

Iteration 3
Cleaned the whole area with a roomba average movements of 89.36

Iteration 4
Did not cleaned the whole area. Missing 5 cells out of 2500, which is
the 0.2%
Roomba average movements is 99.41

Iteration 5
Did not cleaned the whole area. Missing 13 cells out of 2500, which is
the 0.52%
Roomba average movements is 99.4

Iteration 6
Did not cleaned the whole area. Missing 13 cells out of 2500, which is
the 0.52%
Roomba average movements is 99.49

Iteration 7
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.38

Iteration 8
Did not cleaned the whole area. Missing 16 cells out of 2500, which is
the 0.64%
Roomba average movements is 99.37

Iteration 9
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.42

Iteration 10
Did not cleaned the whole area. Missing 2 cells out of 2500, which is
the 0.08%
Roomba average movements is 99.37

::- Batch results::-
Roomba average movements per batch is 98.39
Roomba reached max time 9 out of 10 times
Roomba time per batch not including max time reached is 90.0
Running batch 10 time(s)
```

```
Iteration 1
Did not cleaned the whole area. Missing 5 cells out of 2500, which is
the 0.2%
Roomba average movements is 99.38

Iteration 2
Did not cleaned the whole area. Missing 3 cells out of 2500, which is
the 0.12%
Roomba average movements is 99.37

Iteration 3
Did not cleaned the whole area. Missing 5 cells out of 2500, which is
the 0.2%
Roomba average movements is 99.36

Iteration 4
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.45

Iteration 5
Cleaned the whole area with a roomba average movements of 84.44

Iteration 6
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.24

Iteration 7
Cleaned the whole area with a roomba average movements of 87.45

Iteration 8
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.49

Iteration 9
Did not cleaned the whole area. Missing 1 cells out of 2500, which is
the 0.04%
Roomba average movements is 99.4

Iteration 10
Did not cleaned the whole area. Missing 4 cells out of 2500, which is
the 0.16%
Roomba average movements is 99.47

::- Batch results::-
Roomba average movements per batch is 96.71
```

```
Roomba reached max time 8 out of 10 times
Roomba time per batch not including max time reached is 86.5
```