实验报告

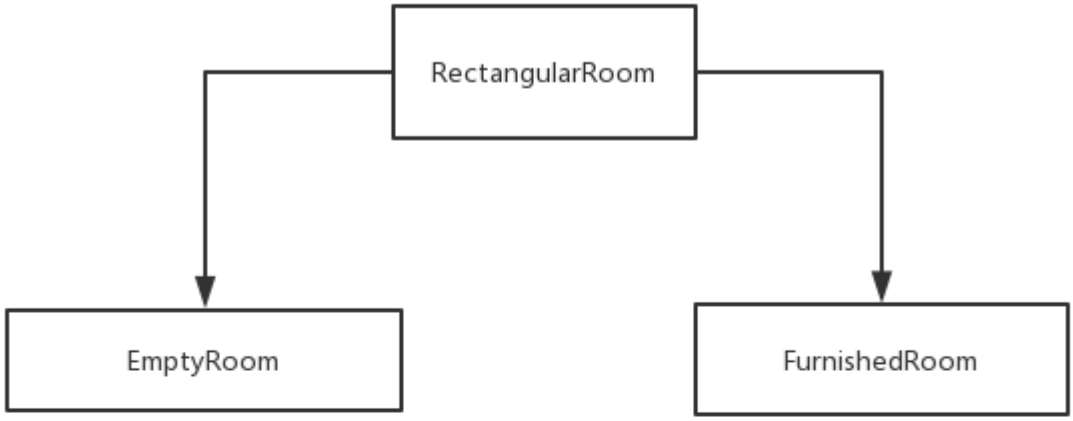
一、 实验目的

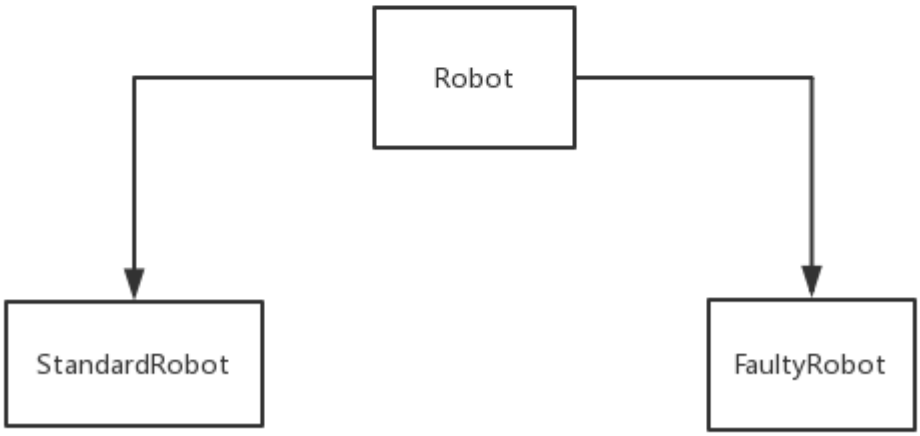
编写程序模拟房间内扫地机器人的移动。

二、 实验思路

- 首先，确定一个Position类，表示机器人在房间中的位置。
- 对于房间，首先编写一个抽象基类表示房间的一些共性。然后再根据房间的类型，在继承抽象基类的基础上，派生出不同类型的房间。
- 对于机器人，与房间类似，首先编写一个抽象基类表示机器人的共性，然后再根据机器人的清扫策略，派生出标准的机器人（StandardRobot）和出错的机器人（FaultyRobot）。
- 根据机器人类和房间类，模拟机器人清扫房间的行为。

三、 关键代码





1. 房间抽象基类

```
class RectangularRoom(object):
    def __init__(self, width, height, dirt_amount):
        self.width=math.ceil(width)#房间宽度
        self.height=math.ceil(height)#房间高度
        self.dirt_amount=dirt_amount#房间每个区块初始灰尘数量
        self.clean_tiles=0#干净的区块数量
        self.dirty_tiles=width*height#脏的区块数量

        self.tile_dirt=[]#初始化每个区块的灰尘数目
        for x in range(self.width):
            temp=[]
            for y in range(self.height):
                temp.append(dirt_amount)#初始值为dirt_amount
            self.tile_dirt.append(temp[:])
```

```
    def clean_tile_at_position(self, pos, capacity):
        #获得区块的坐标
        x=math.floor(pos.get_x())
        y=math.floor(pos.get_y())
        before=False#区块在清理前是否干净，默认为否
        if self.tile_dirt[x][y]<0.000001:#如果区块灰尘数量为0，则干净
            before=True
        self.tile_dirt[x][y]=max(self.tile_dirt[x][y]-capacity,0)#清理该区块

        after=False##区块在清理后是否干净，默认为否
        if self.tile_dirt[x][y]<0.000001:#如果区块灰尘数量为0，则干净
            after=True

        if before and not after:#如果打扫前干净、打扫后不干净
            self.clean_tiles-=1#干净区块数减1
            self.dirty_tiles+=1#脏的区块数加1
        elif not before and after:#如果打扫前不干净，打扫后干净
            self.clean_tiles+=1#干净区块数加1
            self.dirty_tiles-=1#脏的区块数减1
        #其他情况干净和脏的区块数都不变


    def is_tile_cleaned(self, m, n):#判断区块是否干净
        return self.tile_dirt[m][n]<0.000001

    def get_num_cleaned_tiles(self):#获取干净区块的数量
        return self.clean_tiles

    def is_position_in_room(self, pos):#判断位置是否在房间中
        #获取区块的坐标
        x=pos.get_x()
        y=pos.get_y()
        if x<0 or x>=self.width:
            return False
        if y<0 or y>=self.height:
            return False
        return True

    def get_dirt_amount(self, m, n):#获取脏的区块数量
        return self.tile_dirt[m][n]
```

2. 机器人抽象基类

```
class Robot(object):
    def __init__(self, room, speed, capacity):
        self.room=room#机器人所在房间
        self.speed=speed#机器人的速度
        self.capacity=capacity#机器人的清扫能力
        self.position=room.get_random_position()#机器人的初始位置
        self.direction=random.random()*360#机器人的初始方向
```

```
    def get_robot_position(self):#获取机器人的位置
        return self.position

    def get_robot_direction(self):#获取机器人的方向
        return self.direction

    def set_robot_position(self, position):#设置机器人的位置
        self.position=position

    def set_robot_direction(self, direction):#设置机器人的方向
        self.direction=direction
```

3. RectangularRoom的派生类EmptyRoom

```
class EmptyRoom(RectangularRoom):
    def get_num_tiles(self):#返回房间中区块数量
        return self.width*self.height

    def is_position_valid(self, pos):#判断一个位置是否合法
        return RectangularRoom.is_position_in_room(self,pos)

    def get_random_position(self):#获取房间中的一个随机位置
        x=random.random()*self.width
        y=random.random()*self.height
        return Position(x,y)
```

4. RectangularRoom的派生类FurnishedRoom

```
class FurnishedRoom(RectangularRoom):
    def __init__(self, width, height, dirt_amount):
        初始化父类
        RectangularRoom.__init__(self, width, height, dirt_amount)
        self.furniture_tiles = []#家具所在的区块

    def add_furniture_to_room(self):
        pass

    def is_tile_furnished(self, m, n):#判断某个区块是否有家具
        return (m,n) in self.furniture_tiles

    def is_position_furnished(self, pos):#判断某个位置是否有家具
        #获取区块的坐标
        m=math.floor(pos.get_x())
        n=math.floor(pos.get_y())
        return (m,n) in self.furniture_tiles

    def is_position_valid(self, pos):#判断某个位置是否合法
        #是否在房间内以及位置上是否有家具
```

```
        return RectangularRoom.is_position_in_room(self,pos) and not
            self.is_position_furnished(pos)

    def get_num_tiles(self):#获取房间内有效区块的数量
        return self.width*self.height-len(self.furniture_tiles)

    def get_random_position(self):#获取房间内的一个随机位置
        temp=[]#当前区块是否为有效区块
        for x in range(self.width):
            t=[]
            for y in range(self.height):
                t.append(True)#初始值为有效区块
            temp.append(t)

        #遍历self.furniture_tiles，其中的区块设置为无效区块
        for t in self.furniture_tiles:
            temp[t[0]][t[1]]=False

        no_furniture_tile=[]#有效区块
        #将temp中为True的区块加入no_furniture_tile中
        for i in range(self.width):
            for j in range(self.height):
                if temp[i][j]:
                    no_furniture_tile.append((i,j))

        #偏移值
        delta_x=random.random()
        delta_y=random.random()
        #随机选择一个区块
        (m,n)=random.choice(no_furniture_tile)
        return Position(m+delta_x,n+delta_y)#返回一个有效的随机位置
```

5. Robot的派生类StandardRobot

```
class StandardRobot(Robot):

    def update_position_and_clean(self):#重写update_position_and_clean方法
        #计算机器人的下一个位置
        next_pos=self.position.get_new_position(self.direction,self.speed)
        #如果位置合法
        if self.room.is_position_valid(next_pos):
            self.position=next_pos#移动到新位置
            #打扫新位置
            self.room.clean_tile_at_position(self.position,self.capacity)
        else:
            #否则随机选择一个方向
            self.direction=random.random()*360
```

6. Robot的派生类FaultyRobot

```
class FaultyRobot(Robot):
    p = 0.15#出错的概率

    @staticmethod
    def set_faulty_probability(prob):#设置出错概率
        FaultyRobot.p = prob

    def gets_faulty(self):#决定这次机器人是否出错
        return random.random() < FaultyRobot.p

    def update_position_and_clean(self):#重写update_position_and_clean方法
        faulty=self.gets_faulty()#这次机器人是否出错
        if faulty:#如果出错
            self.direction=random.random()*360#随机选择一个新方向
        else:#否则行为与StandardRobot一致

next_pos=self.position.get_new_position(self.direction,self.speed)
            if self.room.is_position_valid(next_pos):
                self.position=next_pos

self.room.clean_tile_at_position(self.position,self.capacity)
            else:
                self.direction=random.random()*360
```

7. 模拟机器人的运行情况

```
def run_simulation(num_robots, speed, capacity, width, height, dirt_amount,
        min_coverage, num_trials, robot_type):

    # num_robots: 房间内机器人数量
    # speed: 机器人的速度
    # capacity: 机器人的清扫能力
    # width: 房间宽度
    # height: 房间高度
    # dirt_amount: 每个区块的初始灰尘数量
    # min_coverage: 最低的清扫目标
    # num_trials: 模拟次数
    # robot_type: 机器人的类型

    tile_num=width*height#房间的区块数
    time_step=[]#每次测试所需的时间
    for i in range(num_trials):#测试num_trials次
        # anim=ps3_visualize.RobotVisualization(num_robots, width,
height,False)
        robots=[]#机器人
        #房间
        room=EmptyRoom(width,height,dirt_amount)

        for i in range(num_robots):#创建num_robots个机器人
            robots.append(robot_type(room,speed,capacity))
```

```
        count=0#计算时间
        #当干净的区块数没有达到要求时
        while room.get_num_cleaned_tiles()<tile_num*min_coverage:
            for robot in robots:#每个机器人单独行动
                robot.update_position_and_clean()
            count+=1
            # anim.update(room,robots)
        time_step.append(count)
        # anim.done()
    sum=0
    for time in time_step:
        sum+=time
    return sum/num_trials#返回平均值
```

四、 运行结果

1. ps3_tests_f16.py测试结果

```
ps3_tests_f16.py:9: DeprecationWarning: the imp module is deprecated in
favour of importlib; see the module's documentation for alternative uses
import imp
test_clean_tile_at_position_PosToPos (__main__.ps3_P1A)
Test if clean_tile_at_position removes all dirt ... ok
test_clean_tile_at_position_PosToZero (__main__.ps3_P1A)
Test if clean_tile_at_position removes all dirt ... ok
test_clean_tile_at_position_ZeroToZero (__main__.ps3_P1A)
Test if clean_tile_at_position removes all dirt ... ok
test_get_num_cleaned_tiles_FullIn1 (__main__.ps3_P1A)
Test get_num_cleaned_tiles for cleaning subset of room completely with 1
call ... ok
test_get_num_cleaned_tiles_FullIn2 (__main__.ps3_P1A)
Test get_num_cleaned_tiles for cleaning subset of room in two calls ... ok
test_get_num_cleaned_tiles_OverClean (__main__.ps3_P1A)
Test cleaning already clean tiles does not increment counter ... ok
test_get_num_cleaned_tiles_Partial (__main__.ps3_P1A)
Test get_num_cleaned_tiles for cleaning subset of room incompletely ... ok
test_is_position_in_room (__main__.ps3_P1A)
Test is_position_in_room ... ps3_tests_f16.py:181: DeprecationWarning:
Please use assertEqual instead.
"position {},{} is incorrect: expected {}, got {}".format(x, y,
solution_room.is_position_in_room(pos), room.is_position_in_room(pos))
ok
test_is_tile_cleaned_clean (__main__.ps3_P1A)
Test is_tile_cleaned ... ok
test_is_tile_cleaned_dirty (__main__.ps3_P1A)
Test is_tile_cleaned ... ok
test_room_dirt_clean (__main__.ps3_P1A) ... ps3_tests_f16.py:53:
DeprecationWarning: Please use assertEqual instead.
"Tile {} was not initialized with correct dirt amount".format((x, y))
ok
test_room_dirt_dirty (__main__.ps3_P1A) ... ps3_tests_f16.py:41:
```

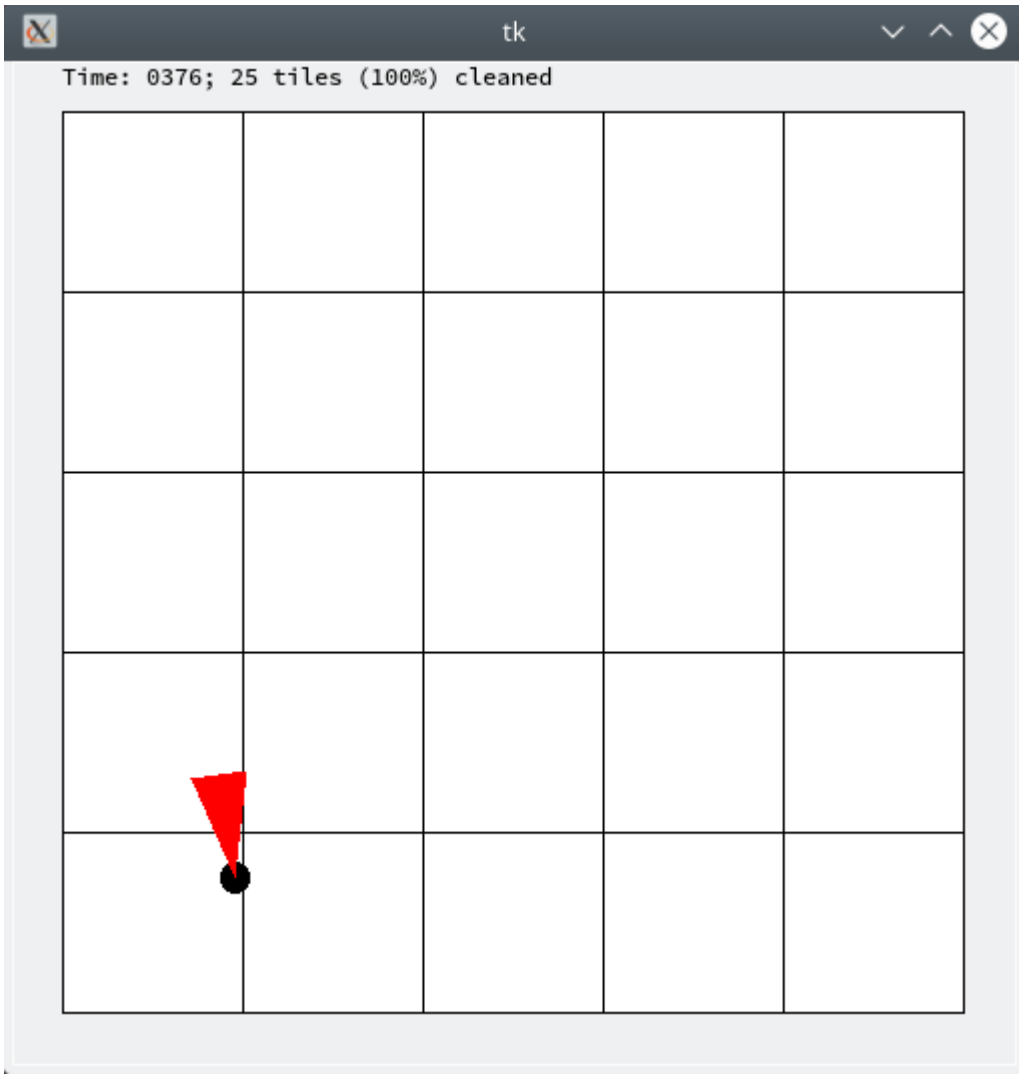
```
DeprecationWarning: Please use assertEqual instead.
"Tile {} was not initialized with correct dirt amount".format((x, y))
ok
test_unimplemented_methods (__main__.ps3_P1A)
Test if student implemented methods in RectangularRoom abstract class that
should not be implemented ... ok
test_getset_robot_direction (__main__.ps3_P1B)
Test get_robot_direction and set_robot_direction ... ps3_tests_f16.py:205:
DeprecationWarning: Please use assertEqual instead.
"Robot direction set or retrieved incorrectly: expected {}, got
{}".format(directions[dir_index], robot_dir)
ok
test_unimplemented_methods (__main__.ps3_P1B)
Test if student implemented methods in Robot abstract class that should not
be implemented ... ok
test_get_num_tiles (__main__.ps3_P2_ER)
test get_num_tiles method ... ps3_tests_f16.py:247: DeprecationWarning:
Please use assertEqual instead.
"student code number of room tiles = {}, not equal to solution code num
tiles {}".format(room_num_tiles, sol_room_tiles)
ok
test_get_random_position (__main__.ps3_P2_ER)
Test get_random_position ... ok
test_is_position_valid (__main__.ps3_P2_ER)
Test is_position_valid ... ps3_tests_f16.py:262: DeprecationWarning: Please
use assertEqual instead.
"student code and solution code disagree on whether position is valid"
ok
test_get_num_tiles (__main__.ps3_P2_FR)
test get_num_tiles method ... ps3_tests_f16.py:331: DeprecationWarning:
Please use assertEqual instead.
"student code number of room tiles = {}, not equal to solution code num
tiles {}".format(room_num_tiles, sol_room_num_tiles)
ok
test_get_random_position (__main__.ps3_P2_FR)
Test get_random_position for FurnishedRoom ... ok
test_is_position_furnished (__main__.ps3_P2_FR)
test_is_position_furnished ... ps3_tests_f16.py:295: DeprecationWarning:
Please use assertEqual instead.
"student code and solution code disagree on whether position is furnished"
ok
test_is_position_valid (__main__.ps3_P2_FR)
Test is_position_valid ... ps3_tests_f16.py:312: DeprecationWarning: Please
use assertEqual instead.
"student code and solution code disagree on whether position is valid"
ok
test_is_tile_furnished (__main__.ps3_P2_FR)
test is_tile_furnished ... ps3_tests_f16.py:279: DeprecationWarning: Please
use assertEqual instead.
"student code and solution code disagree on whether tile is furnished"
ok
testRobot (__main__.ps3_P3)
Test StandardRobot ... ok
test_BoundaryConditions (__main__.ps3_P3)
```

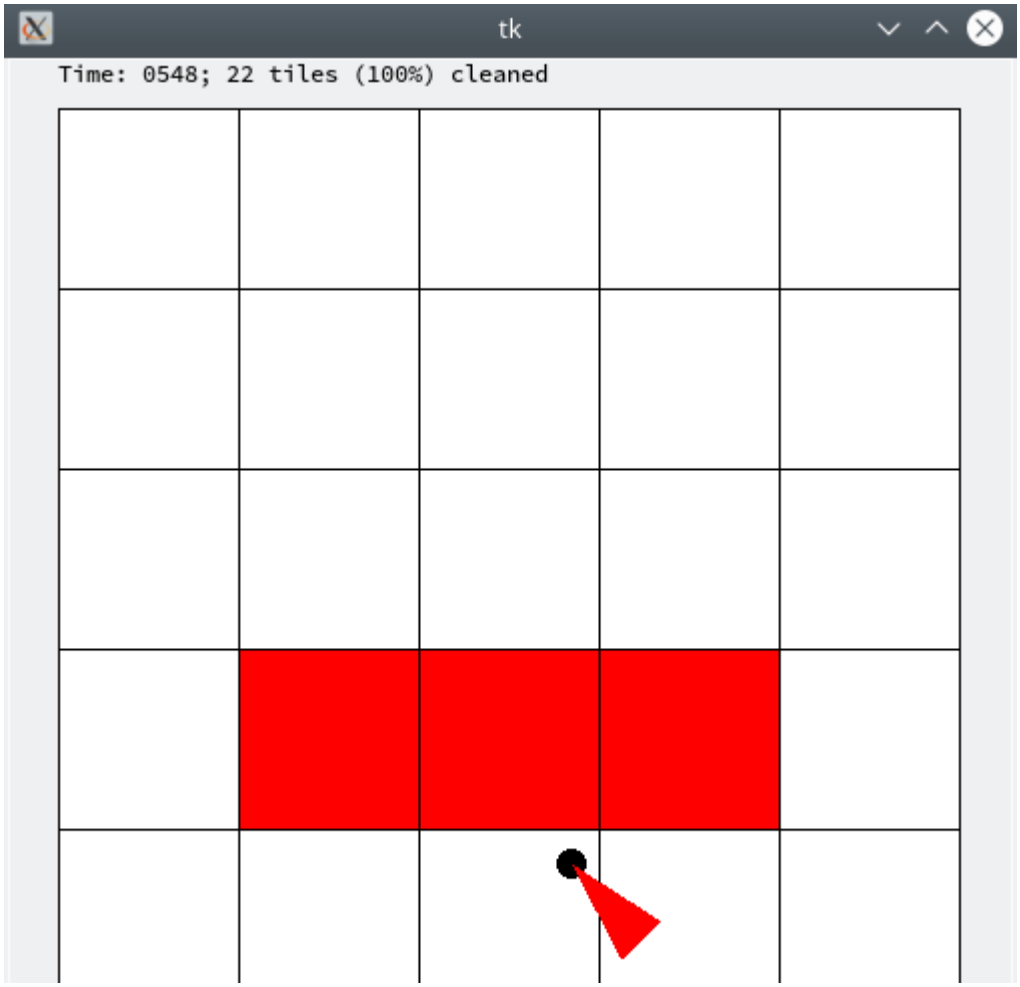
```
Test strict inequalities in random positions for the EmptyRoom and
StandardRobot ... ok
test_update_position_and_cleanStandardRobot (__main__.ps3_P3)
Test StandardRobot.update_position_and_clean ... ps3_tests_f16.py:425:
DeprecationWarning: Please use assertEqual instead.
(90, robot.get_robot_direction()))
ps3_tests_f16.py:443: DeprecationWarning: Please use assertNotEqual instead.
"Robot direction should have been changed in update_position_and_clean")
ok
testSimulation1 (__main__.ps3_P5_Standard)
Test cleaning 100% of a 5x5 room ... ok
testSimulation10 (__main__.ps3_P5_Standard)
Test multiple robots (95% of a 10x10 room with 5 robots (Standard Robot))
capacity = 2, 6 dirt/tile ... ok
testSimulation11 (__main__.ps3_P5_Standard)
Test multiple robots and different speeds (90% of a 5x5 room with 3 robots
of speed 0.5 ... ok
testSimulation2 (__main__.ps3_P5_Standard)
Test cleaning 75% of a 10x10 room (Standard Robot) ... ok
testSimulation3 (__main__.ps3_P5_Standard)
Test cleaning 90% of a 10x10 room (Standard Robot) ... ok
testSimulation4 (__main__.ps3_P5_Standard)
Test multiple robots (95% of a 20x20 room with 5 robots (Standard Robot))
... ok
testSimulation5 (__main__.ps3_P5_Standard)
Test different speeds (90% of a 5x20 room with a robot of speed 0.2
(Standard Robot)) ... ok
testSimulation6 (__main__.ps3_P5_Standard)
Test multiple robots and different speeds (90% of a 10x10 room with 3 robots
of speed 0.5 (Standard Robot)) ... ok
testSimulation7 (__main__.ps3_P5_Standard)
Test cleaning 100% of a 5x5 room (Standard Robot, 5 dirt/tile, capcity = 3)
... ok
testSimulation8 (__main__.ps3_P5_Standard)
Test cleaning 100% of a 5x5 room (Standard Robot, 6 dirt/tile, capacity = 3)
... ok
testSimulation9 (__main__.ps3_P5_Standard)
Test different speeds (90% of a 3x10 room with a robot of speed 0.2
(Standard Robot)), ... ok
testSimulation1 (__main__.ps3_P5_Faulty)
Test cleaning 100% of a 5x5 room with FaultyRobot ... ok
testSimulation2 (__main__.ps3_P5_Faulty)
Test cleaning 75% of a 10x10 room with FaultyRobot ... ok
testSimulation3 (__main__.ps3_P5_Faulty)
Test cleaning 90% of a 10x10 room with FaultyRobot ... ok
testSimulation4 (__main__.ps3_P5_Faulty)
Test cleaning 100% of a 5x5 room with FaultyRobot ... ok
testSimulation5 (__main__.ps3_P5_Faulty)
Test cleaning 75% of a 10x10 room with FaultyRobot ... ok
testSimulation6 (__main__.ps3_P5_Faulty)
Test cleaning 90% of a 10x10 room with FaultyRobot ... ok

----------------------------------------------------------------------
Ran 43 tests in 4.451s
```

```
OK
```

2. 测试Standard在EmptyRoom和FurnishedRoom中的行为

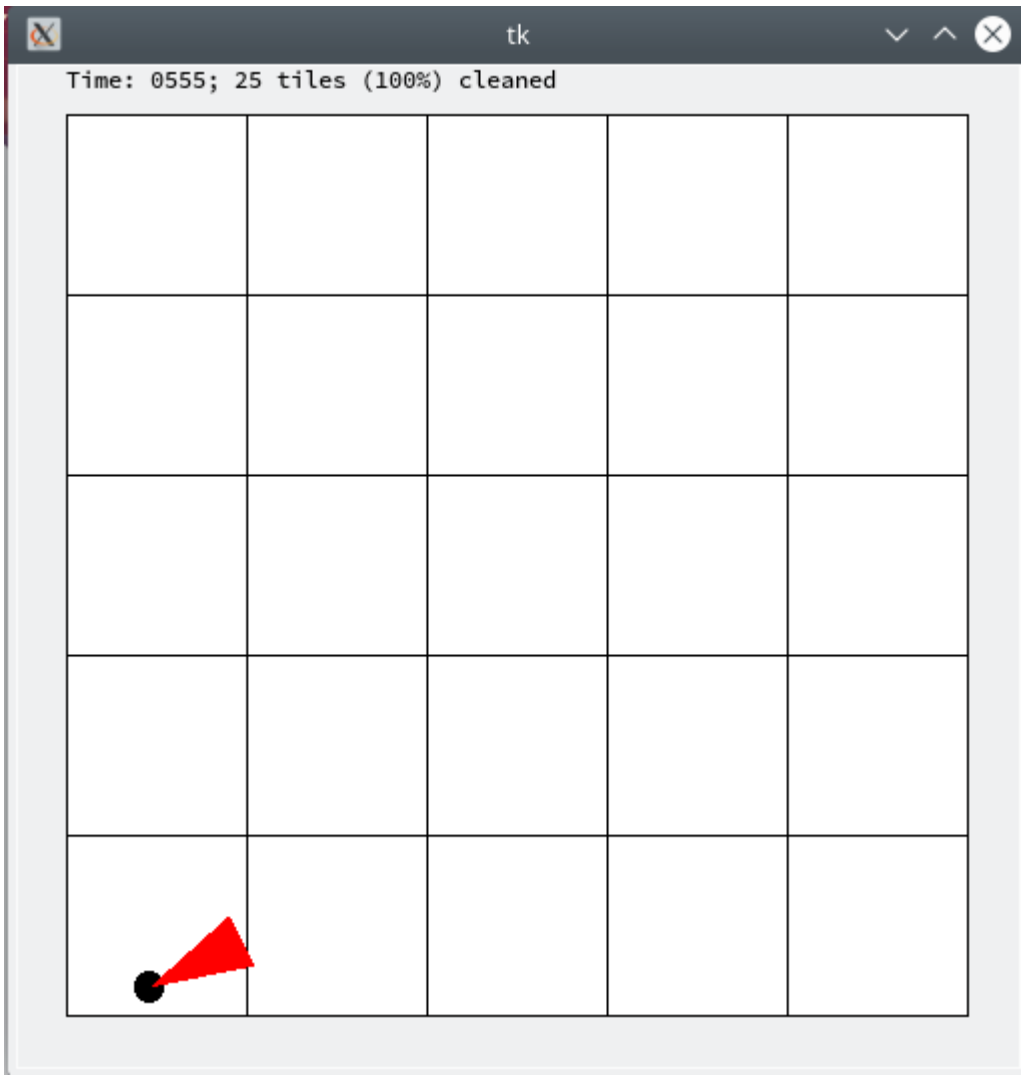
```
test_robot_movement(StandardRobot, EmptyRoom)
test_robot_movement(StandardRobot, FurnishedRoom)
```


tk
Time: 0376; 25 tiles (100%) cleaned


tk
Time: 0548; 22 tiles (100%) cleaned

3. 测试FaultyRobot在EmptyRoom中的行为

```
test_robot_movement(FaultyRobot, EmptyRoom)
```



4. 测试模拟机器人

```
print ('avg time steps: ' +
    str(run_simulation(1, 1.0, 1, 5, 5, 3, 1.0, 50, StandardRobot)))
print ('avg time steps: ' +
    str(run_simulation(1, 1.0, 1, 10, 10, 3, 0.8, 50, StandardRobot)))
print ('avg time steps: ' +
    str(run_simulation(1, 1.0, 1, 10, 10, 3, 0.9, 50, StandardRobot)))
print ('avg time steps: ' +
    str(run_simulation(1, 1.0, 1, 20, 20, 3, 0.5, 50, StandardRobot)))
print ('avg time steps: ' +
    str(run_simulation(3, 1.0, 1, 20, 20, 3, 0.5, 50, StandardRobot)))
```

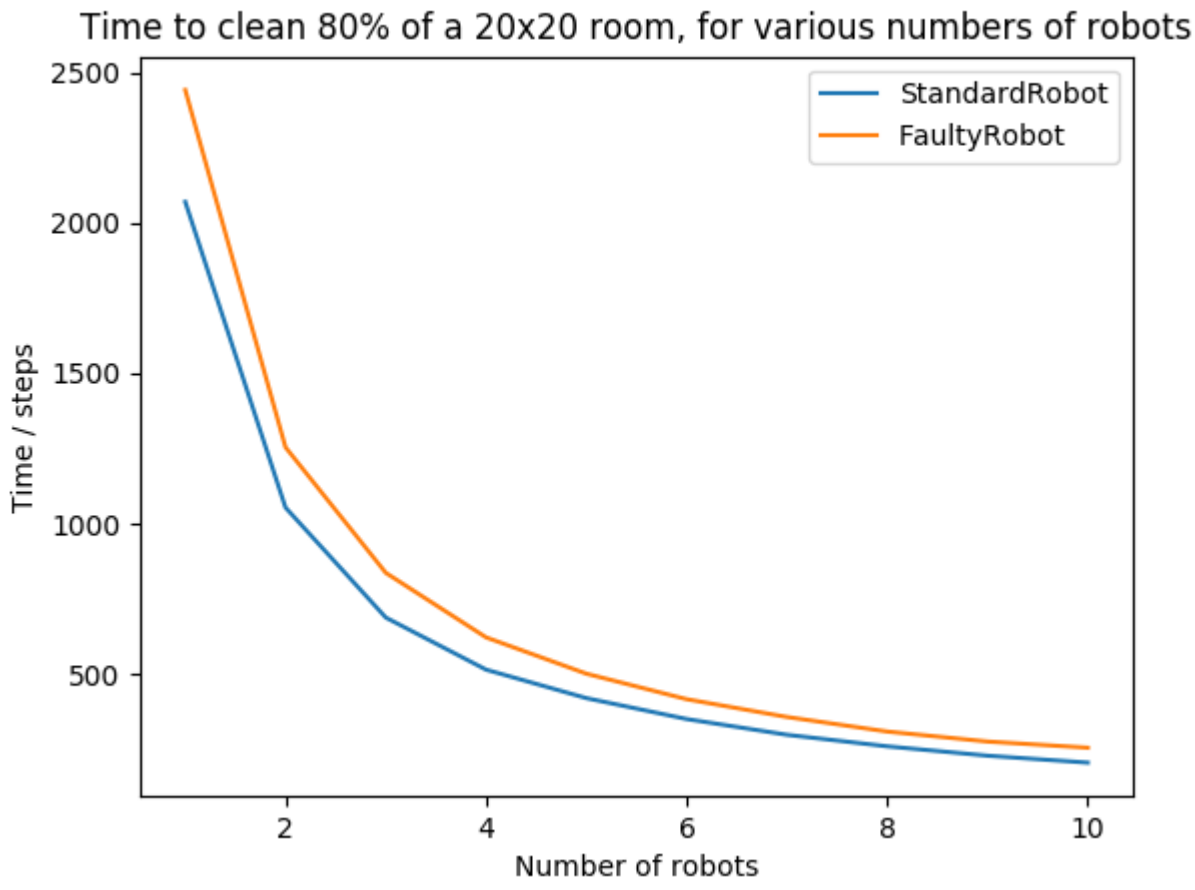
结果：

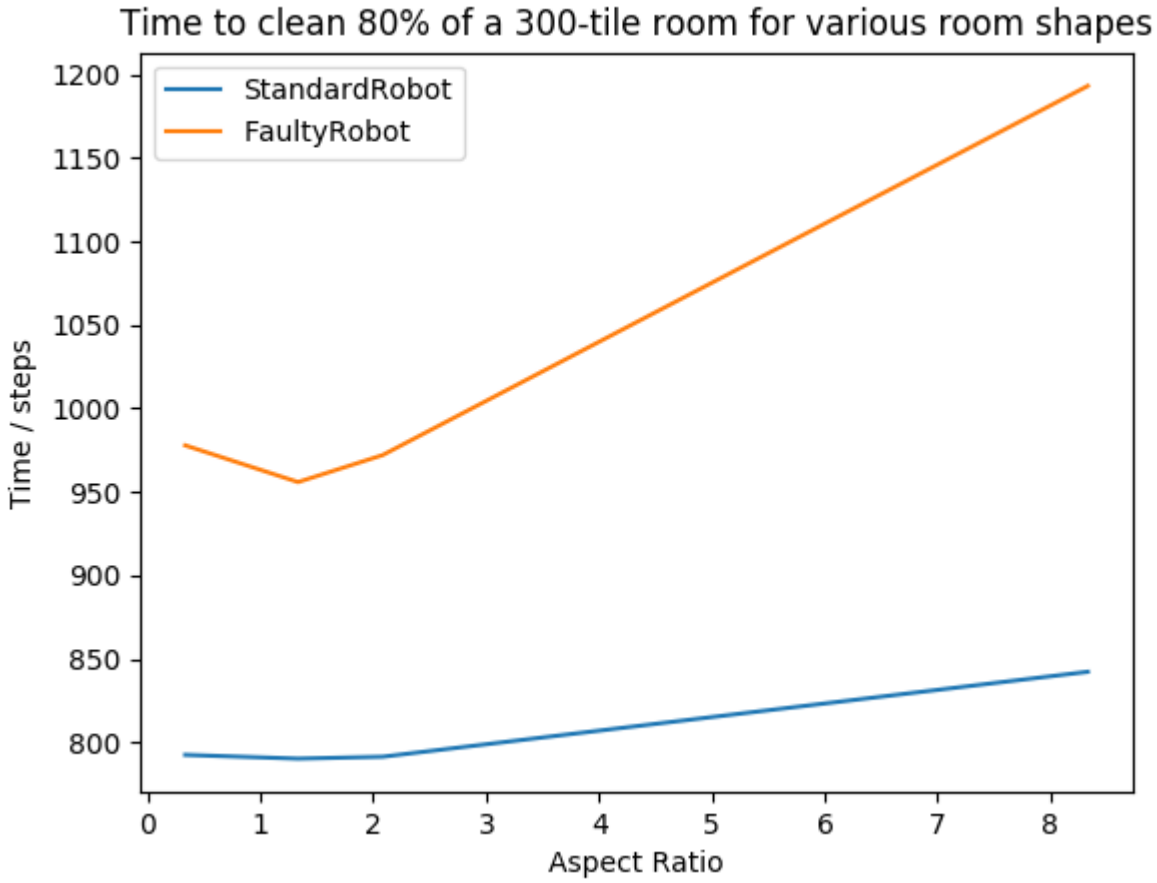
```
> python3 ps3.py

avg time steps: 302.54
avg time steps: 573.94
avg time steps: 707.38
avg time steps: 1245.78
avg time steps: 416.34
```

5. 可视化模拟结果

```
show_plot_compare_strategies('Time to clean 80% of a 20x20 room,
    for various numbers of robots','Number of robots','Time / steps')
show_plot_room_shape('Time to clean 80% of a 300-tile room for various room
shapes',
    'Aspect Ratio', 'Time / steps')
```

结果：





分析：

- 当房间规模固定为20*20时，增加机器人的数量。 可以看到随着机器人数目的增加，机器人所需的时间大致成反比例减少。 StandardRobot所需的时间更少，大致比FaultyRobot所需时间少15%，即FaultyRobot出错的概率。
- 当机器人数量为2，房间面积为300时，改变房间的长宽比。 当房间规模为20x15（长宽比为1.333）时，两种机器人的效率达到最高。 长宽比大于1.333后，随着房间长宽比的增加，两种机器人所需的时间大致成正比例增加。 StandardRobot所需的时间更少，大致比FaultyRobot所需时间少15%，即FaultyRobot出错的概率。

五、 实验心得

- 在RectangularRoom中，原本用的是下面的语句来初始化房间中每个区块的初始灰尘数量：

```
self.tile_dirt=[[dirt_amount]*self.height]*self.width
```

但是在运行后发现会出现莫名其妙的bug，在进行debug时发现在修改self.tile_dirt[0][j] (0<=j<height)后，self.tile_dirt[i][j] (0<=i<width)的值均会改变。

```
>>> a=[[1,2,3,4]]*3
>>> a
[[1, 2, 3, 4], [1, 2, 3, 4], [1, 2, 3, 4]]
>>> id(a[0])
```

```
2408686105288
>>> id(a[1])
2408686105288
>>> id(a[2])
2408686105288
```

使用上述的小程序测试后发现，a[0]、a[1]、a[2]的地址均相同，即a[0]、a[1]、a[2]指向的是同一个地址，因此改变a[0]中的元素，a[1]、a[2]中元素的值也会改变。

继续使用下面的程序测试：

```
>>> a=[[1]*3]*4
>>> a
[[1, 1, 1], [1, 1, 1], [1, 1, 1], [1, 1, 1]]
>>> id(a[0][0])          #所有的元素地址相同
1615421664
>>> id(a[0][1])
1615421664
>>> id(a[0][2])
1615421664
>>> a[0][0]=2            #修改a[0][0]的值为2
>>> a
[[2, 1, 1], [2, 1, 1], [2, 1, 1], [2, 1, 1]]
>>> id(a[0][0])          #a[0][0]的地址改变
1615421696
>>> id(a[0][1])          #a[0][1]、a[0][2]地址不变
1615421664
>>> id(a[0][2])
1615421664
>>> a[0][1]=3       #修改a[0][1]的值为3
>>> a
[[2, 3, 1], [2, 3, 1], [2, 3, 1], [2, 3, 1]]
>>> id(a[0][0])          #a[0][0]保持上面的地址
1615421696
>>> id(a[0][1])          #a[0][1]地址变化
1615421728
>>> id(a[0][2])          #a[0][2]仍为最初的地址
1615421664
>>> a[0][2]=4            #修改a[0][2]的值
>>> a
[[2, 3, 4], [2, 3, 4], [2, 3, 4], [2, 3, 4]]
>>> id(a[0][0])
1615421696
>>> id(a[0][1])
1615421728
>>> id(a[0][2])          #a[0][2]地址变化
1615421760
>>> id(a[1][0])          #a[1]中元素地址与a[0]中元素地址一致
1615421696
>>> id(a[1][2])
1615421760
```

```
>>> id(a[1][1])
1615421728
>>> a[1][0]=5
>>> a
[[5, 3, 4], [5, 3, 4], [5, 3, 4], [5, 3, 4]]
```

根据以上现象，猜测在定义a=[[1]*3]*4时，python并没有为a分配12个int的内存，而是只申请了一个int的内存空间，当修改a[0]中的元素时，才会为修改过的元素重新分配内存空间。并且修改a[0][j] (0<=j<self.height)后，a[i][j] (0<=i<self.width)仍具有相同的地址。修改任一个元素，仍然会改变这一列所有元素的值。

在发现了这个问题后，于是采取了下面的代码存储房间每个区块的初始灰尘数量：

```
self.tile_dirt=[]
    for x in range(self.width):
        temp=[]
        for y in range(self.height):
            temp.append(dirt_amount)
        self.tile_dirt.append(temp[:])
```