

## *Programming: Practical 5*

We wish to determine the properties on which a player is most likely to land during a game of monopoly. To simplify things, we assume there is only a single player, ignore everything to do with money and also ignore the 'Get out of Jail Free Cards'.

### *1 Monopoly: overview of the problem*

The algorithm we will use is:

1. Begin the game on GO;
2. `current := current + dice roll`
3. Make a note of the new position.
  - If we land on 'Chance' or 'Community Chest', draw a card;
  - If we land on 'Go To Jail', move to Jail;
  - If we move, make a note of the new position;
4. Go back to step 2

After rolling the dice 100,000 times or so, stop.

### *2 Dice rolling*

When we roll a single die, each side has an equal probability of occurring. This means we can use the `sample` function to simulate a die roll:

```
sample(1:6, 1)
```

To roll two dice, we simply call this function:

```
RollTwoDice = function() {  
  total = sample(1:6, 1) + sample(1:6, 1)  
  return(total)  
}
```

#### *2.1 The Monopoly board*

In monopoly there are forty properties or squares, see table 1 at the end of this practical for a complete list. If we set the first square 'Go' to be number 1, then we can represent all forty squares as a vector in R. For example

```
## This creates a vector of 40 values;  
## All values are initially zero  
landings = numeric(40)
```

Then, when we land on a square we simply increase the associated landings entry by one. Suppose we landed on 'Old Kent Rd', we would represent this as:

```
landings[2] = landings[2] + 1
```

since 'Old Kent Road' is square 2 (see table 1).

## 2.2 Going round the board

Our first go at simulating Monopoly will ignore community chest, chance cards, and the 'Go To Jail' square. This means that we are simply going round the board. The code in the `SimulateMonopoly` function, rolls the dice `no_of_rolls` time, and stores the squares that are landed on in the vector `landings`.

```
SimulateMonopoly = function(no_of_rolls) {
  landings = numeric(40)
  ## Start at GO
  current = 1
  for(i in 1:no_of_rolls) {
    current = current + RollTwoDice()
    if(current > 40) {
      current = current - 40
    }
    landings[current] = landings[current] + 1
  }
  return(landings)
}
no_of_rolls = 50000
```

We can then call the function using:

```
sim = SimulateMonopoly(no_of_rolls)
```

We can then plot the results

```
library("ggplot2")
library("tibble")
monopoly = tibble(index = seq_along(sim),
                  sim = sim/sum(sim))
ggplot(monopoly) +
  geom_line(aes(x = index,
                y = sim)) +
  ylim(0, 0.06) +
  labs(x = "Square",
       y = "Probability")
```

## 2.3 Incorporating Community Chest Cards

There are three community chest squares on the board - squares 3, 18 and 34. In the code below we will just consider square 3. There are

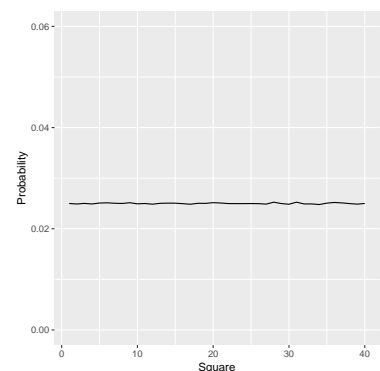


Figure 1: Probability of landing on monopoly square.

sixteen cards in total, hence the probability of drawing any particular card is  $1/16$ . In the code below we will **only implement the first two community chest cards**:

```
CommunityChest = function(current) {
  goto = current
  u = runif(1)
  if(u < 1/16) {
    goto = 1#Move to Go
  }else if(u < 2/16) {
    goto = 11#Go To Jail :(
  }
  return(goto)
}
```

This function takes in the current position, with probability  $1/16$  we 'Move to Go', with probability  $1/16$  we 'Go to Jail' and with probability  $14/16$  we stay in our current position. We now alter the simulate function to incorporate the CommunityChest function:

```
SimulateMonopoly = function(no_of_rolls) {
  landings = numeric(40)
  ## Start at GO
  current = 1
  for(i in 1:no_of_rolls) {
    current = current + RollTwoDice()
    if(current > 40) {
      current = current - 40
    }
    landings[current] = landings[current] + 1
    if(current == 3) {
      cc_move = CommunityChest(current)
      if(cc_move != current){
        current = cc_move
        landings[current] = landings[current] + 1
      }
    }
  }
  return(landings)
}
```

We can then call this function:

```
sim2 = SimulateMonopoly(no_of_rolls)
```

and plot

```
monopoly2 = tibble(index = seq_along(sim2),
  sim = sim/sum(sim2))
ggplot(monopoly2) +
```

```
geom_line(aes(x = index,
               y = sim)) +
ylim(0, 0.06) +
labs(x = "Square",
     y = "Probability")
```

What is the the rationale for lines 14-20?

### 3 Additional questions

Each question adds an additional layer of complexity to your code.

1. Add in the two other community squares, i.e. squares 18 and 34 into the SimulateMonopoly code.
2. Add in 'Go to Old Kent Road' into your CommunityChest function.
3. Square 31 is 'Go To Jail.' Implement this in your main simulation function.
4. Create a Chance function, that implements the first six Chance cards. When you land on a Chance square, call this function.
5. Add in Community Chest card four.
6. Add in Chance card 8.
7. Add in Chance card 7, 'Go back 3 spaces'.
8. Rolling a double (a pair of 1's, 2's, ..., 6's) is special:
  - (a) Roll two dice (total1): `total_score = total1`
  - (b) If you get a double, roll again (total2) and `total_score = total1 + total2`
  - (c) If you get a double, roll again (total3) and `total_score = total1 + total2 + total3`
  - (d) If roll three is a double, Go To Jail, otherwise move `total_score`

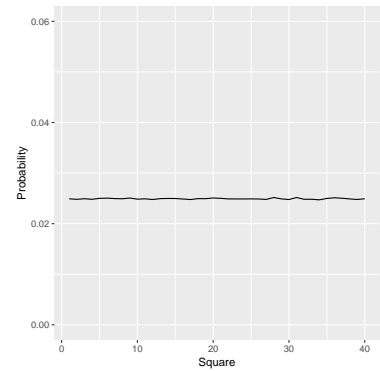


Figure 2: Probability of landing on monopoly square with the first community chest card implemented. Incorporating a single community chest card has very little effect. For this graphic, I used 2 million simulations!

## 4 *Additional Information*

### *Community Chest Cards*

There are three community chest areas on the board (see Table 1). In total, there are 16 community chest cards.

1. Advance to Go;
2. Go to jail;
3. Go to Old Kent Road;
4. Take a Chance card instead;

### *Chance Cards*

A Chance card is most likely to move players. There are three chance areas on the board (see Table 1). There are 16 chance cards in total, of which eight cards move the player:

1. Advance to Go;
2. Advance to Trafalgar Square;
3. Advance to Pall Mall;
4. Go directly to Jail;
5. Take a trip to Marylebone Station;
6. Advance to Mayfair;
7. Go back 3 spaces;
8. Advance token to nearest Utility. The utility squares are the water works and the electric company.

### *Solutions*

Solutions are contained within this package:

```
vignette("monopoly_solutions", package = "jrProgramming")
```

Square Number	Name	Square Number	Name
1	Go	11	Jail
2	Old Kent Road	12	Pall Mall
3	Community Chest	13	Electric Company
4	WhiteChapel Road	14	Whitehall
5	Income Tax	15	Northumberland Avenue
6	King's Cross Station	16	Marylebone Station
7	The Angel Islington	17	Bow Street
8	Chance	18	Community Chest
9	Euston Road	19	Marlborough Street
10	Pentonville Road	20	Vine Street
21	Free Parking	31	Go To Jail
22	Strand	32	Regent Street
23	Chance	33	Oxford Street
24	Fleet Street	34	Community Chest
25	Trafalgar Square	35	Bond Street
26	Fenchurch Street Station	36	Liverpool St Station
27	Leicester Square	37	Chance
28	Coventry St	38	Park Lane
29	Water Works	39	Super Tax
30	Piccadilly	40	Mayfair

Table 1: Monopoly squares with associated square numbers