# Machine Learning with R: Evaluation of Movie Recommendation System with RMSE

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```
library(tidyverse)
```

```
## -- Attaching packages ---------------------------------------------------------------------------------
---------------------- tidyverse 1.2.1 --
```

```
## v ggplot2 3.1.0     v purrr   0.2.5
## v tibble  1.4.2     v dplyr   0.7.8
## v tidyr   0.8.2     v stringr 1.3.1
## v readr   1.3.1     v forcats 0.3.0
```

```
## -- Conflicts ------------------------------------------------------------------------------------------
----------------- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(dslabs)
data("movielens")


movielens %>% as_tibble()
```

```
## # A tibble: 100,004 x 7
##    movieId title               year genres          userId rating timestamp
##      <int> <chr>              <int> <fct>            <int>  <dbl>     <int>
##  1      31 Dangerous Minds     1995 Drama                1    2.5    1.26e9
##  2    1029 Dumbo               1941 Animation|Chil~      1    3      1.26e9
##  3    1061 Sleepers            1996 Thriller             1    3      1.26e9
##  4    1129 Escape from New Y~  1981 Action|Adventu~      1    2      1.26e9
##  5    1172 Cinema Paradiso (~  1989 Drama                1    4      1.26e9
##  6    1263 Deer Hunter, The    1978 Drama|War            1    2      1.26e9
##  7    1287 Ben-Hur             1959 Action|Adventu~      1    2      1.26e9
##  8    1293 Gandhi              1982 Drama                1    2      1.26e9
##  9    1339 Dracula (Bram Sto~  1992 Fantasy|Horror~      1    3.5    1.26e9
## 10    1343 Cape Fear           1991 Thriller             1    2      1.26e9
## # ... with 99,994 more rows
```

```
movielens %>%
  summarize(n_users = n_distinct(userId),
            n_movies = n_distinct(movieId))
```

```
##   n_users n_movies
## 1     671     9066
```

```
#gather


library(caret)
```

```
## Loading required package: lattice
```

```
##
## Attaching package: 'caret'
```

```
## The following object is masked from 'package:purrr':
##
##     lift
```

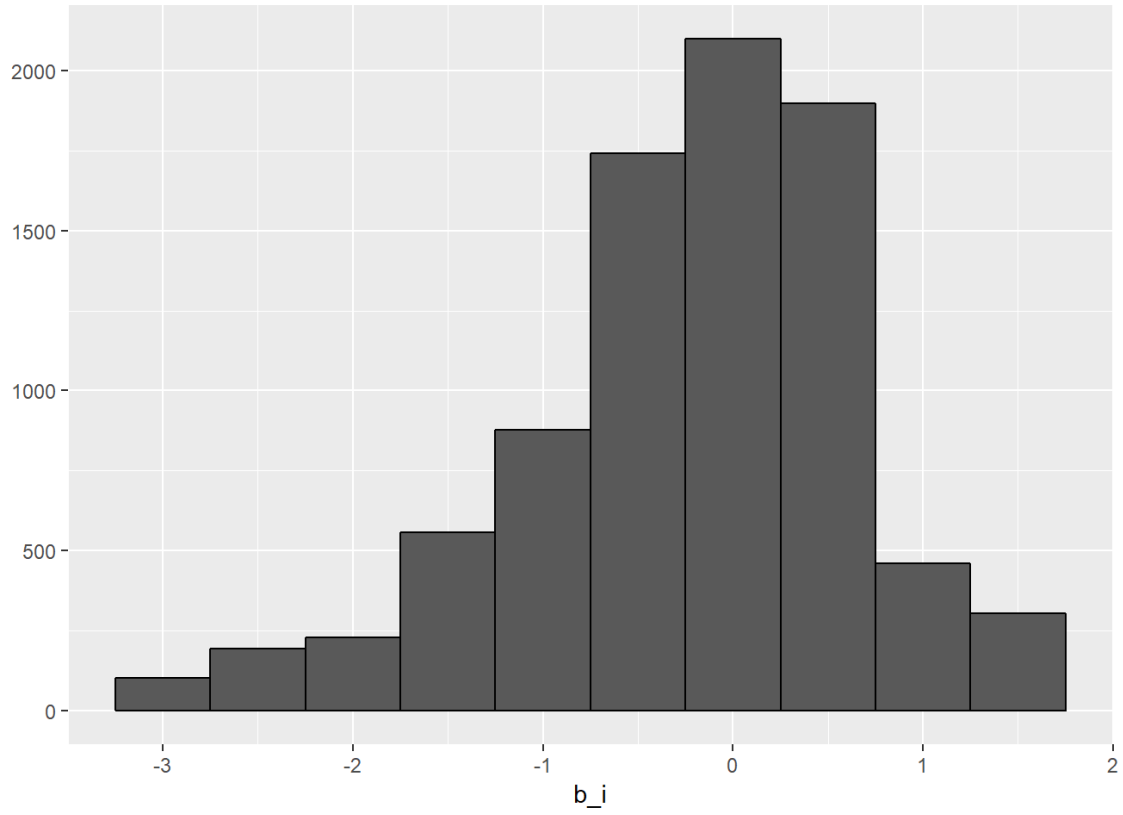
```
set.seed(755)
test_index <- createDataPartition(y = movielens$rating, times = 1, p = 0.2, list = FALSE)
train_set <- movielens[-test_index,]
test_set <- movielens[test_index,]


test_set <- test_set %>%
  semi_join(train_set, by = "movieId") %>%
  semi_join(train_set, by = "userId")

RMSE <- function(true_ratings, predicted_ratings){
  sqrt(mean((true_ratings - predicted_ratings)^2))
}


mu_hat <- mean(train_set$rating)
mu_hat
```

```
## [1] 3.542793
```

```
naive_rmse <- RMSE(test_set$rating, mu_hat)
naive_rmse
```

```
## [1] 1.04822
```

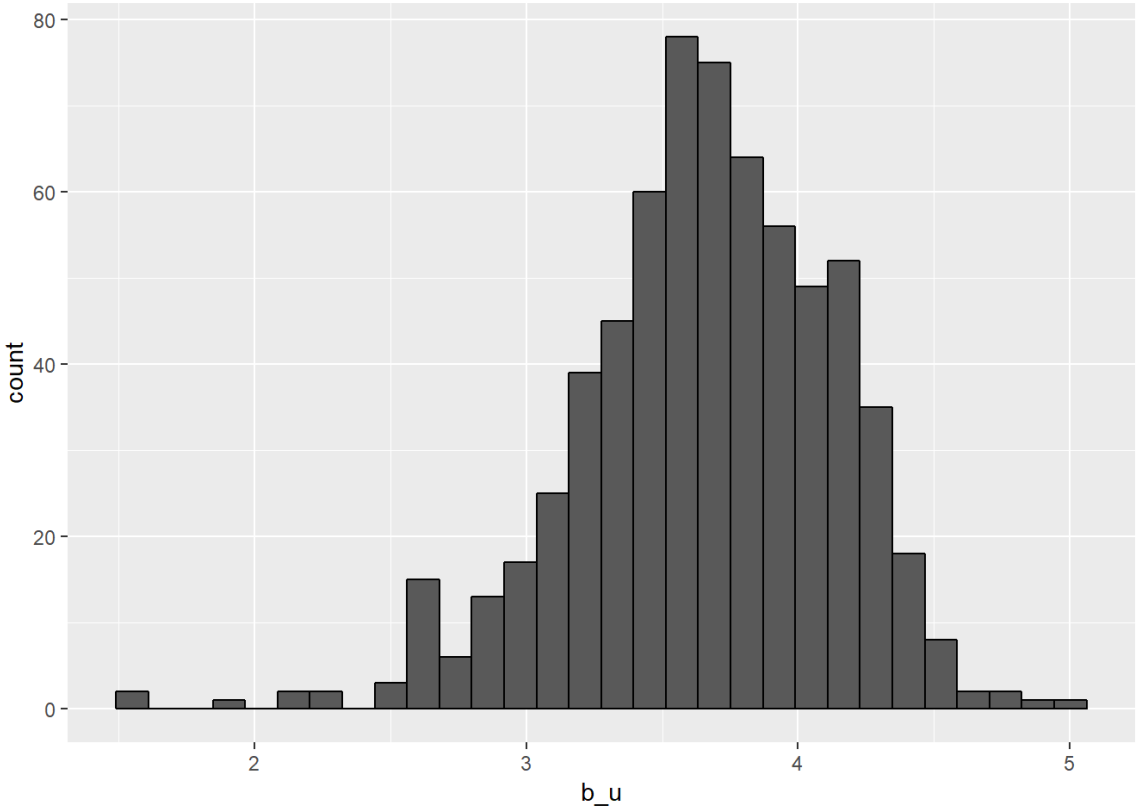
```
rmse_results <- data_frame(method = "Just the average", RMSE = naive_rmse)

#fit <- lm(rating ~ as.factor(movieId), data = movielens)

mu <- mean(train_set$rating)
movie_avgs <- train_set %>%
  group_by(movieId) %>%
  summarize(b_i = mean(rating - mu))

movie_avgs %>% qplot(b_i, geom ="histogram", bins = 10, data = ., color = I("black"))
```




```
predicted_ratings <- mu + test_set %>%
  left_join(movie_avgs, by='movieId') %>%
  pull(b_i)

model_1_rmse <- RMSE(predicted_ratings, test_set$rating)
rmse_results <- bind_rows(rmse_results,
                          data_frame(method="Movie Effect Model",
                                     RMSE = model_1_rmse))
rmse_results
```

```
## # A tibble: 2 x 2
##   method              RMSE
##   <chr>              <dbl>
## 1 Just the average   1.05
## 2 Movie Effect Model 0.986
```

```
train_set %>%
  group_by(userId) %>%
  summarize(b_u = mean(rating)) %>%
  filter(n()>=100) %>%
  ggplot(aes(b_u)) +
  geom_histogram(bins = 30, color = "black")
```




```
#lm(rating ~ as.factor(movieId) + as.factor(userId))

user_avgs <- train_set %>%
  left_join(movie_avgs, by='movieId') %>%
  group_by(userId) %>%
  summarize(b_u = mean(rating - mu - b_i))


predicted_ratings <- test_set %>%
  left_join(movie_avgs, by='movieId') %>%
  left_join(user_avgs, by='userId') %>%
  mutate(pred = mu + b_i + b_u) %>%
  pull(pred)


model_2_rmse <- RMSE(predicted_ratings, test_set$rating)
rmse_results <- bind_rows(rmse_results,
                          data_frame(method="Movie + User Effects Model",
                                     RMSE = model_2_rmse))
rmse_results
```

```
## # A tibble: 3 x 2
##   method                     RMSE
##   <chr>                     <dbl>
## 1 Just the average          1.05
## 2 Movie Effect Model        0.986
## 3 Movie + User Effects Model 0.908
```

```
test_set %>%
  left_join(movie_avgs, by='movieId') %>%
  mutate(residual = rating - (mu + b_i)) %>%
  arrange(desc(abs(residual))) %>%
  select(title,  residual) %>% slice(1:10)
```

```
##                                           title  residual
## 1      Day of the Beast, The (Día de la Bestia, El)  4.500000
## 2                                   Horror Express -4.000000
## 3                                No Holds Barred  4.000000
## 4  Dear Zachary: A Letter to a Son About His Father -4.000000
## 5                                           Faust -4.000000
## 6                                     Hear My Song -4.000000
## 7                       Confessions of a Shopaholic -4.000000
## 8        Twilight Saga: Breaking Dawn - Part 1, The -4.000000
## 9                                     Taxi Driver -3.806931
## 10                                    Taxi Driver -3.806931
```

```
movie_titles <- movielens %>%
  select(movieId, title) %>%
  distinct()

movie_avgs %>% left_join(movie_titles, by="movieId") %>%
  arrange(desc(b_i)) %>%
  select(title, b_i) %>%
  slice(1:10)
```

```
## # A tibble: 10 x 2
##    title                                                     b_i
##    <chr>                                                   <dbl>
##  1 Lamerica                                                 1.46
##  2 Love & Human Remains                                     1.46
##  3 Enfer, L'                                                1.46
##  4 Picture Bride (Bijo photo)                               1.46
##  5 Red Firecracker, Green Firecracker (Pao Da Shuang Deng)  1.46
##  6 Faces                                                    1.46
##  7 Maya Lin: A Strong Clear Vision                          1.46
##  8 Heavy                                                    1.46
##  9 Gate of Heavenly Peace, The                              1.46
## 10 Death in the Garden (Mort en ce jardin, La)              1.46
```

```
movie_avgs %>% left_join(movie_titles, by="movieId") %>%
  arrange(b_i) %>%
  select(title, b_i) %>%
  slice(1:10)
```

```
## # A tibble: 10 x 2
##    title                                      b_i
##    <chr>                                    <dbl>
##  1 Santa with Muscles                       -3.04
##  2 B*A*P*S                                  -3.04
##  3 3 Ninjas: High Noon On Mega Mountain     -3.04
##  4 Barney's Great Adventure                 -3.04
##  5 Merry War, A                             -3.04
##  6 Day of the Beast, The (Día de la Bestia, El) -3.04
##  7 Children of the Corn III                 -3.04
##  8 Whiteboyz                                -3.04
##  9 Catfish in Black Bean Sauce              -3.04
## 10 Watcher, The                             -3.04
```

```
train_set %>% count(movieId) %>%
  left_join(movie_avgs) %>%
  left_join(movie_titles, by="movieId") %>%
  arrange(desc(b_i)) %>%
  select(title, b_i, n) %>%
  slice(1:10)
```

```
## Joining, by = "movieId"
```

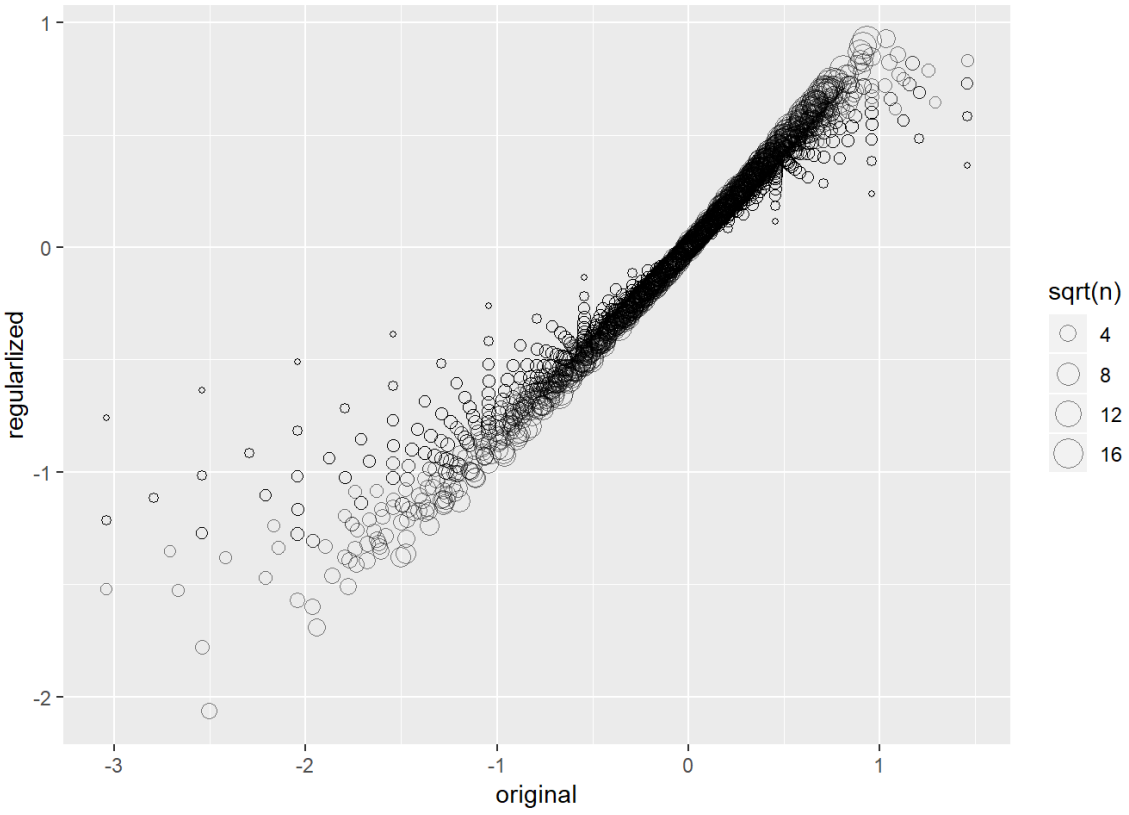
```
## # A tibble: 10 x 3
##    title                                                 b_i     n
##    <chr>                                               <dbl> <int>
##  1 Lamerica                                             1.46     1
##  2 Love & Human Remains                                 1.46     3
##  3 Enfer, L'                                            1.46     1
##  4 Picture Bride (Bijo photo)                           1.46     1
##  5 Red Firecracker, Green Firecracker (Pao Da Shuang Deng)  1.46     3
##  6 Faces                                                1.46     1
##  7 Maya Lin: A Strong Clear Vision                      1.46     2
##  8 Heavy                                                1.46     1
##  9 Gate of Heavenly Peace, The                          1.46     1
## 10 Death in the Garden (Mort en ce jardin, La)          1.46     1
```

```
train_set %>% count(movieId) %>%
  left_join(movie_avgs) %>%
  left_join(movie_titles, by="movieId") %>%
  arrange(b_i) %>%
  select(title, b_i, n) %>%
  slice(1:10)
```

```
## Joining, by = "movieId"
```

```
## # A tibble: 10 x 3
##    title                                       b_i     n
##    <chr>                                     <dbl> <int>
##  1 Santa with Muscles                        -3.04     1
##  2 B*A*P*S                                   -3.04     1
##  3 3 Ninjas: High Noon On Mega Mountain      -3.04     1
##  4 Barney's Great Adventure                  -3.04     1
##  5 Merry War, A                              -3.04     1
##  6 Day of the Beast, The (Día de la Bestia, El) -3.04     1
##  7 Children of the Corn III                  -3.04     1
##  8 Whiteboyz                                 -3.04     1
##  9 Catfish in Black Bean Sauce               -3.04     1
## 10 Watcher, The                              -3.04     1
```

```
lambda <- 3
mu <- mean(train_set$rating)
movie_reg_avgs <- train_set %>%
  group_by(movieId) %>%
  summarize(b_i = sum(rating - mu)/(n()+lambda), n_i = n())

data_frame(original = movie_avgs$b_i,
           regularlized = movie_reg_avgs$b_i,
           n = movie_reg_avgs$n_i) %>%
  ggplot(aes(original, regularlized, size=sqrt(n))) +
  geom_point(shape=1, alpha=0.5)
```




```
train_set %>%
  count(movieId) %>%
  left_join(movie_reg_avgs, by = "movieId") %>%
  left_join(movie_titles, by = "movieId") %>%
  arrange(desc(b_i)) %>%
  select(title, b_i, n) %>%
  slice(1:10)
```

```
## # A tibble: 10 x 3
##    title                              b_i     n
##    <chr>                            <dbl> <int>
##  1 All About Eve                    0.927    26
##  2 Shawshank Redemption, The        0.921   240
##  3 Godfather, The                   0.897   153
##  4 Godfather: Part II, The          0.871   100
##  5 Maltese Falcon, The              0.860    47
##  6 Best Years of Our Lives, The     0.859    11
##  7 On the Waterfront                0.847    23
##  8 Face in the Crowd, A             0.833     4
##  9 African Queen, The               0.832    36
## 10 All Quiet on the Western Front 0.824    11
```

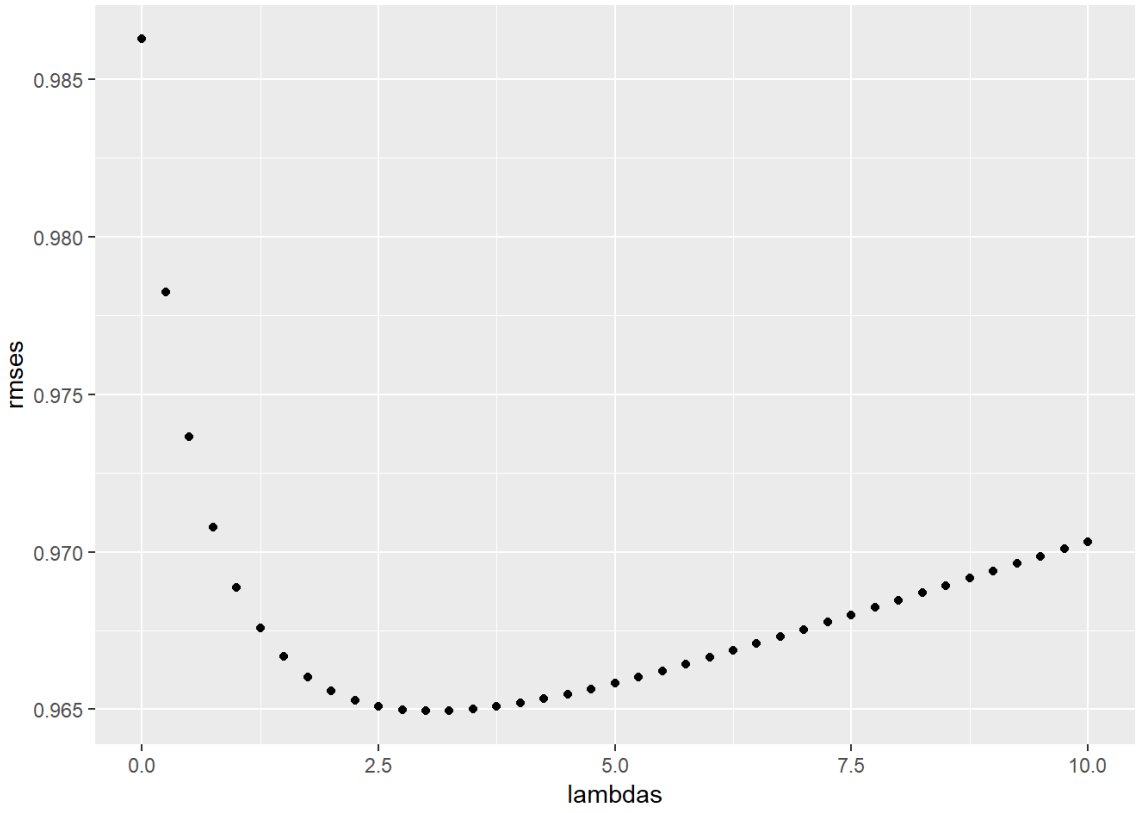
```
train_set %>%
  count(movieId) %>%
  left_join(movie_reg_avgs, by = "movieId") %>%
  left_join(movie_titles, by="movieId") %>%
  arrange(b_i) %>%
  select(title, b_i, n) %>%
  slice(1:10)
```

```
## # A tibble: 10 x 3
##    title                                b_i     n
##    <chr>                              <dbl> <int>
##  1 Battlefield Earth                  -2.06    14
##  2 Joe's Apartment                    -1.78     7
##  3 Speed 2: Cruise Control            -1.69    20
##  4 Super Mario Bros.                  -1.60    13
##  5 Police Academy 6: City Under Siege -1.57    10
##  6 After Earth                        -1.52     4
##  7 Disaster Movie                     -1.52     3
##  8 Little Nicky                       -1.51    17
##  9 Cats & Dogs                        -1.47     6
## 10 Blade: Trinity                     -1.46    11
```

```
predicted_ratings <- test_set %>%
  left_join(movie_reg_avgs, by = "movieId") %>%
  mutate(pred = mu + b_i) %>%
  pull(pred)

model_3_rmse <- RMSE(predicted_ratings, test_set$rating)
rmse_results <- bind_rows(rmse_results,
                          data_frame(method="Regularized Movie Effect Model",
                                     RMSE = model_3_rmse))
rmse_results
```

```
## # A tibble: 4 x 2
##   method                          RMSE
##   <chr>                          <dbl>
## 1 Just the average               1.05
## 2 Movie Effect Model             0.986
## 3 Movie + User Effects Model     0.908
## 4 Regularized Movie Effect Model 0.965
```

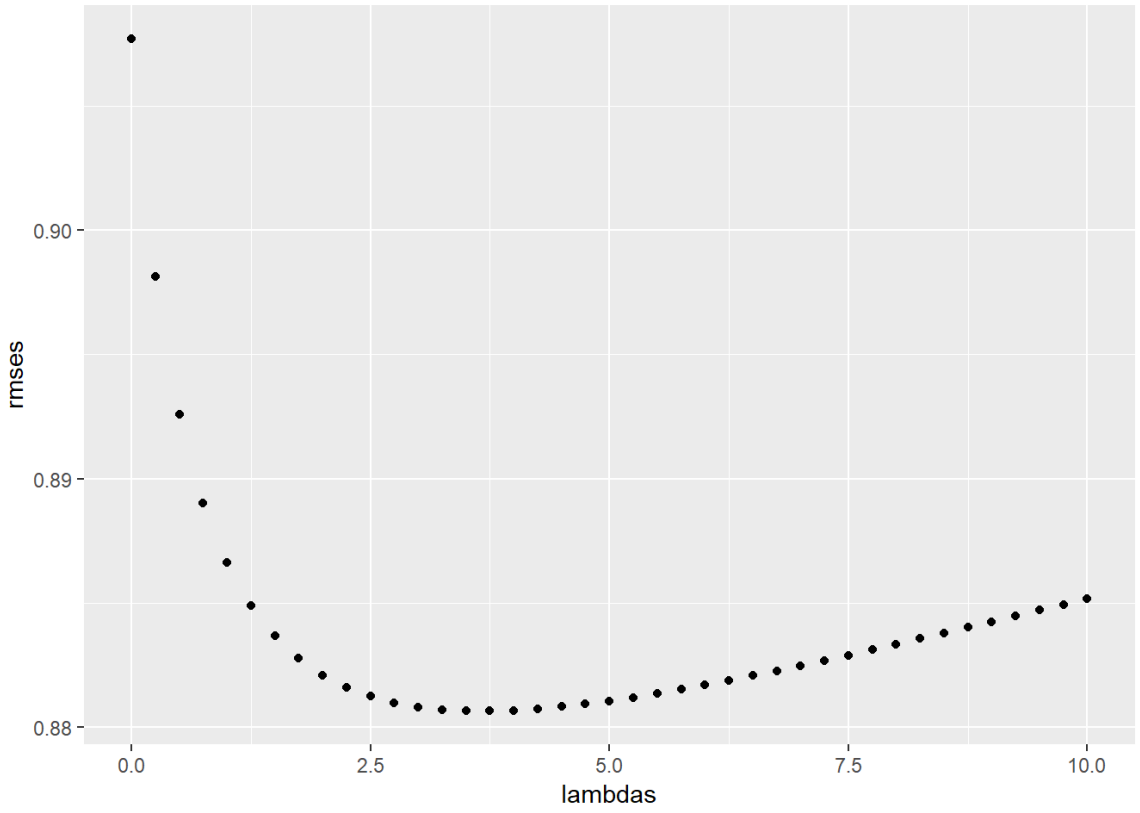
```
lambdas <- seq(0, 10, 0.25)

mu <- mean(train_set$rating)
just_the_sum <- train_set %>%
  group_by(movieId) %>%
  summarize(s = sum(rating - mu), n_i = n())

rmses <- sapply(lambdas, function(l){
  predicted_ratings <- test_set %>%
    left_join(just_the_sum, by='movieId') %>%
    mutate(b_i = s/(n_i+l)) %>%
    mutate(pred = mu + b_i) %>%
    pull(pred)
  return(RMSE(predicted_ratings, test_set$rating))
})
qplot(lambdas, rmses)
```




```
lambdas[which.min(rmses)]
```

```
## [1] 3
```

```
lambdas <- seq(0, 10, 0.25)

rmses <- sapply(lambdas, function(l){

  mu <- mean(train_set$rating)

  b_i <- train_set %>%
    group_by(movieId) %>%
    summarize(b_i = sum(rating - mu)/(n()+l))

  b_u <- train_set %>%
    left_join(b_i, by="movieId") %>%
    group_by(userId) %>%
    summarize(b_u = sum(rating - b_i - mu)/(n()+l))

  predicted_ratings <-
    test_set %>%
    left_join(b_i, by = "movieId") %>%
    left_join(b_u, by = "userId") %>%
    mutate(pred = mu + b_i + b_u) %>%
    pull(pred)

  return(RMSE(predicted_ratings, test_set$rating))
})

qplot(lambdas, rmses)
```




```
lambda <- lambdas[which.min(rmses)]
lambda
```

```
## [1] 3.75
```

```
rmse_results <- bind_rows(rmse_results,
                          data_frame(method="Regularized Movie + User Effect Model",
                                     RMSE = min(rmses)))
rmse_results %>% knitr::kable()
```

| method | RMSE |
|---|---|
| Just the average | 1.0482202 |
| Movie Effect Model | 0.9862839 |
| Movie + User Effects Model | 0.9077043 |
| Regularized Movie Effect Model | 0.9649457 |
| Regularized Movie + User Effect Model | 0.8806419 |