Лабораторная работа №7

Дисциплина: Компьютерный практикум по статистическому моделированию

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Содержание

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Список таблиц

1 Техническое оснащение:

- Персональный компьютер с операционной системой Windows 10;
- Планшет для записи видеосопровождения и голосовых комментариев;
- Microsoft Teams, использующийся для записи скринкаста лабораторной работы;
- Приложение Pycharm для редактирования файлов формата *md*;
- *pandoc* для конвертации файлов отчётов и презентаций.

2 Цели и задачи работы

2.1 Цель

Основной целью работы является освоение специализированных пакетов Julia для обработки данных.

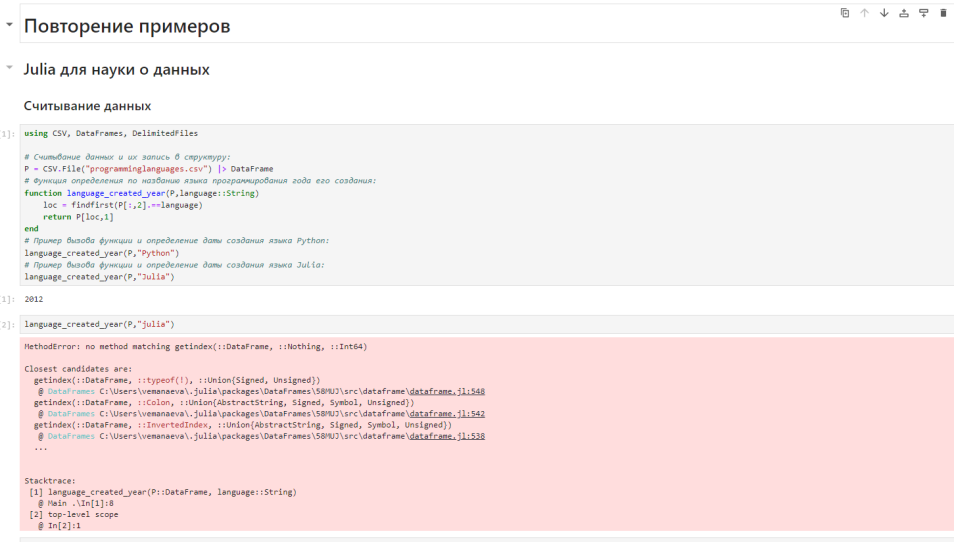
2.2 Задачи [1]

1. Повторить примеры из раздела 7.2
2. Выполнить задания для самостоятельной работы из раздела 7.4

3 Выполнение лабораторной работы

3.1 Повторение примеров

Повторение примеров (3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10 , 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19)



Повторение примеров

Julia для науки о данных

Считывание данных

```
using CSV, DataFrames, DelimitedFiles

# Считывание данных и их запись в структуру:
P = CSV.File("programminglanguages.csv") |> DataFrame
# функция определения по названию языка программирования года его создания:
function language_created_year(P,language::String)
    loc = findfirst(P[:,2].==language)
    return P[loc,1]
end
# Пример вызова функции и определение даты создания языка Python:
language_created_year(P,"Python")
# Пример вызова функции и определение даты создания языка Julia:
language_created_year(P,"Julia")
```

```
2012
```

```
language_created_year(P,"julia")
```

```
MethodError: no method matching getindex(::DataFrame, ::Nothing, ::Int64)

Closest candidates are:
  getindex(::DataFrame, ::typeof(!), ::Union{Signed, Unsigned})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MJ3\src\dataframe\dataframe.jl:548
  getindex(::DataFrame, ::Colon, ::Union{AbstractString, Signed, Symbol, Unsigned})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MJ3\src\dataframe\dataframe.jl:542
  getindex(::DataFrame, ::InvertedIndex, ::Union{AbstractString, Signed, Symbol, Unsigned})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MJ3\src\dataframe\dataframe.jl:538
  ...


Stacktrace:
 [1] language_created_year(P::DataFrame, language::String)
   @ Main .\In[1]:8
 [2] top-level scope
   @ In[2]:1
```

Рис. 3.1: Повторение примеров (1)

[3]:
```
# Функция определения по названию языка программирования года его создания (без учёта регистра):
function language_created_year_v2(P,language::String)
loc = findfirst(lowercase.(P[:,2]).==lowercase.(language))
return P[loc,1]
end
# Пример вызова функции и определение даты создания языка julia:
language_created_year_v2(P,"julia")
```

[3]:
```
2012
```

[4]:
```
# Построчное считывание данных с указанием разделителя:
Tx = readdlm("programminglanguages.csv", ',')
```

[4]:
```
74×2 Matrix{Any}:
     "year"  "language"
 1951        "Regional Assembly Language"
 1952        "Autocode"
 1954        "IPL"
 1955        "FLOW-MATIC"
 1957        "FORTRAN"
 1957        "COMTRAN"
 1958        "LISP"
 1958        "ALGOL 58"
 1959        "FACT"
 1959        "COBOL"
 1959        "RPG"
 1962        "APL"
    ⋮
 2003        "Scala"
 2005        "F#"
 2006        "PowerShell"
 2007        "Clojure"
 2009        "Go"
 2010        "Rust"
 2011        "Dart"
 2011        "Kotlin"
 2011        "Red"
 2011        "Elixir"
 2012        "Julia"
 2014        "Swift"
```

Запись данных в файл ¶

[5]:
```
# Запись данных в CSV-файл:
CSV.write("programming_languages_data2.csv", P)
```

Рис. 3.2: Повторение примеров (2)

[6]:
```
# Пример записи данных в текстовый файл с разделителем ',':
writedlm("programming_languages_data.txt", Tx, ',')
```

[7]:
```
# Пример записи данных в текстовый файл с разделителем '-':
writedlm("programming_languages_data2.txt", Tx, '-')
```

[8]:
```
# Построчное считывание данных с указанием разделителя:
P_new_delim = readdlm("programming_languages_data2.txt", '-')
```

[8]:
```
74×2 Matrix{Any}:
     "year"  "language"
 1951        "Regional Assembly Language"
 1952        "Autocode"
 1954        "IPL"
 1955        "FLOW-MATIC"
 1957        "FORTRAN"
 1957        "COMTRAN"
 1958        "LISP"
 1958        "ALGOL 58"
 1959        "FACT"
 1959        "COBOL"
 1959        "RPG"
 1962        "APL"
    ⋮
 2003        "Scala"
 2005        "F#"
 2006        "PowerShell"
 2007        "Clojure"
 2009        "Go"
 2010        "Rust"
 2011        "Dart"
 2011        "Kotlin"
 2011        "Red"
 2011        "Elixir"
 2012        "Julia"
 2014        "Swift"
```

Словари

[9]:
```
# Инициализация словаря:
dict = Dict{Integer,Vector{String}}()
```

[9]:
```
Dict{Integer, Vector{String}}()
```

[10]:
```
# Инициализация словаря:
dict2 = Dict()
```

Рис. 3.3: Повторение примеров (3)

[11]:
```
# Заполнение словаря данными:
for i = 1:size(P,1)
    year,lang = P[i,:]
    if year in keys(dict)
        dict[year] = push!(dict[year],lang)
    else
        dict[year] = [lang]
    end
end
dict
```

[11]:
```
Dict{Integer, Vector{String}} with 45 entries:
  1985 => ["Eiffel"]
  2002 => ["Scratch"]
  1952 => ["Autocode"]
  1963 => ["CPL"]
  1964 => ["Speakeasy", "BASIC", "PL/I"]
  1967 => ["BCPL"]
  2001 => ["C#", "D"]
  1991 => ["Python", "Visual Basic"]
  1957 => ["FORTRAN", "COMTRAN"]
  1988 => ["Tcl", "Wolfram Language "]
  1955 => ["FLOW-MATIC"]
  1951 => ["Regional Assembly Language"]
  1994 => ["CLOS "]
  2011 => ["Dart", "Kotlin", "Red", "Elixir"]
  1959 => ["FACT", "COBOL", "RPG"]
  1962 => ["APL", "Simula", "SNOBOL"]
  2005 => ["F#"]
  1969 => ["B"]
  1972 => ["C", "Smalltalk", "Prolog"]
  1997 => ["Rebol"]
  1986 => ["Objective-C", "LabVIEW ", "Erlang"]
  1993 => ["Lua", "R"]
  1958 => ["LISP", "ALGOL 58"]
  1987 => ["Perl"]
  1954 => ["IPL"]
  ⋮    => ⋮
```

[12]:
```
# Пример определения в словаре языков программирования, созданных в 2003 году:
dict[2003]
```

[12]:
```
2-element Vector{String}:
 "Groovy"
 "Scala"
```

Рис. 3.4: Повторение примеров (4)

DataFrames

[13]:
```
# Задаём переменную со структурой DataFrame:
df = DataFrame(year = P[:,1], language = P[:,2])
# Вывод всех значения столбца year:
df[!,:year]
```

[13]:
```
73-element Vector{Int64}:
 1951
 1952
 1954
 1955
 1957
 1957
 1958
 1958
 1959
 1959
 1959
 1962
 1962
    ⋮
 2003
 2005
 2006
 2007
 2009
 2010
 2011
 2011
 2011
 2011
 2012
 2014
```

[14]:
```
# Получение статистических сведений о фрейме:
describe(df)
```

[14]: 2×7 DataFrame

Row	variable	mean	min	median	max	nmissing	eltype
	Symbol	Union...	Any	Union...	Any	Int64	DataType
1	year	1982.99	1951	1986.0	2014	0	Int64
2	language		ALGOL 58		dBase III	0	String31

Рис. 3.5: Повторение примеров (5)

RDatasets

```
[15]: # Подгружаем пакет RDatasets:
using RDatasets
# Задаём структуру данных в виде набора данных:
iris = dataset("datasets", "iris")
```

[15]: 150×5 DataFrame — *125 rows omitted*

Row	SepalLength	SepalWidth	PetalLength	PetalWidth	Species
	Float64	Float64	Float64	Float64	Cat...
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3.0	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa
4	4.6	3.1	1.5	0.2	setosa
5	5.0	3.6	1.4	0.2	setosa
6	5.4	3.9	1.7	0.4	setosa
7	4.6	3.4	1.4	0.3	setosa
8	5.0	3.4	1.5	0.2	setosa
9	4.4	2.9	1.4	0.2	setosa
10	4.9	3.1	1.5	0.1	setosa
11	5.4	3.7	1.5	0.2	setosa
12	4.8	3.4	1.6	0.2	setosa
13	4.8	3.0	1.4	0.1	setosa
⋮	⋮	⋮	⋮	⋮	⋮
139	6.0	3.0	4.8	1.8	virginica
140	6.9	3.1	5.4	2.1	virginica
141	6.7	3.1	5.6	2.4	virginica
142	6.9	3.1	5.1	2.3	virginica
143	5.8	2.7	5.1	1.9	virginica
144	6.8	3.2	5.9	2.3	virginica
145	6.7	3.3	5.7	2.5	virginica

Рис. 3.6: Повторение примеров (6)

```
[16]: # Определения типа переменной:
typeof(iris)
```

[16]: DataFrame

```
[17]: describe(iris)
```

[17]: 5×7 DataFrame

Row	variable	mean	min	median	max	nmissing	eltype
	Symbol	Union...	Any	Union...	Any	Int64	DataType
1	SepalLength	5.84333	4.3	5.8	7.9	0	Float64
2	SepalWidth	3.05733	2.0	3.0	4.4	0	Float64
3	PetalLength	3.758	1.0	4.35	6.9	0	Float64
4	PetalWidth	1.19933	0.1	1.3	2.5	0	Float64
5	Species		setosa		virginica	0	CategoricalValue{String, UInt8}

Работа с переменными отсутствующего типа (Missing Values)

```
[18]: # Отсутствующий тип:
a = missing
typeof(a)
```

[18]: Missing

```
[19]: # Пример операции с переменной отсутствующего типа:
a + 1
```

[19]: missing

```
[20]: # Определение перечня продуктов:
foods = ["apple", "cucumber", "tomato", "banana"]
# Определение калорий:
calories = [missing,47,22,105]
```

```
[20]: 4-element Vector{Union{Missing, Int64}}:
     missing
  47
  22
 105
```

Рис. 3.7: Повторение примеров (7)

```
[21]: # Определение типа переменной:
      typeof(calories)

[21]: Vector{Union{Missing, Int64}} (alias for Array{Union{Missing, Int64}, 1})

[22]: # Подключаем пакет Statistics:
      using Statistics
      # Определение среднего значения:
      mean(calories)

[22]: missing

[23]: # Определение среднего значения без значений с отсутствующим типом:
      mean(skipmissing(calories))

[23]: 58.0

[24]: # Задание сведений о ценах:
      prices = [0.85,1.6,0.8,0.6]
      # Формирование данных о калориях:
      dataframe_calories = DataFrame(item=foods,calories=calories)
      # Формирование данных о ценах:
      dataframe_prices = DataFrame(item=foods,price=prices)
      # Объединение данных о калориях и ценах:
      DF = innerjoin(dataframe_calories,dataframe_prices,on=:item)

[24]: 4×3 DataFrame
```

Row	item	calories	price
	String	Int64?	Float64
1	apple	*missing*	0.85
2	cucumber	47	1.6
3	tomato	22	0.8
4	banana	105	0.6

FileIO

```
[25]: # Подключаем пакет FileIO:
      using FileIO
      using ImageIO
      # Загрузка изображения:
```

Рис. 3.8: Повторение примеров (8)

```
      X1 = load("julialogo.png")

[25]: 250×400 Array{RGBA{N0f8},2} with eltype ColorTypes.RGBA{FixedPointNumbers.N0f8}:
       RGBA(N0f8)(0.0,0.0,0.0,0.0)  …  RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)  …  RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)  …  RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       ⋮                            ⋱
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)  …  RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)  …  RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)
       RGBA(N0f8)(0.0,0.0,0.0,0.0)     RGBA(N0f8)(0.0,0.0,0.0,0.0)

[26]: # Определение типа и размера данных:
      @show typeof(X1);
      @show size(X1);

      typeof(X1) = Matrix{ColorTypes.RGBA{FixedPointNumbers.N0f8}}
      size(X1) = (250, 400)
```

Обработка данных: стандартные алгоритмы машинного обучения в Julia

Кластеризация данных. Метод k-средних

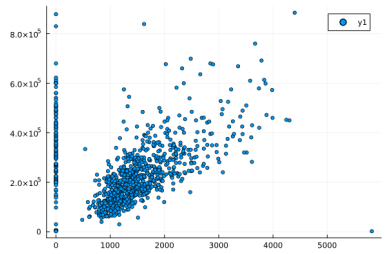
```
[27]: using Plots
      # Загрузка данных:
      houses = CSV.File("houses.csv") |> DataFrame

[27]: 985×12 DataFrame                                          960 rows omitted
```

Рис. 3.9: Повторение примеров (9)

[28]:
```
plot(size=(500,500),leg=false)
x = houses[!,:sq__ft]
y = houses[!,:price]
scatter(x,y,markersize=3)
```

[28]:



[29]:
```
# Фильтрация данных по заданному условию:
filter_houses = houses[houses[!,:sq__ft].>0,:]
# Построение графика:
x = filter_houses[!,:sq__ft]
y = filter_houses[!,:price]
scatter(x,y)
```

[29]:

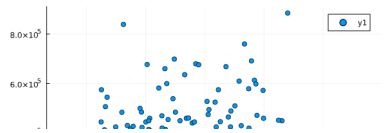


Рис. 3.10: Повторение примеров (10)

[30]:
```
# Определение средней цены для определённого типа домов:
by(filter_houses,:type,filter_houses->mean(filter_houses[!,:price]))
```

```
ArgumentError: by function was removed from DataFrames.jl. Use the `combine(groupby(...), ...)` or `combine(f, groupby(...))` instead.

Stacktrace:
 [1] by(::DataFrame, ::Vararg{Any}; kwargs::Base.Pairs{Symbol, Union{}, Tuple{}, NamedTuple{(), Tuple{}}})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\5BMUJ\src\deprecated.jl:4
 [2] by(::DataFrame, ::Vararg{Any})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\5BMUJ\src\deprecated.jl:4
 [3] top-level scope
   @ In[30]:2
```

[31]:
```
combine(filter_houses->mean(filter_houses[!,:price]), groupby(filter_houses,:type))
```

[31]: 3×2 DataFrame

Row	type	x1
	String15	Float64
1	Residential	2.34802e5
2	Condo	1.34213e5
3	Multi-Family	2.24535e5

[32]:
```
using Clustering
# Добавление данных :Latitude и :Longitude в новый фрейм:
X = filter_houses[:, [:latitude,:longitude]]
```

[32]: 814×2 DataFrame *789 rows omitted*

Row	latitude	longitude
	Float64	Float64
1	38.6319	-121.435
2	38.4789	-121.431
3	38.6183	-121.444
4	38.6168	-121.439
5	38.5195	-121.436
6	38.6626	-121.328
7	38.6817	-121.352

Рис. 3.11: Повторение примеров (11)

```
[33]: # Конвертация данных в матричный вид:
      X = Matrix(X[:, 1:2])
```

```
[33]: 814×2 Matrix{Float64}:
       38.6319  -121.435
       38.4789  -121.431
       38.6183  -121.444
       38.6168  -121.439
       38.5195  -121.436
       38.6626  -121.328
       38.6817  -121.352
       38.5351  -121.481
       38.6212  -121.271
       38.7009  -121.443
       38.6377  -121.452
       38.4707  -121.459
       38.6187  -121.436
        ⋮
       38.7035  -121.375
       38.7031  -121.235
       38.3898  -121.446
       38.8978  -121.325
       38.4679  -121.445
       38.4453  -121.442
       38.4174  -121.484
       38.4577  -121.36
       38.4999  -121.459
       38.7088  -121.257
       38.417   -121.397
       38.6552  -121.076
```

```
[34]: # Транспонирование матрицы с данными:
      X = X'
      # Задание количества кластеров:
      k = length(unique(filter_houses[!,:zip]))
      # Определение k-среднего:
      C = kmeans(X,k)
```

```
[34]: KmeansResult{Matrix{Float64}, Float64, Int64}([38.47975119354839 38.737452 … 38.63562266666667 38.60819775; -121.41092403225811 -120.910963 … -121.33890555555556 -121.371695125], [41, 1, 41, 41, 26, 30, 19, 36, 58, 27  …  39, 20, 24, 17, 13, 35, 24, 4, 29, 62], [0.0001203139036078937 4, 0.00040489065213478 17, 0.0002828492943081073 5, 0.0003708190743054729, 0.0001553982801851816 5, 0.0001471057985327206 6, 0.0002775993452814873 3, 0.0002675153446034528 3, 1.1448970326455 31e-5, 0.0003407085860089864 6  …  5.7846707932185 38e-5, 5.2415255616556685e-5, 0.0002126721228705719, 0.0001633529973327702, 0.0007778412618790753, 7.293177623068914e-5, 0.0004220604350848589, 0.0003248968314437661 3, 0.0003879064279317 39, 0.0001105941701098345 2], [31, 1, 36, 9, 4, 18, 15, 8, 5, 9  …  4, 9, 12, 4, 19, 5, 8, 15, 9, 8], [31, 1, 36, 9, 4, 18, 15, 8, 5, 9  …  4, 9, 12, 4, 19, 5, 8, 15, 9, 8], 0.1989128205095767, 11, true)
```

Рис. 3.12: Повторение примеров (12)

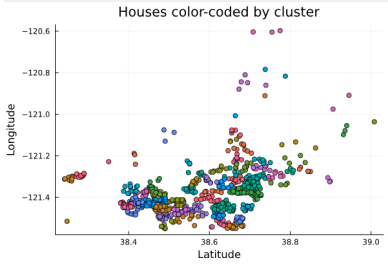
```
[35]: # Формирование фрейма данных:
      df = DataFrame(cluster = C.assignments,city = filter_houses[!,:city], latitude = filter_houses[!,:latitude],longitude = filter_houses[!,:longitude],zip = filter_houses[!,:zip])
```

[35]: 814×5 DataFrame — *789 rows omitted*

Row	cluster	city	latitude	longitude	zip
	Int64	String15	Float64	Float64	Int64
1	41	SACRAMENTO	38.6319	-121.435	95838
2	1	SACRAMENTO	38.4789	-121.431	95823
3	41	SACRAMENTO	38.6183	-121.444	95815
4	41	SACRAMENTO	38.6168	-121.439	95815
5	26	SACRAMENTO	38.5195	-121.436	95824
6	30	SACRAMENTO	38.6626	-121.328	95841
7	19	SACRAMENTO	38.6817	-121.352	95842
8	36	SACRAMENTO	38.5351	-121.481	95820
9	58	RANCHO CORDOVA	38.6212	-121.271	95670
10	27	RIO LINDA	38.7009	-121.443	95673
11	41	SACRAMENTO	38.6377	-121.452	95838
12	24	SACRAMENTO	38.4707	-121.459	95823
13	41	SACRAMENTO	38.6187	-121.436	95815
⋮	⋮	⋮	⋮	⋮	⋮
803	3	NORTH HIGHLANDS	38.7035	-121.375	95660
804	48	ORANGEVALE	38.7031	-121.235	95662
805	39	ELK GROVE	38.3898	-121.446	95757
806	20	LINCOLN	38.8978	-121.325	95648
807	24	SACRAMENTO	38.4679	-121.445	95823
808	17	SACRAMENTO	38.4453	-121.442	95823
809	13	ELK GROVE	38.4174	-121.484	95758
810	35	SACRAMENTO	38.4577	-121.36	95829
811	24	SACRAMENTO	38.4999	-121.459	95823

Рис. 3.13: Повторение примеров (13)

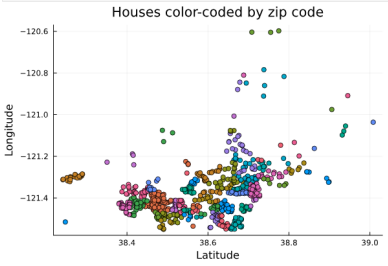
```
[36]: clusters_figure = plot(legend = false)
for i = 1:k
clustered_houses = df[df[!,:cluster].== i,:]
xvals = clustered_houses[!,:latitude]
yvals = clustered_houses[!,:longitude]
scatter!(clusters_figure,xvals,yvals,markersize=4)
end
xlabel!("Latitude")
ylabel!("Longitude")
title!("Houses color-coded by cluster")
display(clusters_figure)
```




```
[37]: unique_zips = unique(filter_houses[!,:zip])
zips_figure = plot(legend = false)
for uzip in unique_zips
subs = filter_houses[filter_houses[!,:zip].==uzip,:]
x = subs[!,:latitude]
y = subs[!,:longitude]
scatter!(zips_figure,x,y)
end
xlabel!("Latitude")
ylabel!("Longitude")
```

Рис. 3.14: Повторение примеров (14)

```
title!("Houses color-coded by zip code")
display(zips_figure)
```

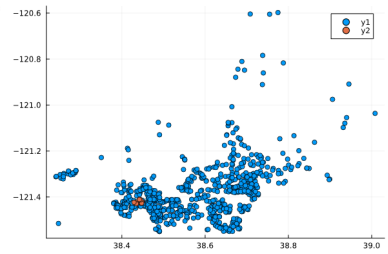


Кластеризация данных. Метод k ближайших соседей

```
[38]: using NearestNeighbors
knearest = 10
id = 70
point = X[:,id]
# Поиск ближайших соседей:
kdtree = KDTree(X)
idxs, dists = knn(kdtree, point, knearest, true)
# Все объекты необязательно:
x = filter_houses[!,:latitude];
y = filter_houses[!,:longitude];
scatter(x,y)
# Соседи:
x = filter_houses[idxs,:latitude];
y = filter_houses[idxs,:longitude];
scatter!(x,y)
```

Рис. 3.15: Повторение примеров (15)

[38]:



[39]:
```
# Фильтрация по районам соседних домов:
cities = filter_houses[idxs,:city]
```

[39]:
```
10-element PooledArrays.PooledVector{String15, UInt32, Vector{UInt32}}:
 "SACRAMENTO"
 "ELK GROVE"
 "SACRAMENTO"
 "SACRAMENTO"
 "SACRAMENTO"
 "SACRAMENTO"
 "ELK GROVE"
 "ELK GROVE"
 "ELK GROVE"
 "ELK GROVE"
```

Обработка данных. Метод главных компонент

[40]:
```
# Фрейм с указанием площади и цены недвижимости:
F = filter_houses[!,[:sq__ft,:price]]
# Конвертация данных в массив:
F = Array{float64,2}(F)'
# Подключение пакета MultivariateStats:
using MultivariateStats
```

Рис. 3.16: Повторение примеров (16)

```
M = fit(PCA, F)
# Выделение значений главных компонент в отдельную переменную:
Xr = reconstruct(M, y)
# Построение графика с выделением главных компонент:
scatter(F[1,:],F[2,:])
scatter!(Xr[1,:],Xr[2,:])
```

```
DimensionMismatch: second dimension of A, 1, does not match length of x, 10

Stacktrace:
 [1] gemv!(y::Vector{float64}, tA::Char, A::Matrix{Float64}, x::Vector{Float64}, α::Bool, β::Bool)
   @ LinearAlgebra C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia\stdlib\v1.9\LinearAlgebra\src\matmul.jl:493
 [2] mul!
   @ C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia\stdlib\v1.9\LinearAlgebra\src\matmul.jl:65 [inlined]
 [3] mul!
   @ C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia\stdlib\v1.9\LinearAlgebra\src\matmul.jl:276 [inlined]
 [4] *(A::Matrix{float64}, x::Vector{float64})
   @ LinearAlgebra C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia\stdlib\v1.9\LinearAlgebra\src\matmul.jl:52
 [5] reconstruct(M::PCA{float64}, y::Vector{float64})
   @ MultivariateStats C:\Users\vemanaeva\.julia\packages\MultivariateStats\F3eLE\src\pca.jl:135
 [6] top-level scope
   @ In[40]:10
```

Обработка данных. Линейная регрессия

[41]:
```
xvals = repeat(1:0.5:10,inner=2)
yvals = 3 .+ xvals + 2*rand(length(xvals)) .- 1
scatter(xvals,yvals,color=:black,leg=false)
```

[41]:

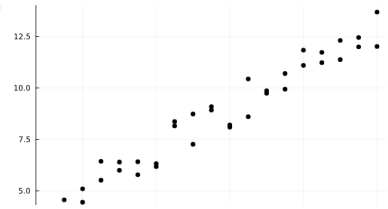


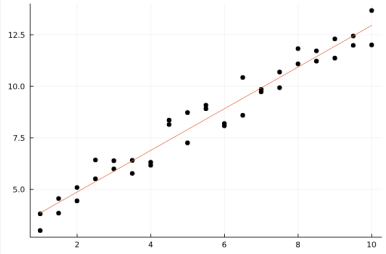
Рис. 3.17: Повторение примеров (17)

```
[42]: function find_best_fit(xvals,yvals)
      meanx = mean(xvals)
      meany = mean(yvals)
      stdx = std(xvals)
      stdy = std(yvals)
      r = cor(xvals,yvals)
      a = r*stdy/stdx
      b = meany - a*meanx
      return a,b
      end

[42]: find_best_fit (generic function with 1 method)

[43]: a,b = find_best_fit(xvals,yvals)
      ynew = a * xvals .+ b
      plot!(xvals,ynew)

[43]:
```




```
[44]: xvals = 1:100000;
      xvals = repeat(xvals,inner=3);
      yvals = 3 .+ xvals + 2*rand(length(xvals)) .- 1;
      @show size(xvals)
      @show size(yvals)
```

Рис. 3.18: Повторение примеров (18)

```
      @time a,b = find_best_fit(xvals,yvals)

      size(xvals) = (300000,)
      size(yvals) = (300000,)
        0.042879 seconds (23.13 k allocations: 1.507 MiB, 96.45% compilation time)
[44]: (1.0000000044268917, 2.998837311293755)

[45]: using PyCall
      using Conda
      py"""
      import numpy
      def find_best_fit_python(xvals,yvals):
          meanx = numpy.mean(xvals)
          meany = numpy.mean(yvals)
          stdx = numpy.std(xvals)
          stdy = numpy.std(yvals)
          r = numpy.corrcoef(xvals,yvals)[0][1]
          a = r*stdy/stdx
          b = meany - a*meanx
      return a,b
      """
      xpy = PyObject(xvals)
      ypy = PyObject(yvals)
      @time a,b = find_best_fit_python(xpy,ypy)

      PyError ($(Expr(:escape, :(ccall(#= C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\pyeval.jl:34 =# @pysym(:Py_CompileString), PyPtr, (Cstring, Cstring, Cint), s, fname, input_type))))) <class
      'SyntaxError'>
      SyntaxError("'return' outside function", ("C:\\Users\\vemanaeva\\.julia\\packages\\PyCall\\ilqDX\\src\\pyeval.jl", 10, 1, '            return PyDict{String,PyObject,true}(pyincref(@pycheckn ccall((@
      pysym :PyModule_GetDict), PyPtr, (PyPtr,), pyimport("__main__")))\n', 10, 11))


      Stacktrace:
       [1] pyerr_check
         @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:75 [inlined]
       [2] pyerr_check
         @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:79 [inlined]
       [3] _handle_error(msg::String)
         @ PyCall C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:96
       [4] macro expansion
         @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:110 [inlined]
       [5] pyeval_(s::String, globals::PyDict{String, PyObject, true}, locals::PyDict{String, PyObject, true}, input_type::Int64, fname::String)
         @ PyCall C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\pyeval.jl:34
       [6] top-level scope
         @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\pyeval.jl:230

[46]: using BenchmarkTools
      @btime a,b = find_best_fit_python(xvals,yvals)
      @btime a,b = find_best_fit(xvals,yvals)
```

Рис. 3.19: Повторение примеров (19)

3.2 Самостоятельная работа [2]

Самостоятельная работа (3.20, 3.21, 3.22, 3.23, 3.24, 3.25, 3.26)

Самостоятельная работа

Кластеризация

Используйте Clustering.jl для кластеризации на основе k-средних. Сделайте точечную диаграмму полученных кластеров. Подсказка: вам нужно будет проиндексировать фрейм данных, преобразовать его в массив и транспонировать.

[47]:
```
using GLM
```

[48]:
```
iris = dataset("datasets", "iris")
select!(iris, Not(:Species))
X = Matrix(iris)
X = X'

result = kmeans(X, 10, maxiter=10, display=:iter)
display(result)

scatter(iris.PetalLength, iris.PetalWidth, marker_z=result.assignments, color=:lightrainbow, legend=false)
```

```
  Iters               objv        objv-change | affected
------------------------------------------------------------
      0       5.666000e+01
      1       3.367176e+01      -2.298824e+01 |        9
      2       3.065446e+01      -3.017298e+00 |        6
      3       2.882822e+01      -1.826248e+00 |        5
      4       2.814717e+01      -6.810483e-01 |        5
      5       2.795575e+01      -1.914226e-01 |        3
      6       2.785331e+01      -1.024312e-01 |        2
      7       2.783033e+01      -2.298006e-02 |        0
      8       2.783033e+01       0.000000e+00 |        0
K-means converged with 8 iterations (objv = 27.830334723886182)
KmeansResult{Matrix{Float64}, Float64, Int64}([7.800000000000001 4.818181818181818 … 5.370588235294117 6.005882352941764; 3.8 3.236363636363636 … 3.8 2.7352941176470593; 6.550000000000001 1.4333333333333331 … 1.5176470588235293 5.011764705882351; 2.1 0.2303030303030303 … 0.2764705882352942 1.788235294117647], [2, 2, 2, 2, 2, 9, 2, 2, 2, 2  …  7, 6, 10, 7, 7, 6, 10, 6, 6, 10], [0.15095500459136701, 0.06459136822772393, 0.03398530762167695, 0.07156106519741456, 0.16731864095498885, 0.05937716262975812, 0.08034894398529957, 0.06519742883377982, 0.2900459136822633, 0.04671258034895231 … 0.08703124999999545, 0.31775086505194485, 0.06391003460205980, 0.09953125000000095, 0.05453124999996817, 0.13892733564001759, 0.15449826989620874, 0.06539792387542332, 0.30069204152246704, 0.08920415224912404], [2, 33, 12, 8, 23, 17, 8, 13, 17, 17], [2, 33, 12, 8, 23, 17, 8, 13, 17, 17], 27.830334723886182, 8, true)
```

[48]:

Рис. 3.20: Самостоятельная работа (1)

Регрессия (метод наименьших квадратов в случае линейной регрессии)

Часть 1.

Для самостоятельного решения необходимо добавить колонку единиц и решить СЛАУ, где матрица X с добавленной колонкой единиц является матрицей коэффициентов, а вектор y --- вектором ответов. Колонка единиц добавляется для того, чтобы решение ограничивалось исключительно линейными случаями (так как производная линейной функции равна 1).

[49]:
```
X = randn(1000, 3)
a0 = rand(3)
y = X * a0 + 0.1 * randn(1000)
```

[49]:
```
1000-element Vector{Float64}:
 -0.7945765229015872
 -0.6720209638517435
  1.3716244627873222
  2.1785938205075484
 -0.3260138255273183
  0.26170158513295094
  0.9557760816312258
 -2.30497167056572
 -0.6942984013717575
 -0.9267042171300182
 -1.2557384299492562
 -1.6445050915198212
  1.5532534557172666
  ⋮
 -1.6250530641171432
  0.6461356986934509
 -0.6007257958443772
 -0.010337923351421996
  1.328135396010722
 -1.9834012006898946
 -0.14795949976911234
 -1.3949207950494904
  1.3520963911727373
 -1.8038372400597185
  0.6129175787211228
 -0.16580110961773115
```

[50]:
```
N = 1000
X2 = hcat(ones(N), X)
```

[50]:
```
1000×4 Matrix{Float64}:
 1.0  -1.11694     0.644413   -0.217648
 1.0   0.0169132  -3.37187    -0.46774
 1.0  -0.377588   -0.516486    2.02971
```

Рис. 3.21: Самостоятельная работа (2)

[51]:
```
betahat1 = X2 \ y
yp = X2 * betahat1
mse1 = sqrt(sum(abs2.(y - yp)) / N)
display(betahat1)
mse1
```

```
4-element Vector{Float64}:
 0.003675260146041499
 0.7485522672623919
 0.09827734019830424
 0.8080809386336673
```

[51]: 0.09996843006061548

[52]:
```
betahat2 = llsq(X, y; bias=false)
yp = X * betahat2
mse2 = sqrt(sum(abs2.(y - yp)) / N)
display(betahat2)
mse2
```

```
3-element Vector{Float64}:
 0.7485913584036923
 0.09817586710246 7
 0.8079549588733729
```

[52]: 0.10003581652171566

[53]:
```
X3 = DataFrame(a=y, b=X[:,1], c=X[:,2], d=X[:,3])
lmMSE = lm(@formula(a ~ b + c + d), X3)
betahat3 = GLM.coeftable(lmMSE).cols[1]
yp = X2 * betahat3
mse3 = sqrt(sum(abs2.(y - yp)) / N)
display(betahat3)
mse3
```

```
4-element Vector{Float64}:
 0.003675260146041532 2
 0.7485522672623924
 0.09827734019830442
 0.8080809386336726
```

[53]: 0.09996843006061547

Часть 2.

[54]:
```
X = rand(100)
y = 2X + 0.1 * randn(100)
Xh = hcat(ones(100), X)
```

Рис. 3.22: Самостоятельная работа (3)

```
y = 2X + 0.1 * randn(100)
Xh = hcat(ones(100), X)
lm2 = fit(LinearModel, Xh, y)
display(lm2)

Plots.plot(title="График регрессии", xlabel="x", ylabel="y", legend=:topleft)
Plots.plot!(X, predict(lm2), label="Линия регрессии")
Plots.scatter!(X, y, label="Данные")
```

```
LinearModel{GLM.LmResp{Vector{Float64}}, GLM.DensePredChol{Float64, LinearAlgebra.CholeskyPivoted{Float64, Matrix{Float64}, Vector{Int64}}}}:

Coefficients:
──────────────────────────────────────────────────────────────────────────
              Coef.  Std. Error      t  Pr(>|t|)   Lower 95%  Upper 95%
──────────────────────────────────────────────────────────────────────────
x1  -0.00481807   0.0181552  -0.27    0.7913  -0.0408465  0.0312103
x2   2.00541      0.0341101  58.79    <1e-77   1.93772    2.0731
──────────────────────────────────────────────────────────────────────────
```

[54]:

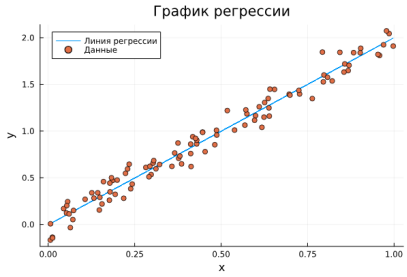


Рис. 3.23: Самостоятельная работа (4)

Модель ценообразования биномиальных опционов

Пункты *a* и *d*.

[55]:
```
function binomial_stock_price(S, T, n, sigma, r)
    h = T/n
    u = exp(r * h + sigma * sqrt(h))
    d = exp(r * h - sigma * sqrt(h))
    p = (exp(r * h) - d) / (u - d)
    stock_prices = zeros(n+1)
    stock_prices[1] = S
    for i in 2:n+1
        epsilon = rand()
        if epsilon > 0.5
            stock_prices[i] = stock_prices[i-1]*u
        else
            stock_prices[i] = stock_prices[i-1]*d
        end
    end
    return stock_prices
end

S, T, n, sigma, r = 100.0, 1.0, 10000, 0.3, 0.08
stock_prices = binomial_stock_price(S, T, n, sigma, r)

plot(stock_prices, xlabel="Время", ylabel="Цена", label="Стоимость акции")
```

[55]:

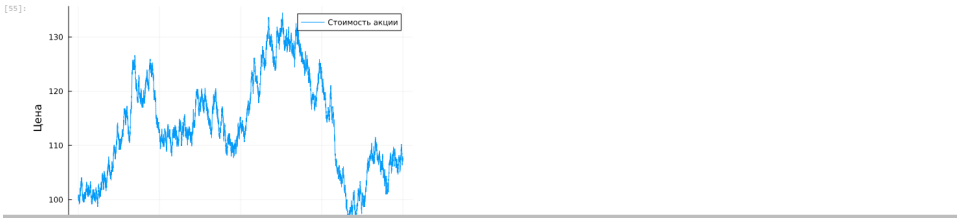


Рис. 3.24: Самостоятельная работа (5)

[56]:
```
function createPath(S::Float64, r::Float64, sigma::Float64, T::Float64, n::Int64)
    dt = T / n
    path = [S]

    for i in 1:n
        epsilon = randn()
        S = S * exp((r - 0.5 * sigma^2) * dt + sigma * sqrt(dt) * epsilon)
        push!(path, S)
    end
    return path
end

paths = [createPath(S, r, sigma, T, n) for i in 1:10]
plot(paths, title="Траектории", xlabel="Время", ylabel="Цена", legend=false)
```

[56]:

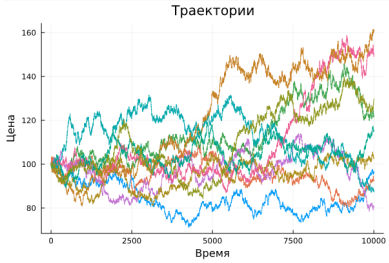


Рис. 3.25: Самостоятельная работа (6)

[57]:
```
using Random
using Base.Threads

paths2 = []
@threads for i = 1:10
    push!(paths2, createPath(S, r, sigma, T, n))
end

plot(paths2, title="Stock Price Paths (threads)", xlabel="Time", ylabel="Price", legend=false)
```

[57]:

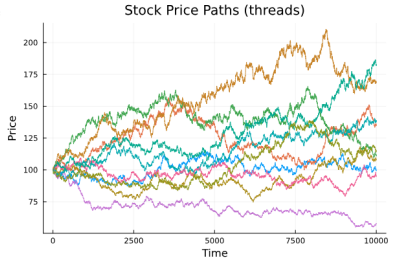


Рис. 3.26: Самостоятельная работа (7)

4 Выводы по проделанной работе

4.1 Вывод

В результате выполнения работы мы освоили специальные пакеты Julia для обработки данных.

Были записаны скринкасты выполнения и защиты лабораторной работы.

Ссылки на скринкасты:

- Выполнение, Youtube
- Выполнение, Rutube
- Защита презентации, Youtube
- Защита презентации, Rutube

Список литературы

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2. Julia official documentation [Электронный ресурс]. 2023. URL: https://docs.julialang.org/en/v1/.

Повторение примеров

Julia для науки о данных

Считывание данных

In [1]:
```
using CSV, DataFrames, DelimitedFiles

# Считывание данных и их запись в структуру:
P = CSV.File("programminglanguages.csv") |> DataFrame
# Функция определения по названию языка программирования года его создания:
function language_created_year(P,language::String)
    loc = findfirst(P[:,2].==language)
    return P[loc,1]
end
# Пример вызова функции и определение даты создания языка Python:
language_created_year(P,"Python")
# Пример вызова функции и определение даты создания языка Julia:
language_created_year(P,"Julia")
```

Out[1]:
```
2012
```

In [2]:
```
language_created_year(P,"julia")
```

```
MethodError: no method matching getindex(::DataFrame, ::Nothing, ::Int64)

Closest candidates are:
  getindex(::DataFrame, ::typeof(!), ::Union{Signed, Unsigned})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MUJ\src\dataframe\dataframe.jl:548
  getindex(::DataFrame, ::Colon, ::Union{AbstractString, Signed, Symbol, Unsigned})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MUJ\src\dataframe\dataframe.jl:542
  getindex(::DataFrame, ::InvertedIndex, ::Union{AbstractString, Signed, Symbol, Unsigned})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MUJ\src\dataframe\dataframe.jl:538
  ...


Stacktrace:
 [1] language_created_year(P::DataFrame, language::String)
   @ Main .\In[1]:8
 [2] top-level scope
   @ In[2]:1
```

In [3]:
```
# Функция определения по названию языка программирования года его создания (без учё
function language_created_year_v2(P,language::String)
loc = findfirst(lowercase.(P[:,2]).==lowercase.(language))
return P[loc,1]
```

```
end
# Пример вызова функции и определение даты создания языка julia:
language_created_year_v2(P,"julia")
```

Out[3]: 2012

In [4]:
```
# Построчное считывание данных с указанием разделителя:
Tx = readdlm("programminglanguages.csv", ',')
```

Out[4]:
```
74×2 Matrix{Any}:
     "year"  "language"
 1951        "Regional Assembly Language"
 1952        "Autocode"
 1954        "IPL"
 1955        "FLOW-MATIC"
 1957        "FORTRAN"
 1957        "COMTRAN"
 1958        "LISP"
 1958        "ALGOL 58"
 1959        "FACT"
 1959        "COBOL"
 1959        "RPG"
 1962        "APL"
    ⋮
 2003        "Scala"
 2005        "F#"
 2006        "PowerShell"
 2007        "Clojure"
 2009        "Go"
 2010        "Rust"
 2011        "Dart"
 2011        "Kotlin"
 2011        "Red"
 2011        "Elixir"
 2012        "Julia"
 2014        "Swift"
```

Запись данных в файл

In [5]:
```
# Запись данных в CSV-файл:
CSV.write("programming_languages_data2.csv", P)
```

Out[5]: "programming_languages_data2.csv"

In [6]:
```
# Пример записи данных в текстовый файл с разделителем ',':
writedlm("programming_languages_data.txt", Tx, ',')
```

In [7]:
```
# Пример записи данных в текстовый файл с разделителем '-':
writedlm("programming_languages_data2.txt", Tx, '-')
```

In [8]:
```
# Построчное считывание данных с указанием разделителя:
P_new_delim = readdlm("programming_languages_data2.txt", '-')
```

Out[8]:
```
74×2 Matrix{Any}:
     "year"  "language"
 1951        "Regional Assembly Language"
 1952        "Autocode"
 1954        "IPL"
 1955        "FLOW-MATIC"
 1957        "FORTRAN"
 1957        "COMTRAN"
 1958        "LISP"
 1958        "ALGOL 58"
 1959        "FACT"
 1959        "COBOL"
 1959        "RPG"
 1962        "APL"
    ⋮
 2003        "Scala"
 2005        "F#"
 2006        "PowerShell"
 2007        "Clojure"
 2009        "Go"
 2010        "Rust"
 2011        "Dart"
 2011        "Kotlin"
 2011        "Red"
 2011        "Elixir"
 2012        "Julia"
 2014        "Swift"
```

Словари

In [9]:
```
# Инициализация словаря:
dict = Dict{Integer,Vector{String}}()
```

Out[9]:
```
Dict{Integer, Vector{String}}()
```

In [10]:
```
# Инициализация словаря:
dict2 = Dict()
```

Out[10]:
```
Dict{Any, Any}()
```

In [11]:
```
# Заполнение словаря данными:
for i = 1:size(P,1)
    year,lang = P[i,:]
    if year in keys(dict)
        dict[year] = push!(dict[year],lang)
    else
        dict[year] = [lang]
    end
end
dict
```

Out[11]:
```
Dict{Integer, Vector{String}} with 45 entries:
  1985 => ["Eiffel"]
  2002 => ["Scratch"]
  1952 => ["Autocode"]
  1963 => ["CPL"]
  1964 => ["Speakeasy", "BASIC", "PL/I"]
  1967 => ["BCPL"]
  2001 => ["C#", "D"]
  1991 => ["Python", "Visual Basic"]
  1957 => ["FORTRAN", "COMTRAN"]
  1988 => ["Tcl", "Wolfram Language "]
  1955 => ["FLOW-MATIC"]
  1951 => ["Regional Assembly Language"]
  1994 => ["CLOS "]
  2011 => ["Dart", "Kotlin", "Red", "Elixir"]
  1959 => ["FACT", "COBOL", "RPG"]
  1962 => ["APL", "Simula", "SNOBOL"]
  2005 => ["F#"]
  1969 => ["B"]
  1972 => ["C", "Smalltalk", "Prolog"]
  1997 => ["Rebol"]
  1986 => ["Objective-C", "LabVIEW ", "Erlang"]
  1993 => ["Lua", "R"]
  1958 => ["LISP", "ALGOL 58"]
  1987 => ["Perl"]
  1954 => ["IPL"]
  ⋮    => ⋮
```

In [12]:
```
# Пример определения в словаре языков программирования, созданных в 2003 году:
dict[2003]
```

Out[12]:
```
2-element Vector{String}:
 "Groovy"
 "Scala"
```

DataFrames

In [13]:
```
# Задаём переменную со структурой DataFrame:
df = DataFrame(year = P[:,1], language = P[:,2])
# Вывод всех значения столбца year:
df[!,:year]
```

Out[13]:
```
73-element Vector{Int64}:
 1951
 1952
 1954
 1955
 1957
 1957
 1958
 1958
 1959
 1959
 1959
 1962
 1962
    ⋮
 2003
 2005
 2006
 2007
 2009
 2010
 2011
 2011
 2011
 2011
 2012
 2014
```

In [14]:
```
# Получение статистических сведений о фрейме:
describe(df)
```

Out[14]: 2×7 DataFrame

Row	variable	mean	min	median	max	nmissing	eltype
	Symbol	Union…	Any	Union…	Any	Int64	DataType
1	year	1982.99	1951	1986.0	2014	0	Int64
2	language		ALGOL 58		dBase III	0	String31

RDatasets

In [15]:
```
# Подгружаем пакет RDatasets:
using RDatasets
# Задаём структуру данных в виде набора данных:
iris = dataset("datasets", "iris")
```

Out[15]: 150×5 DataFrame *125 rows omitted*

Row	SepalLength	SepalWidth	PetalLength	PetalWidth	Species
	Float64	Float64	Float64	Float64	Cat...
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3.0	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa
4	4.6	3.1	1.5	0.2	setosa
5	5.0	3.6	1.4	0.2	setosa
6	5.4	3.9	1.7	0.4	setosa
7	4.6	3.4	1.4	0.3	setosa
8	5.0	3.4	1.5	0.2	setosa
9	4.4	2.9	1.4	0.2	setosa
10	4.9	3.1	1.5	0.1	setosa
11	5.4	3.7	1.5	0.2	setosa
12	4.8	3.4	1.6	0.2	setosa
13	4.8	3.0	1.4	0.1	setosa
⋮	⋮	⋮	⋮	⋮	⋮
139	6.0	3.0	4.8	1.8	virginica
140	6.9	3.1	5.4	2.1	virginica
141	6.7	3.1	5.6	2.4	virginica
142	6.9	3.1	5.1	2.3	virginica
143	5.8	2.7	5.1	1.9	virginica
144	6.8	3.2	5.9	2.3	virginica
145	6.7	3.3	5.7	2.5	virginica
146	6.7	3.0	5.2	2.3	virginica
147	6.3	2.5	5.0	1.9	virginica
148	6.5	3.0	5.2	2.0	virginica
149	6.2	3.4	5.4	2.3	virginica
150	5.9	3.0	5.1	1.8	virginica

In [16]:
```
# Определения типа переменной:
typeof(iris)
```

Out[16]: DataFrame

In [17]:
```
describe(iris)
```

Out[17]: 5×7 DataFrame

Row	variable	mean	min	median	max	nmissing	eltype
	Symbol	Union…	Any	Union…	Any	Int64	DataType
1	SepalLength	5.84333	4.3	5.8	7.9	0	Float64
2	SepalWidth	3.05733	2.0	3.0	4.4	0	Float64
3	PetalLength	3.758	1.0	4.35	6.9	0	Float64
4	PetalWidth	1.19933	0.1	1.3	2.5	0	Float64
5	Species		setosa		virginica	0	CategoricalValue{String, UInt8}

Работа с переменными отсутствующего типа (Missing Values)

In [18]:
```
# Отсутствующий тип:
a = missing
typeof(a)
```

Out[18]: Missing

In [19]:
```
# Пример операции с переменной отсутствующего типа:
a + 1
```

Out[19]: missing

In [20]:
```
# Определение перечня продуктов:
foods = ["apple", "cucumber", "tomato", "banana"]
# Определение калорий:
calories = [missing,47,22,105]
```

Out[20]:
```
4-element Vector{Union{Missing, Int64}}:
     missing
  47
  22
 105
```

In [21]:
```
# Определение типа переменной:
typeof(calories)
```

Out[21]: Vector{Union{Missing, Int64}} (alias for Array{Union{Missing, Int64}, 1})

In [22]:
```
# Подключаем пакет Statistics:
using Statistics
```

```
# Определение среднего значения:
mean(calories)
```

Out[22]: missing

In [23]:
```
# Определение среднего значения без значений с отсутствующим типом:
mean(skipmissing(calories))
```

Out[23]: 58.0

In [24]:
```
# Задание сведений о ценах:
prices = [0.85,1.6,0.8,0.6]
# Формирование данных о калориях:
dataframe_calories = DataFrame(item=foods,calories=calories)
# Формирование данных о ценах:
dataframe_prices = DataFrame(item=foods,price=prices)
# Объединение данных о калориях и ценах:
DF = innerjoin(dataframe_calories,dataframe_prices,on=:item)
```

Out[24]: 4×3 DataFrame

Row	item	calories	price
	String	Int64?	Float64
1	apple	*missing*	0.85
2	cucumber	47	1.6
3	tomato	22	0.8
4	banana	105	0.6

FileIO

In [25]:
```
# Подключаем пакет FileIO:
using FileIO
using ImageIO
# Загрузка изображения:
X1 = load("julialogo.png")
```

Out[25]:
```
250×400 Array{RGBA{N0f8},2} with eltype ColorTypes.RGBA{FixedPointNumbers.N0f8}:
 RGBA{N0f8}(0.0,0.0,0.0,0.0)  …  RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)  …  RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)  …  RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 ⋮                            ⋱
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)  …  RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)  …  RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
 RGBA{N0f8}(0.0,0.0,0.0,0.0)     RGBA{N0f8}(0.0,0.0,0.0,0.0)
```

In [26]:
```
# Определение типа и размера данных:
@show typeof(X1);
@show size(X1);
```

```
typeof(X1) = Matrix{ColorTypes.RGBA{FixedPointNumbers.N0f8}}
size(X1) = (250, 400)
```

Обработка данных: стандартные алгоритмы машинного обучения в Julia

Кластеризация данных. Метод k-средних

In [27]:
```
using Plots
# Загрузка данных:
houses = CSV.File("houses.csv") |> DataFrame
```

Out[27]: 985×12 DataFrame *960 rows omitted*

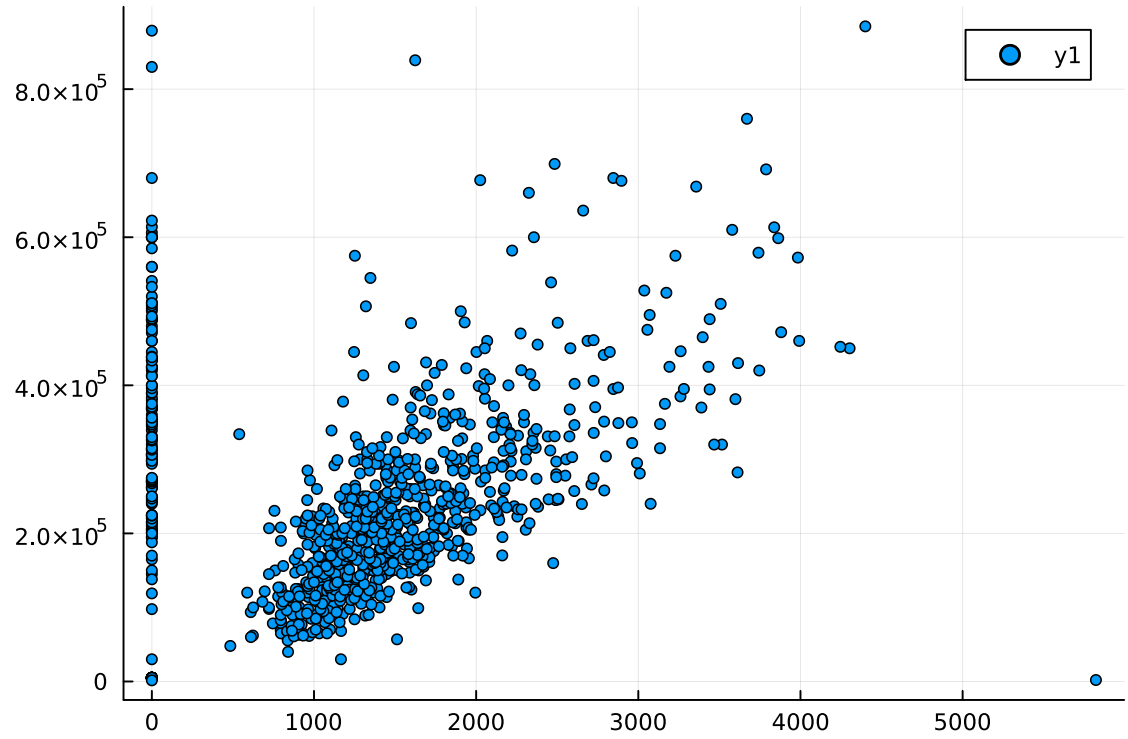
Row	street	city	zip	state	beds	baths	sq__ft	type	sal
	String	String15	Int64	String3	Int64	Int64	Int64	String15	Str
1	3526 HIGH ST	SACRAMENTO	95838	CA	2	1	836	Residential	We 21 00: ED
2	51 OMAHA CT	SACRAMENTO	95823	CA	3	1	1167	Residential	We 21 00: ED
3	2796 BRANCH ST	SACRAMENTO	95815	CA	2	1	796	Residential	We 21 00: ED
4	2805 JANETTE WAY	SACRAMENTO	95815	CA	2	1	852	Residential	We 21 00: ED
5	6001 MCMAHON DR	SACRAMENTO	95824	CA	2	1	797	Residential	We 21 00: ED
6	5828 PEPPERMILL CT	SACRAMENTO	95841	CA	3	1	1122	Condo	We 21 00: ED
7	6048 OGDEN NASH WAY	SACRAMENTO	95842	CA	3	2	1104	Residential	We 21 00: ED
8	2561 19TH AVE	SACRAMENTO	95820	CA	3	1	1177	Residential	We 21 00: ED
9	11150 TRINITY RIVER DR Unit 114	RANCHO CORDOVA	95670	CA	2	2	941	Condo	We 21 00: ED
10	7325 10TH ST	RIO LINDA	95673	CA	3	2	1146	Residential	We 21 00: ED
11	645 MORRISON AVE	SACRAMENTO	95838	CA	3	2	909	Residential	We 21

Row	street	city	zip	state	beds	baths	sq__ft	type	sal
	String	String15	Int64	String3	Int64	Int64	Int64	String15	Str
									00: ED
12	4085 FAWN CIR	SACRAMENTO	95823	CA	3	2	1289	Residential	We 21 00: ED
13	2930 LA ROSA RD	SACRAMENTO	95815	CA	1	1	871	Residential	We 21 00: ED
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
974	2181 WINTERHAVEN CIR	CAMERON PARK	95682	CA	3	2	0	Residential	Thu 15 00: ED
975	7540 HICKORY AVE	ORANGEVALE	95662	CA	3	1	1456	Residential	Thu 15 00: ED
976	5024 CHAMBERLIN CIR	ELK GROVE	95757	CA	3	2	1450	Residential	Thu 15 00: ED
977	2400 INVERNESS DR	LINCOLN	95648	CA	3	2	1358	Residential	Thu 15 00: ED
978	5 BISHOPGATE CT	SACRAMENTO	95823	CA	4	2	1329	Residential	Thu 15 00: ED
979	5601 REXLEIGH DR	SACRAMENTO	95823	CA	4	2	1715	Residential	Thu 15 00: ED
980	1909 YARNELL WAY	ELK GROVE	95758	CA	3	2	1262	Residential	Thu 15 00: ED
981	9169 GARLINGTON CT	SACRAMENTO	95829	CA	4	3	2280	Residential	Thu 15 00: ED

Row	street	city	zip	state	beds	baths	sq__ft	type	sal
	String	String15	Int64	String3	Int64	Int64	Int64	String15	Str
982	6932 RUSKUT WAY	SACRAMENTO	95823	CA	3	2	1477	Residential	Thu 15 00: ED
983	7933 DAFFODIL WAY	CITRUS HEIGHTS	95610	CA	3	2	1216	Residential	Thu 15 00: ED
984	8304 RED FOX WAY	ELK GROVE	95758	CA	4	2	1685	Residential	Thu 15 00: ED
985	3882 YELLOWSTONE LN	EL DORADO HILLS	95762	CA	3	2	1362	Residential	Thu 15 00: ED

In [28]:
```
plot(size=(500,500),leg=false)
x = houses[!,:sq__ft]
y = houses[!,:price]
scatter(x,y,markersize=3)
```

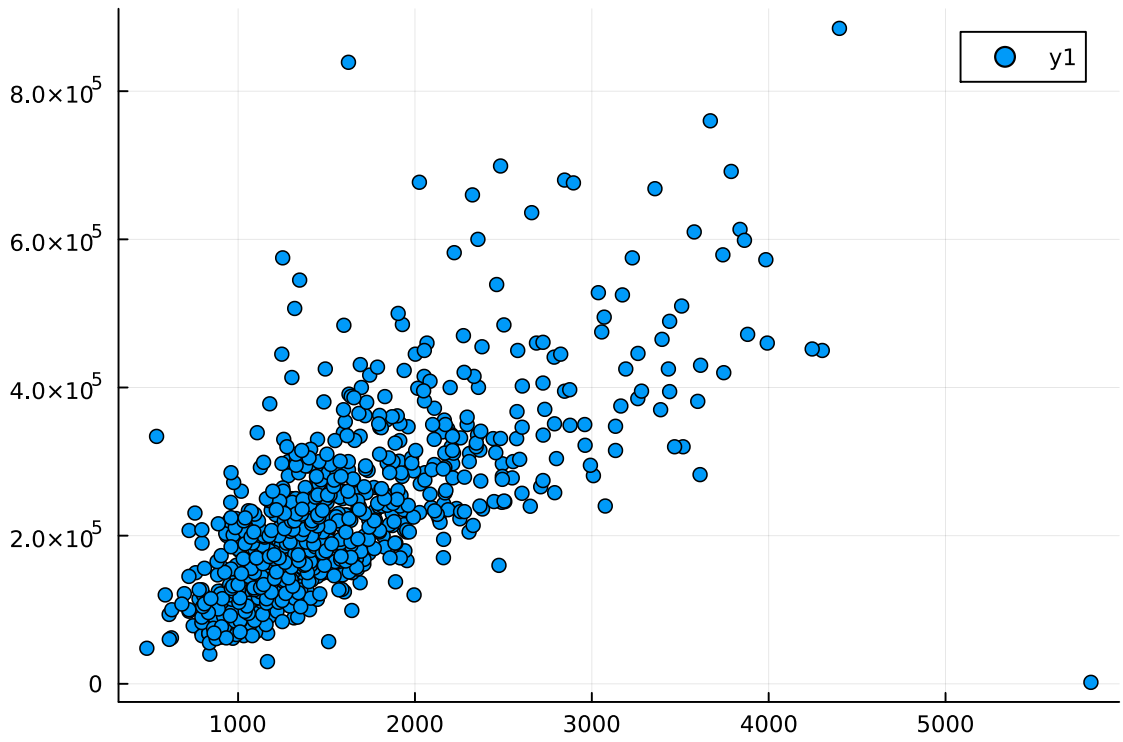
Out[28]:



In [29]:
```
# Фильтрация данных по заданному условию:
filter_houses = houses[houses[!,:sq__ft].>0,:]
# Построение графика:
```

```
x = filter_houses[!,:sq__ft]
y = filter_houses[!,:price]
scatter(x,y)
```

Out[29]:



In [30]:
```
# Определение средней цены для определённого типа домов:
by(filter_houses,:type,filter_houses->mean(filter_houses[!,:price]))
```

```
ArgumentError: by function was removed from DataFrames.jl. Use the `combine(groupby
(...), ...)` or `combine(f, groupby(...))` instead.

Stacktrace:
 [1] by(::DataFrame, ::Vararg{Any}; kwargs::Base.Pairs{Symbol, Union{}, Tuple{}, Nam
edTuple{(), Tuple{}}})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MUJ\src\deprecated.j
l:4
 [2] by(::DataFrame, ::Vararg{Any})
   @ DataFrames C:\Users\vemanaeva\.julia\packages\DataFrames\58MUJ\src\deprecated.j
l:4
 [3] top-level scope
   @ In[30]:2
```

In [31]:
```
combine(filter_houses->mean(filter_houses[!,:price]), groupby(filter_houses,:type))
```

Out[31]: 3×2 DataFrame

Row	type	x1
	String15	Float64
1	Residential	2.34802e5
2	Condo	1.34213e5
3	Multi-Family	2.24535e5

In [32]:
```
using Clustering
# Добавление данных :latitude и :longitude в новый фрейм:
X = filter_houses[:, [:latitude,:longitude]]
```

Out[32]: 814×2 DataFrame *789 rows omitted*

Row	latitude	longitude
	Float64	Float64
1	38.6319	-121.435
2	38.4789	-121.431
3	38.6183	-121.444
4	38.6168	-121.439
5	38.5195	-121.436
6	38.6626	-121.328
7	38.6817	-121.352
8	38.5351	-121.481
9	38.6212	-121.271
10	38.7009	-121.443
11	38.6377	-121.452
12	38.4707	-121.459
13	38.6187	-121.436
⋮	⋮	⋮
803	38.7035	-121.375
804	38.7031	-121.235
805	38.3898	-121.446
806	38.8978	-121.325
807	38.4679	-121.445
808	38.4453	-121.442
809	38.4174	-121.484
810	38.4577	-121.36
811	38.4999	-121.459
812	38.7088	-121.257
813	38.417	-121.397
814	38.6552	-121.076

In [33]:
```
# Конвертация данных в матричный вид:
X = Matrix(X[:, 1:2])
```

Out[33]:
```
814×2 Matrix{Float64}:
 38.6319  -121.435
 38.4789  -121.431
 38.6183  -121.444
 38.6168  -121.439
 38.5195  -121.436
 38.6626  -121.328
 38.6817  -121.352
 38.5351  -121.481
 38.6212  -121.271
 38.7009  -121.443
 38.6377  -121.452
 38.4707  -121.459
 38.6187  -121.436
  ⋮
 38.7035  -121.375
 38.7031  -121.235
 38.3898  -121.446
 38.8978  -121.325
 38.4679  -121.445
 38.4453  -121.442
 38.4174  -121.484
 38.4577  -121.36
 38.4999  -121.459
 38.7088  -121.257
 38.417   -121.397
 38.6552  -121.076
```

In [34]:
```
# Транспонирование матрицы с данными:
X = X'
# Задание количества кластеров:
k = length(unique(filter_houses[!,:zip]))
# Определение k-среднего:
C = kmeans(X,k)
```

Out[34]:
```
KmeansResult{Matrix{Float64}, Float64, Int64}([38.47975119354839 38.737452 … 38.63
562266666667 38.60819775; -121.41092403225811 -120.910963 … -121.33890555555556 -1
21.371695125], [41, 1, 41, 41, 26, 30, 19, 36, 58, 27  …  39, 20, 24, 17, 13, 35,
24, 4, 29, 62], [0.00012031390360789374, 0.0004048906521347817, 0.0002828492943081
0735, 0.0003708190743054729, 0.00015539828018518165, 0.00014710579853272066, 0.000
27759934528148733, 0.00026751534460345283, 1.144897032645531e-5, 0.000340708586008
98646  …  5.784670793218538e-5, 5.241325561655685e-5, 0.0002126721228705719, 0.000
16335299733327702, 0.0007778412618790753, 7.293177623068914e-5, 0.0004220604350848
589, 0.00032489683144376613, 0.000387906427931739, 0.00011059417010983452], [31,
1, 36, 9, 4, 18, 15, 8, 5, 9  …  4, 9, 12, 4, 19, 5, 8, 15, 9, 8], [31, 1, 36, 9,
4, 18, 15, 8, 5, 9  …  4, 9, 12, 4, 19, 5, 8, 15, 9, 8], 0.1989128205095767, 11, t
rue)
```

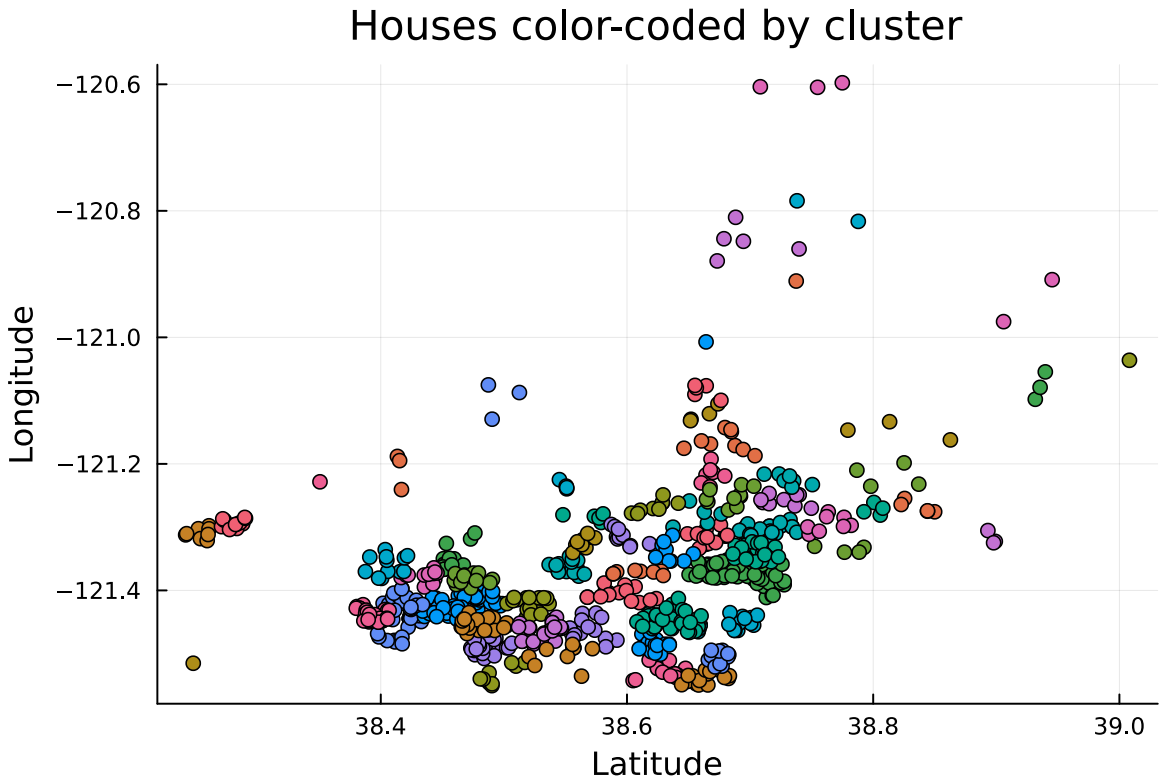
In [35]:
```
# Формирование фрейма данных:
df = DataFrame(cluster = C.assignments,city = filter_houses[!,:city], latitude = fi
```

Out[35]: 814×5 DataFrame *789 rows omitted*

Row	cluster	city	latitude	longitude	zip
	Int64	String15	Float64	Float64	Int64
1	41	SACRAMENTO	38.6319	-121.435	95838
2	1	SACRAMENTO	38.4789	-121.431	95823
3	41	SACRAMENTO	38.6183	-121.444	95815
4	41	SACRAMENTO	38.6168	-121.439	95815
5	26	SACRAMENTO	38.5195	-121.436	95824
6	30	SACRAMENTO	38.6626	-121.328	95841
7	19	SACRAMENTO	38.6817	-121.352	95842
8	36	SACRAMENTO	38.5351	-121.481	95820
9	58	RANCHO CORDOVA	38.6212	-121.271	95670
10	27	RIO LINDA	38.7009	-121.443	95673
11	41	SACRAMENTO	38.6377	-121.452	95838
12	24	SACRAMENTO	38.4707	-121.459	95823
13	41	SACRAMENTO	38.6187	-121.436	95815
⋮	⋮	⋮	⋮	⋮	⋮
803	3	NORTH HIGHLANDS	38.7035	-121.375	95660
804	48	ORANGEVALE	38.7031	-121.235	95662
805	39	ELK GROVE	38.3898	-121.446	95757
806	20	LINCOLN	38.8978	-121.325	95648
807	24	SACRAMENTO	38.4679	-121.445	95823
808	17	SACRAMENTO	38.4453	-121.442	95823
809	13	ELK GROVE	38.4174	-121.484	95758
810	35	SACRAMENTO	38.4577	-121.36	95829
811	24	SACRAMENTO	38.4999	-121.459	95823
812	4	CITRUS HEIGHTS	38.7088	-121.257	95610
813	29	ELK GROVE	38.417	-121.397	95758
814	62	EL DORADO HILLS	38.6552	-121.076	95762

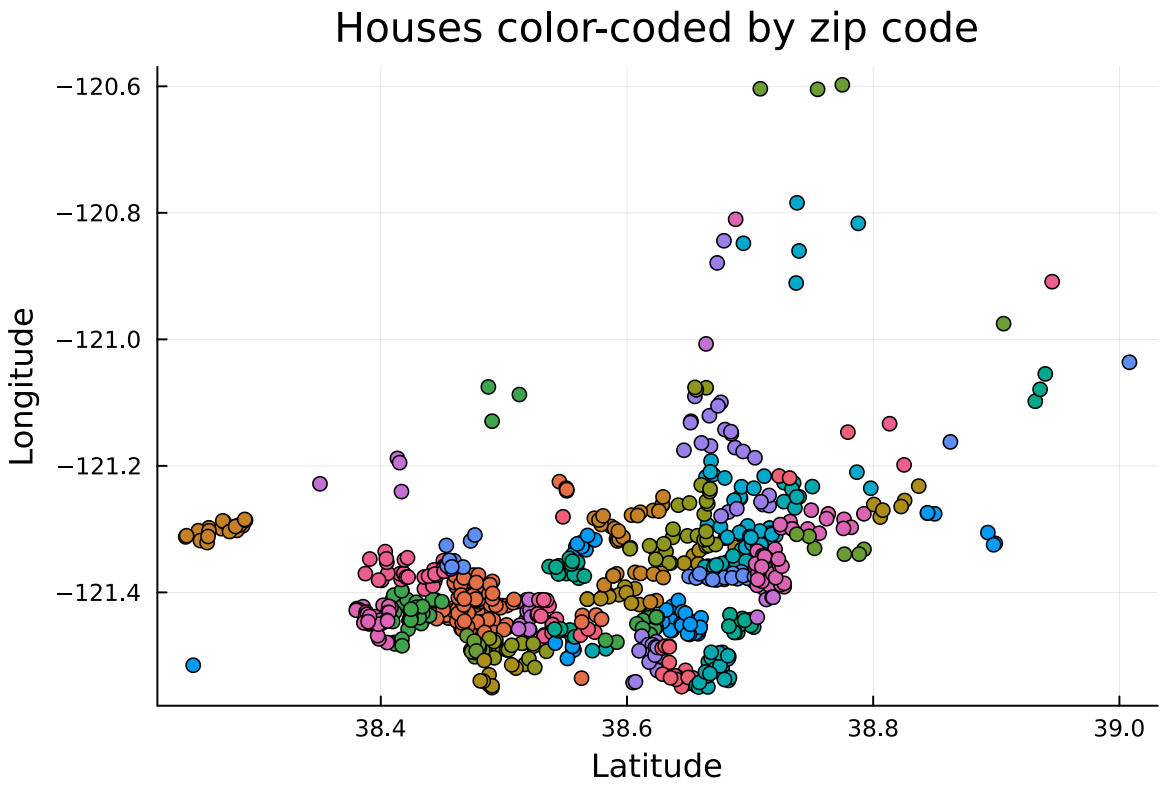
In [36]:
```
clusters_figure = plot(legend = false)
for i = 1:k
clustered_houses = df[df[!,:cluster].== i,:]
```

```
xvals = clustered_houses[!,:latitude]
yvals = clustered_houses[!,:longitude]
scatter!(clusters_figure,xvals,yvals,markersize=4)
end
xlabel!("Latitude")
ylabel!("Longitude")
title!("Houses color-coded by cluster")
display(clusters_figure)
```



In [37]:

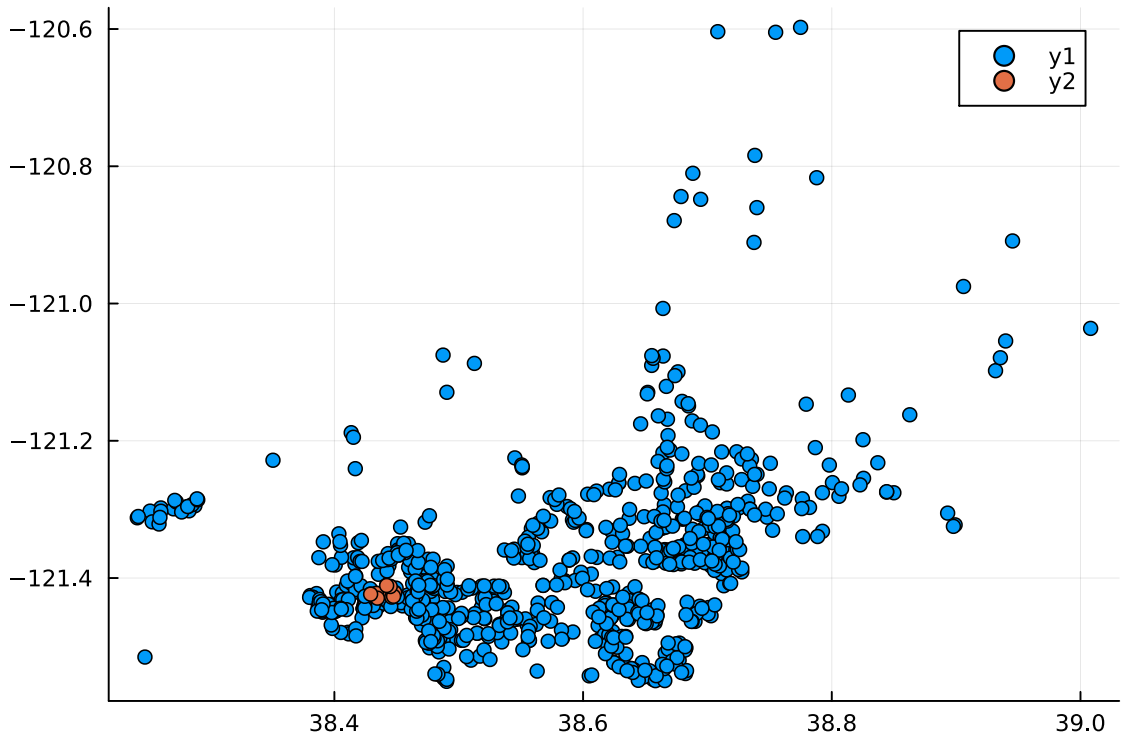
```
unique_zips = unique(filter_houses[!,:zip])
zips_figure = plot(legend = false)
for uzip in unique_zips
subs = filter_houses[filter_houses[!,:zip].==uzip,:]
x = subs[!,:latitude]
y = subs[!,:longitude]
scatter!(zips_figure,x,y)
end
xlabel!("Latitude")
ylabel!("Longitude")
title!("Houses color-coded by zip code")
display(zips_figure)
```



Кластеризация данных. Метод k ближайших соседей

In [38]:
```
using NearestNeighbors
knearest = 10
id = 70
point = X[:,id]
# Поиск ближайших соседей:
kdtree = KDTree(X)
idxs, dists = knn(kdtree, point, knearest, true)
# Все объекты недвижимости:
x = filter_houses[!,:latitude];
y = filter_houses[!,:longitude];
scatter(x,y)
# Соседи:
x = filter_houses[idxs,:latitude];
y = filter_houses[idxs,:longitude];
scatter!(x,y)
```

Out[38]:



In [39]:
```
# Фильтрация по районам соседних домов:
cities = filter_houses[idxs,:city]
```

Out[39]:
```
10-element PooledArrays.PooledVector{String15, UInt32, Vector{UInt32}}:
 "SACRAMENTO"
 "ELK GROVE"
 "SACRAMENTO"
 "SACRAMENTO"
 "SACRAMENTO"
 "SACRAMENTO"
 "ELK GROVE"
 "ELK GROVE"
 "ELK GROVE"
 "ELK GROVE"
```

Обработка данных. Метод главных компонент

In [40]:
```
# Фрейм с указанием площади и цены недвижимости:
F = filter_houses[!,[:sq__ft,:price]]
# Конвертация данных в массив:
F = Array{Float64,2}(F)'
# Подключение пакета MultivariateStats:
using MultivariateStats
# Приведение типов данных к распределению для PCA:
M = fit(PCA, F)
# Выделение значений главных компонент в отдельную переменную:
Xr = reconstruct(M, y)
# Построение графика с выделением главных компонент:
scatter(F[1,:],F[2,:])
scatter!(Xr[1,:],Xr[2,:])
```

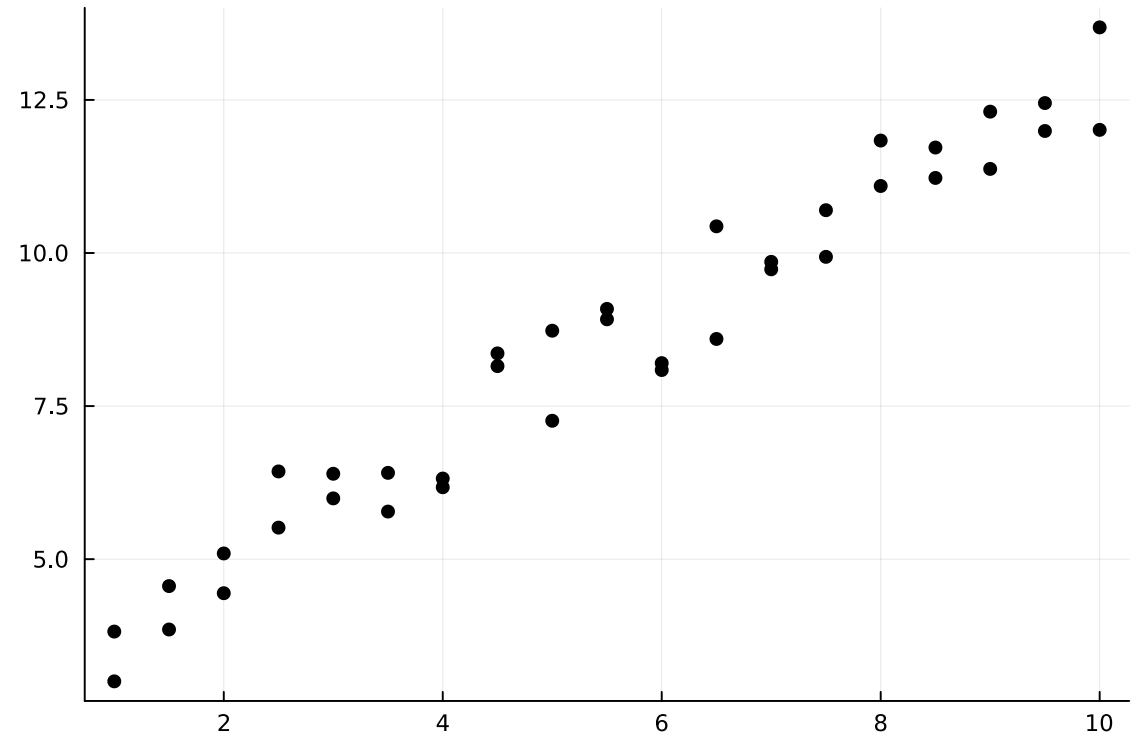
```
DimensionMismatch: second dimension of A, 1, does not match length of x, 10

Stacktrace:
 [1] gemv!(y::Vector{Float64}, tA::Char, A::Matrix{Float64}, x::Vector{Float64}, α::
Bool, β::Bool)
   @ LinearAlgebra C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia
\stdlib\v1.9\LinearAlgebra\src\matmul.jl:493
 [2] mul!
   @ C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia\stdlib\v1.9\L
inearAlgebra\src\matmul.jl:65 [inlined]
 [3] mul!
   @ C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia\stdlib\v1.9\L
inearAlgebra\src\matmul.jl:276 [inlined]
 [4] *(A::Matrix{Float64}, x::Vector{Float64})
   @ LinearAlgebra C:\Users\vemanaeva\AppData\Local\Programs\Julia-1.9.3\share\julia
\stdlib\v1.9\LinearAlgebra\src\matmul.jl:52
 [5] reconstruct(M::PCA{Float64}, y::Vector{Float64})
   @ MultivariateStats C:\Users\vemanaeva\.julia\packages\MultivariateStats\F3eLE\sr
c\pca.jl:135
 [6] top-level scope
   @ In[40]:10
```

Обработка данных. Линейная регрессия

In [41]:
```
xvals = repeat(1:0.5:10,inner=2)
yvals = 3 .+ xvals + 2*rand(length(xvals)) .- 1
scatter(xvals,yvals,color=:black,leg=false)
```

Out[41]:



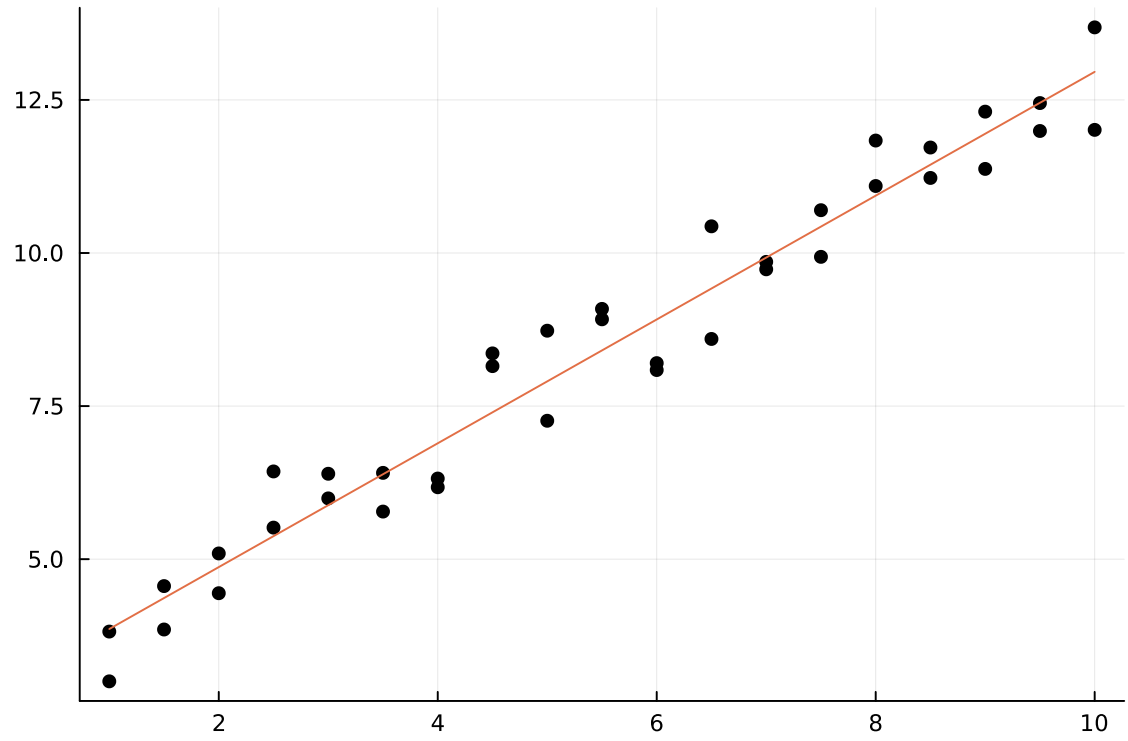
In [42]:
```
function find_best_fit(xvals,yvals)
meanx = mean(xvals)
meany = mean(yvals)
```

```
stdx = std(xvals)
stdy = std(yvals)
r = cor(xvals,yvals)
a = r*stdy/stdx
b = meany - a*meanx
return a,b
end
```

Out[42]: find_best_fit (generic function with 1 method)

In [43]:
```
a,b = find_best_fit(xvals,yvals)
ynew = a * xvals .+ b
plot!(xvals,ynew)
```

Out[43]:



In [44]:
```
xvals = 1:100000;
xvals = repeat(xvals,inner=3);
yvals = 3 .+ xvals + 2*rand(length(xvals)) .- 1;
@show size(xvals)
@show size(yvals)
@time a,b = find_best_fit(xvals,yvals)
```

```
size(xvals) = (300000,)
size(yvals) = (300000,)
  0.042879 seconds (23.13 k allocations: 1.507 MiB, 96.45% compilation time)
```

Out[44]: (1.000000044268917, 2.998837311293755)

In [45]:
```
using PyCall
using Conda
py"""
import numpy
def find_best_fit_python(xvals,yvals):
```

```
    meanx = numpy.mean(xvals)
    meany = numpy.mean(yvals)
    stdx = numpy.std(xvals)
    stdy = numpy.std(yvals)
    r = numpy.corrcoef(xvals,yvals)[0][1]
    a = r*stdy/stdx
    b = meany - a*meanx
return a,b
"""
xpy = PyObject(xvals)
ypy = PyObject(yvals)
@time a,b = find_best_fit_python(xpy,ypy)
```

```
PyError ($(Expr(:escape, :(ccall(#= C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX
\src\pyeval.jl:34 =# @pysym(:Py_CompileString), PyPtr, (Cstring, Cstring, Cint), s,
fname, input_type))))) <class 'SyntaxError'>
SyntaxError("'return' outside function", ('C:\\Users\\vemanaeva\\.julia\\packages\\P
yCall\\ilqDX\\src\\pyeval.jl', 10, 1, '            return PyDict{String,PyObject,tru
e}(pyincref(@pycheckn ccall((@pysym :PyModule_GetDict), PyPtr, (PyPtr,), pyimport("_
_main__"))))\n', 10, 11))


Stacktrace:
 [1] pyerr_check
   @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:75 [inlined]
 [2] pyerr_check
   @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:79 [inlined]
 [3] _handle_error(msg::String)
   @ PyCall C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:96
 [4] macro expansion
   @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\exception.jl:110 [inlined]
 [5] pyeval_(s::String, globals::PyDict{String, PyObject, true}, locals::PyDict{Stri
ng, PyObject, true}, input_type::Int64, fname::String)
   @ PyCall C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\pyeval.jl:34
 [6] top-level scope
   @ C:\Users\vemanaeva\.julia\packages\PyCall\ilqDX\src\pyeval.jl:230
```

In [46]:
```
using BenchmarkTools
@btime a,b = find_best_fit_python(xvals,yvals)
@btime a,b = find_best_fit(xvals,yvals)
```

```
UndefVarError: `find_best_fit_python` not defined

Stacktrace:
  [1] var"##core#304"()
    @ Main C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\execution.jl:
489
  [2] var"##sample#305"(::Tuple{}, __params::BenchmarkTools.Parameters)
    @ Main C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\execution.jl:
495
  [3] _run(b::BenchmarkTools.Benchmark, p::BenchmarkTools.Parameters; verbose::Bool,
pad::String, kwargs::Base.Pairs{Symbol, Integer, NTuple{4, Symbol}, NamedTuple{(:sam
ples, :evals, :gctrial, :gcsample), Tuple{Int64, Int64, Bool, Bool}}})
    @ BenchmarkTools C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\exe
cution.jl:99
  [4] #invokelatest#2
    @ .\essentials.jl:821 [inlined]
  [5] invokelatest
    @ .\essentials.jl:816 [inlined]
  [6] #run_result#45
    @ C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\execution.jl:34 [i
nlined]
  [7] run_result
    @ C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\execution.jl:34 [i
nlined]
  [8] run(b::BenchmarkTools.Benchmark, p::BenchmarkTools.Parameters; progressid::Not
hing, nleaves::Float64, ndone::Float64, kwargs::Base.Pairs{Symbol, Integer, NTuple
{5, Symbol}, NamedTuple{(:verbose, :samples, :evals, :gctrial, :gcsample), Tuple{Boo
l, Int64, Int64, Bool, Bool}}})
    @ BenchmarkTools C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\exe
cution.jl:117
  [9] run (repeats 2 times)
    @ C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\execution.jl:117
[inlined]
 [10] #warmup#54
    @ C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\execution.jl:169
[inlined]
 [11] warmup(item::BenchmarkTools.Benchmark)
    @ BenchmarkTools C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\exe
cution.jl:168
 [12] top-level scope
    @ C:\Users\vemanaeva\.julia\packages\BenchmarkTools\0owsb\src\execution.jl:575
```

Самостоятельная работа

Кластеризация

Используйте Clustering.jl для кластеризации на основе k-средних. Сделайте точечную диаграмму полученных кластеров. Подсказка: вам нужно будет проиндексировать фрейм данных, преобразовать его в массив и транспонировать.

In [47]:
```
using GLM
```

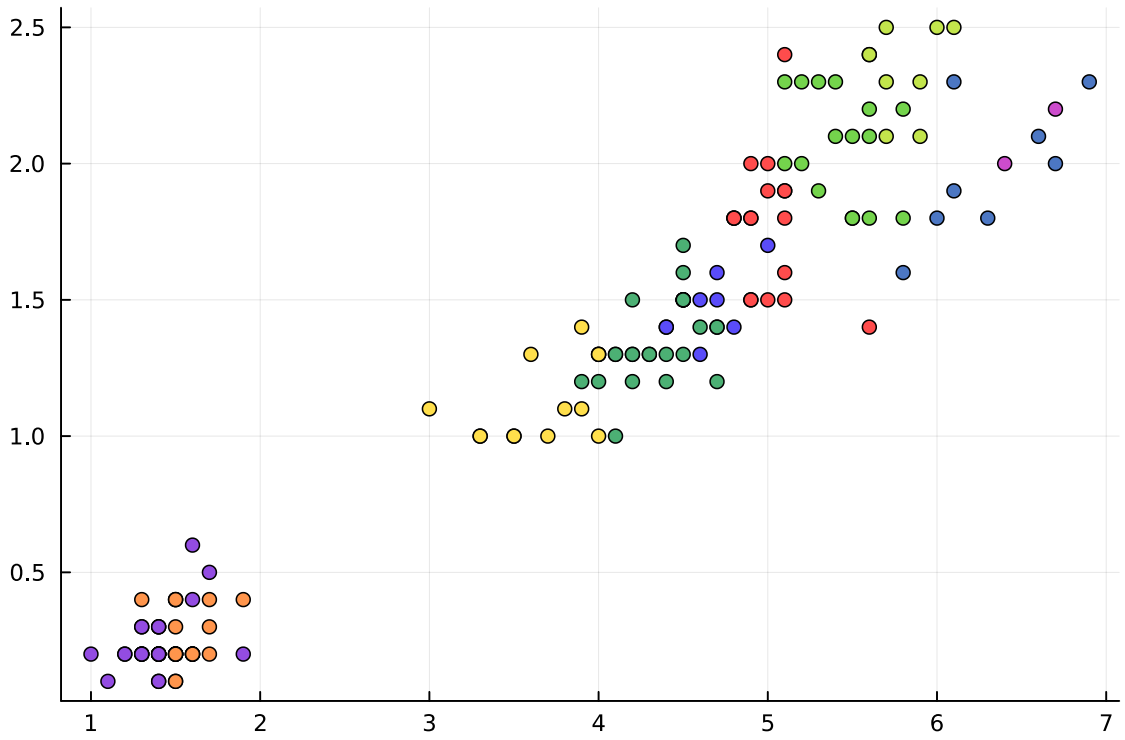
In [48]:
```
iris = dataset("datasets", "iris")
select!(iris, Not(:Species))
X = Matrix(iris)
X = X'

result = kmeans(X, 10, maxiter=10, display=:iter)
display(result)

scatter(iris.PetalLength, iris.PetalWidth, marker_z=result.assignments, color=:ligh
```

```
 Iters               objv        objv-change | affected
------------------------------------------------------------
      0       5.666000e+01
      1       3.367176e+01      -2.298824e+01 |        9
      2       3.065446e+01      -3.017298e+00 |        6
      3       2.882822e+01      -1.826248e+00 |        5
      4       2.814717e+01      -6.810483e-01 |        5
      5       2.795575e+01      -1.914226e-01 |        3
      6       2.785331e+01      -1.024312e-01 |        2
      7       2.783033e+01      -2.298006e-02 |        0
      8       2.783033e+01       0.000000e+00 |        0
K-means converged with 8 iterations (objv = 27.830334723886182)
KmeansResult{Matrix{Float64}, Float64, Int64}([7.800000000000001 4.818181818181818 …
5.370588235294117 6.0058823529411764; 3.8 3.236363636363636 … 3.8 2.735294117647059
3; 6.550000000000001 1.4333333333333331 … 1.5176470588235293 5.011764705882351; 2.1
0.23030303030303034 … 0.2764705882352942 1.788235294117647], [2, 2, 2, 2, 2, 9, 2,
2, 2, 2  …  7, 6, 10, 7, 7, 6, 10, 6, 6, 10], [0.15095500459136701, 0.06459136822772
393, 0.03398530762167695, 0.07156106519741456, 0.1673186409549885, 0.059377162629758
12, 0.08034894398529957, 0.0651974288337982, 0.2900459136822633, 0.04671258034895231
5  …  0.08703124999999545, 0.3177508650519485, 0.0639100346020598, 0.009531250000009
095, 0.05453124999996817, 0.1389273356401759, 0.15449826989620874, 0.065397923875423
2, 0.300692041522467, 0.08920415224912404], [2, 33, 12, 8, 23, 17, 8, 13, 17, 17],
[2, 33, 12, 8, 23, 17, 8, 13, 17, 17], 27.830334723886182, 8, true)
```

Out[48]:



Регрессия (метод наименьших квадратов в случае линейной регрессии)

Часть 1.

Для самостоятельного решения необходимо добавить колонку единиц и решить СЛАУ, где матрица X с добавленной колонкой единиц является матрицей коэффициентов, а вектор y --- вектором ответов. Колонка единиц добавляется для того, чтобы решение ограничивалось исключительно линейными случаями (так как производная линейной функции равна 1).

In [49]:
```
X = randn(1000, 3)
a0 = rand(3)
y = X * a0 + 0.1 * randn(1000)
```

Out[49]:
```
1000-element Vector{Float64}:
 -0.7945765229015872
 -0.6720296638517435
  1.3716244627873222
  2.1785938205075484
 -0.3260138255273183
  0.26170158513295094
  0.9557760816312258
 -2.304971670565372
 -0.6942984013717575
 -0.9267042171300182
 -1.2557384299492562
 -1.6445050915198212
  1.5532534557172666
  ⋮
 -1.6250530641171432
  0.6461356986934509
 -0.6007257958443772
 -0.010337923351421996
  1.328135396010722
 -1.983401200698946
 -0.14795949976913234
 -1.3949207950494904
  1.3520963911727373
 -1.8038372400597185
  0.6129175787211228
 -0.16580110961773115
```

In [50]:
```
N = 1000
X2 = hcat(ones(N), X)
```

Out[50]:
```
1000×4 Matrix{Float64}:
 1.0  -1.11694     0.644413   -0.217648
 1.0   0.0169132  -3.37187    -0.46774
 1.0  -0.377588   -0.516486    2.02971
 1.0   1.76627    -0.0865646   1.21452
 1.0  -0.160411    1.0795     -0.616407
 1.0  -0.239455   -1.6024      0.592198
 1.0  -0.294295   -0.119782    1.64942
 1.0   0.174658   -1.81967    -2.58481
 1.0   0.586109   -0.217839   -1.3919
 1.0  -0.227832   -1.57785    -0.780279
 1.0  -0.779791    0.705667   -0.947964
 1.0  -1.06939    -2.02278    -0.96679
 1.0   1.9599      0.108364    0.154524
 ⋮
 1.0  -1.87459    -0.0208567  -0.152682
 1.0  -0.343614   -0.24057     1.08071
 1.0   0.468206    1.78004    -1.55159
 1.0  -0.524671    2.51546     0.178462
 1.0   2.25013    -0.118962   -0.477887
 1.0  -1.27969    -2.2827     -1.07568
 1.0  -1.29073     0.22623     1.09623
 1.0  -1.96463    -0.676192    0.228304
 1.0   0.794014   -0.378956    0.901407
 1.0  -2.10044     0.719611   -0.520299
 1.0   1.91276    -2.24416    -0.702585
 1.0   0.591597   -0.296568   -0.848651
```

In [51]:
```
betahat1 = X2 \ y
yp = X2 * betahat1
mse1 = sqrt(sum(abs2.(y - yp)) / N)
display(betahat1)
mse1
```

```
4-element Vector{Float64}:
 0.003675260146041499
 0.7485522672623919
 0.09827734019830424
 0.808080938633673
```

Out[51]:
```
0.09996843006061548
```

In [52]:
```
betahat2 = llsq(X, y; bias=false)
yp = X * betahat2
mse2 = sqrt(sum(abs2.(y - yp)) / N)
display(betahat2)
mse2
```

```
3-element Vector{Float64}:
 0.7485913584036923
 0.0981758667102467
 0.8079549588733729
```

Out[52]:
```
0.10003581652171566
```

In [53]:
```
X3 = DataFrame(a=y, b=X[:,1], c=X[:,2], d=X[:,3])
lmMSE = lm(@formula(a ~ b + c + d), X3)
```

```
betahat3 = GLM.coeftable(lmMSE).cols[1]
yp = X2 * betahat3
mse3 = sqrt(sum(abs2.(y - yp)) / N)
display(betahat3)
mse3
```

```
4-element Vector{Float64}:
 0.0036752601460415322
 0.7485522672623924
 0.09827734019830442
 0.8080809386336726
```

Out[53]: 0.09996843006061547

Часть 2.

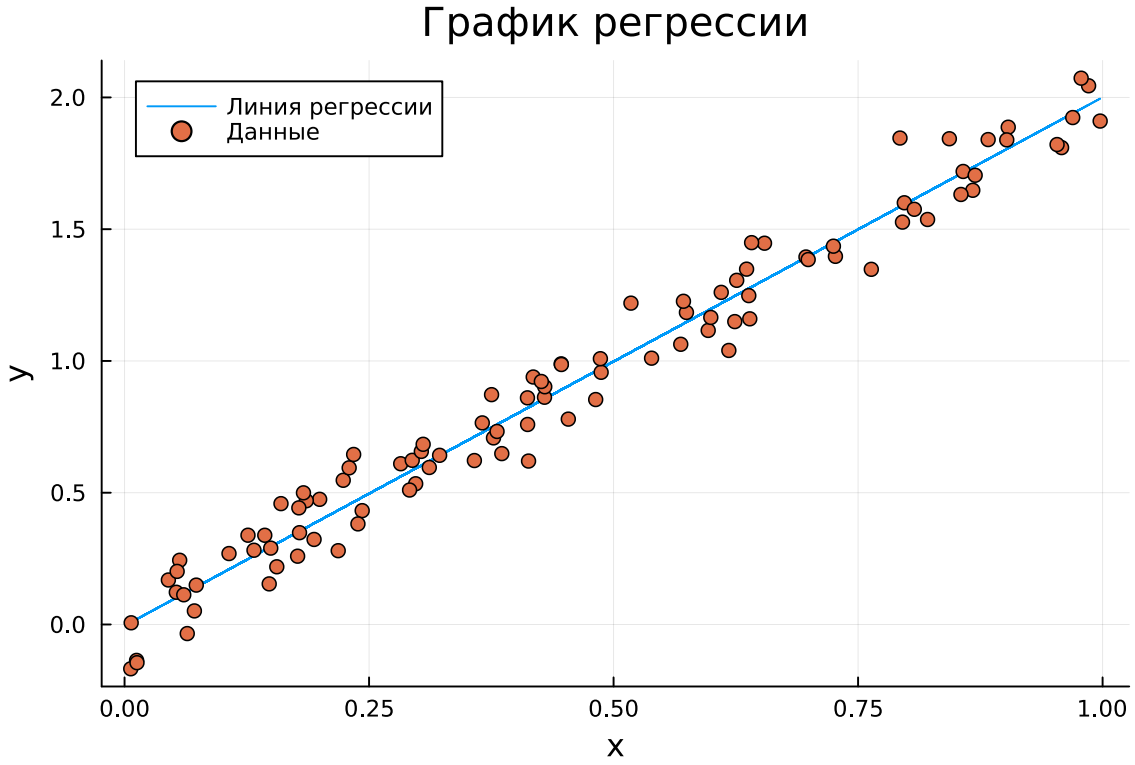
In [54]:
```
X = rand(100)
y = 2X + 0.1 * randn(100)
Xh = hcat(ones(100), X)
lm2 = fit(LinearModel, Xh, y)
display(lm2)

Plots.plot(title="График регрессии", xlabel="x", ylabel="y", legend=:topleft)
Plots.plot!(X, predict(lm2), label="Линия регрессии")
Plots.scatter!(X, y, label="Данные")
```

```
LinearModel{GLM.LmResp{Vector{Float64}}, GLM.DensePredChol{Float64, LinearAlgebra.Ch
oleskyPivoted{Float64, Matrix{Float64}, Vector{Int64}}}}:

Coefficients:
──────────────────────────────────────────────────────────────────────────────
          Coef.  Std. Error      t  Pr(>|t|)   Lower 95%  Upper 95%
──────────────────────────────────────────────────────────────────────────────
x1  -0.00481807   0.0181552  -0.27    0.7913  -0.0408465  0.0312103
x2   2.00541      0.0341101  58.79    <1e-77   1.93772    2.0731
──────────────────────────────────────────────────────────────────────────────
```

Out[54]:



Модель ценообразования биномиальных опционов

Пункты a и d.

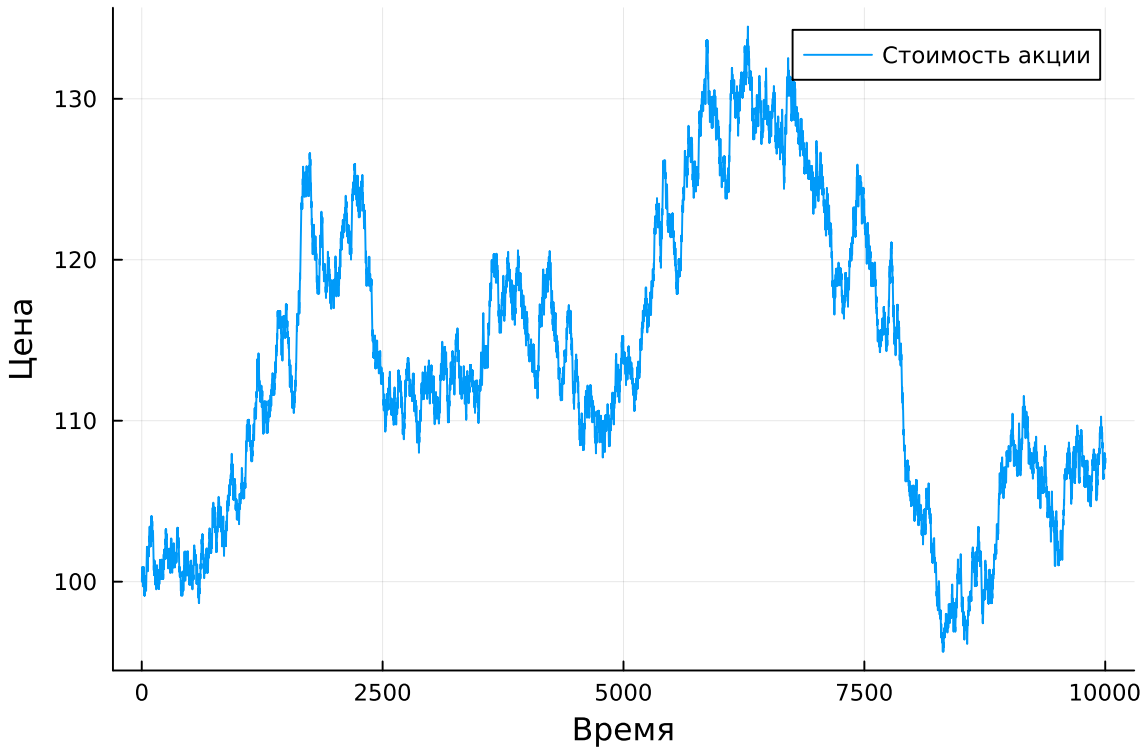
In [55]:

```
function binomial_stock_price(S, T, n, sigma, r)
    h = T/n
    u = exp(r * h + sigma * sqrt(h))
    d = exp(r * h - sigma * sqrt(h))
    p = (exp(r * h) - d) / (u - d)
    stock_prices = zeros(n+1)
    stock_prices[1] = S
    for i in 2:n+1
        epsilon = rand()
        if epsilon > 0.5
            stock_prices[i] = stock_prices[i-1]*u
        else
            stock_prices[i] = stock_prices[i-1]*d
        end
    end
    return stock_prices
end

S, T, n, sigma, r = 100.0, 1.0, 10000, 0.3, 0.08
stock_prices = binomial_stock_price(S, T, n, sigma, r)

plot(stock_prices, xlabel="Время", ylabel="Цена", label="Стоимость акции")
```

Out[55]:



In [56]:

```julia
function createPath(S::Float64, r::Float64, sigma::Float64, T::Float64, n::Int64)
    dt = T / n
    path = [S]

    for i in 1:n
        epsilon = randn()
        S = S * exp((r - 0.5 * sigma^2) * dt + sigma * sqrt(dt) * epsilon)
        push!(path, S)
    end
    return path
end

paths = [createPath(S, r, sigma, T, n) for i in 1:10]
plot(paths, title="Траектории", xlabel="Время", ylabel="Цена", legend=false)
```

Out[56]:

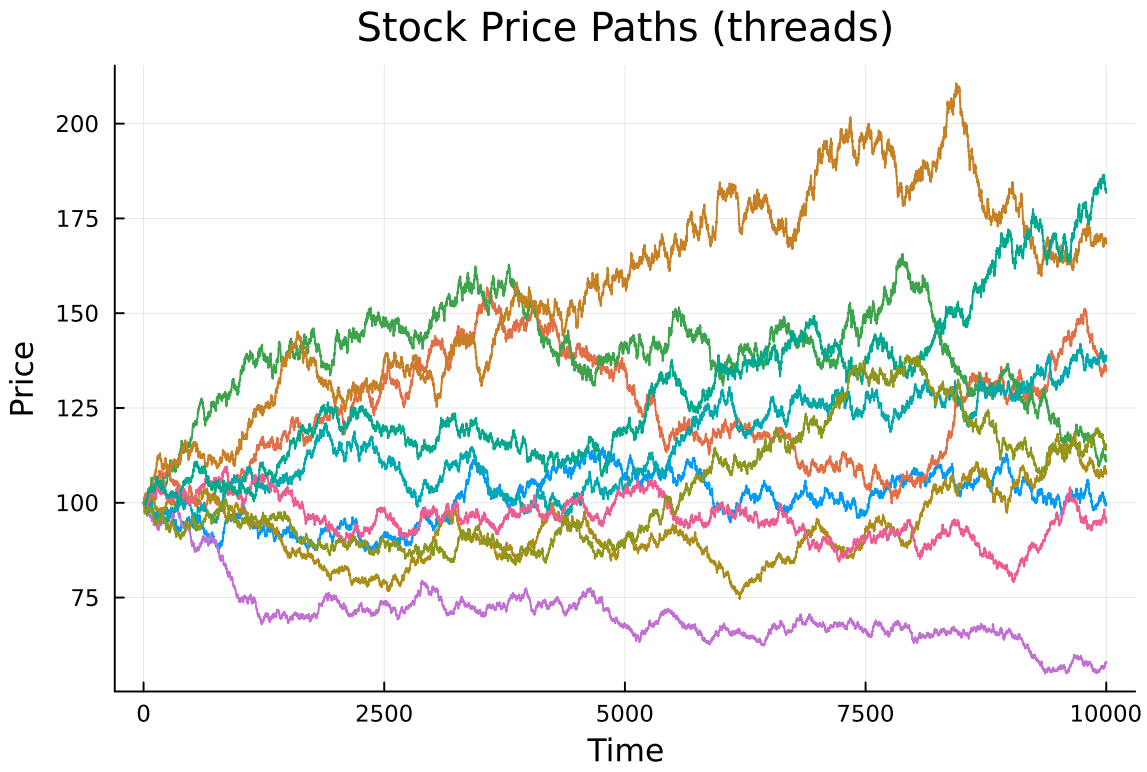
In [57]:

```
using Random
using Base.Threads

paths2 = []
@threads for i = 1:10
    push!(paths2, createPath(S, r, sigma, T, n))
end

plot(paths2, title="Stock Price Paths (threads)", xlabel="Time", ylabel="Price", le
```

Out[57]:


Stock Price Paths (threads)
Price
200
175
150
125
100
75
0
2500
5000
7500
10000
Time

In [ ]: