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Кафедра вычислительной математики и программирования

Курсовой проект по курсу «Дискретный анализ»

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Курсовой проект

Задача: Реализуйте систему, которая на основе базы вопросов и тегов к ним, буде предлагать варианты тегов, которые подходят к новым вопросам.

Формат ввода
Формат запуска программы в режиме обучения:
./prog learn –input <input file> –output <stats file>

Ключ	Значение
$--input$	входной файл с вопросами
$--output$	выходной файл с рассчитанной статистикой

Формат запуска программы в режиме классификации:
./prog classify −−stats <stats file> −−input <input file> −−output <output file>

Ключ	Значение
$--stats$	файл со статистикой полученной на предыдущем этапе
$--input$	входной файл с вопросами
$--output$	выходной файл с тегами к вопросам

Формат входных файлов при обучении:
<Количество строк в вопросе [n]>
<Тег 1>,<Тег 2>,...,<Тег m>
<Заголовок вопроса>
<Текст вопроса [n строк]>
Формат входных файлов при запросах:
<Количество строк в вопросе [n]>
<Заголовок вопроса>
<Текст вопроса [n строк]>
Формат выходного файла: для каждого запроса в отдельной строке выводится предполагаемый набор тегов, через запятую.

Формат вывода
Для каждого запроса в отдельной строке выводится предполагаемый набор тегов, через запятую.

1 Описание

Подсчет вероятности подхода тегов к вопросам осуществляется с помощью наивного Байесовского алгоритма.
Наивный байесовский алгоритм – это алгоритм классификации, основанный на теореме Байеса с допущением о независимости признаков. Другими словами, НБА предполагает, что наличие какого-либо признака в классе не связано с наличием какого-либо другого признака. Например, фрукт может считаться яблоком, если он красный, круглый и его диаметр составляет порядка 8 сантиметров. Даже если эти признаки зависят друг от друга или от других признаков, в любом случае они вносят независимый вклад в вероятность того, что этот фрукт является яблоком. В связи с таким допущением алгоритм называется «наивным».
Модели на основе НБА достаточно просты и крайне полезны при работе с очень большими наборами данных. При своей простоте НБА способен превзойти даже некоторые сложные алгоритмы классификации.

$P(A|B) = \frac{P(B|A)*P(A)}{P(B)}$ **- формула Байеса**

Теорема Байеса (или формула Байеса) ¯ одна из основных теорем элементарной теории вероятностей, которая позволяет определить вероятность события при условии, что произошло другое статистически взаимозависимое с ним событие. Другими словами, по формуле Байеса можно уточнить вероятность какого-либо события, взяв в расчёт как ранее известную информацию, так и данные новых наблюдений. Формула Байеса может быть выведена из основных аксиом теории вероятностей, в частности из условной вероятности. Особенность теоремы Байеса заключается в том, что для её практического применения требуется большое количество расчётов, вычислений, поэтому байесовские оценки стали активно использовать только после революции в компьютерных и сетевых технологиях. На сегодняшний день активно применяется в машинном обучении и технологиях искусственного интеллекта.

Стоит отметить одну из основных отрицательных сторон алгоритма. Если в тестовом наборе данных присутствует некоторое значение категорийного признака, которое не встречалось в обучающем наборе данных, то модель присвоит нулевую вероятность этому значению и не сможет сделать прогноз. Это явление известно под названием «нулевая частота» (zero frequency). Данную проблему можно решить с помощью сглаживания. Одним из самых простых методов является сглаживание по Лапласу (Laplace smoothing).

2 Исходный код

Файл main.cpp:

```
#include <cstring>
#include <fstream>
#include <unordered_set>
#include <cmath>
#include "Bayes.h"
using namespace std;

file makeVector(std::string &text) { //
    std::vector<std::string> words;
    std::string readingWord;

  for (int i = 0; i < text.size(); i++) {
    char c = tolower(text[i]);
    if (c >= 'a' && c <= 'z') {
      readingWord += c;
    } else if (readingWord.length() > 0) {
      words.push_back(readingWord);
      readingWord = "";
    }
    if (i + 1 == text.size() && readingWord.length() > 0) {
      words.push_back(readingWord);
    }
  }
  return words;
}

std::unordered_map<std::string,long double> softmax(std::unordered_map<std::string,
    long double>& probs);

void printError() {
    std::cerr << "Invalid syntax\n"
             "./prog learn --input <input file> --output <stats file>\n"
             "./prog classify --stats <stats file> --input <input file> --output <
                output file>\n";
}

void printEmptyError() {
    std::cerr << "Invalid syntax:\n"
              "<input file> (or <output file>) field is empty\n";
}

bool checkParamLearn(int argc, char* argv[]) {
    if (argc == 6 && !strcmp(argv[2], "--input") && !strcmp(argv[4], "--output") &&
        strcmp(argv[3], argv[5])) {
        return true;
    } else {
```

```
44          printError();
45          return false;
46      }
47  }
48
49  bool checkParamClassify(int argc, char* argv[]) {
50      if (argc == 8 && !strcmp(argv[2], "--stats") && !strcmp(argv[4], "--input") && !
            strcmp(argv[6], "--output") && strcmp(argv[3], argv[5]) && strcmp(argv[5], argv
            [7]) && strcmp(argv[3], argv[7])) {
51          return true;
52      } else {
53          printError();
54          return false;
55      }
56  }
57
58  void readText(std::ifstream& inStream, ::string& text, int lines) {
59      for (int i = 0; i < lines + 1; ++i) {
60          std::string cur_line;
61          getline(inStream, cur_line);
62          text += " " + cur_line;
63      }
64  }
65
66  void readFileToDataset(std::ifstream& inStream, std::vector<data>& dataset) {
67      int lines;
68      while (inStream >> lines) {
69          std::string types;
70          std::string text;
71          inStream.ignore();
72          getline(inStream, types);
73          readText(inStream, text, lines);
74          dataset.push_back({makeVector(types), makeVector(text)});
75      }
76  }
77
78  void writeToOutStream(std::ofstream& outStream, std::unordered_map<std::string, long
        double> preds, double threshold) {
79      bool comma = false;
80      for (const auto& pred : preds) {
81          if (pred.second > threshold) {
82              if (comma) {
83                  outStream << ", ";
84              }
85              outStream << pred.first;
86              comma = true;
87          }
88      }
89      outStream << "\n";
```

```
90  }
91
92  bool wrongArgsCount(int argc) {
93      return argc < 6;
94  }
95
96
97  std::unordered_map<std::string,long double> softmax(std::unordered_map<std::string,
        long double>& probs) {
98      long double max = -1e10;
99      for (const auto& prob : probs) {
100         if (prob.second > max) {
101             max = prob.second;
102         }
103     }
104
105     long double sum = 0;
106     for (auto& prob : probs) {
107         sum += exp(prob.second - max);
108     }
109
110     long double constant = max + log(sum);
111     std::unordered_map<std::string, long double> res;
112     for (auto prob : probs) {
113         res[prob.first] = exp(prob.second - constant);
114     }
115     return res;
116 }
117
118 void makePredictAndWriteOutput(std::ifstream& inStream, std::ofstream& outStream,
        BayesClassifier& BC) {
119     int lines;
120     while (inStream >> lines) {
121         std::string text;
122         inStream.ignore();
123         readText(inStream, text, lines);
124         file doc = makeVector(text);
125
126         std::unordered_map<std::string, long double> probas = BC.predict(doc);
127         std::unordered_map<std::string,long double> preds = softmax(probas);
128
129         double threshold = 1. / BC.getTagsCount();
130         writeToOutStream(outStream, preds, threshold);
131     }
132 }
133
134 int main(int argc, char* argv[]) {
135     std::string inFile;
136     std::string statsFile;
```

```
137     std::string outFile;
138     if (wrongArgsCount(argc)) {
139         printError();
140         return 1;
141     }
142 
143     if (!strcmp(argv[1], "learn")) {
144         if (!checkParamLearn(argc, argv)) {
145             return 1;
146         }
147         inFile = argv[3];
148         statsFile = argv[5];
149 
150         std::ifstream inStream(inFile);
151         std::ofstream statsStream(statsFile);
152         std::vector<data> dataset;
153         readFileToDataset(inStream, dataset);
154         BayesClassifier BC;
155         BC.initMaps(dataset);
156         BC.saveStats(statsStream);
157 
158     } else if (argc >= 6 && !strcmp(argv[1], "classify")) {
159         if (!checkParamClassify(argc, argv)) {
160             return 1;
161         }
162         statsFile = argv[3];
163         inFile = argv[5];
164         outFile = argv[7];
165 
166         std::ifstream inStream(inFile);
167         std::ifstream statsStream(statsFile);
168         std::ofstream outStream(outFile);
169 
170         BayesClassifier BC;
171         BC.loadStats(statsStream);
172         makePredictAndWriteOutput(inStream, outStream, BC);
173     } else {
174         printError();
175         return 1;
176     }
177 }
```

Файл Bayes.h:

```
1  #pragma once
2  #include <iostream>
3  #include <vector>
4  #include <unordered_map>
5 
6  using file = std::vector<std::string>;
```

```
7
8  struct data {
9      file tag;
10     file doc;
11 };
12
13 class BayesClassifier {
14 public:
15     void initMaps(std::vector<data>& dataset) {
16         for (const auto& data : dataset) {
17             file fileTypes = data.tag;
18             file doc = data.doc;
19             for (auto& type : fileTypes) {
20                 for (auto& word : doc) {
21                     wordsInType[type][word]++;
22             wordsCount[word]++;
23             fileTypesCount[type]++;
24                 }
25             }
26             totalCount += doc.size();
27         }
28     }
29
30     std::unordered_map<std::string, long double> predict(file &doc) {
31         std::unordered_map<std::string, long double> probabilities;
32         for (auto& data : wordsInType) {
33             std::string curType = data.first;
34             probabilities[curType] = probability(curType, doc);
35         }
36         return probabilities;
37     }
38
39     void saveStats(std::ofstream &out) {
40         out << totalCount << "\n";
41         for (auto& dataType : wordsInType) {
42             std::string tag = dataType.first;
43             auto data = dataType.second;
44             out << tag << " " << data.size() << " ";
45             for (auto& wordsCount : data) {
46                 out << wordsCount.first << " " << wordsCount.second << " ";
47             }
48             out << "\n";
49         }
50     }
51
52     void loadStats(std::ifstream &in) {
53         in >> totalCount;
54         std::string tag;
55         while (in >> tag) {
```

```
56              int amountOfWords;
57              in >> amountOfWords;
58              for (int i = 0; i < amountOfWords; ++i) {
59                  std::string word;
60                  int count;
61                  in >> word >> count;
62          wordsInType[tag][word] = count;
63          wordsCount[word] += count;
64            fileTypesCount[tag] += count;
65              }
66          }
67      }
68
69      int getTagsCount() {
70          return fileTypesCount.size();
71      }
72
73  private:
74      long double alpha = 1;
75      std::unordered_map<std::string, int> fileTypesCount; //-
76      std::unordered_map<std::string, std::unordered_map<std::string, int>> wordsInType;
            //     <, <, ->>
77      std::unordered_map<std::string, int> wordsCount; //  <, ->
78      int totalCount = 0; //
79
80      long double probability(std::string& fileType, file& doc) { // P(type | doc) ,
            doc   fileType
81          long double prob = 0;
82          for (auto word : doc) {
83              prob += log(probability(word, fileType));
84          }
85          prob += log(probability(fileType));
86          return prob;
87      }
88
89      long double probability(std::string &tag) { // P(type)
90          return (long double) (fileTypesCount[tag] + alpha) / (totalCount + alpha *
                totalCount);
91      }
92
93      long double probability(std::string& word, std::string& fileType) { // P(word |
            type)
94          return (long double) (wordsInType[fileType][word] + alpha) / (wordsCount[word]
                + alpha * wordsInType.size());
95      }
96  };
```

3 Консоль и тестовые файлы

Файл study: (содержит набор данных для обучения)

```
1
Fish
Common info
Fish are creatures that live in water and cannot survive on land. Pet fish live in small aquariums. Usually domestic fish are small
1
Cats, fish
Dangerous
Is it dangerous to leave a cat at home alone with fish? an a cat get into an aquarium and eat all the pet fish?
1
Fish
kinds
Are pet fish as cockerel, guppy, scalar, catfish the most popular?
1
Fish
Care
To keep the fish, you need to have an aquarium with a filter that will supply oxygen to the fish. And also periodically feed them and wash the walls of the vessel.
1
Dogs
Buying a dog
Where can I buy a dog? Most of all I would like a little puppy who could make friends with my pet cat
1
Dogs
Puppies
How many puppies are there in his house?
1
Dogs
Cute animals
What are the most beautiful breeds of dogs?
2
Dogs
Lost my dog
Ive lost my dog.
How can I find it now?
1
Cats
A name for a cat
What are the best names for cats?
1
Cats
Mother cat with her kittens
My cat has many kittens. How should I take care of them?
1
```

```
Cats
Different cats
How many different kinds of cats exist?
1
Cats
Black cat
Is it true that a black cat causes problems?
1
Cats, dogs
Friendship between cats and dogs
Can cats and dogs live together?
2
Cats
Benefit
Did you know that cats can improve your health? Cats help calm down and cope with stress.
In a house where cats live, people quarrel and get annoyed less.
1
Cats
Ancient animal
Cats are very ancient animals. They existed on earth almost fifty million years ago
2
Cats
Age
If the age of a cat is translated to a person, fifteen years for a cat is about seventy human years.
A threeyear-old cat is quite an adult animal, like people in their twenties.
1
Cats
big dormice
Cats spend two thirds of the day sleeping. The rest of the time is devoted to self-care.
1
Dogs
Friendly tail
The tail of the helicopter, which the dog wags from side to side, is a sign of friendliness.
1
Dogs
Lifespan
Dogs live an average of 10 to 14 years.
1
Dogs
understanding
When we pet a dog and look into its eyes, the feel-good hormone is released in both humans and dogs.
1
Dogs
unique nose
```

```
Just as with human fingerprints, no dog nose prints are the same.
1
Dogs
color discrimination
Dogs are not colorblind, but their eyes dont have red receptors. They see shades of black and white, as well as blue and yellow.
1
Dogs
Taste
Dogs have about 1,700 taste buds compared to 9,000 in humans.
1
Dogs
loneliness
Dogs are herd animals, they dont like being alone.
13
Dogs
Text about dog
There are moments in our lives when all the people close to us turn away from us. Or when you come home and theres no one there. The best solution to this problem is a dog.
No one can say how easy it will be for you with this decision, but here you have to think it over.
Its hard with a dog, especially the first days. A dog is the same child that is sick or sad, sometimes you really want to play.
It seems that you took it in vain, did something stupid and hurried. But hurry up if you immediately give it away or throw it away. The love of a dog also needs to be earned.
As soon as you come home, you mentally ask the question, what did he do. If the dog wags its tail and its happy eyes are the first thing you see, then everything that the dog did is no longer important.
A wet nose, a long tongue that tries to kiss you, thats what matters.
With each success of your dog, you become happier. Here the dog understood the command to sit, lie down, brought a toy, does not pull the leash, asks to go to the toilet, and you are happier than he is.
The dog is protection and support. As soon as you see how your dog does not let someone near you or barks if something is wrong, then you have nothing to fear.
Even the smallest puppy will not leave its owner in trouble.
You need to communicate with the dog, you need to love it and endure its antics many times.
But when you suddenly get sick, and your dog does not leave you a single step, then you will understand what it was all for, and that it was all worth it.
Dogs often rescue drowning people, find children, and help in rescue operations. The dog will undoubtedly be your family member and friend.
And how do dogs sit for many days near the place where they were thrown out? They can neither eat nor drink nor move. They are the most loyal and devoted creatures.
14
Cats
domestic cat cat cat
```

119 These cute animals belong to the genus of mammals, the cat family, which has existed on earth for 10 thousand years. Man domesticated the cat over 6,000 years ago.
120 Everyone knows the domestic cat, but there are also wild cats in nature.
121 The life span of a domestic cat is generally 12-14 years. On average, the animal weighs about four kilograms. These gentle, fluffy pets are very capricious.
122 Cats purr loudly in a calm, peaceful state, hiss and growl when they are angry.
123 If the pet is laid on its back, then it feels protected. And if he starts to twitch or wag his tail, then he is angry. If a cat looks into your eyes and meows plaintively, she is begging for something.
124 Sensing danger, the animal arches its back in order to appear larger and frighten the enemy
125 This cute pet is very independent and independent. The cat walks where she wants, but in the end she always returns to people.
126 There are more than forty types of cats, each breed has its own peculiarity. Some representatives have too short legs and no tail. Most domestic cats are a mixture of several breeds.
127 A cats eyesight is six times sharper than a humans. Her eyes glow in the dark. These fluffy pets capture scents that humans cannot smell. They recognize other felines by smell.
128 They constantly mark their territory to scare off strangers. Cats have excellent hearing. They are very picky eaters. They love to jump and climb. Good hunters.
129 Animals are very clean. They like to wash themselves with their paws, licking them. Cats sleep for most of their lives.
130 These pets have fur that keeps them warm in cold weather. In summer, the wool partially falls out.
131 Cats are very prolific animals. They often have kittens. At what several at once, about three five kittens at a time. One cat can have kittens of different colors.
132 Cats are very intelligent creatures, without which it is difficult for a person to imagine his life.
133 10
134 Fish
135 Aquarium fish
136 Aquarium fish are diverse in body shape and color. There are those that can easily fit in a teaspoon, some the size of a childs palm.
137 Nature endowed them with different colors - red, yellow, blue, green, blue, white, black, some completely multi-colored: striped, spotted, with neon color.
138 The same goes for their body shape. Some fish are flat like a leaf, others with round, thick barrels. Some inhabitants of the aquarium have a lush, large caudal fin or a narrow and long one.
139 Mostly common aquarium fish feed on food of animal origin, although some species eat plants and cannot develop normally without them. However, they also eat animal food from time to time.
140 The most common food for aquarium fish is dry food, which we buy at a regular pet store.
141 However, those who wish to diversify the diet of the inhabitants of aquariums should pay attention to small crustaceans - daphnia, cyclops.
142 They can also be caught in ponds, or you can buy them in specialized stores. If possible, diversify the food base of your pets. For small aquarium fish, bloodworms, enchitrei, coretra are suitable.

```
They can be easily bred at home.
All aquarium fish have well developed sense organs. Most of the tactile cells are located in the upper layer of the body.
In sturgeon, carp and catfish, they are concentrated in additional organs, such as antennae.
7
Fish
My little fish
Aquarium fish live in my house: goldfish, neons, swordtails, several snails and a small catfish. My parents gave me an aquarium with fish for my birthday.
In the pet store, we buy fish not only special dry food, but also live food - these are tiny crustaceans and worms. I feed them a little three times a day.
The fish live in a large rectangular aquarium. At the bottom of the aquarium is a special soil. And at the bottom there are multi-colored glass pebbles and beautiful shells.
The fish have a large underwater castle and various labyrinths. Real live algae grow in the aquarium, which create the appearance that the fish are in the ocean. By the way, fish also eat live algae, it is good for their health.
For a comfortable life of the fish, the parents bought a special lighting for the aquarium. And an air filter is attached to the back wall of the aquarium.
It simultaneously enriches the water with oxygen and filters it so that it is clean and free of debris. The filter needs to be washed periodically.
About once every few weeks, my dad and I clean the aquarium. This is necessary so that the water does not turn green and is not cloudy.
```

Файл test: (тестовые запросы)

```
1
Feeding
How to feed my little friends who lives with me?
1
Many animals
Can two black cats live together in peace with a small dog?
1
Keeping
How should I care to keep pet fish? do I need a aquarium?
1
aquarium
Who is small lives in an aquarium and swims in the water?
1
friend
Who is man best fluffy friend?
1
relation
Who needs to be treated with kindness and care?
1
valerian
who is fluffy and loves valerian?
1
who is it
```

```
a small animal, furry and with four legs?
1
who is it
very small animal with fins, cant walk, lives in water?
1
qqq
asdq?
1
together
What animals can live in an apartment?
1
food
what should you feed your pets?
1
health
Do cats help with various diseases?
1
saving
can dogs save people from dangerous situations?
1
like
what animals do you like the most of all?
1
present
what kind of fish did they give you yesterday and do you have an aquarium with a lump
    for them?
1
help
my master does not feed me, what should I do?
1
thinks
I am thinking of getting a cat, but I already have a dog, is it dangerous?
1
eating
Do dogs eat house fish?
1
legal
Is it legal to have 100 cats at home?
1
allergic
I am allergic to wool, can I get a pet?
1
Money
What is the cheapest pet to keep?
1
charity
today I have a salary, and I will donate a share of it to a cat and dog shelter!1
1
choose
```

```
my daughter asks for a hamster, but I think that a dog or a cat is better, what should
     I do?
1
strange behavior
the cat constantly jumps into the aquarium and swims there, what should I do?
1
mess
when I come home, all things are scattered around the apartment. Was it the fish or
    the sleeping cat?
1
no limit
my dog drinks all the water in a second and eats all the food off the table, how to
    limit it?
1
no  wool
I want an animal without wool, who should I take?
1
crossing
If you cross a dog and an aquarium, you get a fish with paws?
1
bites
do dogs and cats bite their owners, how to protect themselves?
1
health of animals
What are the diseases of pets and how dangerous is this disease for people?
1
age
how to calculate the age of my fish in human years?
1
fear
how to overcome fear of dogs on the street?
1
emotions
Do animals have emotions, can they smile or cry?
```

console input:

```
./prog learn --input dataset/study --output dataset/stats
./prog classify --stats dataset/stats --input dataset/test --output dataset/testOUT
```

Файл testOUT:

```
fish, dogs
dogs, cats
fish
fish
dogs, cats
fish, dogs
cats
fish
```

```
fish
fish, dogs
cats
fish, dogs
cats
dogs
dogs
fish
dogs
dogs
fish
cats
dogs
dogs
dogs
dogs
fish, cats
dogs
dogs
cats
fish, dogs
dogs, cats
cats
cats
dogs
dogs
```

В текущих данных на обучение дано 1586 слов, среди которых 265 относятся к тегу "cats 254 к тегу "dogs 245 - "fish".
Тестовых запросов подано 34. На каждый из запросов программа предложила набор подходящих к нему тегов. Путем анализа запросов и предполагаемых тегов подсчитано: среди предложенных программой тегов 18 из них точно соответствуют действительности, 10 частично удовлетворяют запросу и 5 не удовлетворяют совсем. Таким образом, округляя, можно сказать, что половина тегов предсказана верно, а остальная половина либо удовлетворяет запросу частично, либо не удовлетворяет совсем.

4 Оценка сложности

Произведем некоторую оценку подсчета вероятности для тегов тестовых наборов.
Пусть tests – количество данных тестовых наборов;
types – общее число тегов;
words – число слов в конкретном тестовом наборе.
Тогда сложностная оценка подсчета вероятностей тегов для всех тестовых наборов - O(tests*types*words).

5 Выводы

Подводя итог по выполненному курсовому проекту, наивный Байесовский классификатор является одним из самых популярных и простых алгоритмов в машинном обучении. Он имеет ряд своих плюсов и минусов.
Положительные стороны:

- Классификация, в том числе многоклассовая, выполняется легко и быстро.
- Когда допущение о независимости выполняется, НБА превосходит другие алгоритмы, такие как логистическая регрессия (logistic regression), и при этом требует меньший объем обучающих данных.
- НБА лучше работает с категорийными признаками, чем с непрерывными. Для непрерывных признаков предполагается нормальное распределение, что является достаточно сильным допущением.

Отрицательные стороны:

- Если в тестовом наборе данных присутствует некоторое значение категорийного признака, которое не встречалось в обучающем наборе данных, тогда модель присвоит нулевую вероятность этому значению и не сможет сделать прогноз. Это явление известно под названием «нулевая частота» (zero frequency). Данную проблему можно решить с помощью сглаживания. Одним из самых простых методов является сглаживание по Лапласу (Laplace smoothing).
- Хотя НБА является хорошим классификатором, значения спрогнозированных вероятностей не всегда являются достаточно точными. Поэтому не следует слишком полагаться на результаты, возвращенные методом $predict\_proba$.
- Еще одним ограничением НБА является допущение о независимости признаков. В реальности наборы полностью независимых признаков встречаются крайне редко.

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