



Міністерство освіти і науки України

Національний технічний університет України

«Київський політехнічний інститут імені Ігоря Сікорського»

Фізико-технічний інститут

## **ЛАБОРАТОРНА РОБОТА №1**

**з дисципліни**

**«Криптографія»**

**на тему: «Експериментальна оцінка ентропії на символ джерела відкритого  
тексту»**

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## Мета роботи :

Засвоєння понять ентропії на символ джерела та його надлишковості, вивчення та порівняння різних моделей джерела відкритого тексту для наближеного визначення ентропії, набуття практичних навичок щодо оцінки ентропії на символ джерела.

## Порядок виконання роботи

0. Уважно прочитати методичні вказівки до виконання комп'ютерного практикуму.
1. Написати програми для підрахунку частот букв і частот біграм в тексті, а також підрахунку  $H_1$  та  $H_2$  за безпосереднім означенням. Підрахувати частоти букв та біграм, а також значення  $H_1$  та  $H_2$  на довільно обраному тексті російською мовою достатньої довжини (щонайменше 1Мб), де імовірності замінити відповідними частотами. Також одержати значення  $H_1$  та  $H_2$  на тому ж тексті, в якому вилучено всі пробіли.
2. За допомогою програми CoolPinkProgram оцінити значення  $H^{10}$ ,  $H^{20}$ ,  $H^{30}$ .
3. Використовуючи отримані значення ентропії, оцінити надлишковість російської мови в різних моделях джерела.

## Результати:

Монограми з пробілами: 4.334820041850319 //  $R=0.1330359916299362$

Монограми без пробілів: 4.486335038535828 //  $R=0.1027329922928344$

### Крок (1)

Біграми з пробілами: 3.991066700884154 //  $R=0.2017866598231692$

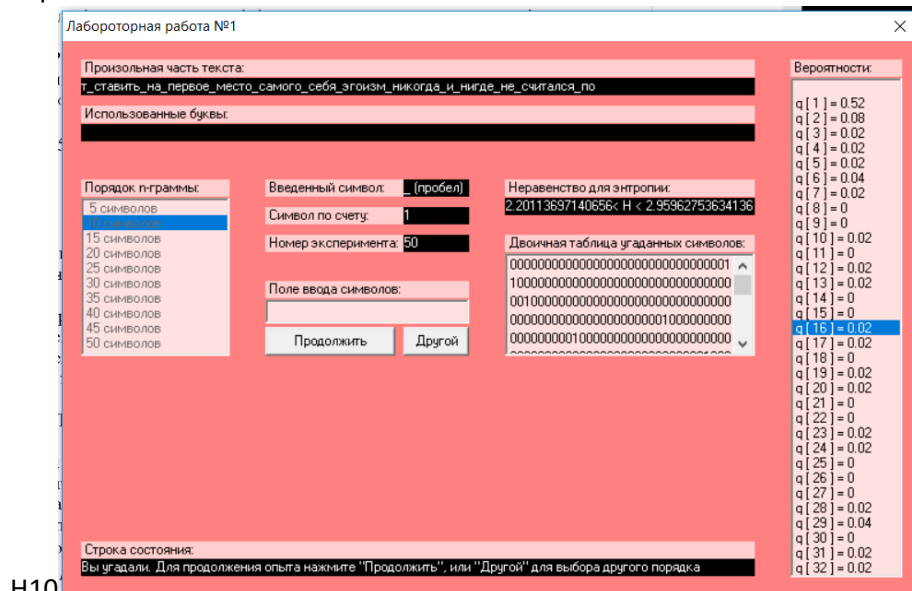
Біграми без пробілів: 4.135250911878292 //  $R=0.1729498176243416$

### Крок(2)

Біграми з пробілами: 3.991658986375305 //  $R=0.201668202724939$

Біграми без пробілів: 4.135306517921239 //  $R=0.1729386964157522$

Скріншоти CPP:



$H_{10}$

$RH_{10min}=0.5597726057$

$RH_{10max}=0.4080744928$

Лабораторная работа №1

Произвольная часть текста:  
 ьно\_в\_заслуг\_себе\_итак\_я\_кощ\_обратить\_ваше\_внимание\_на\_два\_пункта\_первое\_

Использованные буквы:  
 н, о, л, т,

Порядок n-граммы:  
 5 символов  
 10 символов  
 15 символов  
 20 символов  
 25 символов  
 30 символов  
 35 символов  
 40 символов  
 45 символов  
 50 символов

Введенный символ: и

Символ по счету: 5

Номер эксперимента: 50

Неравенство для энтропии:  
 $1.6817459863676 < H < 2.45112946255746$

Двоичная таблица угаданных символов:

00000100000000000000000000000000
10000000000000000000000000000000
10000000000000000000000000000000
10000000000000000000000000000000
10000000000000000000000000000000
10000000000000000000000000000000

Поле ввода символов:  
 и

Продолжить Другой

Вероятности:

q(1) = 0.58
q(2) = 0.08
q(3) = 0.06
q(4) = 0
q(5) = 0.04
q(6) = 0.04
q(7) = 0.02
q(8) = 0
q(9) = 0.02
q(10) = 0
q(11) = 0.04
q(12) = 0
q(13) = 0.02
q(14) = 0
q(15) = 0
<b>q(16) = 0</b>
q(17) = 0.02
q(18) = 0
q(19) = 0
q(20) = 0
q(21) = 0.02
q(22) = 0.02
q(23) = 0
q(24) = 0.02
q(25) = 0
q(26) = 0
q(27) = 0
q(28) = 0.02
q(29) = 0
q(30) = 0
q(31) = 0
q(32) = 0

Строка состояния:  
 Вы угадали. Для продолжения опыта нажмите "Продолжить", или "Другой" для выбора другого порядка

H20

RH20min=0.6636508028

RH20max=0.5097741075

Лабораторная работа №1

Произвольная часть текста:  
 с\_этим\_стандартом\_поведения\_а\_если\_все\_таки\_идет\_то\_для\_этого\_имеются\_особы

Использованные буквы:  
 а, н, п, в, д, т, с, м, ц, э, х, б, л, ф, й, я, ч, ы, у, к, е, и, р, г, о, ь, ш, ж, э, ю,

Порядок n-граммы:  
 5 символов  
 10 символов  
 15 символов  
 20 символов  
 25 символов  
 30 символов  
 35 символов  
 40 символов  
 45 символов  
 50 символов

Введенный символ: \_ (пробел)

Символ по счету: 32

Номер эксперимента: 50

Неравенство для энтропии:  
 $1.84525534162799 < H < 2.57382862903118$

Двоичная таблица угаданных символов:

10000000000000000000000000000000
00000000000000000000000000000000
10000000000000000000000000000000
00000000000000000000000000000000
00001000000000000000000000000000
00001000000000000000000000000000

Поле ввода символов:

Продолжить Другой

Вероятности:

q(1) = 0.54
q(2) = 0.04
q(3) = 0.06
q(4) = 0.04
q(5) = 0.1
q(6) = 0.06
q(7) = 0.02
q(8) = 0
q(9) = 0
q(10) = 0.02
q(11) = 0.02
q(12) = 0
q(13) = 0
q(14) = 0
q(15) = 0
<b>q(16) = 0</b>
q(17) = 0
q(18) = 0
q(19) = 0.02
q(20) = 0
q(21) = 0.02
q(22) = 0
q(23) = 0
q(24) = 0.02
q(25) = 0
q(26) = 0
q(27) = 0
q(28) = 0.02
q(29) = 0
q(30) = 0
q(31) = 0
q(32) = 0.02

Строка состояния:  
 Вы угадали. Для продолжения опыта нажмите "Продолжить", или "Другой" для выбора другого порядка

H30

RH30min=0.6309489317

RH30max=0.4852342742

## Таблиці:

### Монограма з

### пробілами:

а: 0.06758546315827196  
 б: 0.01306772297427375  
 в: 0.03437277846625936  
 г: 0.01587795013430252  
 д: 0.02455115121805679  
 е: 0.06601200263687981  
 ё: 0.0003625293044521099  
 ж: 0.009552438822138123  
 з: 0.01510122068200513  
 и: 0.054171045492844  
 й: 0.01017248894285621

к: 0.02845229989424145  
 л: 0.04458527064271028  
 м: 0.02397777153653254  
 н: 0.05268675884634008  
 о: 0.09362090102283267  
 п: 0.02110003891981269  
 р: 0.03681130891413723  
 с: 0.04172837304348768  
 т: 0.04857059278958382  
 у: 0.0242369591541983  
 ф: 0.001790144703363522  
 х: 0.006755546073307592  
 ц: 0.003214426499475374  
 ч: 0.01146509342838546  
 ш: 0.007299756730335702  
 щ: 0.002366857987687338

ы: 0.01552042123404975  
 ь: 0.01600296023928601  
 э: 0.002733554295638897  
 ю: 0.005037073830134603  
 я: 0.01712055057783838  
 пробіл: 0.01712055057783838

### Монограма без

### пробілів:

а: 0.08283512341612147  
 б: 0.01601626140826656  
 в: 0.04212848759710114  
 г: 0.01946057476723817  
 д: 0.03009075540982937  
 е: 0.08090663479757509  
 ё: 0.0004443286806502521

ж: 0.01170780537382342  
з: 0.01850858780087946  
и: 0.06639394078681927  
й: 0.01246776063452179  
к: 0.03487214059172323  
л: 0.05464527760328088  
м: 0.02938800108273196  
н: 0.06457474680926042  
о: 0.1147450728035097

п: 0.02586095065908754  
р: 0.04511723637775088  
с: 0.05114376331070832  
т: 0.05952982875470503  
у: 0.02970567055326582  
ф: 0.002194064381693658  
х: 0.0082798351387378  
ц: 0.003939714301765568  
ч: 0.01405202220621958

ш: 0.008946838882334615  
щ: 0.002900904489762565  
ы: 0.01902237475804516  
ь: 0.01961379155366929  
э: 0.003350340396627188  
ю: 0.006173615047931318  
я: 0.02098354962436351

Программи:

```
std::cout << 1 - (4.334820041850319 / 5);  
std::cout << 1 - (4.486335038535828 / 5);  
std::cout << 1 - (3.991066700884154 / 5);  
std::cout << 1 - (4.135250911878292 / 5);  
std::cout << 1 - (3.991658986375305 / 5);  
std::cout << 1 - (4.135306517921239 / 5);
```

Header.h

```
#include <iostream>  
#include <unordered_set>  
#include <array>  
  
struct Bigram  
{  
    wchar_t x;  
    wchar_t y;  
};  
  
class Bigram_info  
{  
public:  
    double H2 = 0;  
    Bigram_info(const std::wstring& input, bool readFromFile = false);  
  
    double getCount(Bigram bigram);  
  
    double getFrequency(Bigram bigram);  
  
    void printDetailedInfo();  
private:  
    class Bigram_stat  
    {  
    public:  
        Bigram self = { '\\0', '\\0' };  
        mutable double frequency = 0;  
        mutable unsigned int count = 0;  
  
        bool operator==(const Bigram_stat& other) const;  
    };  
  
    struct KeyHasher  
    {  
        std::size_t operator()(const Bigram_stat& k) const;  
    };  
  
    void calculateFrequency();  
  
    std::wstring readData(const std::wstring& path);  
  
    std::unordered_set<Bigram_stat, KeyHasher> data;  
    static constexpr int rus_lang_symbols_size = 33;  
};  
Source.cpp  
#include "Header.h"
```

```

#include <iostream>
#include <map>
#include <array>
#include<stdio.h>
#include<windows.h>
#include <string>

int main()
{
    SetConsoleOutputCP(1251);
    SetConsoleCP(1251);
    ::setlocale(LC_ALL, "russian_russia.866");
    std::wstring str = L"E:/text.txt";

    Bigram_info info(str, true);

    std::wcout << str.c_str() << std::endl;

    info.printDetailedInfo();
    std::cin.get();
}
CP-1_1.cpp
#include "Header.h"
#include <iomanip>
#include <string>
#include <vector>
#include <algorithm>
#include <fstream>
#include <sstream>
#include <codecvt>

Bigram_info::Bigram_info(const std::wstring& input, bool readFromFile)
{
    // read from file if user want it, otherwise we interpret this line as input
    const std::wstring& str = !readFromFile ? input : readData(input);

    data.reserve(pow(rus_lang_symbols_size, 2));

    for (int i = 0; i < str.length() - 1; i++)
    {
        Bigram entry{ '\\0', '\\0' };

        // filling our pair of symbols
        int j = i;
        for (; entry.y == '\\0' && i < str.length(); i++)
            if (str[i] >= L'a' && str[i] <= L'я')
                if (entry.x == '\\0')
                    entry.x = str[i];
                else entry.y = str[i];
            else if (str[i] >= L'A' && str[i] <= L'Я')
                // set number to lower case
                if (entry.x == '\\0')
                    entry.x = str[i] - (L'A' - L'a');
                else entry.y = str[i] - (L'Я' - L'я');
            else
                break;

        // reset i to prev value
        i = j+1; //or j for 1 step

        // if pair of symbols invalid
        if (entry.y == '\\0')
            continue;

        auto entity = data.find(Bigram_stat({ entry }));

        if (entity == data.end())
            data.insert({ { entry} , 0., 1 }); // create new item
        else
            entity->count++; // update existing one
    }

    // calculation is possible only after filling all pairs

```

```

        calculateFrequency();
    }

std::wstring Bigram_info::readData(const std::wstring & path)
{
    std::wifstream wif(path);
    wif.imbue(std::locale(std::locale::empty(), new std::codecvt_utf8<wchar_t>));
    std::wstringstream wss;
    wss << wif.rdbuf();
    return wss.str();
}

void Bigram_info::calculateFrequency()
{
    std::size_t overall_count = 0;

    for (auto& entity : data)
        overall_count += entity.count;

    for (auto& entity : data)
        entity.frequency = static_cast<double>(entity.count) / overall_count;

    for (auto& entity : data)
        H2 = H2 - log(entity.frequency) * entity.frequency / log(2);
}

double Bigram_info::getCount(Bigram bigram)
{
    auto entity = data.find({ bigram });

    return (entity == data.end()) ? 0 : entity->count;
}

double Bigram_info::getFrequency(Bigram bigram)
{
    auto entity = data.find({ bigram });

    return (entity == data.end()) ? 0 : entity->frequency;
}

void Bigram_info::printDetailedInfo()
{
    // this vector will be created only once per program run!!!
    static std::vector<Bigram_stat> sorted_array;

    // create vector so we can sort or elements by frequency
    // after second function call this block shall not executed
    if (sorted_array.size() == 0)
    {
        for (auto& el : data)
            sorted_array.push_back(el);

        std::sort(sorted_array.begin(), sorted_array.end(),
            [](const Bigram_stat & a, const Bigram_stat & b) -> bool
            {
                return a.frequency > b.frequency;
            });
    }

    for (auto& entity : sorted_array)
    {
        std::wcout << "'" << entity.self.x << entity.self.y << "\" ";
        std::wcout << "f: " << entity.frequency * 100 << "% ";
        std::wcout << "c : " << entity.count << std::endl;
    }

    std::cout << std::setprecision(16);
    std::cout << H2/2 << std::endl;
}

bool Bigram_info::Bigram_stat::operator==(const Bigram_stat & other) const
{
    return self.x == other.self.x

```

```

        && self.y == other.self.y;
    }

std::size_t Bigram_info::KeyHasher::operator()(const Bigram_stat & k) const
{
    return k.self.x* k.self.y* k.self.y << k.self.x;
}

```

## Висновок:

Даний комп'ютерний практикум нас навчив визначати ентропію на символ джерела та його надлишковості. Порівняли різні моделі джерел відкритого тексту для наближеного визначення ентропії та набули практичних навичок оцінки ентропії на символ джерела.

### Біграма з пробілами

"го" f: 1.98133% c: 8033	"ви" f: 0.46592% c: 1889	"ый" f: 0.214338% c: 869	"пи" f: 0.128011% c: 519
"на" f: 1.52651% c: 6189	"сь" f: 0.446928% c: 1812	"эн" f: 0.213352% c: 865	"ен" f: 0.127271% c: 516
"ст" f: 1.50061% c: 6084	"ми" f: 0.442489% c: 1794	"кн" f: 0.211625% c: 858	"ек" f: 0.127024% c: 515
"по" f: 1.3726% c: 5565	"ма" f: 0.434103% c: 1760	"жа" f: 0.209159% c: 848	"жо" f: 0.126284% c: 512
"ал" f: 1.36224% c: 5523	"ей" f: 0.430896% c: 1747	"оч" f: 0.207679% c: 842	"пл" f: 0.126038% c: 511
"не" f: 1.2959% c: 5254	"ну" f: 0.430896% c: 1747	"чи" f: 0.205952% c: 835	"ых" f: 0.123571% c: 501
"но" f: 1.27222% c: 5158	"ме" f: 0.429416% c: 1741	"ус" f: 0.197566% c: 801	"аб" f: 0.121598% c: 493
"ко" f: 1.19477% c: 4844	"ны" f: 0.429416% c: 1741	"ят" f: 0.196579% c: 797	"ап" f: 0.120858% c: 490
"ро" f: 1.17183% c: 4751	"че" f: 0.42399% c: 1719	"ев" f: 0.195346% c: 792	"ай" f: 0.120611% c: 489
"ра" f: 1.11436% c: 4518	"ис" f: 0.423497% c: 1717	"св" f: 0.1951% c: 791	"лю" f: 0.120365% c: 488
"ов" f: 1.06331% c: 4311	"ру" f: 0.419797% c: 1702	"лү" f: 0.194606% c: 789	"сц" f: 0.119872% c: 486
"ка" f: 1.04629% c: 4242	"се" f: 0.409931% c: 1662	"са" f: 0.190907% c: 774	"үч" f: 0.119872% c: 486
"ни" f: 1.02779% c: 4167	"тр" f: 0.398585% c: 1616	"ым" f: 0.187453% c: 760	"ар" f: 0.119872% c: 486
"ро" f: 1.0231% c: 4148	"ар" f: 0.398339% c: 1615	"ия" f: 0.186467% c: 756	"вш" f: 0.119872% c: 486
"он" f: 1.00584% c: 4078	"ки" f: 0.393652% c: 1596	"үж" f: 0.185727% c: 753	"нд" f: 0.118638% c: 481
"ли" f: 0.995723% c: 4037	"им" f: 0.381073% c: 1545	"ра" f: 0.18252% c: 740	"ха" f: 0.117158% c: 475
"от" f: 0.985364% c: 3995	"сл" f: 0.376633% c: 1527	"аж" f: 0.182274% c: 739	"аю" f: 0.116418% c: 472
"ер" f: 0.958972% c: 3888	"вы" f: 0.375647% c: 1523	"ее" f: 0.180547% c: 732	"аш" f: 0.115925% c: 470
"ол" f: 0.948613% c: 3846	"нн" f: 0.3754% c: 1522	"он" f: 0.179314% c: 727	"еш" f: 0.114939% c: 466
"ос" f: 0.924441% c: 3748	"ам" f: 0.371207% c: 1505	"гр" f: 0.179067% c: 726	"ех" f: 0.112719% c: 457
"ен" f: 0.922962% c: 3742	"вс" f: 0.367261% c: 1489	"мн" f: 0.176354% c: 715	"вл" f: 0.112225% c: 455
"ор" f: 0.914575% c: 3708	"ди" f: 0.364548% c: 1478	"вн" f: 0.175861% c: 713	"гү" f: 0.108279% c: 439
"ла" f: 0.899777% c: 3648	"ня" f: 0.353942% c: 1435	"ий" f: 0.174628% c: 708	"үв" f: 0.107539% c: 436
"ло" f: 0.888431% c: 3602	"ед" f: 0.344816% c: 1398	"ще" f: 0.170681% c: 692	"ги" f: 0.107539% c: 436
"пр" f: 0.878318% c: 3561	"бо" f: 0.340623% c: 1381	"жи" f: 0.169941% c: 689	"пу" f: 0.105566% c: 428
"во" f: 0.876345% c: 3553	"со" f: 0.339636% c: 1377	"ьн" f: 0.168955% c: 685	"ир" f: 0.104579% c: 424
"ре" f: 0.871165% c: 3532	"эт" f: 0.338896% c: 1374	"иц" f: 0.166242% c: 674	"ев" f: 0.104333% c: 423
"ел" f: 0.836881% c: 3393	"не" f: 0.333716% c: 1353	"ьк" f: 0.166242% c: 674	"сц" f: 0.103593% c: 420
"за" f: 0.813943% c: 3300	"ив" f: 0.324097% c: 1314	"бр" f: 0.166242% c: 674	"сс" f: 0.103593% c: 420
"та" f: 0.813696% c: 3299	"хо" f: 0.32385% c: 1313	"еб" f: 0.164762% c: 668	"ои" f: 0.103099% c: 418
"ил" f: 0.807283% c: 3273	"ая" f: 0.319411% c: 1295	"рд" f: 0.163282% c: 662	"ав" f: 0.102359% c: 415
"ва" f: 0.80235% c: 3253	"ше" f: 0.313245% c: 1270	"үм" f: 0.163035% c: 661	"оя" f: 0.101619% c: 412
"ом" f: 0.781878% c: 3170	"ча" f: 0.306585% c: 1243	"ош" f: 0.162789% c: 660	"ца" f: 0.10088% c: 409
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## Біграма без пробілів крок 1

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## Біграма з пробілами крок 1

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