



Федеральное государственное автономное образовательное учреждение высшего образования «Национальный Исследовательский Университет ИТМО»

**ЛАБОРАТОРНАЯ РАБОТА №2**  
**ПРЕДМЕТ «МАТЕМАТИЧЕСКАЯ СТАТИСТИКА»**  
**ТЕМА «ДОВЕРИТЕЛЬНЫЕ ИНТЕРВАЛЫ»**

Вариант 1, 1

Преподаватель: Лимар И. А.  
Студент: Румянцев А. А.  
Поток: Мат Стат 31.2

Факультет: СУиР  
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# 1 Задание 1

## 1.1 Условие

Предъявите доверительный интервал уровня  $1 - \alpha$  для указанного параметра при данных предположениях (с математическими обоснованиями). Сгенерируйте 2 выборки объёма 25 и посчитайте доверительный интервал. Повторить 1000 раз. Посчитайте, сколько раз 95-процентный доверительный интервал покрывает реальное значение параметра. То же самое сделайте для объёма выборки 10000. Как изменился результат? Как объяснить? Что изменяется при росте объёмов выборок?

Даны две независимые выборки  $X_1, X_2$  из нормальных распределений  $\mathcal{N}(\mu_1, \sigma_1^2)$ ,  $\mathcal{N}(\mu_2, \sigma_2^2)$  объёмов  $n_1, n_2$  соответственно. Сначала указывается оцениваемая функция, потом данные об остальных параметрах, затем параметры эксперимента и подсказки.

$\tau = \mu_1 - \mu_2$ ;  $\sigma_1^2, \sigma_2^2$  известны;  $\mu_1 = 2, \mu_2 = 1, \sigma_1^2 = 1, \sigma_2^2 = 0.5$ ; воспользуйтесь функцией

$$\frac{\bar{X}_1 - \bar{X}_2 - \tau}{\sigma}, \quad \sigma^2 = \frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}$$

## 1.2 Выполнение

$$Z = \sqrt{n} \cdot \frac{\bar{X} - \mu}{\sigma} \sim \mathcal{N}(0, 1)$$

$$\gamma = 1 - \alpha$$

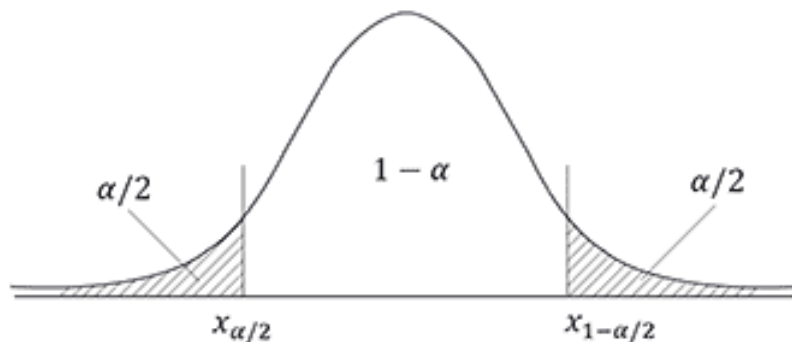


Рис. 1: Двусторонняя критическая область

$$r_1 = x_{\frac{\alpha}{2}}, \quad r_2 = x_{1-\frac{\alpha}{2}}$$

$$\mathbb{P}\left(r_1 \leq \sqrt{n} \cdot \frac{\bar{X} - \mu}{\sigma} \leq r_2\right) = \gamma = 1 - \alpha$$

$$r_1 = -r_2 = -x_{1-\frac{\alpha}{2}}$$

$$\left| \sqrt{n} \cdot \frac{\bar{X} - \mu}{\sigma} \right| \leq x_{1-\frac{\alpha}{2}}$$

$$\bar{X}_1 \sim \mathcal{N}\left(\mu_1, \frac{\sigma_1^2}{n_1}\right), \quad \bar{X}_2 \sim \mathcal{N}\left(\mu_2, \frac{\sigma_2^2}{n_2}\right)$$

$$\begin{aligned}
\overline{X_1} - \overline{X_2} &\sim \mathcal{N}\left(\mu_1 - \mu_2, \frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right) \equiv \overline{X_1} - \overline{X_2} \sim \mathcal{N}(\tau, \sigma^2) \\
\overline{X_1} - \overline{X_2} - \tau &\sim \mathcal{N}(0, \sigma^2) \\
\frac{\overline{X_1} - \overline{X_2} - \tau}{\sigma} &\sim \mathcal{N}(0, 1) \\
\sigma &= \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}} = \sqrt{\frac{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}{n_1 \cdot n_2}} = \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} \\
\frac{\overline{X_1} - \overline{X_2} - \tau}{\frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}}}} &= \sqrt{n_1 \cdot n_2} \cdot \frac{\overline{X_1} - \overline{X_2} - \tau}{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}} \\
\left| \sqrt{n_1 \cdot n_2} \cdot \frac{\overline{X_1} - \overline{X_2} - \tau}{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}} \right| &\leq x_{1-\frac{\alpha}{2}} \Rightarrow \left| \overline{X_1} - \overline{X_2} - \tau \right| \leq x_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} \\
-x_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} &\leq \overline{X_1} - \overline{X_2} - \tau \leq x_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} \\
-(\overline{X_1} - \overline{X_2}) - x_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} &\leq -\tau \leq -(\overline{X_1} - \overline{X_2}) + x_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} \\
(\overline{X_1} - \overline{X_2}) - x_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} &\leq \tau \leq (\overline{X_1} - \overline{X_2}) + x_{1-\frac{\alpha}{2}} \cdot \frac{\sqrt{n_2 \cdot \sigma_1^2 + n_1 \cdot \sigma_2^2}}{\sqrt{n_1 \cdot n_2}} \\
(\overline{X_1} - \overline{X_2}) - x_{1-\frac{\alpha}{2}} \cdot \sigma &\leq \tau \leq (\overline{X_1} - \overline{X_2}) + x_{1-\frac{\alpha}{2}} \cdot \sigma
\end{aligned}$$

```

mu_1, mu_2 = 2, 1
tau = mu_1 - mu_2
sigma2_1, sigma2_2 = 1, 0.5
n_1, n_2 = 25, 25
alpha = 0.05
n = 1

```

Листинг 1: Задаем данные по условию

```

count = 0
for i in range(n):
    X_1 = np.random.normal(mu_1, sigma2_1, n_1)
    X_2 = np.random.normal(mu_2, sigma2_2, n_2)

    X_1_mean = np.mean(X_1)
    X_2_mean = np.mean(X_2)

    sigma = np.sqrt(sigma2_1 / n_1 + sigma2_2 / n_2)

    z = st.norm.ppf(1 - alpha / 2)

    lower_bound = (X_1_mean - X_2_mean) - z * sigma
    upper_bound = (X_1_mean - X_2_mean) + z * sigma
    print(f'{lower_bound:.4f}<={tau}<={upper_bound:.4f}')

    if lower_bound <= tau <= upper_bound:
        count += 1

print(f'covers_tau_count={count}, ratio={count / n}')

```

Листинг 2: Код для подсчета доверительного интервала и кол-во попаданий

```
0.5934<=1<=1.5536
```

Листинг 3: Посчитанный доверительный интервал

```
covers_tau_count=975, ratio=0.975
```

Листинг 4: Покрывает 95-% для  $n = 1000$

```
covers_tau_count=9688, ratio=0.9688
```

Листинг 5: Покрывает 95-% для  $n = 10000$

Тут будет вывод (очевидно, что точность увеличивается)

## 2 Задание 2

### 2.1 Условие

Постройте асимптотический доверительный интервал уровня  $1 - \alpha$  для указанного параметра. Проведите эксперимент по схеме, аналогичной первой задаче.

Сначала указывается класс распределений (однопараметрический), затем параметры эксперимента и подсказки.

$\text{Exp}(\lambda)$ ; медиана;  $\lambda = 1$

### 2.2 Выполнение

тут будет выполнение

## 3 Приложение

```
0.5660<=1<=1.5261
0.2217<=1<=1.1819
0.7579<=1<=1.7180
0.4166<=1<=1.3768
0.4333<=1<=1.3935
0.4581<=1<=1.4183
0.4382<=1<=1.3984
0.4570<=1<=1.4172
0.8915<=1<=1.8517
0.2173<=1<=1.1774
1.0895<=1<=2.0496
0.2755<=1<=1.2357
0.6532<=1<=1.6134
0.7485<=1<=1.7087
0.8897<=1<=1.8499
0.7571<=1<=1.7173
0.4854<=1<=1.4456
0.6416<=1<=1.6018
0.8973<=1<=1.8574
0.7142<=1<=1.6744
0.7495<=1<=1.7097
0.5683<=1<=1.5285
```

0.5137<=1<=1.4739  
0.6053<=1<=1.5655  
0.3834<=1<=1.3436  
0.3189<=1<=1.2791  
0.5901<=1<=1.5503  
0.5340<=1<=1.4942  
0.3704<=1<=1.3306  
-0.1471<=1<=0.8131  
0.7327<=1<=1.6929  
0.9195<=1<=1.8797  
0.4716<=1<=1.4318  
0.3997<=1<=1.3599  
0.0478<=1<=1.0080  
0.6888<=1<=1.6490  
0.6068<=1<=1.5669  
0.7800<=1<=1.7402  
0.4915<=1<=1.4517  
0.3822<=1<=1.3424  
0.6097<=1<=1.5699  
0.4078<=1<=1.3680  
0.5701<=1<=1.5303  
0.1196<=1<=1.0798  
0.6584<=1<=1.6186  
0.7529<=1<=1.7131  
0.6581<=1<=1.6183  
1.1010<=1<=2.0612  
0.0696<=1<=1.0297  
0.4589<=1<=1.4191  
0.3129<=1<=1.2731  
0.0326<=1<=0.9928  
0.6259<=1<=1.5861  
0.7903<=1<=1.7505  
0.7759<=1<=1.7361  
0.6810<=1<=1.6412  
0.4191<=1<=1.3793  
0.4544<=1<=1.4146  
0.5814<=1<=1.5416  
0.3519<=1<=1.3120  
0.6045<=1<=1.5647  
0.4921<=1<=1.4523  
0.2109<=1<=1.1710  
0.2897<=1<=1.2499  
0.5243<=1<=1.4844  
0.5353<=1<=1.4955  
0.4075<=1<=1.3677  
0.7567<=1<=1.7169  
0.4611<=1<=1.4213  
1.0540<=1<=2.0142  
0.4628<=1<=1.4229  
1.0119<=1<=1.9721  
0.3980<=1<=1.3582  
0.8031<=1<=1.7632  
0.7407<=1<=1.7009  
0.3622<=1<=1.3224  
0.9330<=1<=1.8932  
0.6358<=1<=1.5960  
0.4934<=1<=1.4536  
0.9610<=1<=1.9212  
0.5299<=1<=1.4901  
0.6551<=1<=1.6153

0.6408<=1<=1.6009  
0.9610<=1<=1.9212  
0.2264<=1<=1.1866  
0.4388<=1<=1.3989  
0.4766<=1<=1.4368  
0.1496<=1<=1.1098  
0.2915<=1<=1.2517  
0.8817<=1<=1.8419  
0.5964<=1<=1.5566  
0.3932<=1<=1.3533  
0.6471<=1<=1.6073  
0.4933<=1<=1.4535  
0.3421<=1<=1.3023  
0.5397<=1<=1.4999  
0.4293<=1<=1.3895  
0.6418<=1<=1.6020  
0.7231<=1<=1.6833  
0.6510<=1<=1.6112  
0.3565<=1<=1.3167  
0.5999<=1<=1.5601  
0.4839<=1<=1.4440  
0.5042<=1<=1.4644  
0.5537<=1<=1.5139  
0.6879<=1<=1.6481  
0.3606<=1<=1.3208  
0.1537<=1<=1.1139  
0.8055<=1<=1.7657  
0.4716<=1<=1.4318  
0.3849<=1<=1.3451  
0.2225<=1<=1.1827  
0.4705<=1<=1.4307  
0.7445<=1<=1.7047  
0.9262<=1<=1.8864  
0.5634<=1<=1.5236  
0.6008<=1<=1.5610  
0.4903<=1<=1.4504  
1.0690<=1<=2.0292  
0.8462<=1<=1.8063  
0.3467<=1<=1.3068  
0.3839<=1<=1.3441  
0.6645<=1<=1.6246  
0.1154<=1<=1.0756  
0.4775<=1<=1.4377  
0.4131<=1<=1.3732  
0.5602<=1<=1.5203  
0.4841<=1<=1.4443  
0.3554<=1<=1.3156  
0.2731<=1<=1.2332  
1.0776<=1<=2.0377  
0.6653<=1<=1.6255  
0.3750<=1<=1.3352  
0.4088<=1<=1.3690  
0.3172<=1<=1.2774  
0.3135<=1<=1.2737  
0.4453<=1<=1.4055  
0.2893<=1<=1.2495  
0.5317<=1<=1.4919  
0.5164<=1<=1.4766  
0.5804<=1<=1.5405  
0.3787<=1<=1.3389

0.3822<=1<=1.3424  
0.4548<=1<=1.4149  
0.7114<=1<=1.6716  
0.8069<=1<=1.7671  
0.0690<=1<=1.0292  
0.4701<=1<=1.4303  
0.3730<=1<=1.3332  
0.8322<=1<=1.7924  
0.7292<=1<=1.6894  
0.7302<=1<=1.6904  
0.2718<=1<=1.2320  
0.4110<=1<=1.3712  
0.4384<=1<=1.3986  
0.5227<=1<=1.4829  
0.3060<=1<=1.2662  
0.3836<=1<=1.3438  
0.3470<=1<=1.3072  
0.8330<=1<=1.7931  
0.3136<=1<=1.2738  
0.3571<=1<=1.3173  
0.3824<=1<=1.3426  
0.8981<=1<=1.8583  
0.7005<=1<=1.6607  
0.8094<=1<=1.7696  
0.2930<=1<=1.2531  
0.5892<=1<=1.5493  
0.3003<=1<=1.2604  
0.4934<=1<=1.4536  
0.4230<=1<=1.3832  
0.3774<=1<=1.3376  
0.6335<=1<=1.5937  
0.4971<=1<=1.4573  
0.3573<=1<=1.3174  
0.0567<=1<=1.0169  
0.8045<=1<=1.7647  
0.7207<=1<=1.6809  
0.4812<=1<=1.4413  
0.3386<=1<=1.2988  
0.5217<=1<=1.4818  
0.4946<=1<=1.4547  
0.6071<=1<=1.5673  
0.1072<=1<=1.0674  
0.2178<=1<=1.1780  
0.4510<=1<=1.4112  
0.5163<=1<=1.4765  
0.4343<=1<=1.3944  
0.3659<=1<=1.3261  
0.5566<=1<=1.5167  
0.5669<=1<=1.5270  
0.8230<=1<=1.7832  
0.4487<=1<=1.4089  
0.6128<=1<=1.5729  
0.8433<=1<=1.8035  
0.5151<=1<=1.4753  
0.6049<=1<=1.5650  
0.3821<=1<=1.3423  
0.5801<=1<=1.5403  
0.5846<=1<=1.5448  
0.3884<=1<=1.3486  
0.5946<=1<=1.5547



0.6920<=1<=1.6522  
0.4488<=1<=1.4090  
0.5091<=1<=1.4693  
0.1438<=1<=1.1040  
0.1889<=1<=1.1491  
0.8817<=1<=1.8419  
0.6293<=1<=1.5894  
0.6841<=1<=1.6443  
0.4843<=1<=1.4445  
0.5754<=1<=1.5356  
0.5409<=1<=1.5011  
0.6846<=1<=1.6448  
0.6363<=1<=1.5965  
0.1330<=1<=1.0932  
0.5847<=1<=1.5449  
0.5836<=1<=1.5438  
0.5103<=1<=1.4705  
0.3148<=1<=1.2750  
0.7007<=1<=1.6608  
0.4393<=1<=1.3995  
0.6435<=1<=1.6037  
0.3329<=1<=1.2931  
0.6596<=1<=1.6198  
0.5247<=1<=1.4849  
0.4075<=1<=1.3677  
0.5482<=1<=1.5084  
0.5005<=1<=1.4607  
0.3750<=1<=1.3352  
0.5608<=1<=1.5210  
0.8818<=1<=1.8420  
0.6105<=1<=1.5707  
0.8676<=1<=1.8278  
0.5224<=1<=1.4825  
0.7073<=1<=1.6674  
0.0523<=1<=1.0125  
0.8623<=1<=1.8225  
0.4924<=1<=1.4526  
0.4797<=1<=1.4399  
0.8255<=1<=1.7857  
0.7485<=1<=1.7087  
0.2501<=1<=1.2103  
0.6026<=1<=1.5628  
0.7253<=1<=1.6855  
0.9945<=1<=1.9546  
0.1533<=1<=1.1135  
0.4561<=1<=1.4163  
0.4901<=1<=1.4503  
0.2281<=1<=1.1883  
0.6756<=1<=1.6358  
0.5633<=1<=1.5235  
0.3235<=1<=1.2837  
0.3387<=1<=1.2989  
0.5751<=1<=1.5353  
0.6685<=1<=1.6287  
0.6585<=1<=1.6186  
0.6182<=1<=1.5784  
0.3232<=1<=1.2834  
0.7793<=1<=1.7395  
0.7849<=1<=1.7450  
0.8116<=1<=1.7717

0.1519<=1<=1.1121  
0.0739<=1<=1.0341  
0.3483<=1<=1.3085  
0.6623<=1<=1.6225  
0.3002<=1<=1.2604  
0.5778<=1<=1.5380  
0.6507<=1<=1.6109  
0.3380<=1<=1.2982  
0.6734<=1<=1.6336  
0.4254<=1<=1.3856  
0.6011<=1<=1.5613  
0.4368<=1<=1.3970  
1.0127<=1<=1.9729  
0.2673<=1<=1.2275  
0.4291<=1<=1.3893  
0.3799<=1<=1.3401  
0.6911<=1<=1.6513  
0.4687<=1<=1.4289  
1.0150<=1<=1.9752  
-0.1880<=1<=0.7722  
0.6767<=1<=1.6368  
0.5097<=1<=1.4699  
0.5813<=1<=1.5415  
0.9280<=1<=1.8882  
0.7893<=1<=1.7495  
0.3828<=1<=1.3430  
0.4633<=1<=1.4234  
0.5610<=1<=1.5212  
0.8376<=1<=1.7978  
1.0800<=1<=2.0401  
0.6216<=1<=1.5817  
0.5491<=1<=1.5093  
0.3747<=1<=1.3348  
0.4413<=1<=1.4014  
0.7314<=1<=1.6916  
0.7797<=1<=1.7398  
0.3462<=1<=1.3064  
0.1881<=1<=1.1483  
0.7543<=1<=1.7145  
0.2360<=1<=1.1962  
0.4978<=1<=1.4580  
0.6979<=1<=1.6580  
0.2806<=1<=1.2408  
0.6098<=1<=1.5700  
0.7194<=1<=1.6796  
0.9029<=1<=1.8631  
0.4025<=1<=1.3627  
0.3061<=1<=1.2663  
0.3622<=1<=1.3224  
0.4020<=1<=1.3621  
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0.2473<=1<=1.2075  
0.6513<=1<=1.6115  
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0.8446<=1<=1.8048  
0.6430<=1<=1.6032  
0.2728<=1<=1.2330  
0.7141<=1<=1.6743  
0.7488<=1<=1.7090  
0.4256<=1<=1.3858

0.0902<=1<=1.0504  
0.4132<=1<=1.3734  
0.8987<=1<=1.8589  
0.6075<=1<=1.5677  
0.8162<=1<=1.7764  
0.2698<=1<=1.2300  
0.7166<=1<=1.6768  
0.4875<=1<=1.4477  
0.6077<=1<=1.5679  
0.6653<=1<=1.6255  
0.6038<=1<=1.5640  
0.3810<=1<=1.3411  
0.4598<=1<=1.4200  
0.5811<=1<=1.5413  
0.2746<=1<=1.2348  
0.4135<=1<=1.3737  
0.4840<=1<=1.4441  
0.6046<=1<=1.5648  
0.7877<=1<=1.7479  
0.6816<=1<=1.6418  
0.6864<=1<=1.6466  
0.1547<=1<=1.1149  
-0.0629<=1<=0.8973  
0.1835<=1<=1.1437  
0.4369<=1<=1.3971  
0.5950<=1<=1.5552  
0.6084<=1<=1.5686  
0.8966<=1<=1.8568  
0.5788<=1<=1.5389  
0.7700<=1<=1.7302  
0.3960<=1<=1.3562  
0.5705<=1<=1.5307  
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0.3697<=1<=1.3299  
0.3978<=1<=1.3580  
0.6938<=1<=1.6540  
0.4349<=1<=1.3951  
0.4698<=1<=1.4300  
0.2227<=1<=1.1829  
0.6557<=1<=1.6159  
0.2951<=1<=1.2553  
1.0619<=1<=2.0221  
0.5810<=1<=1.5412  
0.4212<=1<=1.3813  
0.3334<=1<=1.2936  
0.8427<=1<=1.8029  
0.3792<=1<=1.3394  
0.2708<=1<=1.2310  
0.4657<=1<=1.4258  
0.3143<=1<=1.2745  
0.6760<=1<=1.6362  
0.9150<=1<=1.8752  
0.4420<=1<=1.4022  
0.6157<=1<=1.5759  
0.8133<=1<=1.7735  
0.6609<=1<=1.6210  
0.7338<=1<=1.6940  
0.4442<=1<=1.4044  
0.8065<=1<=1.7667  
0.1361<=1<=1.0963  
0.8790<=1<=1.8392  
0.6004<=1<=1.5606  
0.7571<=1<=1.7173  
0.8663<=1<=1.8265  
0.7359<=1<=1.6961  
0.2941<=1<=1.2543  
0.4593<=1<=1.4195  
0.7927<=1<=1.7529  
0.6323<=1<=1.5925  
0.3847<=1<=1.3449  
0.6485<=1<=1.6087  
0.8780<=1<=1.8382  
0.5364<=1<=1.4966  
0.6540<=1<=1.6142  
0.7744<=1<=1.7345  
0.5922<=1<=1.5524  
1.0263<=1<=1.9865

```
0.3049<=1<=1.2651
0.5064<=1<=1.4666
0.2726<=1<=1.2328
0.8137<=1<=1.7739
0.1745<=1<=1.1347
0.2345<=1<=1.1947
0.2080<=1<=1.1682
0.5557<=1<=1.5159
0.3143<=1<=1.2745
0.3814<=1<=1.3415
0.1872<=1<=1.1474
0.5293<=1<=1.4895
0.8781<=1<=1.8383
0.3618<=1<=1.3220
0.4305<=1<=1.3907
0.3768<=1<=1.3369
0.2902<=1<=1.2504
0.6350<=1<=1.5952
```

Листинг 6: Доверительные интервалы при  $n = 1000$