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| Федеральное государственное бюджетное  образовательное учреждение высшего образования «Новосибирский государственный технический университет» | | |
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| Кафедра прикладной математики | | |
| Лабораторная работа № 1 | | |
| по дисциплине «Методы оптимизации» | | |
| **МЕТОДЫ ОДНОМЕРНОГО ПОИСКА** | | |
|  | | |
|  | Бригада 1 | исакин даниил |
| Группа ПМ-13 | вострецова екатерина |
| Вариант 1 |  |
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|  |  |
|  |  |
| Преподаватели | Филиппова Елена Владимировна |
|  |  |
| Новосибирск, 2024 | | |

1. **Цель**

Ознакомиться с методами одномерного поиска, используемыми в многомерных методах минимизации функций n переменных. Сравнить различные алгоритмы по эффективности на тестовых примерах.

1. **Задание**

Реализовать три метода поиска экстремума унимодальной одномерной функции: метод дихотомии, метод золотого сечения и метод Фибоначчи. Реализовать метод поиска отрезка, содержащего минимум.

1. **Результаты исследования**

Метод дихотомии

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |
| 1 | 9 | 9 | 64 | 64 | -2 | 9 | 11 | 2 |
| 2 | 3.5 | 3.5 | 6.25 | 6.25 | -2 | 3.5 | 5.5 | 2 |
| 3 | 0.75 | 0.75 | 0.0625 | 0.0625 | 0.75 | 3.5 | 2.75 | 2 |
| 4 | 2.125 | 2.125 | 1.26562 | 1.26563 | 0.75 | 2.125 | 1.375 | 2 |
| 5 | 1.4375 | 1.4375 | 0.191406 | 0.191406 | 0.75 | 1.4375 | 0.6875 | 2 |
| 6 | 1.09375 | 1.09375 | 0.00878906 | 0.00878906 | 0.75 | 1.09375 | 0.34375 | 2 |
| 7 | 0.921875 | 0.921875 | 0.00610352 | 0.00610351 | 0.921875 | 1.09375 | 0.171875 | 2 |
| 8 | 1.00781 | 1.00781 | 6.10351e-05 | 6.10353e-05 | 0.921875 | 1.00781 | 0.0859375 | 2 |
| 9 | 0.964844 | 0.964844 | 0.00123596 | 0.00123596 | 0.964844 | 1.00781 | 0.0429688 | 2 |
| 10 | 0.986328 | 0.986328 | 0.00018692 | 0.00018692 | 0.986328 | 1.00781 | 0.0214844 | 2 |
| 11 | 0.99707 | 0.99707 | 8.58308e-06 | 8.58302e-06 | 0.99707 | 1.00781 | 0.0107422 | 2 |
| 12 | 1.00244 | 1.00244 | 5.96046e-06 | 5.96051e-06 | 0.99707 | 1.00244 | 0.0053711 | 2 |
| 13 | 0.999756 | 0.999756 | 5.96053e-08 | 5.96004e-08 | 0.999756 | 1.00244 | 0.00268556 | 2 |
| 14 | 1.0011 | 1.0011 | 1.20699e-06 | 1.20701e-06 | 0.999756 | 1.0011 | 0.00134278 | 1.99999 |
| 15 | 1.00043 | 1.00043 | 1.82538e-07 | 1.82547e-07 | 0.999756 | 1.00043 | 0.000671397 | 1.99999 |
| 16 | 1.00009 | 1.00009 | 8.38165e-09 | 8.38348e-09 | 0.999756 | 1.00009 | 0.000335703 | 1.99997 |
| 17 | 0.999924 | 0.999924 | 5.82097e-09 | 5.81945e-09 | 0.999924 | 1.00009 | 0.000167857 | 1.99994 |
| 18 | 1.00001 | 1.00001 | 5.81869e-11 | 5.83395e-11 | 0.999924 | 1.00001 | 8.39333e-05 | 1.99988 |
| 19 | 0.999966 | 0.999966 | 1.1788e-09 | 1.17811e-09 | 0.999966 | 1.00001 | 4.19717e-05 | 1.99976 |
| 20 | 0.999987 | 0.999987 | 1.78297e-10 | 1.7803e-10 | 0.999987 | 1.00001 | 2.09908e-05 | 1.99952 |
| 21 | 0.999997 | 0.999997 | 8.19326e-12 | 8.13611e-12 | 0.999997 | 1.00001 | 1.05004e-05 | 1.99905 |
| 22 | 1 | 1 | 5.67784e-12 | 5.7256e-12 | 0.999997 | 1 | 5.25521e-06 | 1.9981 |
| 23 | 1 | 1 | 5.74955e-14 | 5.27999e-14 | 1 | 1 | 2.6326e-06 | 1.9962 |
| 24 | 1 | 1 | 1.14816e-12 | 1.16969e-12 | 1 | 1 | 1.3213e-06 | 1.99243 |
| 25 | 1 | 1 | 1.72947e-13 | 1.81364e-13 | 1 | 1 | 6.65651e-07 | 1.98498 |
| 26 | 1 | 1 | 7.75163e-15 | 9.61249e-15 | 1 | 1 | 3.37826e-07 | 1.9704 |
| 27 | 1 | 1 | 5.75617e-15 | 4.33878e-15 | 1 | 1 | 1.73913e-07 | 1.9425 |
| 28 | 1 | 1 | 3.70509e-17 | 2.5879e-16 | 1 | 1 | 9.19564e-08 | 1.89125 |

Метод золотого сечения

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |
| 1 | 6.40325 | 11.5967 | 29.1951 | 112.291 | -2 | 11.5967 | 13.5967 | 1.61803 |
| 2 | 3.1935 | 6.40325 | 4.81142 | 29.1951 | -2 | 6.40325 | 8.40325 | 1.61803 |
| 3 | 1.20976 | 3.1935 | 0.0439979 | 4.81142 | -2 | 3.1935 | 5.1935 | 1.61803 |
| 4 | -0.01626 | 1.20976 | 1.03279 | 0.0439979 | -0.01626 | 3.1935 | 3.20976 | 1.61803 |
| 5 | 1.20976 | 1.96748 | 0.0439979 | 0.936013 | -0.01626 | 1.96748 | 1.98374 | 1.61803 |
| 6 | 0.74146 | 1.20976 | 0.0668432 | 0.0439979 | 0.74146 | 1.96748 | 1.22602 | 1.61803 |
| 7 | 1.20976 | 1.49918 | 0.0439979 | 0.249181 | 0.74146 | 1.49918 | 0.757721 | 1.61803 |
| 8 | 1.03088 | 1.20976 | 0.000953768 | 0.0439979 | 0.74146 | 1.20976 | 0.468297 | 1.61803 |
| 9 | 0.920333 | 1.03088 | 0.00634681 | 0.000953768 | 0.920333 | 1.20976 | 0.289424 | 1.61803 |
| 10 | 1.03088 | 1.09921 | 0.000953768 | 0.00984198 | 0.920333 | 1.09921 | 0.178874 | 1.61803 |
| 11 | 0.988657 | 1.03088 | 0.000128668 | 0.000953768 | 0.920333 | 1.03088 | 0.11055 | 1.61803 |
| 12 | 0.962559 | 0.988657 | 0.00140179 | 0.000128668 | 0.962559 | 1.03088 | 0.0683236 | 1.61803 |
| 13 | 0.988657 | 1.00479 | 0.000128668 | 2.29041e-05 | 0.988657 | 1.03088 | 0.0422263 | 1.61803 |
| 14 | 1.00479 | 1.01475 | 2.29041e-05 | 0.000217684 | 0.988657 | 1.01475 | 0.0260973 | 1.61803 |
| 15 | 0.998625 | 1.00479 | 1.8904e-06 | 2.29041e-05 | 0.988657 | 1.00479 | 0.016129 | 1.61803 |
| 16 | 0.994818 | 0.998625 | 2.68579e-05 | 1.8904e-06 | 0.994818 | 1.00479 | 0.00996828 | 1.61803 |
| 17 | 0.998625 | 1.00098 | 1.8904e-06 | 9.57023e-07 | 0.998625 | 1.00479 | 0.00616074 | 1.61803 |
| 18 | 1.00098 | 1.00243 | 9.57023e-07 | 5.91768e-06 | 0.998625 | 1.00243 | 0.00380755 | 1.61803 |
| 19 | 1.00008 | 1.00098 | 6.31005e-09 | 9.57023e-07 | 0.998625 | 1.00098 | 0.00235319 | 1.61803 |
| 20 | 0.999524 | 1.00008 | 2.2665e-07 | 6.31005e-09 | 0.999524 | 1.00098 | 0.00145435 | 1.61803 |
| 21 | 1.00008 | 1.00042 | 6.31005e-09 | 1.78728e-07 | 0.999524 | 1.00042 | 0.00089884 | 1.61803 |
| 22 | 0.999867 | 1.00008 | 1.76229e-08 | 6.31005e-09 | 0.999867 | 1.00042 | 0.000555513 | 1.61803 |
| 23 | 1.00008 | 1.00021 | 6.31005e-09 | 4.43417e-08 | 0.999867 | 1.00021 | 0.000343326 | 1.61803 |
| 24 | 0.999998 | 1.00008 | 2.60006e-12 | 6.31005e-09 | 0.999867 | 1.00008 | 0.000212187 | 1.61803 |
| 25 | 0.999948 | 0.999998 | 2.67321e-09 | 2.60006e-12 | 0.999948 | 1.00008 | 0.000131139 | 1.61803 |
| 26 | 0.999998 | 1.00003 | 2.60006e-12 | 8.61143e-10 | 0.999948 | 1.00003 | 8.10483e-05 | 1.61803 |
| 27 | 0.999979 | 0.999998 | 4.30371e-10 | 2.60006e-12 | 0.999979 | 1.00003 | 5.00906e-05 | 1.61803 |
| 28 | 0.999998 | 1.00001 | 2.60006e-12 | 1.04291e-10 | 0.999979 | 1.00001 | 3.09577e-05 | 1.61803 |
| 29 | 0.999991 | 0.999998 | 7.9577e-11 | 2.60006e-12 | 0.999991 | 1.00001 | 1.91329e-05 | 1.61803 |
| 30 | 0.999998 | 1 | 2.60006e-12 | 8.43436e-12 | 0.999991 | 1 | 1.18248e-05 | 1.61803 |
| 31 | 0.999996 | 0.999998 | 1.93946e-11 | 2.60006e-12 | 0.999996 | 1 | 7.30812e-06 | 1.61803 |
| 32 | 0.999998 | 1 | 2.60006e-12 | 1.27108e-14 | 0.999998 | 1 | 4.51667e-06 | 1.61803 |
| 33 | 1 | 1 | 1.27108e-14 | 1.39e-12 | 0.999998 | 1 | 2.79145e-06 | 1.61803 |
| 34 | 0.999999 | 1 | 2.98368e-13 | 1.27108e-14 | 0.999999 | 1 | 1.72521e-06 | 1.61803 |
| 35 | 1 | 1 | 1.27108e-14 | 2.7041e-13 | 0.999999 | 1 | 1.06624e-06 | 1.61803 |
| 36 | 1 | 1 | 1.93107e-14 | 1.27108e-14 | 1 | 1 | 6.58973e-07 | 1.61803 |
| 37 | 1 | 1 | 1.27108e-14 | 7.19874e-14 | 1 | 1 | 4.07268e-07 | 1.61803 |
| 38 | 1 | 1 | 2.7554e-16 | 1.27108e-14 | 1 | 1 | 2.51705e-07 | 1.61803 |
| 39 | 1 | 1 | 1.83357e-15 | 2.7554e-16 | 1 | 1 | 1.55562e-07 | 1.61803 |
| 40 | 1 | 1 | 2.7554e-16 | 2.84331e-15 | 1 | 1 | 9.61429e-08 | 1.61803 |

Метод Фибоначчи

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |
| 1 | 5.33333 | 12.6667 | 18.7778 | 136.111 | -2 | 12.6667 | 14.6667 | 1.5 |
| 2 | 3.86667 | 6.8 | 8.21778 | 33.64 | -2 | 6.8 | 8.8 | 1.66667 |
| 3 | 1.3 | 3.5 | 0.09 | 6.25 | -2 | 3.5 | 5.5 | 1.6 |
| 4 | 0.115385 | 1.38462 | 0.782544 | 0.147929 | 0.115385 | 3.5 | 3.38462 | 1.625 |
| 5 | 1.40476 | 2.21062 | 0.163832 | 1.46561 | 0.115385 | 2.21062 | 2.09524 | 1.61538 |
| 6 | 0.916505 | 1.4095 | 0.0069714 | 0.167692 | 0.115385 | 1.4095 | 1.29412 | 1.61905 |
| 7 | 0.609502 | 0.915385 | 0.152488 | 0.00715976 | 0.609502 | 1.4095 | 0.8 | 1.61765 |
| 8 | 0.91512 | 1.10388 | 0.00720457 | 0.0107919 | 0.609502 | 1.10388 | 0.494382 | 1.61818 |
| 9 | 0.798329 | 0.915058 | 0.0406713 | 0.00721517 | 0.798329 | 1.10388 | 0.305556 | 1.61798 |
| 10 | 0.915043 | 0.98717 | 0.00721768 | 0.000164611 | 0.915043 | 1.10388 | 0.188841 | 1.61806 |
| 11 | 0.987173 | 1.03175 | 0.000164521 | 0.00100831 | 0.915043 | 1.03175 | 0.116711 | 1.61803 |
| 12 | 0.959623 | 0.987174 | 0.00163032 | 0.0001645 | 0.959623 | 1.03175 | 0.0721311 | 1.61804 |
| 13 | 0.987174 | 1.0042 | 0.000164495 | 1.76597e-05 | 0.987174 | 1.03175 | 0.0445795 | 1.61803 |
| 14 | 1.0042 | 1.01473 | 1.76593e-05 | 0.000216858 | 0.987174 | 1.01473 | 0.0275517 | 1.61803 |
| 15 | 0.997698 | 1.0042 | 5.29819e-06 | 1.76592e-05 | 0.987174 | 1.0042 | 0.0170279 | 1.61803 |
| 16 | 0.993678 | 0.997698 | 3.99615e-05 | 5.29818e-06 | 0.993678 | 1.0042 | 0.0105238 | 1.61803 |
| 17 | 0.997698 | 1.00018 | 5.29818e-06 | 3.33264e-08 | 0.997698 | 1.0042 | 0.00650407 | 1.61803 |
| 18 | 1.00018 | 1.00172 | 3.33264e-08 | 2.95137e-06 | 0.997698 | 1.00172 | 0.00401973 | 1.61803 |
| 19 | 0.999234 | 1.00018 | 5.87331e-07 | 3.33264e-08 | 0.999234 | 1.00172 | 0.00248433 | 1.61803 |
| 20 | 1.00018 | 1.00077 | 3.33264e-08 | 5.91401e-07 | 0.999234 | 1.00077 | 0.0015354 | 1.61803 |
| 21 | 0.99982 | 1.00018 | 3.23655e-08 | 3.33264e-08 | 0.999234 | 1.00018 | 0.00094893 | 1.61803 |
| 22 | 0.999596 | 0.99982 | 1.63148e-07 | 3.23655e-08 | 0.999596 | 1.00018 | 0.000586471 | 1.61803 |
| 23 | 0.99982 | 0.999959 | 3.23655e-08 | 1.71868e-09 | 0.99982 | 1.00018 | 0.000362459 | 1.61803 |
| 24 | 0.999959 | 1.00004 | 1.71868e-09 | 1.94552e-09 | 0.99982 | 1.00004 | 0.000224012 | 1.61803 |
| 25 | 0.999906 | 0.999959 | 8.89985e-09 | 1.71868e-09 | 0.999906 | 1.00004 | 0.000138447 | 1.61803 |
| 26 | 0.999959 | 0.999991 | 1.71868e-09 | 7.6984e-11 | 0.999959 | 1.00004 | 8.5565e-05 | 1.61803 |
| 27 | 0.999991 | 1.00001 | 7.6984e-11 | 1.30533e-10 | 0.999959 | 1.00001 | 5.28821e-05 | 1.61803 |
| 28 | 0.999979 | 0.999991 | 4.51895e-10 | 7.6984e-11 | 0.999979 | 1.00001 | 3.26829e-05 | 1.61803 |
| 29 | 0.999991 | 0.999999 | 7.6984e-11 | 1.12076e-12 | 0.999991 | 1.00001 | 2.01992e-05 | 1.61803 |
| 30 | 0.999999 | 1 | 1.12076e-12 | 1.3762e-11 | 0.999991 | 1 | 1.24838e-05 | 1.61803 |
| 31 | 0.999996 | 0.999999 | 1.60454e-11 | 1.12076e-12 | 0.999996 | 1 | 7.71539e-06 | 1.61803 |
| 32 | 0.999999 | 1 | 1.12076e-12 | 5.81706e-13 | 0.999999 | 1 | 4.76837e-06 | 1.61803 |
| 33 | 1 | 1 | 5.81706e-13 | 3.56589e-12 | 0.999999 | 1 | 2.94702e-06 | 1.61803 |
| 34 | 1 | 1 | 4.48902e-15 | 5.81706e-13 | 0.999999 | 1 | 1.82136e-06 | 1.61803 |
| 35 | 1 | 1 | 1.31743e-13 | 4.48902e-15 | 1 | 1 | 1.12566e-06 | 1.61803 |
| 36 | 1 | 1 | 4.48902e-15 | 1.10711e-13 | 1 | 1 | 6.95696e-07 | 1.61803 |
| 37 | 1 | 1 | 9.45396e-15 | 4.48902e-15 | 1 | 1 | 4.29964e-07 | 1.61803 |
| 38 | 1 | 1 | 4.48902e-15 | 2.83925e-14 | 1 | 1 | 2.65732e-07 | 1.61803 |
| 39 | 1 | 1 | 1.82264e-17 | 4.48902e-15 | 1 | 1 | 1.64232e-07 | 1.61803 |
| 40 | 1 | 1 | 1.19029e-15 | 1.82264e-17 | 1 | 1 | 1.01501e-07 | 1.61803 |
| 41 | 1 | 1 | 1.82264e-17 | 7.9695e-16 | 1 | 1 | 6.27309e-08 | 1.61803 |

**Исследование на количество вычислений от задаваемой точности**

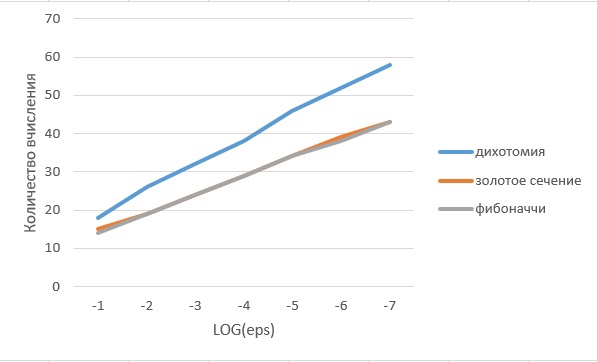
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Метод дихотомии | | | | | Метод золотого сечения | | | | | Метод Фибоначчи | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | -2 | 9 | 11 | 2 | 1 | -2 | 11.5967 | 13.5967 | 1.61803 | 1 | -2 | 12.6667 | 14.6667 | 1.5 |
| 2 | -2 | 3.5 | 5.5 | 2 | 2 | -2 | 6.40325 | 8.40325 | 1.61803 | 2 | -2 | 6.8 | 8.8 | 1.66667 |
| 3 | 0.75 | 3.5 | 2.75 | 2 | 3 | -2 | 3.1935 | 5.1935 | 1.61803 | 3 | -2 | 3.5 | 5.5 | 1.6 |
| 4 | 0.75 | 2.125 | 1.375 | 2 | 4 | -0.016261 | 3.1935 | 3.20976 | 1.61803 | 4 | 0.115385 | 3.5 | 3.38462 | 1.625 |
| 5 | 0.75 | 1.4375 | 0.6875 | 2 | 5 | -0.016261 | 1.96748 | 1.98374 | 1.61803 | 5 | 0.115385 | 2.21062 | 2.09524 | 1.61538 |
| 6 | 0.75 | 1.09375 | 0.34375 | 2 | 6 | 0.74146 | 1.96748 | 1.22602 | 1.61803 | 6 | 0.115385 | 1.4095 | 1.29412 | 1.61905 |
| 7 | 0.92187 | 1.09375 | 0.171875 | 2 | 7 | 0.74146 | 1.49918 | 0.757721 | 1.61803 | 7 | 0.609502 | 1.4095 | 0.8 | 1.61765 |
| 8 | 0.92187 | 1.00781 | 0.0859375 | 2 | 8 | 0.74146 | 1.20976 | 0.468297 | 1.61803 | 8 | 0.609502 | 1.10388 | 0.494382 | 1.61818 |
|  |  |  |  |  | 9 | 0.920333 | 1.20976 | 0.289424 | 1.61803 | 9 | 0.798329 | 1.10388 | 0.305556 | 1.61798 |
|  |  |  |  |  | 10 | 0.920333 | 1.09921 | 0.178874 | 1.61803 | 10 | 0.915043 | 1.10388 | 0.188841 | 1.61806 |
|  |  |  |  |  | 11 | 0.920333 | 1.03088 | 0.11055 | 1.61803 | 11 | 0.915043 | 1.03175 | 0.116711 | 1.61803 |
|  |  |  |  |  | 12 | 0.962559 | 1.03088 | 0.068323 | 1.61803 | 12 | 0.959623 | 1.03175 | 0.0721311 | 1.61804 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Метод дихотомии | | | | | Метод золотого сечения | | | | | Метод Фибоначчи | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | -2 | 9 | 11 | 2 | 1 | -2 | 11.5967 | 13.5967 | 1.61803 | 1 | -2 | 12.6667 | 14.6667 | 1.5 |
| 2 | -2 | 3.5 | 5.5 | 2 | 2 | -2 | 6.40325 | 8.40325 | 1.61803 | 2 | -2 | 6.8 | 8.8 | 1.66667 |
| 3 | 0.75 | 3.5 | 2.75 | 2 | 3 | -2 | 3.1935 | 5.1935 | 1.61803 | 3 | -2 | 3.5 | 5.5 | 1.6 |
| 4 | 0.75 | 2.125 | 1.375 | 2 | 4 | -0.016261 | 3.1935 | 3.20976 | 1.61803 | 4 | 0.115385 | 3.5 | 3.38462 | 1.625 |
| 5 | 0.75 | 1.4375 | 0.6875 | 2 | 5 | -0.016261 | 1.96748 | 1.98374 | 1.61803 | 5 | 0.115385 | 2.21062 | 2.09524 | 1.61538 |
| 6 | 0.75 | 1.09375 | 0.34375 | 2 | 6 | 0.74146 | 1.96748 | 1.22602 | 1.61803 | 6 | 0.115385 | 1.4095 | 1.29412 | 1.61905 |
| 7 | 0.921875 | 1.09375 | 0.171875 | 2 | 7 | 0.74146 | 1.49918 | 0.757721 | 1.61803 | 7 | 0.609502 | 1.4095 | 0.8 | 1.61765 |
| 8 | 0.921875 | 1.00781 | 0.0859375 | 2 | 8 | 0.74146 | 1.20976 | 0.468297 | 1.61803 | 8 | 0.609502 | 1.10388 | 0.494382 | 1.61818 |
| 9 | 0.964844 | 1.00781 | 0.0429688 | 2 | 9 | 0.920333 | 1.20976 | 0.289424 | 1.61803 | 9 | 0.798329 | 1.10388 | 0.305556 | 1.61798 |
| 10 | 0.986328 | 1.00781 | 0.0214844 | 2 | 10 | 0.920333 | 1.09921 | 0.178874 | 1.61803 | 10 | 0.915043 | 1.10388 | 0.188841 | 1.61806 |
| 11 | 0.99707 | 1.00781 | 0.0107422 | 2 | 11 | 0.920333 | 1.03088 | 0.11055 | 1.61803 | 11 | 0.915043 | 1.03175 | 0.116711 | 1.61803 |
| 12 | 0.99707 | 1.00244 | 0.0053711 | 2 | 12 | 0.962559 | 1.03088 | 0.0683236 | 1.61803 | 12 | 0.959623 | 1.03175 | 0.0721311 | 1.61804 |
| 13 | 0.999756 | 1.00244 | 0.00268556 | 2 | 13 | 0.988657 | 1.03088 | 0.0422263 | 1.61803 | 13 | 0.987174 | 1.03175 | 0.0445795 | 1.61803 |
| 14 | 0.999756 | 1.0011 | 0.00134278 | 1.99999 | 14 | 0.988657 | 1.01475 | 0.0260973 | 1.61803 | 14 | 0.987174 | 1.01473 | 0.0275517 | 1.61803 |
| 15 | 0.999756 | 1.00043 | 0.00067139 | 1.99999 | 15 | 0.988657 | 1.00479 | 0.016129 | 1.61803 | 15 | 0.987174 | 1.0042 | 0.0170279 | 1.61803 |
|  |  |  |  |  | 16 | 0.994818 | 1.00479 | 0.00996828 | 1.61803 | 16 | 0.993678 | 1.0042 | 0.0105238 | 1.61803 |
|  |  |  |  |  | 17 | 0.998625 | 1.00479 | 0.00616074 | 1.61803 | 17 | 0.997698 | 1.0042 | 0.00650407 | 1.61803 |
|  |  |  |  |  | 18 | 0.998625 | 1.00243 | 0.00380755 | 1.61803 | 18 | 0.997698 | 1.00172 | 0.00401973 | 1.61803 |
|  |  |  |  |  | 19 | 0.998625 | 1.00098 | 0.00235319 | 1.61803 | 19 | 0.999234 | 1.00172 | 0.00248433 | 1.61803 |
|  |  |  |  |  | 20 | 0.999524 | 1.00098 | 0.00145435 | 1.61803 | 20 | 0.999234 | 1.00077 | 0.0015354 | 1.61803 |
|  |  |  |  |  | 21 | 0.999524 | 1.00042 | 0.00089884 | 1.61803 | 21 | 0.999234 | 1.00018 | 0.00094893 | 1.61803 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Метод дихотомии | | | | | Метод золотого сечения | | | | | Метод Фибоначчи | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | -2 | 9 | 11 | 2 | 1 | -2 | 11.5967 | 13.5967 | 1.61803 | 1 | -2 | 12.6667 | 14.6667 | 1.5 |
| 2 | -2 | 3.5 | 5.5 | 2 | 2 | -2 | 6.40325 | 8.40325 | 1.61803 | 2 | -2 | 6.8 | 8.8 | 1.66667 |
| 3 | 0.75 | 3.5 | 2.75 | 2 | 3 | -2 | 3.1935 | 5.1935 | 1.61803 | 3 | -2 | 3.5 | 5.5 | 1.6 |
| 4 | 0.75 | 2.125 | 1.375 | 2 | 4 | -0.01626 | 3.1935 | 3.20976 | 1.61803 | 4 | 0.115385 | 3.5 | 3.38462 | 1.625 |
| 5 | 0.75 | 1.4375 | 0.6875 | 2 | 5 | -0.01626 | 1.96748 | 1.98374 | 1.61803 | 5 | 0.115385 | 2.21062 | 2.09524 | 1.61538 |
| 6 | 0.75 | 1.09375 | 0.34375 | 2 | 6 | 0.74146 | 1.96748 | 1.22602 | 1.61803 | 6 | 0.115385 | 1.4095 | 1.29412 | 1.61905 |
| 7 | 0.921875 | 1.09375 | 0.171875 | 2 | 7 | 0.74146 | 1.49918 | 0.757721 | 1.61803 | 7 | 0.609502 | 1.4095 | 0.8 | 1.61765 |
| 8 | 0.921875 | 1.00781 | 0.0859375 | 2 | 8 | 0.74146 | 1.20976 | 0.468297 | 1.61803 | 8 | 0.609502 | 1.10388 | 0.494382 | 1.61818 |
| 9 | 0.964844 | 1.00781 | 0.0429688 | 2 | 9 | 0.920333 | 1.20976 | 0.289424 | 1.61803 | 9 | 0.798329 | 1.10388 | 0.305556 | 1.61798 |
| 10 | 0.986328 | 1.00781 | 0.0214844 | 2 | 10 | 0.920333 | 1.09921 | 0.178874 | 1.61803 | 10 | 0.915043 | 1.10388 | 0.188841 | 1.61806 |
| 11 | 0.99707 | 1.00781 | 0.0107422 | 2 | 11 | 0.920333 | 1.03088 | 0.11055 | 1.61803 | 11 | 0.915043 | 1.03175 | 0.116711 | 1.61803 |
| 12 | 0.99707 | 1.00244 | 0.0053711 | 2 | 12 | 0.962559 | 1.03088 | 0.0683236 | 1.61803 | 12 | 0.959623 | 1.03175 | 0.0721311 | 1.61804 |
| 13 | 0.999756 | 1.00244 | 0.00268556 | 2 | 13 | 0.988657 | 1.03088 | 0.0422263 | 1.61803 | 13 | 0.987174 | 1.03175 | 0.0445795 | 1.61803 |
| 14 | 0.999756 | 1.0011 | 0.00134278 | 1.99999 | 14 | 0.988657 | 1.01475 | 0.0260973 | 1.61803 | 14 | 0.987174 | 1.01473 | 0.0275517 | 1.61803 |
| 15 | 0.999756 | 1.00043 | 0.000671397 | 1.99999 | 15 | 0.988657 | 1.00479 | 0.016129 | 1.61803 | 15 | 0.987174 | 1.0042 | 0.0170279 | 1.61803 |
| 16 | 0.999756 | 1.00009 | 0.000335703 | 1.99997 | 16 | 0.994818 | 1.00479 | 0.0099682 | 1.61803 | 16 | 0.993678 | 1.0042 | 0.0105238 | 1.61803 |
| 17 | 0.999924 | 1.00009 | 0.000167857 | 1.99994 | 17 | 0.998625 | 1.00479 | 0.0061607 | 1.61803 | 17 | 0.997698 | 1.0042 | 0.00650407 | 1.61803 |
| 18 | 0.999924 | 1.00001 | 8.39333e-05 | 1.99988 | 18 | 0.998625 | 1.00243 | 0.0038075 | 1.61803 | 18 | 0.997698 | 1.00172 | 0.00401973 | 1.61803 |
| 19 | 0.999966 | 1.00001 | 4.19717e-05 | 1.99976 | 19 | 0.998625 | 1.00098 | 0.0023531 | 1.61803 | 19 | 0.999234 | 1.00172 | 0.00248433 | 1.61803 |
| 20 | 0.999987 | 1.00001 | 2.09908e-05 | 1.99952 | 20 | 0.999524 | 1.00098 | 0.0014543 | 1.61803 | 20 | 0.999234 | 1.00077 | 0.0015354 | 1.61803 |
| 21 | 0.999997 | 1.00001 | 1.05004e-05 | 1.99905 | 21 | 0.999524 | 1.00042 | 0.0008988 | 1.61803 | 21 | 0.999234 | 1.00018 | 0.00094893 | 1.61803 |
| 22 | 0.999997 | 1 | 5.25521e-06 | 1.9981 | 22 | 0.999867 | 1.00042 | 0.00055551 | 1.61803 | 22 | 0.999596 | 1.00018 | 0.000586471 | 1.61803 |
|  |  |  |  |  | 23 | 0.999867 | 1.00021 | 0.00034332 | 1.61803 | 23 | 0.99982 | 1.00018 | 0.000362459 | 1.61803 |
|  |  |  |  |  | 24 | 0.999867 | 1.00008 | 0.00021218 | 1.61803 | 24 | 0.99982 | 1.00004 | 0.000224012 | 1.61803 |
|  |  |  |  |  | 25 | 0.999948 | 1.00008 | 0.00013113 | 1.61803 | 25 | 0.999906 | 1.00004 | 0.000138447 | 1.61803 |
|  |  |  |  |  | 26 | 0.999948 | 1.00003 | 8.10483e-05 | 1.61803 | 26 | 0.999959 | 1.00004 | 8.5565e-05 | 1.61803 |
|  |  |  |  |  | 27 | 0.999979 | 1.00003 | 5.00906e-05 | 1.61803 | 27 | 0.999959 | 1.00001 | 5.28821e-05 | 1.61803 |
|  |  |  |  |  | 28 | 0.999979 | 1.00001 | 3.09577e-05 | 1.61803 | 28 | 0.999979 | 1.00001 | 3.26829e-05 | 1.61803 |
|  |  |  |  |  | 29 | 0.999991 | 1.00001 | 1.91329e-05 | 1.61803 | 29 | 0.999991 | 1.00001 | 2.01992e-05 | 1.61803 |
|  |  |  |  |  | 30 | 0.999991 | 1 | 1.18248e-05 | 1.61803 | 30 | 0.999991 | 1 | 1.24838e-05 | 1.61803 |
|  |  |  |  |  | 31 | 0.999996 | 1 | 7.30812e-06 | 1.61803 | 31 | 0.999996 | 1 | 7.71539e-06 | 1.61803 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Метод дихотомии | | | | | Метод золотого сечения | | | | | Метод Фибоначчи | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | -2 | 9 | 11 | 2 | 1 | -2 | 11.5967 | 13.5967 | 1.61803 | 1 | -2 | 12.6667 | 14.6667 | 1.5 |
| 2 | -2 | 3.5 | 5.5 | 2 | 2 | -2 | 6.40325 | 8.40325 | 1.61803 | 2 | -2 | 6.8 | 8.8 | 1.66667 |
| 3 | 0.75 | 3.5 | 2.75 | 2 | 3 | -2 | 3.1935 | 5.1935 | 1.61803 | 3 | -2 | 3.5 | 5.5 | 1.6 |
| 4 | 0.75 | 2.125 | 1.375 | 2 | 4 | -0.016261 | 3.1935 | 3.20976 | 1.61803 | 4 | 0.115385 | 3.5 | 3.38462 | 1.625 |
| 5 | 0.75 | 1.4375 | 0.6875 | 2 | 5 | -0.016261 | 1.96748 | 1.98374 | 1.61803 | 5 | 0.115385 | 2.21062 | 2.09524 | 1.61538 |
| 6 | 0.75 | 1.09375 | 0.34375 | 2 | 6 | 0.74146 | 1.96748 | 1.22602 | 1.61803 | 6 | 0.115385 | 1.4095 | 1.29412 | 1.61905 |
| 7 | 0.921875 | 1.09375 | 0.171875 | 2 | 7 | 0.74146 | 1.49918 | 0.757721 | 1.61803 | 7 | 0.609502 | 1.4095 | 0.8 | 1.61765 |
| 8 | 0.921875 | 1.00781 | 0.0859375 | 2 | 8 | 0.74146 | 1.20976 | 0.468297 | 1.61803 | 8 | 0.609502 | 1.10388 | 0.494382 | 1.61818 |
| 9 | 0.964844 | 1.00781 | 0.0429688 | 2 | 9 | 0.920333 | 1.20976 | 0.289424 | 1.61803 | 9 | 0.798329 | 1.10388 | 0.305556 | 1.61798 |
| 10 | 0.986328 | 1.00781 | 0.0214844 | 2 | 10 | 0.920333 | 1.09921 | 0.178874 | 1.61803 | 10 | 0.915043 | 1.10388 | 0.188841 | 1.61806 |
| 11 | 0.99707 | 1.00781 | 0.0107422 | 2 | 11 | 0.920333 | 1.03088 | 0.11055 | 1.61803 | 11 | 0.915043 | 1.03175 | 0.116711 | 1.61803 |
| 12 | 0.99707 | 1.00244 | 0.00537109 | 2 | 12 | 0.962559 | 1.03088 | 0.0683236 | 1.61803 | 12 | 0.959623 | 1.03175 | 0.0721311 | 1.61804 |
| 13 | 0.999756 | 1.00244 | 0.00268555 | 2 | 13 | 0.988657 | 1.03088 | 0.0422263 | 1.61803 | 13 | 0.987174 | 1.03175 | 0.0445795 | 1.61803 |
| 14 | 0.999756 | 1.0011 | 0.00134277 | 2 | 14 | 0.988657 | 1.01475 | 0.0260973 | 1.61803 | 14 | 0.987174 | 1.01473 | 0.0275517 | 1.61803 |
| 15 | 0.999756 | 1.00043 | 0.000671388 | 2 | 15 | 0.988657 | 1.00479 | 0.016129 | 1.61803 | 15 | 0.987174 | 1.0042 | 0.0170279 | 1.61803 |
| 16 | 0.999756 | 1.00009 | 0.000335694 | 2 | 16 | 0.994818 | 1.00479 | 0.00996828 | 1.61803 | 16 | 0.993678 | 1.0042 | 0.0105238 | 1.61803 |
| 17 | 0.999924 | 1.00009 | 0.000167848 | 1.99999 | 17 | 0.998625 | 1.00479 | 0.00616074 | 1.61803 | 17 | 0.997698 | 1.0042 | 0.00650407 | 1.61803 |
| 18 | 0.999924 | 1.00001 | 8.39243e-05 | 1.99999 | 18 | 0.998625 | 1.00243 | 0.00380755 | 1.61803 | 18 | 0.997698 | 1.00172 | 0.00401973 | 1.61803 |
| 19 | 0.999966 | 1.00001 | 4.19627e-05 | 1.99998 | 19 | 0.998625 | 1.00098 | 0.00235319 | 1.61803 | 19 | 0.999234 | 1.00172 | 0.00248433 | 1.61803 |
| 20 | 0.999987 | 1.00001 | 2.09818e-05 | 1.99995 | 20 | 0.999524 | 1.00098 | 0.00145435 | 1.61803 | 20 | 0.999234 | 1.00077 | 0.0015354 | 1.61803 |
| 21 | 0.999997 | 1.00001 | 1.04914e-05 | 1.9999 | 21 | 0.999524 | 1.00042 | 0.00089884 | 1.61803 | 21 | 0.999234 | 1.00018 | 0.00094893 | 1.61803 |
| 22 | 0.999997 | 1 | 5.24621e-06 | 1.99981 | 22 | 0.999867 | 1.00042 | 0.000555513 | 1.61803 | 22 | 0.999596 | 1.00018 | 0.000586471 | 1.61803 |
| 23 | 1 | 1 | 2.6236e-06 | 1.99962 | 23 | 0.999867 | 1.00021 | 0.000343326 | 1.61803 | 23 | 0.99982 | 1.00018 | 0.000362459 | 1.61803 |
| 24 | 1 | 1 | 1.3123e-06 | 1.99924 | 24 | 0.999867 | 1.00008 | 0.000212187 | 1.61803 | 24 | 0.99982 | 1.00004 | 0.000224012 | 1.61803 |
| 25 | 1 | 1 | 6.56651e-07 | 1.99848 | 25 | 0.999948 | 1.00008 | 0.000131139 | 1.61803 | 25 | 0.999906 | 1.00004 | 0.000138447 | 1.61803 |
| 26 | 1 | 1 | 3.28826e-07 | 1.99696 | 26 | 0.999948 | 1.00003 | 8.10483e-05 | 1.61803 | 26 | 0.999959 | 1.00004 | 8.5565e-05 | 1.61803 |
| 27 | 1 | 1 | 1.64913e-07 | 1.99394 | 27 | 0.999979 | 1.00003 | 5.00906e-05 | 1.61803 | 27 | 0.999959 | 1.00001 | 5.28821e-05 | 1.61803 |
| 28 | 1 | 1 | 8.29564e-08 | 1.98795 | 28 | 0.999979 | 1.00001 | 3.09577e-05 | 1.61803 | 28 | 0.999979 | 1.00001 | 3.26829e-05 | 1.61803 |
| 29 | 1 | 1 | 4.19782e-08 | 1.97618 | 29 | 0.999991 | 1.00001 | 1.91329e-05 | 1.61803 | 29 | 0.999991 | 1.00001 | 2.01992e-05 | 1.61803 |
| 30 | 1 | 1 | 2.14891e-08 | 1.95346 | 30 | 0.999991 | 1 | 1.18248e-05 | 1.61803 | 30 | 0.999991 | 1 | 1.24838e-05 | 1.61803 |
| 31 | 1 | 1 | 1.12445e-08 | 1.91107 | 31 | 0.999996 | 1 | 7.30812e-06 | 1.61803 | 31 | 0.999996 | 1 | 7.71539e-06 | 1.61803 |
| 32 | 1 | 1 | 6.12227e-09 | 1.83666 | 32 | 0.999998 | 1 | 4.51667e-06 | 1.61803 | 32 | 0.999999 | 1 | 4.76837e-06 | 1.61803 |
|  |  |  |  |  | 33 | 0.999998 | 1 | 2.79145e-06 | 1.61803 | 33 | 0.999999 | 1 | 2.94702e-06 | 1.61803 |
|  |  |  |  |  | 34 | 0.999999 | 1 | 1.72521e-06 | 1.61803 | 34 | 0.999999 | 1 | 1.82136e-06 | 1.61803 |
|  |  |  |  |  | 35 | 0.999999 | 1 | 1.06624e-06 | 1.61803 | 35 | 1 | 1 | 1.12566e-06 | 1.61803 |
|  |  |  |  |  | 36 | 1 | 1 | 6.58973e-07 | 1.61803 | 36 | 1 | 1 | 6.95696e-07 | 1.61803 |
|  |  |  |  |  | 37 | 1 | 1 | 4.07268e-07 | 1.61803 | 37 | 1 | 1 | 4.29964e-07 | 1.61803 |
|  |  |  |  |  | 38 | 1 | 1 | 2.51705e-07 | 1.61803 | 38 | 1 | 1 | 2.65732e-07 | 1.61803 |
|  |  |  |  |  | 39 | 1 | 1 | 1.55562e-07 | 1.61803 | 39 | 1 | 1 | 1.64232e-07 | 1.61803 |
|  |  |  |  |  | 40 | 1 | 1 | 9.61429e-08 | 1.61803 | 40 | 1 | 1 | 1.01501e-07 | 1.61803 |
|  |  |  |  |  | 41 | 1 | 1 | 5.94196e-08 | 1.61803 | 41 | 1 | 1 | 6.27309e-08 | 1.61803 |
|  |  |  |  |  | 42 | 1 | 1 | 3.67233e-08 | 1.61803 | 42 | 1 | 1 | 3.87698e-08 | 1.61803 |
|  |  |  |  |  | 43 | 1 | 1 | 2.26963e-08 | 1.61803 | 43 | 1 | 1 | 2.39611e-08 | 1.61803 |
|  |  |  |  |  | 44 | 1 | 1 | 1.40271e-08 | 1.61803 | 44 | 1 | 1 | 1.48088e-08 | 1.61803 |
|  |  |  |  |  | 45 | 1 | 1 | 8.6692e-09 | 1.61803 | 45 | 1 | 1 | 9.15231e-09 | 1.61803 |

График зависимости количества вычислений целевой функции от логарифма задаваемой точности



Поиск интервала, содержащего минимум

|  |  |  |
| --- | --- | --- |
|  |  |  |
| 0 | 11,00000000 | 100,00000000 |
| 1 | 10,99999990 | 99,99999800 |
| 2 | 10,99999970 | 99,99999400 |
| 3 | 10,99999930 | 99,99998600 |
| 4 | 10,99999850 | 99,99997000 |
| 5 | 10,99999690 | 99,99993800 |
| 6 | 10,99999370 | 99,99987400 |
| 7 | 10,99998730 | 99,99974600 |
| 8 | 10,99997450 | 99,99949000 |
| 9 | 10,99994890 | 99,99897800 |
| 10 | 10,99989770 | 99,99795401 |
| 11 | 10,99979530 | 99,99590604 |
| 12 | 10,99959050 | 99,99181017 |
| 13 | 10,99918090 | 99,98361867 |
| 14 | 10,99836170 | 99,96723668 |
| 15 | 10,99672330 | 99,93447674 |
| 16 | 10,99344650 | 99,86897295 |
| 17 | 10,98689290 | 99,73802980 |
| 18 | 10,97378570 | 99,47640119 |
| 19 | 10,94757130 | 98,95417477 |
| 20 | 10,89514250 | 97,91384510 |
| 21 | 10,79028490 | 95,84967842 |
| 22 | 10,58056970 | 91,78731578 |
| 23 | 10,16113930 | 83,92647327 |
| 24 | 9,32227850 | 69,26031943 |
| 25 | 7,64455690 | 44,15013640 |
| 26 | 4,28911370 | 10,81826893 |
| 27 | -2,42177270 | 11,70852841 |

|  |  |  |
| --- | --- | --- |
| Интервал сод. мин | -2,42177270 | 7,64455690 |

1. **Вывод**

Метод Дихотомии находит решение за меньшее число итераций чем другие два метода, так как на каждой итерации делит область поиска пополам, но при этом вычисляет функцию два раза. Так же к недостаткам данного метода можно отнести сложность правильного подбора  так в силу проблемы представления чисел в машиной памяти может случиться так что числа ивысчитанные по формулам ,  не будут отличаться, следовательно и значения функции в этих точках.

Метод золотого сечения заключается в том, что отрезок поиска делится в пропорциях, соответствующих золотому сечению. Поэтому на каждой итерации интервал поиска уменьшается всего лишь в  вместо, но при этом на каждой итерации функция вычисляется всего лишь один раз, что является эффективным в случае, если самой дорогостоящей операцией вычисления является операция определения значения функции в точке.

Если сравнивать метод Фибоначчи с дихотомией и золотым сечением, то можно сделать следующие выводы:

Метод Фибоначчи находит решение за большое число итераций, чем метод дихотомии, но при этом он сходится за такое же количество итераций, как и метод золотого сечения, при этом вычисляя на каждой итерации функцию лишь один раз. В методе Фибоначчи мы можем заранее узнать количество итераций. Но при большом отрезке поиска или маленькой желаемой погрешности неравенства   числа Фибоначчи не помещаются в машинную память, поэтому нужно использовать специальные типы значений для их хранения.

1. **Текст программы**

#include <cmath>

#include <iostream>

#include <fstream>

double a = -2;

double b = 20;

double sigma = 1e-8;

double eps = 1e-7;

using namespace std;

double function(double x)

{

return (x - 1) \* (x - 1);

}

double fibonacci(int n)

{

return (pow((1 + sqrt(5)) / 2, n) - pow((1 - sqrt(5)) / 2, n)) / sqrt (5);

}

void dichotomy\_method()

{

ofstream output1("output1.txt");

double x1, x2, a1, a2, b1, b2;

a1 = a;

b1 = b;

for (int i = 1; b1 - a1 >= eps; i++)

{

a2 = a1;

b2 = b1;

x1 = (a1 + b1 - sigma) / 2;

x2 = (a1 + b1 + sigma) / 2;

if (function(x1) > function(x2))

a1 = x1;

else if (function(x1) < function(x2))

b1 = x2;

else

{

a1 = x1;

b1 = x2;

}

output1 << i << " " << x1 << " " << x2 << " " << function(x1) << " " << function(x2) << " " << a1 << " " << b1 << " " << b1 - a1 << " " << (b2 - a2) / (b1 - a1) << endl;

}

}

void golden\_section\_method()

{

ofstream output2("output2.txt");

double x1, x2, a1, a2, b1, b2;

a1 = a;

b1 = b;

for (int i = 1; b1 - a1 >= eps; i++)

{

a2 = a1;

b2 = b1;

x1 = a1 + (3 - sqrt(5)) \* (b1 - a1) / 2;

x2 = a1 + (sqrt(5) - 1) \* (b1 - a1) / 2;

if (function(x1) > function(x2))

a1 = x1;

else if (function(x1) < function(x2))

b1 = x2;

else

{

a1 = x1;

b1 = x2;

}

output2 << i << " " << x1 << " " << x2 << " " << function(x1) << " " << function(x2) << " " << a1 << " " << b1 << " " << b1 - a1 << " " << (b2 - a2) / (b1 - a1) << endl;

}

}

void fibonacci\_method()

{

ofstream output3("output3.txt");

double x1, x2, a1, a2, b1, b2;

a1 = a;

b1 = b;

for (int i = 2; b1 - a1 >= eps; i++)

{

a2 = a1;

b2 = b1;

x1 = a1 + (b1 - a1) \* fibonacci(i) / fibonacci(i + 2);

x2 = a1 + (b1 - a1) \* fibonacci(i + 1) / fibonacci(i + 2);

if (function(x1) > function(x2))

a1 = x1;

else if (function(x1) < function(x2))

b1 = x2;

else

{

a1 = x1;

b1 = x2;

}

output3 << i - 1 << " " << x1 << " " << x2 << " " << function(x1) << " " << function(x2) << " " << a1 << " " << b1 << " " << b1 - a1 << " " << (b2 - a2) / (b1 - a1) << endl;

}

}

void interval\_search()

{

ofstream output4("output4.txt");

sigma = 0.0001;

double x0 = -2;

double x1 = x0 + sigma;

double h = sigma;

int k = 1;

if (function(x0) < function(x1))

{

x1 = x0 - sigma;

h \*= -1;

}

output4 << k << " " << x0 << " " << function(x0) << endl;

bool flag = true;

while (flag)

{

h \*= 2;

x0 = x1;

x1 += h;

k++;

if (function(x0) > function(x1))

{

x0 = x1;

}

else

{

flag = false;

x0 -= h / 2;

}

output4 << k << endl;

output4 << x0 << endl;

output4 << function(x0) << endl;

}

output4 << x0 << " " << x1 << " " << abs(x1 - x0) << " " << endl;

}

int main()

{

dichotomy\_method();

golden\_section\_method();

fibonacci\_method();

interval\_search();

}