**Programowanie Efektywnych Algorytmów  
Zadanie projektowe 3**

„Implementacja i analiza efektywności algorytmu genetycznego dla problemu Komiwojażera”

Kacper Chrostowski 259120

**Problem Komiwojażera**

Problem optymalizacyjny polegający na znalezieniu w n-wierzchołkowym pełnym grafie takiego cyklu Hamiltona(doliczając do tego powrót do wierzchołka startowego), w którym suma długości ścieżek między wierzchołkami jest jak najmniejsza. Algorytm genetyczny jest heurystyką symulującą faktyczne sposoby ewolucji w środowiskach naturalnych. Kolejno przeprowadzana jest krzyżowanie, mutacja i selekcja nowej populacji.

W omawianym rozwiązaniu zastosowano krzyżowanie OrderCrossover (OX) oraz dwa rodzaje mutacji: Scramble oraz Inversion.

**Przebieg algorytmu:**

1)Wygeneruj startową populację składającą się z losowych permutacji rozwiązania tsp

2)Wylosuj dwa chromosomy należące do populacji i porównaj ich długość, zapamiętaj ten w którym trasa jest krótsza jako pierwszego rodzica

3)Powtórz krok 2 i zapamiętaj wynik jako drugiego rodzica

4)Korzystając z krzyżowania wygeneruj parę potomstwa dla wybranych rodziców i zapisz je w wektorze

5)Wróć do punktu 2 i powtarzaj tak długo aż ilość wygenerowanego potomstwa będzie wynosiła rozmiar\_startowej\_populacji \* współczynnik\_krzyżowania.

6)Dla każdego potomka sprawdź prawdopodobieństwo wystąpienia mutacji (określane przez współczynnik mutacji). Jeżeli prawdopodobieństwo na to wskaże, wykonaj odpowiednią mutację na potomku.

7)Połącz ze sobą struktury przechowujących rodziców i dzieci, posortuj populację rosnąco, a następnie usuń nadmiar chromosomów w taki sposób aby struktura miała rozmiar wskazany przez rozmiar startowej populacji

8)Wróć do punktu 2 i powtarzaj dopóki nie minie wskazany czas

9)Najlepsze znalezione rozwiązanie znajduje się w populacji na pierwszym miejscu.

**Opis klas:**

*Menu*: Jest odpowiedzialna za nawigację po programie. Przyjmuje instrukcje od użytkownika, a następnie uruchamia odpowiednie metody.

*Timer*: Klasa odpowiedzialna za pomiar czasu. Zawiera metody uruchamiające pomiar czasu oraz pobierającą aktualny czas.

*Graph*: Klasa, po której dziedziczy klasa Genetic. Służy ona do obsługi danych, na których operuje algorytm (wczytanie i wyświetlanie danych) oraz zawiera metodę obliczającą długość podanej trasy.

*Genetic:* Klasa, która przeprowadza algorytm genetyczny. Zawiera główną metodę , w której wykonuje się główne zadanie oraz metody będące niezbędne do przeprowadzenia algorytmu czyli operator krzyżowania OrderCrossover oraz dwa rodzaje mutacji Scramble oraz Inversion.

**Plan eksperymentu**

Dla każdego algorytmu przeprowadzono 10 testów. Każdy test trwał 120 sekund oraz co 10 sekund pobierano najlepsze znalezione rozwiązanie. W ten sposób będzie można przeanalizować jak z upływem czasu poprawia się rozwiązanie.

Dla każdego zestawu danych testy powtórzono dla dwóch rodzajów mutacji, oraz dla populacji początkowych liczących 100, 500 i 1000 osobników.

Testy przeprowadzone zostały na grafach zapisanych w plikach *br17*, *ft53* oraz *ftv170*. Najlepsze otrzymane wyniki będą porównywane z najlepszymi rozwiązaniami tych problemów rozwiązanych przy pomocy algorytmu TabuSearch z poprzedniego zadania.

**Wyniki eksperymentu**

**17 Miast**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 17 Miast, Populacja 100, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 103 | 41 | 41 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| 2 | 93 | 41 | 41 | 41 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 3 | 85 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 39 | 39 | 39 | 39 | 39 |  |
| 4 | 86 | 40 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 5 | 108 | 41 | 41 | 41 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 6 | 63 | 40 | 40 | 40 | 40 | 40 | 40 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 7 | 100 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 8 | 123 | 40 | 40 | 40 | 40 | 40 | 40 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 9 | 124 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 |  |
| 10 | 105 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Średnia | 99 | 40,3 | 40,2 | 40 | 39,6 | 39,6 | 39,6 | 39,4 | 39,2 | 39,2 | 39,2 | 39,2 | 39,2 |  |
| Błąd | 154% | 3% | 3% | 3% | 2% | 2% | 2% | 1% | 1% | 1% | 1% | 1% | 1% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 17 Miast, Populacja 500, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 87 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| 2 | 84 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 3 | 91 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 4 | 74 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 5 | 77 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 6 | 79 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 7 | 76 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 8 | 68 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 9 | 75 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 10 | 74 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Średnia | 78,5 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Błąd | 101% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 17 Miast, Populacja 1000, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 72 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| 2 | 62 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 3 | 75 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 4 | 64 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 5 | 82 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 6 | 69 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 7 | 60 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 8 | 71 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 9 | 85 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 10 | 82 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Średnia | 72,2 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Błąd | 85% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 17 Miast, Populacja 100, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 82 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| 2 | 94 | 40 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 3 | 115 | 42 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |  |
| 4 | 118 | 40 | 40 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 5 | 130 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 6 | 126 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 7 | 96 | 41 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 8 | 87 | 40 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 9 | 107 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |  |
| 10 | 75 | 40 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Średnia | 103 | 40 | 39,3 | 39,2 | 39,2 | 39,2 | 39,2 | 39,2 | 39,2 | 39,2 | 39,2 | 39,2 | 39,2 |  |
| Błąd | 164% | 3% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 17 Miast, Populacja 500, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 87 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| 2 | 96 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 3 | 74 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 4 | 85 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 5 | 76 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 6 | 68 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 7 | 88 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 8 | 81 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 9 | 106 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 10 | 88 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Średnia | 84,9 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Błąd | 118% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 17 Miast, Populacja 1000, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 87 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| 2 | 73 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 3 | 85 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 4 | 82 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 5 | 64 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 6 | 74 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 7 | 84 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 8 | 80 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 9 | 73 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 10 | 81 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Średnia | 78,3 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| Błąd | 101% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |  |

**53 Miasta**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 53 Miasta, Populacja 100, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 23387 | 10704 | 10704 | 10482 | 10482 | 10482 | 10482 | 10482 | 10482 | 10482 | 10482 | 10482 | 10482 | 6905 |
| 2 | 22796 | 9857 | 9857 | 9857 | 9857 | 9857 | 9857 | 9857 | 9857 | 9857 | 9857 | 9857 | 9857 |  |
| 3 | 23043 | 11374 | 11374 | 11374 | 11374 | 11374 | 11374 | 11374 | 11374 | 11374 | 11374 | 11374 | 11374 |  |
| 4 | 22032 | 11396 | 11396 | 11396 | 11396 | 11396 | 11396 | 11396 | 11396 | 11396 | 11396 | 11396 | 11396 |  |
| 5 | 22974 | 11262 | 11262 | 11262 | 11262 | 11262 | 11262 | 11262 | 11262 | 11262 | 11262 | 11262 | 11262 |  |
| 6 | 23260 | 10713 | 10713 | 10713 | 10713 | 10713 | 10713 | 10713 | 10713 | 10713 | 10713 | 10713 | 10713 |  |
| 7 | 23053 | 9911 | 9911 | 9911 | 9911 | 9911 | 9911 | 9911 | 9911 | 9911 | 9911 | 9911 | 9911 |  |
| 8 | 23179 | 12673 | 12673 | 12673 | 12673 | 12660 | 12660 | 12660 | 12660 | 12660 | 12660 | 12660 | 12660 |  |
| 9 | 22814 | 12757 | 12757 | 12757 | 12757 | 12757 | 12757 | 12748 | 12748 | 12373 | 11788 | 11788 | 11788 |  |
| 10 | 22793 | 12669 | 12669 | 12669 | 12552 | 12552 | 12552 | 12552 | 12552 | 12552 | 12552 | 12552 | 12552 |  |
| Średnia | 22933,1 | 11331,6 | 11331,6 | 11309,4 | 11297,7 | 11296,4 | 11296,4 | 11295,5 | 11295,5 | 11258 | 11199,5 | 11199,5 | 11199,5 |  |
| Błąd | 232% | 64% | 64% | 64% | 64% | 64% | 64% | 64% | 64% | 63% | 62% | 62% | 62% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 53 Miasta, Populacja 500, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 21869 | 9057 | 9057 | 9057 | 9057 | 9057 | 9057 | 9057 | 9057 | 9057 | 9057 | 9057 | 9057 | 6905 |
| 2 | 22795 | 8755 | 8755 | 8755 | 8755 | 8755 | 8755 | 8755 | 8755 | 8747 | 8747 | 8747 | 8747 |  |
| 3 | 21594 | 7964 | 7964 | 7964 | 7964 | 7964 | 7914 | 7914 | 7914 | 7914 | 7914 | 7839 | 7839 |  |
| 4 | 22323 | 8444 | 8444 | 8444 | 8444 | 8444 | 8444 | 8444 | 8444 | 8444 | 8444 | 8444 | 8444 |  |
| 5 | 22395 | 8506 | 8506 | 8506 | 8506 | 8506 | 8506 | 8506 | 8506 | 8506 | 8506 | 8506 | 8506 |  |
| 6 | 21801 | 9059 | 9059 | 9059 | 9059 | 9059 | 9059 | 9059 | 9059 | 9059 | 9059 | 9059 | 9059 |  |
| 7 | 22350 | 9037 | 9037 | 9037 | 9037 | 9037 | 9037 | 9037 | 9037 | 9037 | 9037 | 9037 | 9037 |  |
| 8 | 22003 | 8150 | 8150 | 8150 | 8150 | 8150 | 8150 | 8150 | 8150 | 8150 | 8150 | 8150 | 8150 |  |
| 9 | 23103 | 8806 | 8806 | 8806 | 8806 | 8806 | 8806 | 8806 | 8806 | 8806 | 8806 | 8806 | 8806 |  |
| 10 | 22557 | 8799 | 8799 | 8799 | 8799 | 8799 | 8799 | 8799 | 8799 | 8799 | 8799 | 8799 | 8799 |  |
| Średnia | 22279 | 8657,7 | 8657,7 | 8657,7 | 8657,7 | 8657,7 | 8652,7 | 8652,7 | 8652,7 | 8651,9 | 8651,9 | 8644,4 | 8644,4 |  |
| Błąd | 223% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 53 Miasta, Populacja 1000, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 22104 | 9387 | 7400 | 7400 | 7400 | 7400 | 7400 | 7400 | 7400 | 7400 | 7400 | 7400 | 7400 | 6905 |
| 2 | 22545 | 8743 | 8743 | 8743 | 8743 | 8743 | 8743 | 8743 | 8743 | 8743 | 8743 | 8670 | 8670 |  |
| 3 | 22105 | 9392 | 8218 | 8218 | 8218 | 8218 | 8218 | 8218 | 8218 | 8218 | 8218 | 8218 | 8218 |  |
| 4 | 22025 | 8169 | 8066 | 8066 | 8066 | 8066 | 8066 | 8066 | 8066 | 8066 | 8066 | 8066 | 8066 |  |
| 5 | 21860 | 8381 | 7606 | 7606 | 7606 | 7606 | 7606 | 7606 | 7606 | 7606 | 7606 | 7606 | 7606 |  |
| 6 | 21593 | 8461 | 7336 | 7336 | 7336 | 7336 | 7336 | 7336 | 7336 | 7336 | 7336 | 7336 | 7336 |  |
| 7 | 21501 | 9090 | 8213 | 8213 | 8213 | 8213 | 8213 | 8213 | 8213 | 8213 | 8213 | 8211 | 8211 |  |
| 8 | 21684 | 8406 | 7854 | 7854 | 7854 | 7854 | 7854 | 7854 | 7854 | 7854 | 7854 | 7854 | 7854 |  |
| 9 | 22275 | 9130 | 8625 | 8625 | 8625 | 8625 | 8625 | 8625 | 8625 | 8625 | 8625 | 8625 | 8625 |  |
| 10 | 22224 | 8230 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 |  |
| Średnia | 21991,6 | 8738,9 | 7995,5 | 7995,5 | 7995,5 | 7995,5 | 7995,5 | 7995,5 | 7995,5 | 7995,5 | 7995,5 | 7988 | 7988 |  |
| Błąd | 218% | 27% | 16% | 16% | 16% | 16% | 16% | 16% | 16% | 16% | 16% | 16% | 16% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 53 Miasta, Populacja 100, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 22597 | 10257 | 10077 | 10077 | 10077 | 10077 | 10077 | 10077 | 10077 | 10077 | 10077 | 10077 | 10077 | 6905 |
| 2 | 23010 | 10916 | 10575 | 10575 | 10575 | 10575 | 10575 | 10575 | 10575 | 10575 | 10575 | 10575 | 10575 |  |
| 3 | 22109 | 11811 | 11811 | 10364 | 10364 | 10364 | 10364 | 10364 | 10364 | 10364 | 10364 | 10364 | 10364 |  |
| 4 | 22525 | 13172 | 13172 | 13172 | 13172 | 13172 | 13172 | 13172 | 13142 | 13142 | 13142 | 13142 | 13142 |  |
| 5 | 22420 | 11244 | 11244 | 11244 | 11244 | 11244 | 11244 | 11244 | 11244 | 11244 | 11244 | 11244 | 11244 |  |
| 6 | 21523 | 11314 | 11314 | 11180 | 11180 | 11180 | 11180 | 11180 | 11180 | 11180 | 11180 | 11180 | 11180 |  |
| 7 | 22718 | 9990 | 9990 | 9990 | 9990 | 9990 | 9990 | 9990 | 9990 | 9990 | 9990 | 9990 | 9990 |  |
| 8 | 21835 | 11151 | 11030 | 11030 | 11030 | 11030 | 11030 | 11030 | 11030 | 11020 | 10943 | 10943 | 10943 |  |
| 9 | 23171 | 10080 | 10080 | 10080 | 10080 | 10080 | 10080 | 10080 | 10080 | 10061 | 10061 | 10061 | 10061 |  |
| 10 | 22862 | 12206 | 12206 | 12206 | 12206 | 12206 | 12206 | 12198 | 12198 | 12198 | 12189 | 12189 | 12189 |  |
| Średnia | 22477 | 11214,1 | 11149,9 | 10991,8 | 10991,8 | 10991,8 | 10991,8 | 10991 | 10988 | 10985,1 | 10976,5 | 10976,5 | 10976,5 |  |
| Błąd | 226% | 62% | 61% | 59% | 59% | 59% | 59% | 59% | 59% | 59% | 59% | 59% | 59% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 53 Miasta, Populacja 500, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 21932 | 8868 | 8825 | 8824 | 8824 | 8824 | 8824 | 8824 | 8824 | 8824 | 8824 | 8824 | 8824 | 6905 |
| 2 | 22213 | 9526 | 9526 | 9526 | 9526 | 9526 | 9526 | 9526 | 9526 | 9526 | 9526 | 9526 | 9472 |  |
| 3 | 22742 | 8412 | 8412 | 8412 | 8412 | 8412 | 8412 | 8412 | 8412 | 8412 | 8412 | 8412 | 8412 |  |
| 4 | 21453 | 8415 | 8415 | 8415 | 8415 | 8415 | 8415 | 8415 | 8415 | 8415 | 8415 | 8415 | 8415 |  |
| 5 | 21869 | 8561 | 8561 | 8561 | 8561 | 8243 | 8243 | 8243 | 8243 | 8243 | 8243 | 8243 | 8243 |  |
| 6 | 22667 | 9052 | 9052 | 9052 | 9052 | 9052 | 9052 | 9052 | 9052 | 9052 | 9052 | 9052 | 9052 |  |
| 7 | 21284 | 8732 | 8732 | 8732 | 8732 | 8732 | 8732 | 8732 | 8732 | 8732 | 8719 | 8719 | 8719 |  |
| 8 | 22452 | 9803 | 9803 | 9803 | 9803 | 9803 | 9803 | 9803 | 9803 | 9803 | 9803 | 9803 | 9803 |  |
| 9 | 21557 | 8558 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 |  |
| 10 | 20997 | 9673 | 9673 | 9673 | 9673 | 9673 | 9673 | 9673 | 9673 | 9673 | 9673 | 9673 | 9673 |  |
| Średnia | 21916,6 | 8960 | 8948,3 | 8948,2 | 8948,2 | 8916,4 | 8916,4 | 8916,4 | 8916,4 | 8916,4 | 8915,1 | 8915,1 | 8909,7 |  |
| Błąd | 217% | 30% | 30% | 30% | 30% | 29% | 29% | 29% | 29% | 29% | 29% | 29% | 29% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 53 Miasta, Populacja 1000, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 21359 | 8860 | 8547 | 8538 | 8538 | 8538 | 8538 | 8538 | 8538 | 8401 | 8401 | 8401 | 8401 | 6905 |
| 2 | 22026 | 8895 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 | 8484 |  |
| 3 | 21945 | 9149 | 8091 | 8091 | 8091 | 8091 | 8091 | 8091 | 8091 | 8091 | 8091 | 8091 | 8091 |  |
| 4 | 21966 | 9665 | 8407 | 8407 | 8407 | 8407 | 8407 | 8407 | 8407 | 8407 | 8407 | 8407 | 8407 |  |
| 5 | 21921 | 8006 | 8006 | 8006 | 8006 | 8006 | 8006 | 8006 | 8006 | 8006 | 8006 | 8006 | 8006 |  |
| 6 | 21072 | 8798 | 8798 | 8798 | 8798 | 8798 | 8798 | 8798 | 8798 | 8798 | 8798 | 8798 | 8798 |  |
| 7 | 21643 | 8485 | 8368 | 8368 | 8368 | 8368 | 8368 | 8368 | 8368 | 8368 | 8368 | 8368 | 8368 |  |
| 8 | 21516 | 8777 | 8165 | 8165 | 8165 | 8165 | 8165 | 8165 | 8165 | 8165 | 8165 | 8165 | 8165 |  |
| 9 | 21796 | 8366 | 8117 | 8117 | 8117 | 8117 | 8117 | 8117 | 8117 | 8117 | 8117 | 8117 | 8117 |  |
| 10 | 21217 | 9139 | 8976 | 8976 | 8976 | 8976 | 8976 | 8976 | 8976 | 8738 | 8738 | 8738 | 8738 |  |
| Średnia | 21646,1 | 8814 | 8395,9 | 8395 | 8395 | 8395 | 8395 | 8395 | 8395 | 8357,5 | 8357,5 | 8357,5 | 8357,5 |  |
| Błąd | 213% | 28% | 22% | 22% | 22% | 22% | 22% | 22% | 22% | 21% | 21% | 21% | 21% |  |

170 Miast

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 170 Miast, Populacja 100, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 23163 | 14067 | 14067 | 14067 | 14067 | 14067 | 14067 | 14067 | 14067 | 14067 | 14067 | 14067 | 14067 | 2755 |
| 2 | 24818 | 11798 | 11798 | 11798 | 11798 | 11798 | 11798 | 11451 | 11451 | 11451 | 11451 | 11451 | 11451 |  |
| 3 | 24308 | 12905 | 12905 | 12905 | 12838 | 12838 | 12838 | 12838 | 12838 | 12838 | 12838 | 12838 | 12838 |  |
| 4 | 23945 | 12057 | 12057 | 12057 | 12057 | 12057 | 12057 | 12057 | 12057 | 12057 | 12057 | 11745 | 11745 |  |
| 5 | 23982 | 13712 | 13712 | 13712 | 13712 | 13712 | 13712 | 13712 | 13712 | 13712 | 13712 | 13712 | 13712 |  |
| 6 | 24302 | 14070 | 14070 | 14070 | 14070 | 13487 | 13487 | 13487 | 13487 | 13487 | 13296 | 13296 | 13296 |  |
| 7 | 24086 | 13341 | 12651 | 12651 | 12651 | 12651 | 12651 | 12651 | 12651 | 12651 | 12651 | 12651 | 12651 |  |
| 8 | 24590 | 14678 | 13413 | 13413 | 13413 | 13413 | 13413 | 13413 | 13413 | 13413 | 13411 | 13411 | 13411 |  |
| 9 | 23869 | 11883 | 11883 | 11883 | 11883 | 11883 | 11883 | 11883 | 11883 | 11883 | 11883 | 11813 | 11813 |  |
| 10 | 24432 | 12437 | 12437 | 12094 | 11966 | 11966 | 11966 | 11966 | 11966 | 11966 | 11966 | 11966 | 11966 |  |
| Średnia | 24149,5 | 13094,8 | 12899,3 | 12865 | 12845,5 | 12787,2 | 12787,2 | 12752,5 | 12752,5 | 12752,5 | 12733,2 | 12695 | 12695 |  |
| Błąd | 777% | 375% | 368% | 367% | 366% | 364% | 364% | 363% | 363% | 363% | 362% | 361% | 361% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 170 Miast, Populacja 500, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 23253 | 14709 | 9374 | 9296 | 9296 | 9296 | 9296 | 9296 | 9296 | 9296 | 9296 | 9296 | 9296 | 2755 |
| 2 | 23849 | 15287 | 8907 | 8907 | 8907 | 8907 | 8907 | 8907 | 8907 | 8907 | 8907 | 8907 | 8907 |  |
| 3 | 23316 | 15220 | 8702 | 8702 | 8702 | 8702 | 8702 | 8702 | 8702 | 8702 | 8702 | 8702 | 8702 |  |
| 4 | 23812 | 15065 | 9812 | 9812 | 9812 | 9812 | 9812 | 9812 | 9812 | 9812 | 9812 | 9812 | 9812 |  |
| 5 | 23449 | 15024 | 8886 | 8886 | 8886 | 8886 | 8886 | 8886 | 8886 | 8886 | 8886 | 8886 | 8886 |  |
| 6 | 23920 | 14866 | 9226 | 9226 | 9226 | 9226 | 9226 | 9226 | 9226 | 9226 | 9226 | 9226 | 9226 |  |
| 7 | 24148 | 14822 | 9853 | 9853 | 9853 | 9853 | 9853 | 9853 | 9853 | 9853 | 9853 | 9853 | 9853 |  |
| 8 | 23146 | 14256 | 9256 | 9055 | 9055 | 9055 | 9055 | 9055 | 9055 | 9055 | 9055 | 9055 | 9055 |  |
| 9 | 22766 | 13333 | 11480 | 11480 | 11480 | 11480 | 11480 | 11480 | 11349 | 11349 | 11349 | 11349 | 11349 |  |
| 10 | 23955 | 13910 | 9813 | 9753 | 9645 | 9645 | 9645 | 9645 | 9645 | 9645 | 9645 | 9645 | 9645 |  |
| Średnia | 23561,4 | 14649,2 | 9530,9 | 9497 | 9486,2 | 9486,2 | 9486,2 | 9486,2 | 9473,1 | 9473,1 | 9473,1 | 9473,1 | 9473,1 |  |
| Błąd | 755% | 432% | 246% | 245% | 244% | 244% | 244% | 244% | 244% | 244% | 244% | 244% | 244% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 170 Miast, Populacja 1000, Scramble | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 23502 | 17321 | 8342 | 8342 | 8342 | 8342 | 8342 | 8342 | 8342 | 8342 | 8342 | 8342 | 8342 | 2755 |
| 2 | 23858 | 17059 | 8641 | 8641 | 8641 | 8641 | 8496 | 8496 | 8496 | 8496 | 8496 | 8496 | 8453 |  |
| 3 | 23656 | 17599 | 9787 | 9787 | 9787 | 9787 | 9787 | 9787 | 9787 | 9787 | 9787 | 9787 | 9787 |  |
| 4 | 24197 | 17569 | 8995 | 8917 | 8917 | 8917 | 8917 | 8917 | 8917 | 8917 | 8917 | 8917 | 8917 |  |
| 5 | 24084 | 18012 | 7608 | 7608 | 7608 | 7608 | 7608 | 7608 | 7608 | 7608 | 7608 | 7608 | 7608 |  |
| 6 | 23708 | 18005 | 8797 | 8797 | 8797 | 8797 | 8797 | 8797 | 8797 | 8797 | 8797 | 8797 | 8797 |  |
| 7 | 23979 | 17427 | 8027 | 8027 | 8027 | 8027 | 8027 | 8027 | 8027 | 8027 | 8027 | 8027 | 8027 |  |
| 8 | 23143 | 17855 | 7912 | 7912 | 7912 | 7912 | 7912 | 7912 | 7912 | 7912 | 7912 | 7912 | 7912 |  |
| 9 | 24043 | 17358 | 7761 | 7761 | 7761 | 7761 | 7761 | 7761 | 7761 | 7761 | 7761 | 7761 | 7761 |  |
| 10 | 22857 | 18079 | 8370 | 8370 | 8370 | 8370 | 8370 | 8370 | 8370 | 8370 | 8317 | 8317 | 8317 |  |
| Średnia | 23702,7 | 17628,4 | 8424 | 8416,2 | 8416,2 | 8416,2 | 8401,7 | 8401,7 | 8401,7 | 8401,7 | 8396,4 | 8396,4 | 8392,1 |  |
| Błąd | 760% | 540% | 206% | 205% | 205% | 205% | 205% | 205% | 205% | 205% | 205% | 205% | 205% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 170 Miast, Populacja 100, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 24365 | 13236 | 13221 | 13221 | 13221 | 13221 | 13221 | 13221 | 13221 | 13221 | 12825 | 12825 | 12825 | 2755 |
| 2 | 23788 | 13276 | 13276 | 13276 | 13276 | 13276 | 13276 | 13276 | 13276 | 13276 | 13276 | 13276 | 13276 |  |
| 3 | 23651 | 16296 | 16296 | 16296 | 16296 | 16296 | 16296 | 16296 | 16296 | 16296 | 16296 | 15923 | 15923 |  |
| 4 | 23980 | 14918 | 14918 | 14918 | 14918 | 14918 | 14918 | 14918 | 14918 | 14918 | 14918 | 14918 | 14918 |  |
| 5 | 24534 | 14046 | 14046 | 14046 | 14046 | 14046 | 14046 | 14046 | 14046 | 13955 | 13955 | 13955 | 13955 |  |
| 6 | 24053 | 14292 | 13060 | 13060 | 13060 | 13022 | 12373 | 12373 | 12373 | 12373 | 12373 | 12373 | 12373 |  |
| 7 | 24165 | 13607 | 13561 | 13561 | 13561 | 13561 | 13561 | 13561 | 13561 | 13561 | 13561 | 13561 | 13561 |  |
| 8 | 23978 | 12361 | 12361 | 12361 | 12361 | 12361 | 12361 | 12361 | 12361 | 12361 | 12361 | 12361 | 12361 |  |
| 9 | 24274 | 13390 | 13390 | 13390 | 13390 | 13390 | 13390 | 13390 | 13390 | 13297 | 13297 | 13297 | 13297 |  |
| 10 | 24027 | 12772 | 12772 | 12772 | 12772 | 12772 | 12772 | 12772 | 12772 | 12772 | 12772 | 12549 | 12549 |  |
| Średnia | 24081,5 | 13819,4 | 13690,1 | 13690,1 | 13690,1 | 13686,3 | 13621,4 | 13621,4 | 13621,4 | 13603 | 13563,4 | 13503,8 | 13503,8 |  |
| Błąd | 774% | 402% | 397% | 397% | 397% | 397% | 394% | 394% | 394% | 394% | 392% | 390% | 390% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 170 Miast, Populacja 500, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 24257 | 14108 | 9720 | 9720 | 9720 | 9720 | 9720 | 9720 | 9720 | 9720 | 9720 | 9720 | 9720 | 2755 |
| 2 | 24205 | 13781 | 9551 | 9551 | 9551 | 9551 | 9551 | 9551 | 9551 | 9551 | 9551 | 9551 | 9551 |  |
| 3 | 23395 | 14671 | 9750 | 9750 | 9750 | 9750 | 9750 | 9750 | 9750 | 9750 | 9750 | 9750 | 9750 |  |
| 4 | 23454 | 14874 | 9290 | 9290 | 9290 | 9290 | 9290 | 9290 | 9290 | 9290 | 9290 | 9290 | 9290 |  |
| 5 | 23919 | 14382 | 8720 | 8720 | 8720 | 8720 | 8720 | 8720 | 8720 | 8720 | 8720 | 8720 | 8720 |  |
| 6 | 24007 | 14081 | 8911 | 8911 | 8911 | 8911 | 8911 | 8911 | 8911 | 8911 | 8911 | 8911 | 8911 |  |
| 7 | 23398 | 13556 | 10560 | 10560 | 10560 | 10560 | 10560 | 10560 | 10560 | 10560 | 10560 | 10560 | 10560 |  |
| 8 | 24095 | 14729 | 10284 | 10284 | 9898 | 9898 | 9898 | 9898 | 9898 | 9898 | 9898 | 9898 | 9898 |  |
| 9 | 23930 | 14749 | 8775 | 8775 | 8775 | 8775 | 8775 | 8775 | 8775 | 8775 | 8741 | 8741 | 8741 |  |
| 10 | 24135 | 14111 | 9679 | 9679 | 9679 | 9679 | 9679 | 9679 | 9679 | 9679 | 9679 | 9679 | 9679 |  |
| Średnia | 23879,5 | 14304,2 | 9524 | 9524 | 9485,4 | 9485,4 | 9485,4 | 9485,4 | 9485,4 | 9485,4 | 9482 | 9482 | 9482 |  |
| Błąd | 767% | 419% | 246% | 246% | 244% | 244% | 244% | 244% | 244% | 244% | 244% | 244% | 244% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Genetyczny 170 Miast, Populacja 1000, Inversion | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 23836 | 17637 | 9275 | 9252 | 9252 | 9252 | 9252 | 9252 | 9252 | 9252 | 9252 | 9252 | 9252 | 2755 |
| 2 | 23261 | 17182 | 7553 | 7553 | 7553 | 7553 | 7553 | 7553 | 7553 | 7553 | 7553 | 7553 | 7553 |  |
| 3 | 23800 | 17394 | 8080 | 8080 | 8080 | 8080 | 8080 | 8080 | 8080 | 8080 | 8080 | 8080 | 8080 |  |
| 4 | 23734 | 17487 | 8742 | 8742 | 8742 | 8742 | 8742 | 8742 | 8742 | 8742 | 8742 | 8742 | 8742 |  |
| 5 | 23216 | 17543 | 8760 | 8736 | 8736 | 8736 | 8736 | 8736 | 8736 | 8736 | 8736 | 8736 | 8736 |  |
| 6 | 23746 | 18095 | 8608 | 8608 | 8608 | 8608 | 8608 | 8608 | 8608 | 8608 | 8608 | 8608 | 8608 |  |
| 7 | 23561 | 17242 | 8408 | 8408 | 8408 | 8408 | 8408 | 8408 | 8408 | 8408 | 8408 | 8408 | 8408 |  |
| 8 | 23889 | 17205 | 7633 | 7633 | 7633 | 7633 | 7633 | 7633 | 7633 | 7633 | 7633 | 7633 | 7633 |  |
| 9 | 23841 | 17260 | 7634 | 7634 | 7634 | 7634 | 7634 | 7634 | 7634 | 7634 | 7634 | 7634 | 7634 |  |
| 10 | 23695 | 17652 | 8854 | 8854 | 8854 | 8854 | 8854 | 8854 | 8854 | 8854 | 8854 | 8854 | 8854 |  |
| Średnia | 23657,9 | 17469,7 | 8354,7 | 8350 | 8350 | 8350 | 8350 | 8350 | 8350 | 8350 | 8350 | 8350 | 8350 |  |
| Błąd | 759% | 534% | 203% | 203% | 203% | 203% | 203% | 203% | 203% | 203% | 203% | 203% | 203% |  |

**Porównanie z Tabu Search**

Wyniki z poprzedniego zadania:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Tabu Search (17 miast) | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 280 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 39 |
| 2 | 213 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 3 | 218 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |  |
| 4 | 264 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |  |
| 5 | 108 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |  |
| 6 | 252 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |  |
| 7 | 214 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |  |
| 8 | 259 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |  |
| 9 | 203 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |  |
| 10 | 276 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |  |
| Średnia | 228,7 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 | 45,8 |  |
| Błąd | 486% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Tabu Search (53 miasta) | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 26 441 | 10348 | 10348 | 10348 | 10348 | 10348 | 10348 | 10348 | 10348 | 10348 | 10348 | 10348 | 10348 | 6905 |
| 2 | 26713 | 10596 | 10596 | 10596 | 10596 | 10596 | 10596 | 10596 | 10596 | 10596 | 10596 | 10596 | 10596 |  |
| 3 | 25900 | 11361 | 11361 | 11361 | 11361 | 11361 | 11361 | 11361 | 11361 | 11361 | 11361 | 11361 | 11361 |  |
| 4 | 25028 | 10409 | 10409 | 10409 | 10409 | 10409 | 10409 | 10409 | 10409 | 10409 | 10409 | 10409 | 10409 |  |
| 5 | 26452 | 10127 | 10127 | 10127 | 10127 | 10127 | 10127 | 10127 | 10127 | 10127 | 10127 | 10127 | 10127 |  |
| 6 | 27111 | 10089 | 10089 | 10089 | 10089 | 10089 | 10089 | 10089 | 10089 | 10089 | 10089 | 10089 | 10089 |  |
| 7 | 25825 | 10261 | 10261 | 10261 | 10261 | 10261 | 10261 | 10261 | 10261 | 10261 | 10261 | 10261 | 10261 |  |
| 8 | 26627 | 11346 | 11346 | 11346 | 11346 | 11346 | 11346 | 11346 | 11346 | 11346 | 11346 | 11346 | 11346 |  |
| 9 | 25144 | 11163 | 11163 | 11163 | 11163 | 11163 | 11163 | 11163 | 11163 | 11163 | 11163 | 11163 | 11163 |  |
| 10 | 25788 | 10871 | 10871 | 10871 | 10871 | 10871 | 10871 | 10871 | 10871 | 10871 | 10871 | 10871 | 10871 |  |
| Średnia | 26102,9 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 | 10657,1 |  |
| Błąd | 278% | 54% | 54% | 54% | 54% | 54% | 54% | 54% | 54% | 54% | 54% | 54% | 54% |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Tabu Search (170 miast) | | | | | | | | | | | | |  |
|  | Próbka | | | | | | | | | | | | |  |
| Nr Testu | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | Najlepsza |
| 1 | 25 298 | 7533 | 7533 | 7533 | 7533 | 7533 | 7533 | 7533 | 7533 | 7533 | 7533 | 7533 | 7533 | 2755 |
| 2 | 26504 | 7743 | 7743 | 7743 | 7743 | 7743 | 7743 | 7743 | 7743 | 7743 | 7743 | 7743 | 7743 |  |
| 3 | 26562 | 6763 | 6763 | 6763 | 6763 | 6763 | 6763 | 6763 | 6763 | 6763 | 6763 | 6763 | 6763 |  |
| 4 | 26090 | 7710 | 7710 | 7710 | 7710 | 7710 | 7710 | 7710 | 7710 | 7710 | 7710 | 7710 | 7710 |  |
| 5 | 24828 | 8364 | 8364 | 8364 | 8364 | 8364 | 8364 | 8364 | 8364 | 8364 | 8364 | 8364 | 8364 |  |
| 6 | 25291 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 | 7894 |  |
| 7 | 26293 | 8927 | 8927 | 8927 | 8927 | 8927 | 8927 | 8927 | 8927 | 8927 | 8927 | 8927 | 8927 |  |
| 8 | 26936 | 7372 | 7372 | 7372 | 7372 | 7372 | 7372 | 7372 | 7372 | 7372 | 7372 | 7372 | 7372 |  |
| 9 | 26854 | 7122 | 7122 | 7122 | 7122 | 7122 | 7122 | 7122 | 7122 | 7122 | 7122 | 7122 | 7122 |  |
| 10 | 26500 | 9255 | 9255 | 9255 | 9255 | 9255 | 9255 | 9255 | 9255 | 9255 | 9255 | 9255 | 9255 |  |
| Średnia | 26115,6 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 | 7868,3 |  |
| Błąd | 848% | 186% | 186% | 186% | 186% | 186% | 186% | 186% | 186% | 186% | 186% | 186% | 186% |  |

Porównanie:

|  |  |  |  |
| --- | --- | --- | --- |
|  | TabuSearch | Genetic(Scramble) | Genetic(Invertion) |
| 17 miast | 39 | 39 | 39 |
| 53 miasta | 10089 | 7336 | 8006 |
| 170 miast | 6763 | 7608 | 7553 |

**Wnioski**

Algorytm działa poprawnie. Dla wszystkich rozmiarów problemów wraz ze wzrostem rozmiaru populacji można zaobserwować poprawę wyniku dla każdego problemu. Algorytm dobrze radzi sobie z małymi i średnimi problemami. W najlepszym przypadku znajdowane były rozwiązania o kilku- kilkudziesięcio- procentowym błędzie. Dla dużych instancji natomiast znajdowano bardzo niedobre rozwiązania. W przypadku każdego testu prócz tego z 170 miastami, Algorytm Genetyczny miał lepsze najoptymalniejsze rozwiązanie niż Tabu Search.

Skuteczność badanych metod mutacji jest do siebie zbliżona. W małym stopniu lepsze wyniki, przy mniejszych testach, otrzymano używając Scramble mutation.

Za gorsze wyniki dla dużych instancji można obarczyć optymalizację kodu. Najprawdopodobniej największy wpływ miało zastosowanie gotowego algorytmu sortowania, który do poprawnego działania używał metody obliczającej długość trasy zadanego wektora, w którym przechowywano ścieżkę. Lepsze wyniki można by także otrzymać dzięki lepszemu doborowi parametrów.

**Źródła:**

<http://staff.iiar.pwr.wroc.pl/antoni.sterna/pea/PEA_ZP_3.pdf>  
<https://www.obitko.com/tutorials/genetic-algorithms/index.php>  
<http://aragorn.pb.bialystok.pl/~wkwedlo/EA5.pdf>