

# Adv Statistics. HW2

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GitHub link: [https://github.com/almiradreamer/simulated\\_annealing](https://github.com/almiradreamer/simulated_annealing)

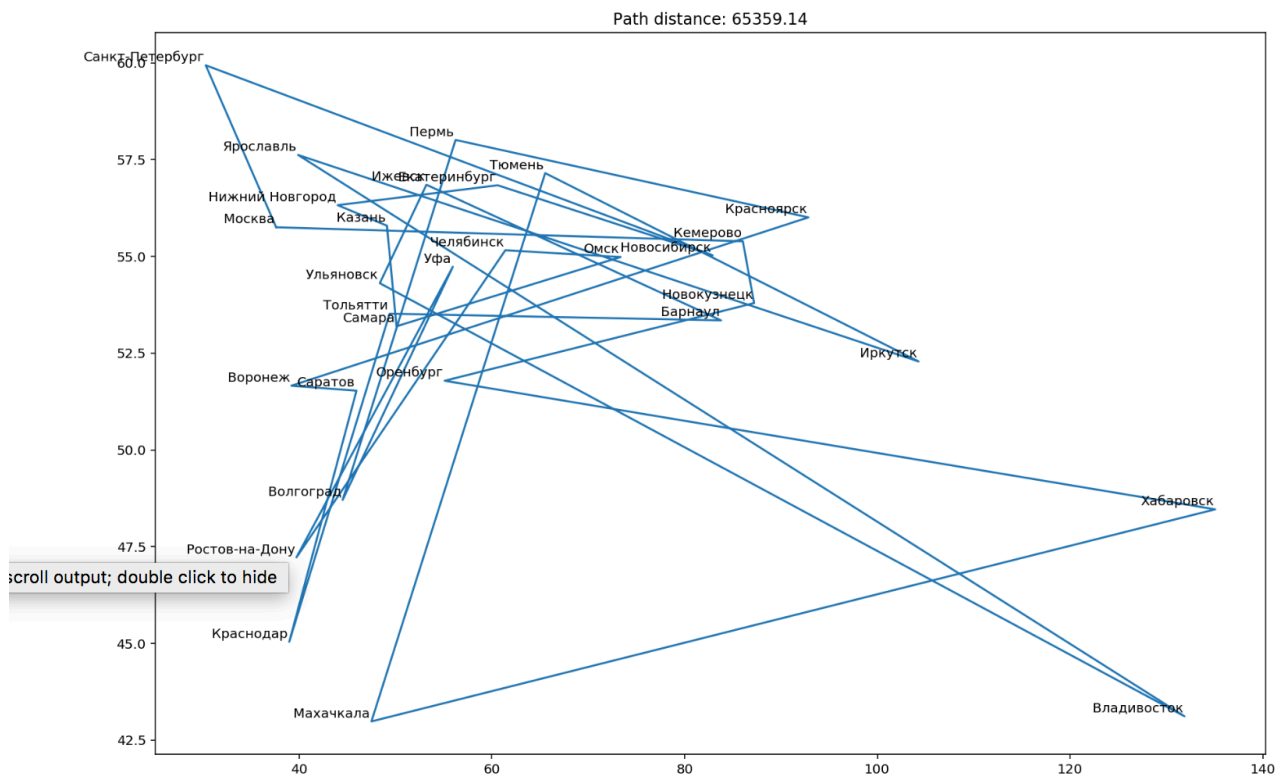
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## Task and initial data

The task is to apply Simulated Annealing to find minimum traveling salesman path among 30 most populated cities from dataset.

Город	Население	Широта	Долгота
Москва	11514330	55.753879	37.620373
Санкт-Петербург	4848742	59.939125	30.315822
Новосибирск	1498921	55.028102	82.921057
Екатеринбург	1377738	56.838633	60.605489
Нижний Новгород	1250615	56.324209	44.005395
Казань	1216965	55.794388	49.111531
Самара	1164900	53.195166	50.106769
Омск	1154000	54.984814	73.367464
Челябинск	1130273	55.160366	61.400786
Ростов-на-Дону	1091544	47.222436	39.718787
Уфа	1062300	54.734853	55.957865
Волгоград	1021244	48.707200	44.517021
Пермь	1000679	58.010321	56.234178
Красноярск	973826	56.009466	92.852416
Воронеж	889680	51.659238	39.196828
Саратов	836900	51.530376	45.953026
Краснодар	744933	45.040235	38.976080
Тольятти	719484	53.520644	49.389461
Барнаул	635585	53.348115	83.779836
Ижевск	628117	56.852744	53.211396
Ульяновск	613793	54.308067	48.374872
Владивосток	592069	43.116381	131.882348
Ярославль	591486	57.621614	39.897878
Иркутск	587225	52.286351	104.280655
Тюмень	581758	57.153082	65.534312
Махачкала	577990	42.984857	47.504630
Хабаровск	577668	48.464799	135.059881
Оренбург	570329	51.787519	55.101738
Новокузнецк	547885	53.794276	87.214405
Кемерово	532884	55.390972	86.046786

The first initial solution is to draw a path in order cities are presented in table. On a map solution looks like that. The distance of a path is around 65,000 km.



## Experiments

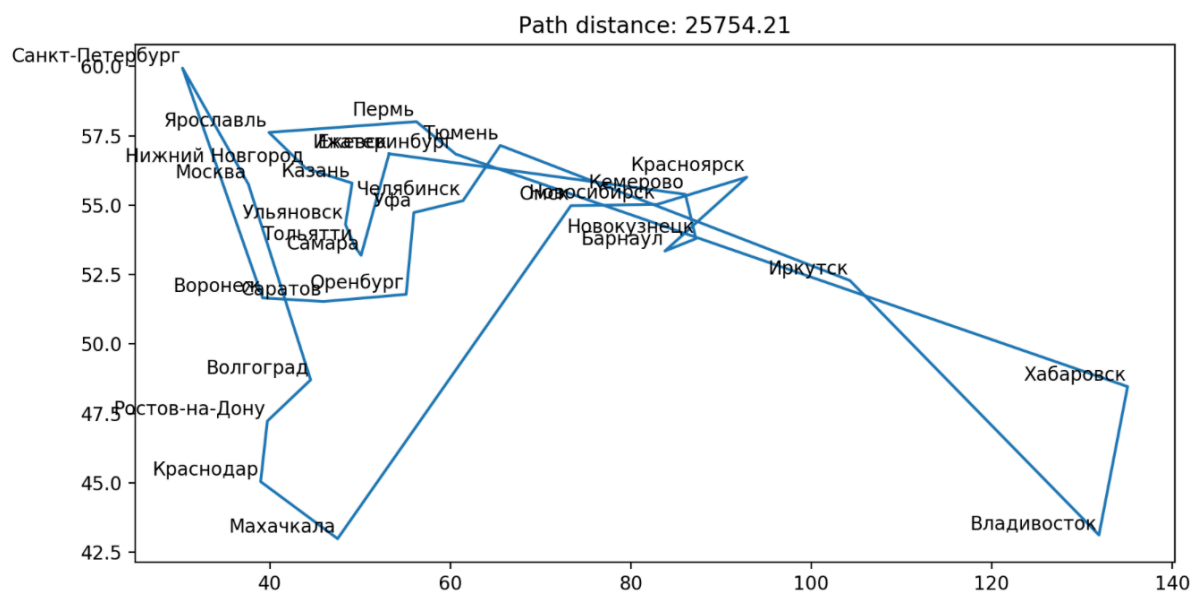
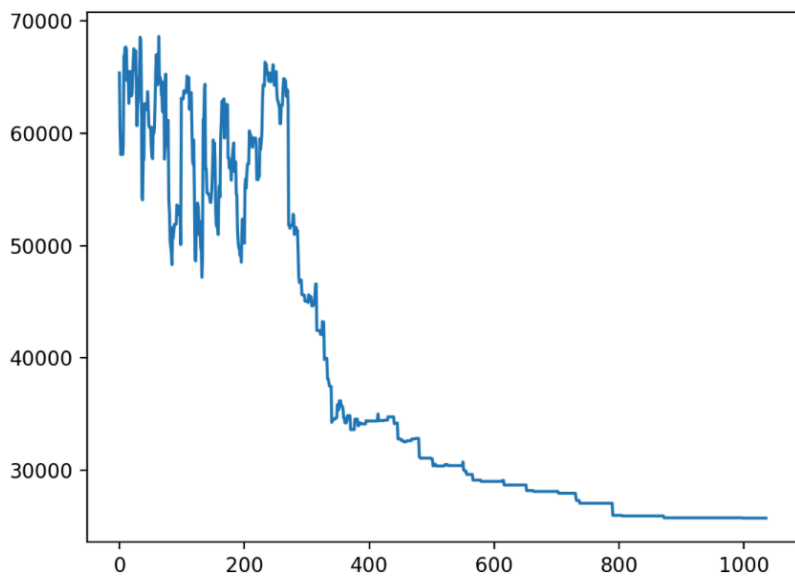
The adjustable parameter of SA algorithm is annealing rate. The higher the rate, the slower temperature cools down. I experimented with a few values for annealing rate, the results can be seen in the table and in convergence plots.

Annealing Rate	Found distance	Iterations
Rate 0.99	25754.21	1035
Rate 0.995	22821.74	2074
Rate 0.999	21198.83	10390
Rate 0.9995	22184.99	20784

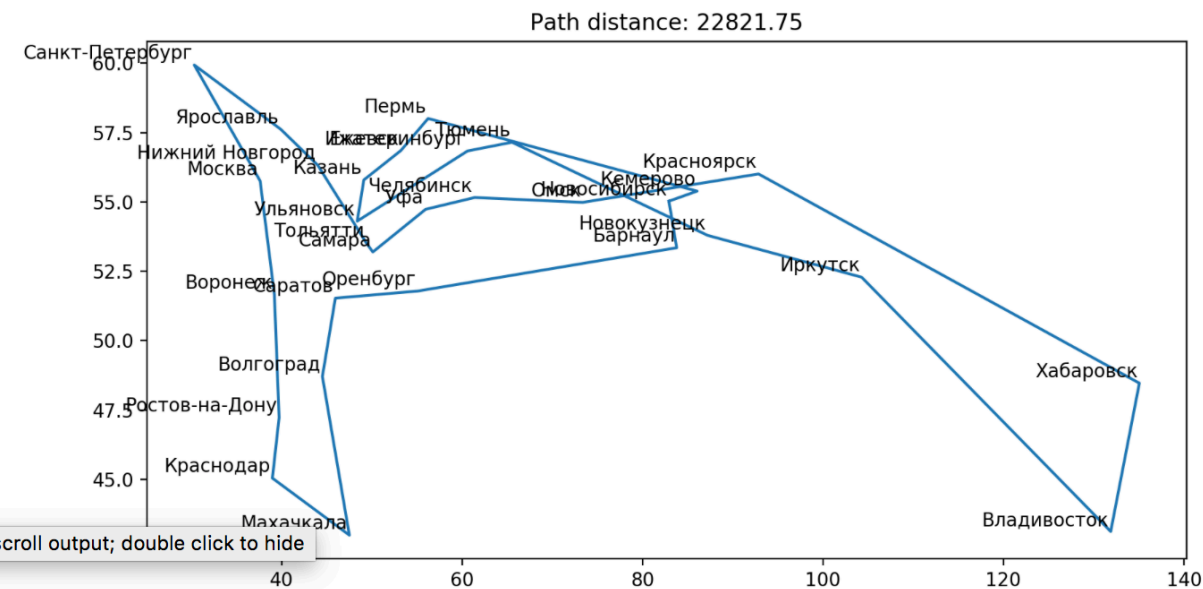
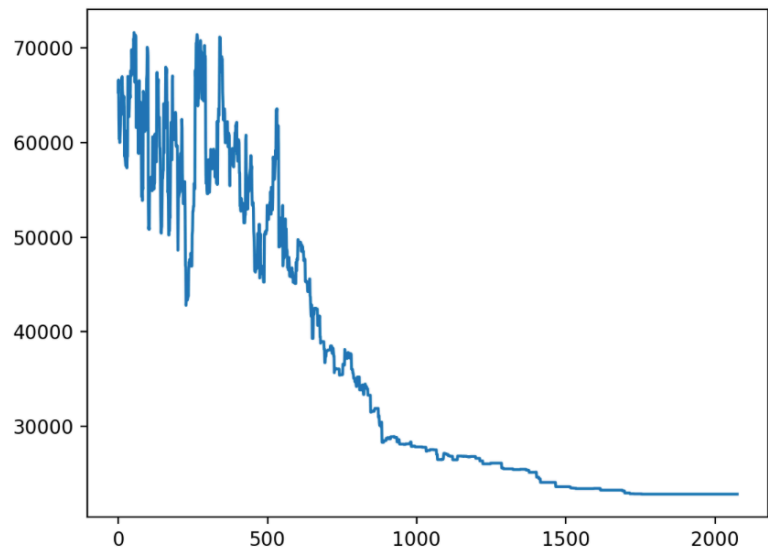
It is seen that the annealing rate (0.999) that leads to slow temperature decrease (but not very slow) finds the most optimal solution.

For each considered annealing rate plots of convergence and found optimal path are presented further.

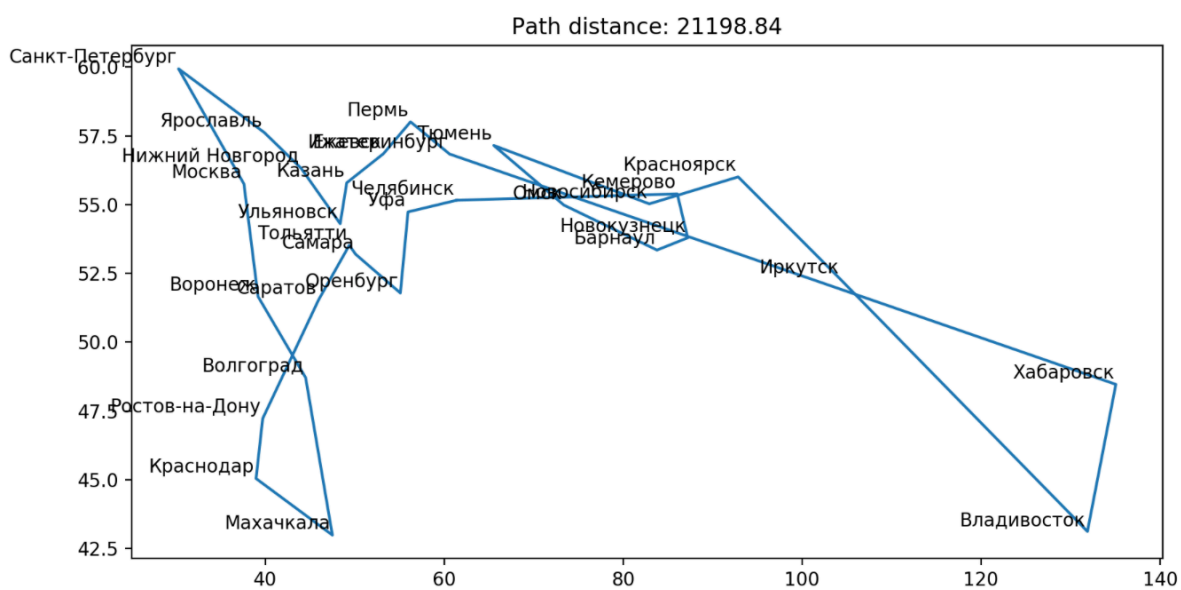
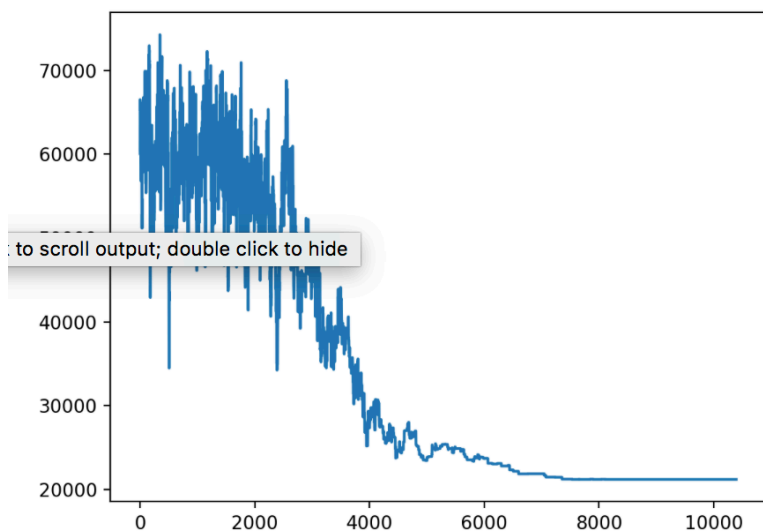
### Convergence when Rate 0.99



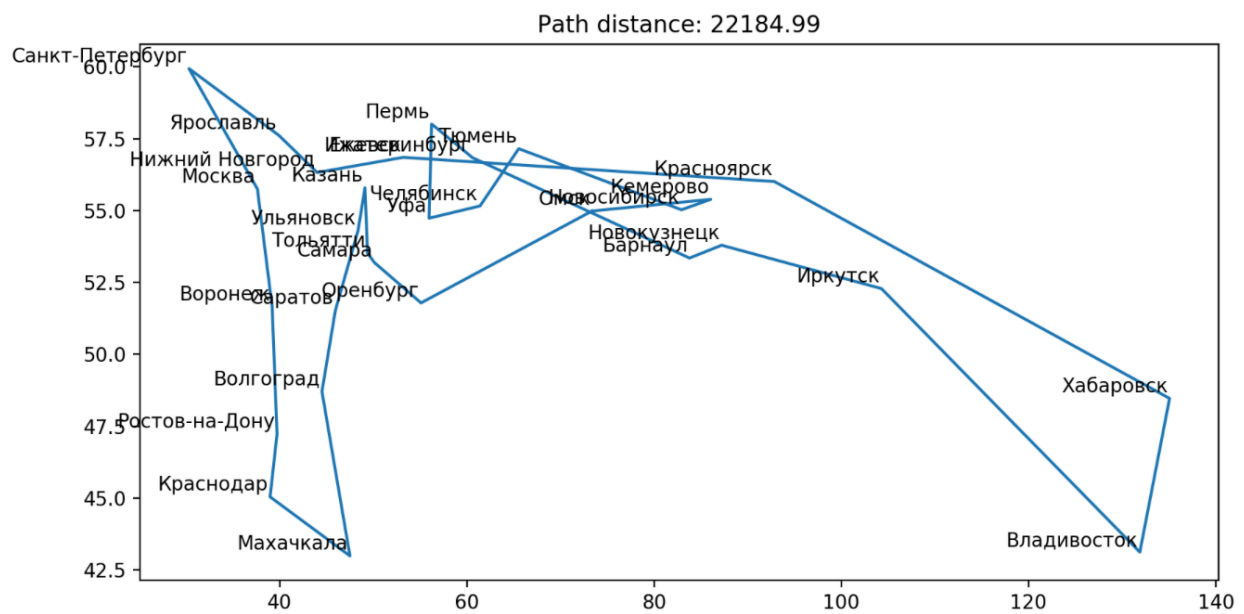
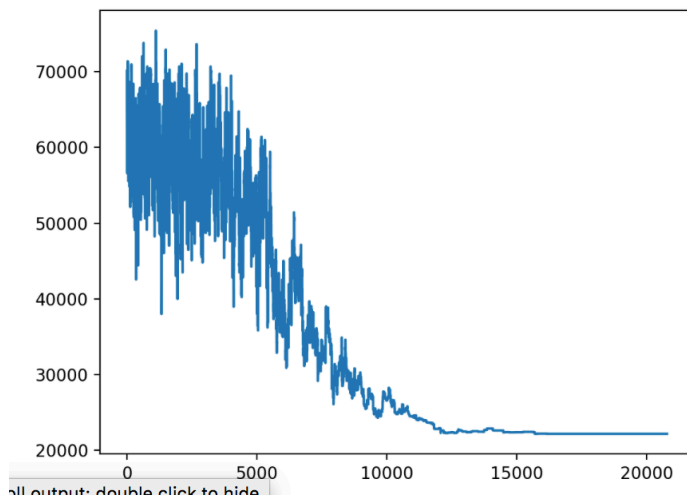
Convergence when Rate 0.995



## Convergence when Rate 0.999



## Convergence when Rate 0.9995



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## Future work

To enhance algorithm a heuristic can be added while generating new solution from previous.