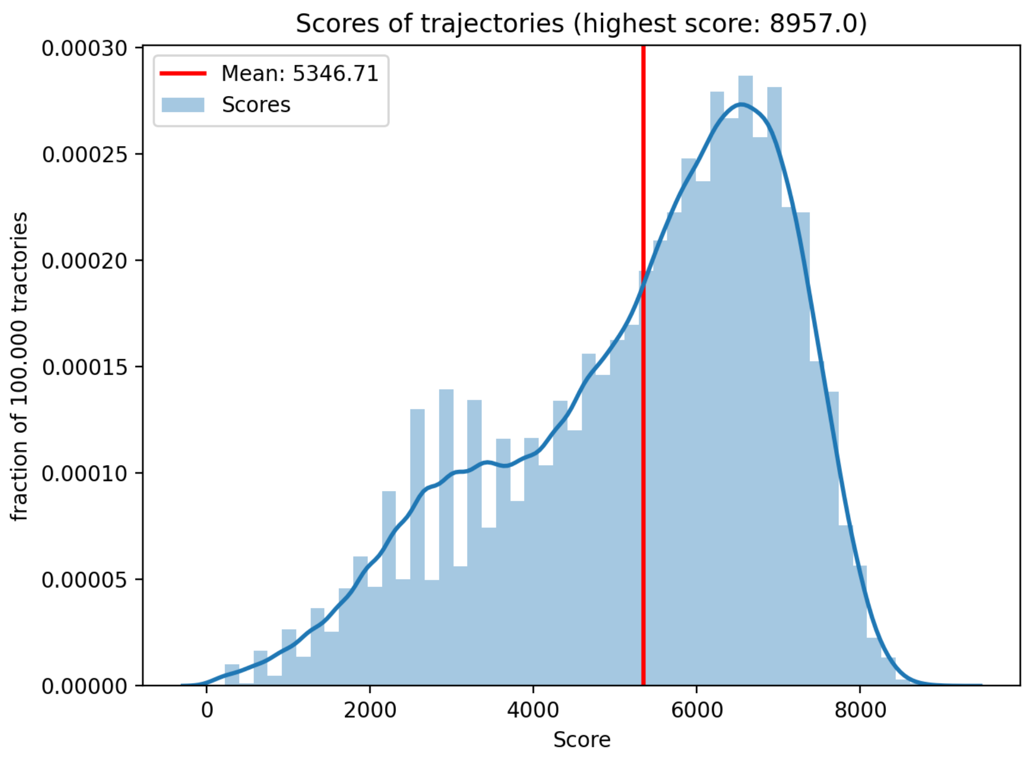
Baseline

When searching for a good solution to the RailNL case, one must ask itself a few things; what kind of solutions are feasible? What contributes to a good solution? Or how can one know that a solution is optimal? To investigate these questions, it is useful to generate some solutions randomly to see what sort solutions come up.

To start off, the case was analyzed by creating 100.000 random solutions. The assignment was: find a combination of at most seven trajectories that covers all connections in North- and South-Holland, where every trajectory takes up at most 2 hours. The second assignment was to choose the trajectories in such a way that the following function (which defines the quality of the solution) is maximized: k = p*10.000 – (100*T - Min), p stands for percentage of connections used, T is the number of trajectories and Min is the total time spend in all trajectories.

Graph A summarizes the results of the random track generator:



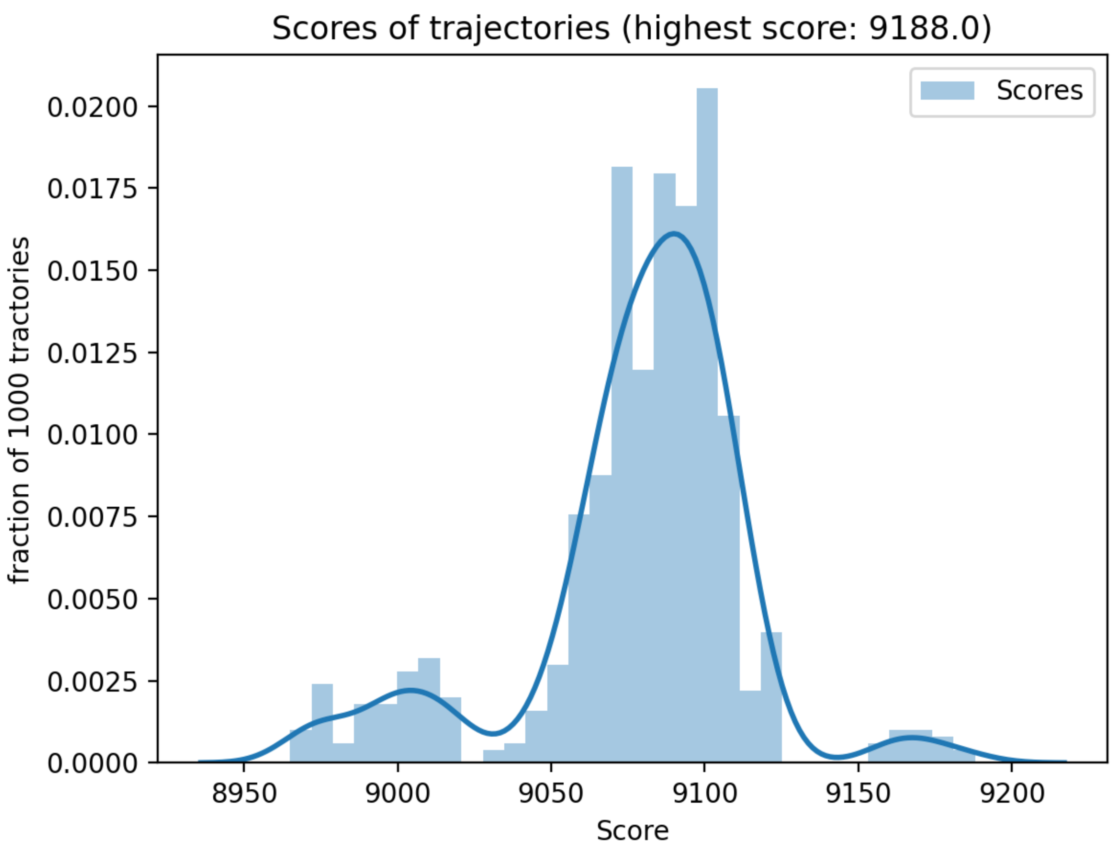
Before analyzing this graph, first some things to keep in mind. This is not a uniform sample from the state space, some constraints have been applied to the random trajectory generator. The first constraint is that a trajectory can at most take up 2 hours. The second constraint is that in the solution there are at most 7 trajectories. We constrained the random trajectory generator, because other solutions are not feasible for the problem stated in the case and are not worthwhile investigating.

First notice that the average of the simulation lies about 5300 points, which is about half the score one could possibly obtain. Secondly, all “low” scores (<5000) are mostly solutions with 1 or 2 trajectories. This is due to the fact that with 1 or 2 trajectories of at most 2 hours only very little connections are used, which is the largest contributor to amount of points scored. Thirdly, observed was that almost all high scores (>8000) seemed to have more than 4 trajectories. So what amount of trajectories is optimal? Looking at the objective function, it can be seen that the number of trajectories should be minimal (every extra trajectory yields -100 points) while using all connections (using a connection yields an increase in the score of (1/28)*10.000=357.14).

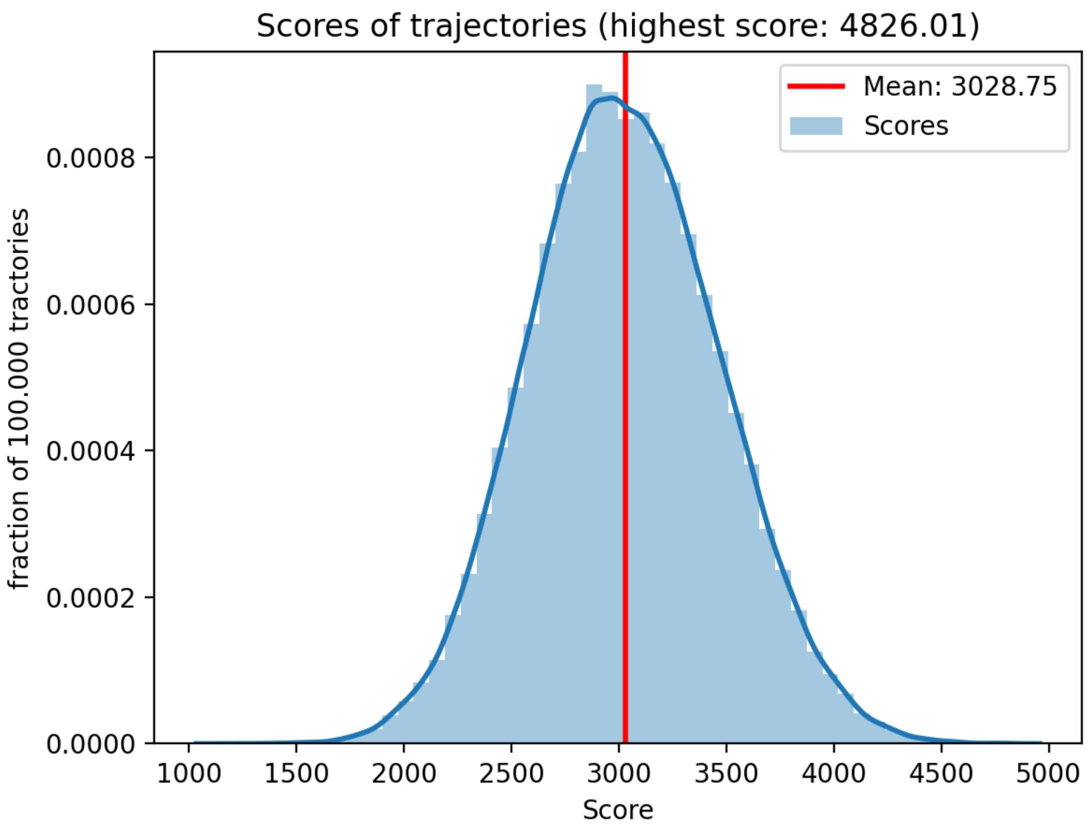
Thereby, the total time of all connections is 381 min, meaning that at least 4 trajectories of 2 hours are necessary if one intends to use all connections. All this combined yields a maximum score of 10.000-100*4-381=9219 points (all connections used, no connections used twice). The random simulation however, almost never surpasses the 9000 points, therefore other algorithms should and can do better (one of our algorithms already reached a score of 9180).

First algorithm

In the search for a better solution to the case, a new algorithm was put in action. The idea behind the algorithm was to start with a random solution containing one trajectory with a length of at most 2 or 3 hours depending on the region chosen (Holland/National). Subsequently, a new trajectory from the list of all possible trajectories (created in advance) is added to this solution, if and only if the objective function increases. This process is therefore probabilistic and not deterministic, because the starting solution differs every time the algorithm runs.
Running this “hill climber” algorithm 1000 times for Holland led to the following results:



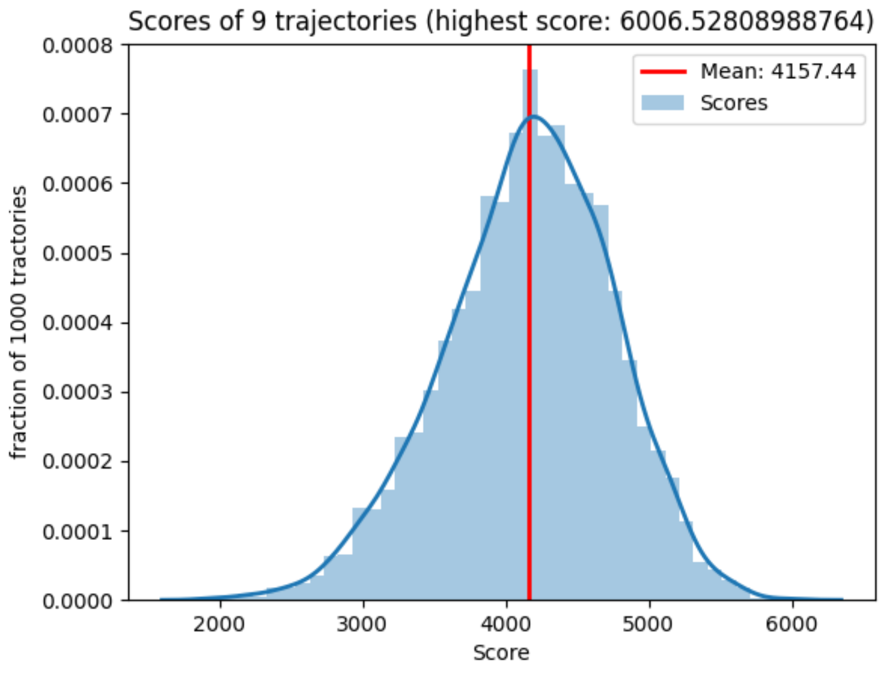
The first thing to notice is that the maximum score of 9188 is close to the best possible solution, considering that this “best” solution is not even known to be existent. It also finds a better solution than the random trajectory generator. The second thing to notice is that the scores vary much less than in the random trajectory generator; scores vary from 8950 to 9200 approximately, whereas the random solution varies from 0 to 9000. Therefore, the standard deviation is much lower than for the random trajectory generator.
The national solution is computational much heavier so running it 1000 times is not possible like in the graph above for Holland. By reasoning the optimal solution for the national problem is around 7500 points, but due to the computational complexity the best solution found is much further off. The algorithm managed to score 7100 points, which is about 2000 points better than the best solution found by the random trajectory generator (see graph on next page).

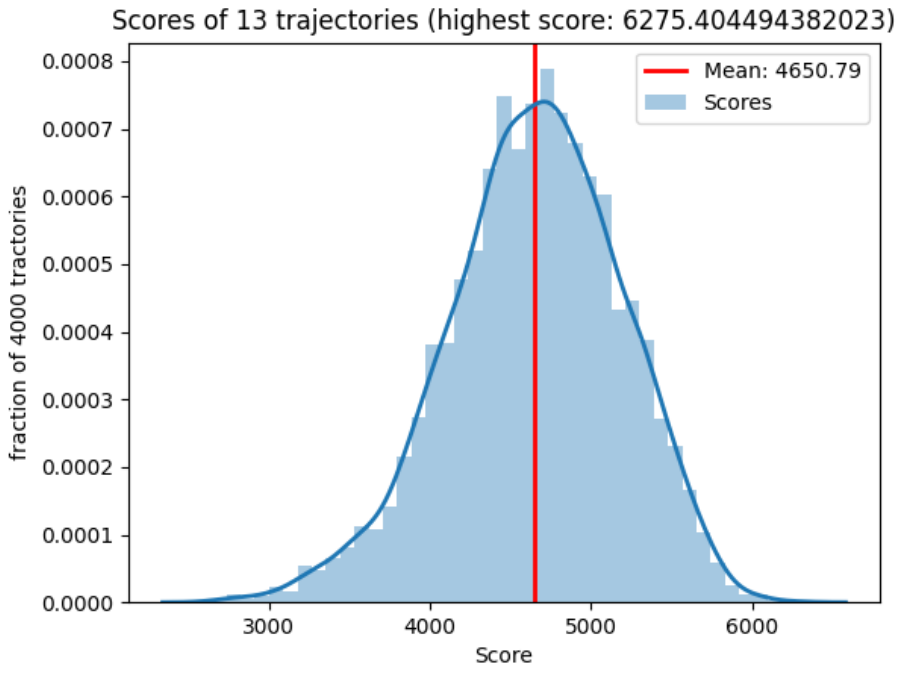


In the coming days this score might still increase, since a better computer can run the algorithm more often. Also, some tweaks to the algorithm might help increase the score as well.

Second algorithm

The second algorithm works different compared to the first one. This algorithm is named a restart hill climb algorithm. It works as follows: the algorithm chooses a few connections at random to start off with (these connections could be considered trajectories of length 1), subsequently a connection that increases the objective function most is added to one of these trajectories of length one, thereby creating a trajectory of length 2. This process of adding more connections to the existing trajectories is repeated until the score stops improving. The advantage of this algorithm is that it runs faster than the other hill climber, the difference is that it doesn't need to loop over the list with all possible trajectories every iteration. Therefore, it was possible to run this algorithm 5000 times on national level, where the other algorithm ran only 50 times (30 minutes per iteration). So, for creating a fast solution to the case or to explore new solutions quickly this algorithm works better, however the highest scores resulting from this algorithm are lower than for the earlier mentioned algorithm. The similarity is that both algorithms are probabilistic, and they both improve their solution by choosing a new trajectory or connection that increases the objective function (hill climb algorithm).





As can been seen from the graphs the shape is similar to the shape of the random trajectory generator. It looks like the cumulative density function of the normal distribution. The difference is that the mean and highest score are higher, meaning it performs better than the random algorithm. Also, looking at the number of iterations it can be observed that it runs faster than the first algorithm implemented. The advantage is that once the map becomes complicated and large, it is still possible to get decent results in little time. The first algorithm might take days when the number of stations and therefore connections increases. The algorithms also differ in the optimal number of trajectories in the best solution found. The restart hill climber needs more trajectories to get to the best score, thus scoring lower than the “normal” hill climber. The restart hill climber managed to get a high score of 6275 on the national level compared to 7145 for the first algorithm.