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Practice Task – Ch 2

Simulated Annealing
Discipline: Intellectual Computing
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Introduction

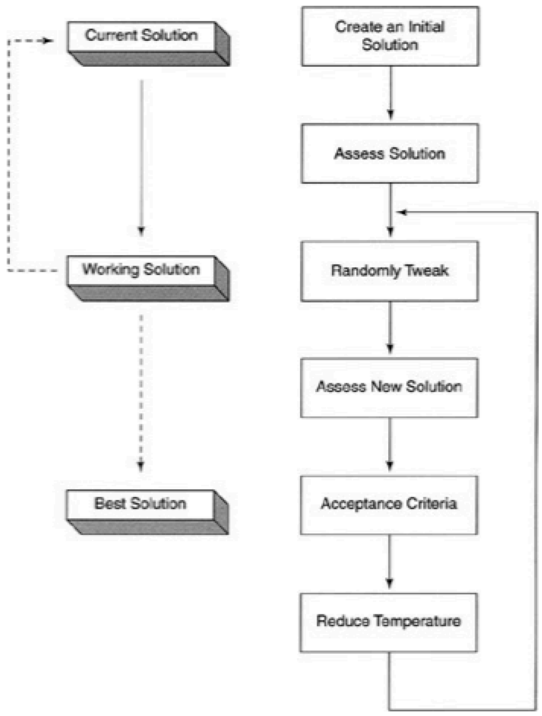
Chapter 2 of "AI Application Programming" by M. Tim Jones is about Simulated Annealing. This method is used as a stochastic optimization technique. It is inspired from the cooling of metals to obtain optimized crystalline structures. The idea is to use a previous solution as the basis for the next solution, but only if it meets a criterial energy function with a lower value.

Two programs, N-Queens and a chess movement program, have been created to show this methodology. An NxN chess board with N queens is created. The goal of the program is to determine the position of all queens such that none may attack each other. After this program was developed and the algorithm was verified, a more complex chess movement program was developed. This chess program uses the same theory but in reverse. It allows both sides to move X number of pieces, and tracks the number of pieces that can attack each other. This number of attacks is used as the energy function. Finally from this energy function, various results are obtained for different numbers of allowed moves.

Background

Algorithm

The main algorithm flow can be seen in the figure below (borrowed from the book). Additionally, the steps are described in the below process steps.



Processing Steps

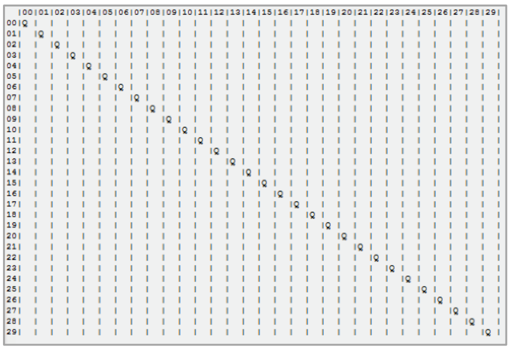
1) Create a copy of the existing situation.
2) Randomly modify the situation a specified number of times.
3) Calculate the energy of the current solution and newly modified solution.
4) Compare solutions
   a) If the modified has less energy, use it.
   b) If the modified has more energy, use the thermodynamic acceptance probability criteria equation.
      i) If it passes, use modified solution.
      ii) If it fails, use current solution.
5) Reduce the temperature.
6) Repeat the tweaking process.
7) Repeat until temperature is below goal.

2.1 Thermodynamic Probability Equation

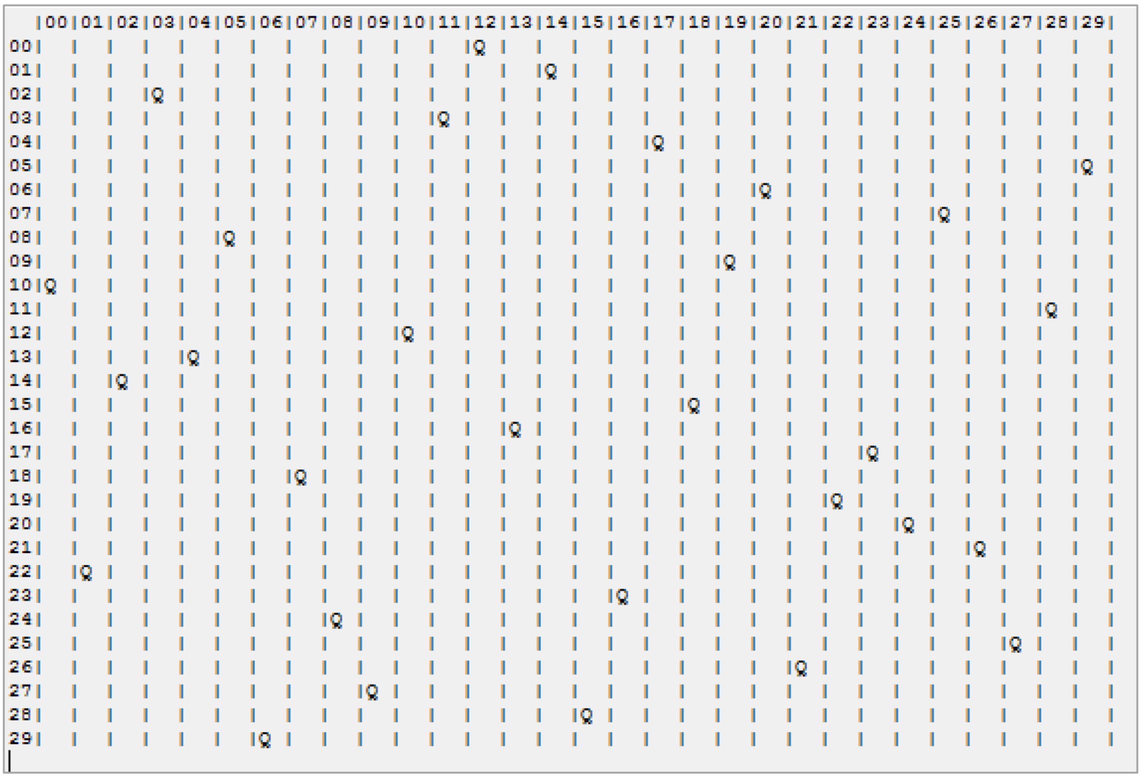
$$P(\delta E = exp\left(-\frac{\delta E}{T}\right)$$

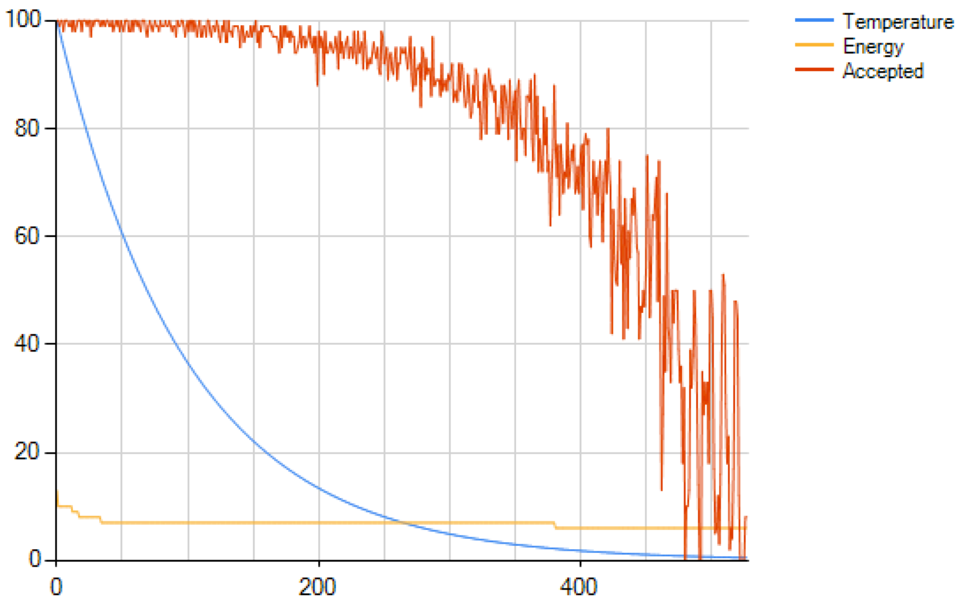
N – Queens Problem

As mentioned, during development of the algorithm, the N-Queens problem was used for testing. This can be seen in the images below below and righ. A grid of 30 queens is based on an oversize chess board (Right).



These queens are then moved stochasticly by the algorithm until they have reached minimum temperature. The chart below shows the temperature, energy, and accepted solutions for each modification pass vs time.





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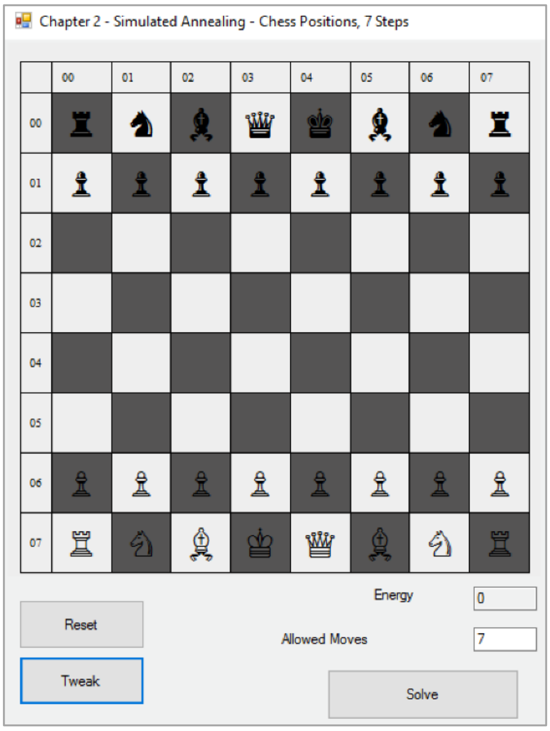
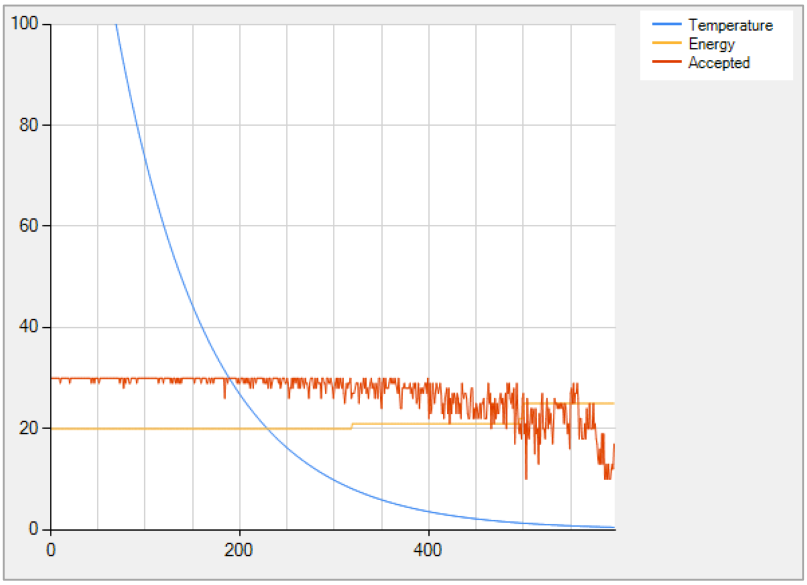
Chess Positions Problem

A digital chess board has been created, and all working knowledge of the pieces are integrated. The only functionality intentionally left out is the end-game situations. These are left out to prevent the game from exiting, thereby defeating the point of the algorithm.



To test the annealing simulation on the chess board, the user simply enters the number “Allowed Moves” and presses the “Solve” button. The user may also invoke one turn by pressing the “Tweak” button or reset the board by pressing the “Reset” button.

After analysis is complete, a report of each simulation is displayed. (See below chart)



Time	Temp	En	Acc
0	200.0	20	30
1	198.0	20	30
2	196.0	20	30
3	194.1	20	30
4	192.1	20	30
5	190.2	20	30
6	188.3	20	30
7	186.4	20	30
8	184.5	20	30
9	182.7	20	30
10	180.9	20	29
11	179.1	20	30
. . .			

Three different curves are shown in the above results graph

1.) **Temperature** – Part of the annealing process to represent the system coming to the desired state.
2.) **Energy** – The number of potential attacks capable on the chess board. Note: Energy rises in this task. Typically the goal is to minimize.
3.) **Accepted** – The number of task that were thermodynamically accepted, even though they did not have lower energy than the current solution.

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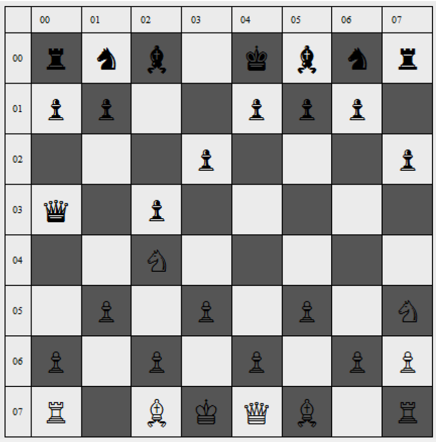
Results

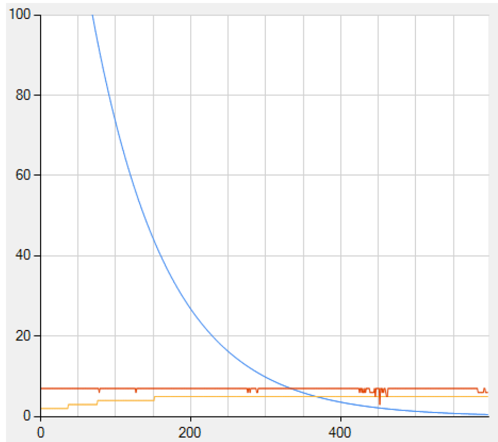
The “Allowable Moves” factor was modified to show its effect on the number of available attacks (energy). This allows each team to make a specified number of movements, taking turns. However, because of the stochastic nature of the annealing process, it is purely random. The piece to be moved, the direction, and how far are all completely randomized.

In the below charts, the effect of annealing process is not apparent unless a larger number of moves are utilized. As the number of moves increases, the possibly energy values (attacks) increases and the natural curve shape of the “Accepted” lines becomes apparent.

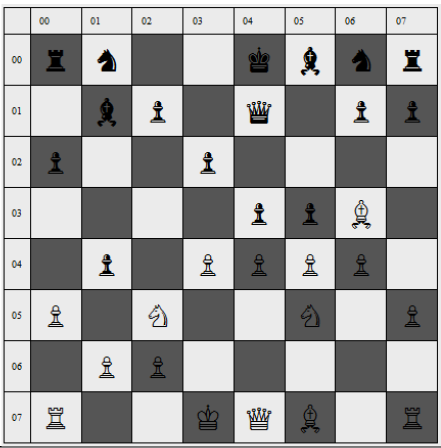
7 Moves



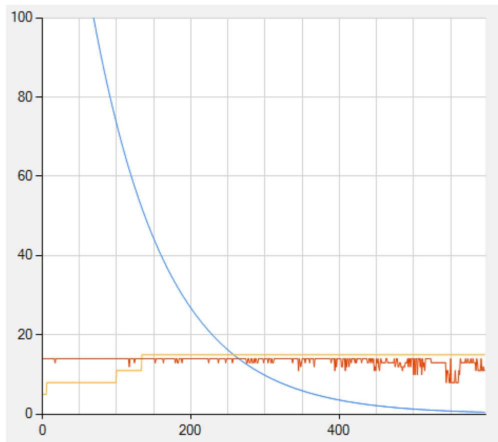
7 Moves



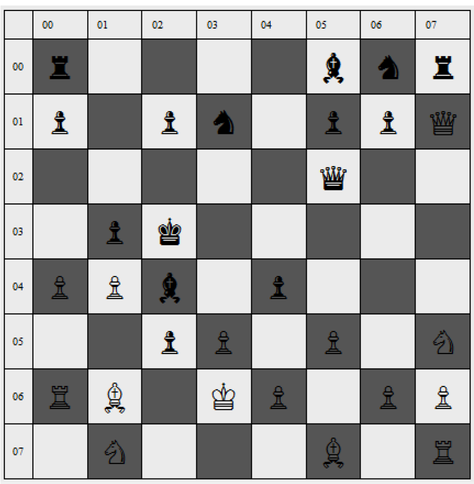
14 Moves



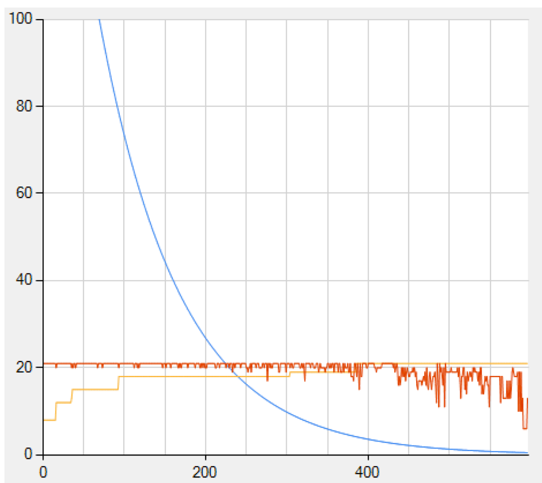
14 Moves

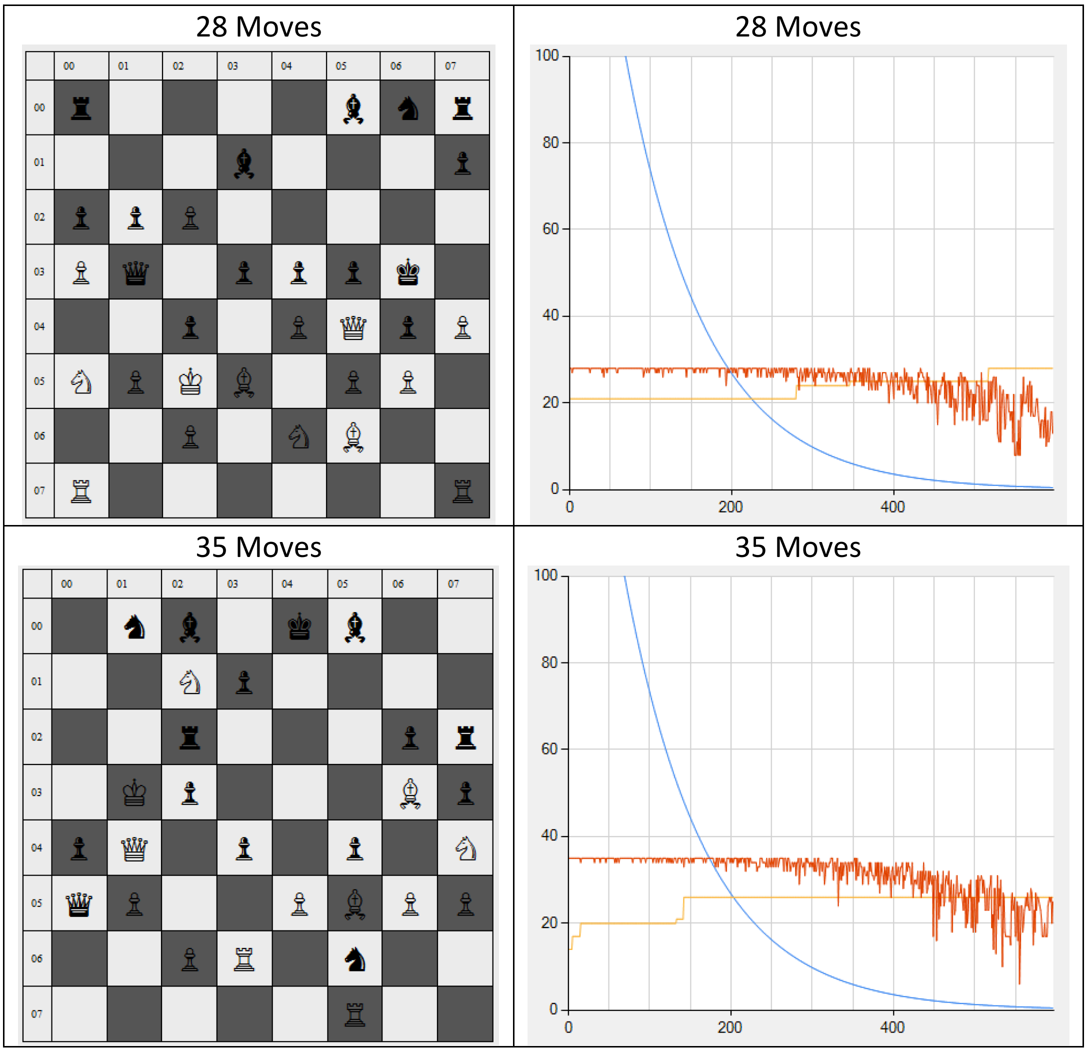


21 Moves



21 Moves





Conclusion

It can be seen that simulated annealing can be used to solve a potentially algorithmically complicated problem. The first example of such a problem was the simple N-Queens situation, for proof of concept. Later, to demonstrate application in a more complex environment, the annealing process was extended to a full chess board.

After applying the annealing process to a full chess board, charts were produced to show the effect of number of moves on the potential attacks available in the game. As more moves were incorporated into the chess game, more possibilities for "max number of attacks" became present. Additionally the typical curve for annealing appeared, which was not present at low number of moves.