Backtracking Algorithm for Deducing Nuclear Power Plant Location

Satria Priambada / 13513034[1]
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung, Jl. Ganesha 10 Bandung 40132, Indonesia
[1]satria.priambada@students.itb.ac.id

***Abstract*—As time pass by people tend to grow more rapidly. This population growth consumes more and more energy. Nuclear power plant can be one of the solution for this problem. However building nuclear power plant is not easy. Nuclear power plant can be very dangerous if the location is not planned carefully. In order to decide a location for nuclear power plant first we need to make a lot of survey and list all the possible location for nuclear power plant. For this early stage before building a real nuclear power plant we can use backtracking algorithm to help us list all the possible location candidate to become a nuclear power plant.**

***Index Terms*—Backtracking Algorithm, N-Queen Problem, Nuclear Power Plant Location, Indonesia**

I. Introduction

Everyday, the world population are increasing. This increase of today population are followed with food consumption and energy consumption. Sadly, when population grows in exponential growth, food and energy supply are often not growing in the same speed. In the long run this can cause a shortage. One of the solution for energy is by building nuclear power plant.

A nuclear reactor can produces and controls the release of energy from splitting the atoms of certain elements.[4] The process of splitting atoms can create heat which the power reactor used to make steam. The steam will then be used to run turbine to generate electricity. In most reactors, steam drives a turbine directly for propulsion.[4]

The principles of nuclear power plant are similar with most types of reactor. One of the difference is that normal power plant used fossile fuels to run turbine and generate electricity. Nuclear power plant, however, used the energy released from continuous fission of the atoms of the fuel then use the heat in either a gas or water to produce steam. The steam is used to drive the turbines which produce electricity.

The idea of nuclear power plant is not new to the nature. The world's first nuclear reactors operated naturally in a uranium deposit about two billion years ago.[4] These were in rich uranium orebodies and moderated by percolating rainwater. The 17 known at Oklo in west Africa, each less than 100 kW thermal, together consumed about six tonnes of that uranium[4]. It is assumed that these were not unique worldwide and there could be more of this natural nuclear power plant.

Today, reactors derived from designs originally developed for propelling submarines and large naval ships generate about 85% of the world's nuclear electricity[4]. The main design is the pressurised water reactor (PWR) which has water at over 300°C under pressure in its primary cooling/heat transfer circuit, and generates steam in a secondary circuit. The less numerous boiling water reactor (BWR) makes steam in the primary circuit above the reactor core, at similar temperatures and pressure. Both types use water as both coolant and moderator, to slow neutrons. Since water normally boils at 100°C, they have robust steel pressure vessels or tubes to enable the higher operating temperature. Another type uses heavy water, with deuterium atoms, as moderator. Hence the term 'light water' is used to differentiate.[4]

Most reactors need to be shut down for refuelling, so that the pressure vessel can be opened up [4]. In this case refuelling is at intervals of 1-2 years when a quarter to a third of the fuel assemblies are replaced with fresh ones, with correct maintenance a nuclear power plant can sustain in making energy for about 30-40 years [4].

Components of a nuclear reactor for most types of reactors can be categorized as :

Fuel. Uranium is the basic fuel. Usually pellets of uranium oxide (UO_2) are arranged in tubes to form fuel rods[4]. The rods are arranged into fuel assemblies in the reactor core. In a new reactor with new fuel a neutron source is needed to get the reaction going.

Moderator. This is some kind of material in the core which slows down the neutrons released from fission so that they cause more fission[4]. The most common being used is water, heavy water or graphite.

Control rods. These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction, or to halt it[4]

Coolant. A fluid circulating through the core so as to transfer the heat from it. In light water reactors the water moderator functions also as primary coolant[4].

Pressure vessel or pressure tubes. Usually a robust steel vessel containing the reactor core and moderator/coolant, but it may be a series of tubes holding the fuel and conveying the coolant through the surrounding moderator[4].

Steam generator. Part of the cooling system of pressurised water reactors (PWR & PHWR) where the high-pressure primary coolant bringing heat from the reactor is used to make steam for the turbine, in a secondary circuit[4].

There are several different types of reactors as indicated in the following Table.

Nuclear power plants in commercial operation

Reactor type	Main Countries	Fuel	Coolant	Mode Rator
Pressurised Water Reactor (PWR)	US, France, Japan, Russia, China	enriched UO_2	water	water
Boiling Water Reactor (BWR)	US, Japan, Sweden	enriched UO_2	water	water
Pressurised Heavy Water Reactor 'CANDU' (PHWR)	Canada	natural UO_2	heavy water	heavy water
Gas-cooled Reactor (AGR & Magnox)	UK	natural U (metal), enriched UO_2	CO_2	graphite
Light Water Graphite Reactor (RBMK & EGP)	Russia	enriched UO_2	water	graphite
Fast Neutron Reactor (FBR)	Russia	PuO_2 and UO_2	liquid sodium	None

IAEA data, end of 2013. GWe = capacity in thousands of megawatts (gross)

Source[4]: Nuclear Engineering International Handbook 2011, updated to 1/1/12

Indonesia is also a country that face this same problem. To cope with the fast-growing demand for power supply in the country, Indonesia is considering building nuclear power plants with an initial capacity of 5,000 MW by 2025 [5]. To pursue 7 percent economy growth by 2018 targeted by the government, it needs 9 percent growth in power supply [5]. In order to do so, the government set a target to building power plants with a total capacity of 35,000 MW within five years of its effective governing period. Government would give priority to the safety concern in building nuclear power plant, a focal issue highlighted by opponents who insist such facility is not environment-friendly and is dangerous for earthquake-prone Indonesia[5]. In order to reduce the risk of danger from earthquake and supply problem to nuclear power plants we can use a backtracking algorithm and n-queen problem to make some inital assumption then deduce the possible location for the nuclear powe plant with minimal risk of earthquake and supply problem.

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II. Theory

A. Backtracking Algortihm

Backtracking algorithm is an algorithm used to move backwards from current solution to the solution before. This backtrack can be viewed as 2 categorize [1] :

1. A phase in DFS (Depth First Search) Algorithm
2. A method to solve problem efficiently and efectively

Backtracking are often being found in the games such as TicTacToe, maze labyrinth, sudoku, crossword puzzle, and many more. This happens because of the nature of this algorithm. In order for this algorithm to be able to work there are some premise we must know [1]:

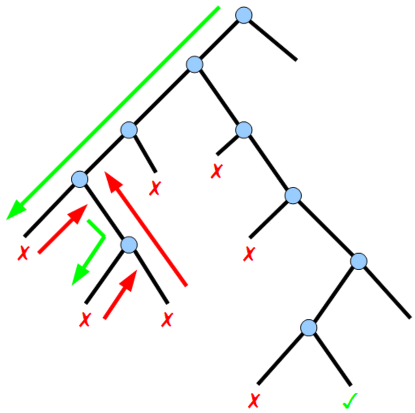
1. We are about to make decision but we have not enough information on what will happen if we ended choosing those decision
2. In every choice we make there will be more choices
3. There can be more than 1 sequence that can act as a solution for our problem

Basicly backtracking is a method of try and error to find a soultion in problem. If we make a wrong choice then we need to go back to the previous state before we make the wrong decision. The step of going back is what called backtracking. This method is being repeated until we found the solution or we have try all possible ways to achieve solution.

The principle and general step for this algorithm are[1] :

1. Solutions are going to be searched using a tree from root to leaf.The tree are constructed using DFS method.
2. Node that has been generated are called live node.
3. Live node that are being tried are called Expand-node (E-node).
4. In every trial of E-node, then the depth of tree are increasing.
5. If the track currently tried are not pointing towards solution, then E-node is killed and become a dead node and will never be tried again.
6. Function to kill E-node is called bounding function.
7. Upon reaching dead node program will do backtrack to the previous live node
8. This step (1-7) is generated over and over again until the algorithm reach goal node.

Illustration of backtrack algorithm



Source [1] : http://www.w3.org/2011/Talks/01-14-steven-phenotype/

This algorithm was first introduced by D.H.Lehmer in 1950[1]. The general steps were introduced later by R.J Walker, Golomb, and Baumert. To this day backtracking algorithm is widely used in many fields including AI(Artificial Intelligence).

B. N-Queen Problem

N-Queen Problem is a problem created from using chess rule and a set of additional rules. Given N chess queens on an N×N chessboard. The N-Queen Problem is a problem of placing the queens so that no two queens attack each other. The puzzle was originally proposed in 1848 by the chess player Max Bezzel, and over the years, many mathematicians, including Gauss, have worked on this puzzle and its generalized N-queens problem. The first solutions were provided by Franz Nauck in 1850. Nauck also extended the puzzle to n-queens problem (on an N×N board—a chessboard of arbitrary size). Edsger Dijkstra used this problem in 1972 to illustrate the power of what he called structured programming. He published a highly detailed description of the development of a depth-first backtracking algorithm.[1].

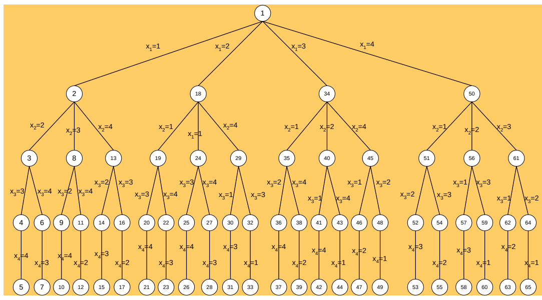
The step of algorithm can be written like this [3] :

1) Start in the leftmost column
2) If all queens are placed
   return true
3) For all rows in the current column do
   a) If the queen can be placed safely in this row then
      mark this [row, column] as part of the solution
      recursively check if leads to a solution.
   b) If placing in [row, column] = solution then
      return true.
   c) If placing queen doesn't lead to a solution then
      umark this [row, column] (Backtrack)
      go to step (a) to try other rows.
4) If all rows have been tried and nothing worked
   return false to trigger backtracking.

If we want to use brute force in 4 queens then we need permutation from 1 to 4 = 4! = 24 possibilities.

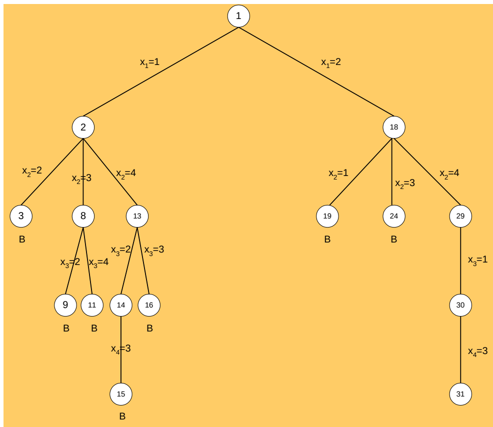
Backtracking can improve the solution. The possible space are exhaustive search , but with backtracking we do not need to go to all possibilities. Here are the drawings solution for 4 Queens.

Ilustration of all sample space



Source [1]

Illustration of solving problem with Backtracking



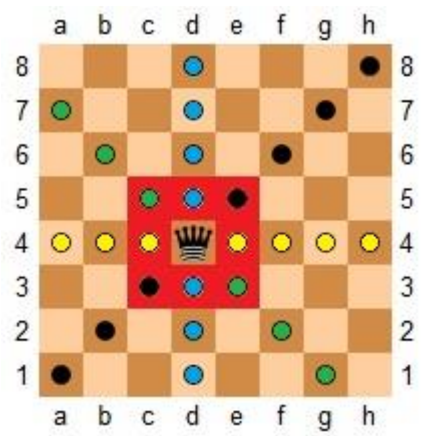
Source [1]

The B in the tree means that node is being bound and searching further for solution in those nodes are not possible. So the programs backtrack and try another possibilities.

III. IMPLEMENTATION

In order for the backtracking algortihm and N-Queen problem capable of deducing the possible location for nuclear power plant first we must make assumption as follows

A. Assumption



Source : http://i.imgur.com/QuxiW.png

First assumption is that every N nuclear power plant we will divide Indonesia map into NxN board. Queen represents the nuclear power plant location

- : represents coolant (water) supply
- : represents fuel (uranium) supply
- : represents earthquake conture line
- : represents electricty produced
- : represents no adjecent block can be filled with another nuclear reactor

Each supply line must be mutual exclusive for each nuclear reactor. This assumption is made so that when one nuclear reactor supply are facing problems the other reactor supply can still works perfectly.

The position adjecent to nuclear reactor cannot be used to create another nuclear reactor because of safety reason. If accident happens to one reactor than there will hopefully no chain reactor to other nuclear reactor, because their location is not adjecent to each other.

Ther purpose of mutual exclution for electricity produced is to make sure all area can have electricity and no area are given excessive amount of electricity.

B. Implementation

Here are the sample code implementation in C#[2] :

```
namespace NQueens
{
    class Program
    {
        const int N = 8;

        static bool Allowed(bool[,] board,
int x, int y)
        {
            for (int i=0; i<=x; i++)
            {
                if (board[i,y] || (i <= y
&& board[x-i,y-i]) || (y+i < N && board[x-
i,y+i]))
                {
                    return false;
                }
            }
            return true;
        }

        static bool FindSolution(bool[,]
board, int x)
        {
            for (int y = 0; y < N; y++)
            {
                if (Allowed(board, x, y))
                {
                    board[x, y] = true;
                    if (x == N-1 ||
FindSolution(board, x + 1))
                    {
                        return true;
                    }
                    board[x, y] = false;
                }
            }
            return false;
        }

        static void Main(string[] args)
        {
            bool[,] board = new bool[N, N];

            if (FindSolution(board, 0))
            {
                for (int i = 0; i < N; i++)
                {
                    for (int j = 0; j < N;
j++)
                    {
Console.Write(board[i, j] ? "|Q" : "| ");
                    }
                    Console.WriteLine("|");
                }
            }
            else
            {
                Console.WriteLine("No
solution found for n = " + N + ".");
            }

            Console.ReadKey(true);
        }
    }
}
```

B. Solution

With the algorithm above here are some possible answer from N = 4.

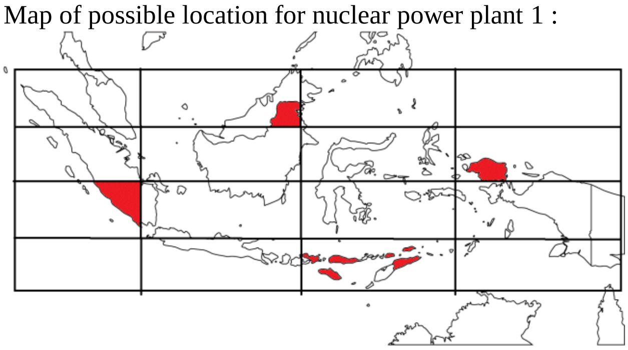
	a	b	c	d
1		Q		
2				Q
3	Q			
4			Q	

	a	b	c	d
1			Q	
2	Q			
3				Q
4		Q		

IV. Analysis

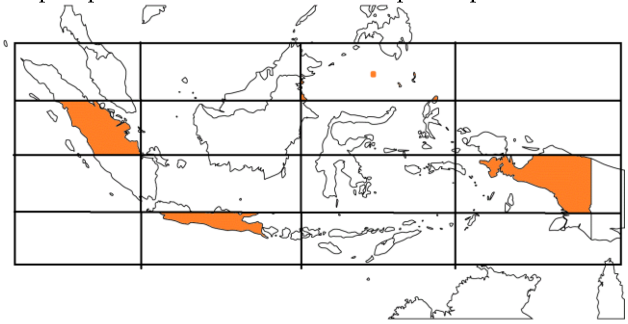
From the implementation we can see that the possible location for the nuclear generator are as follows :

Map of possible location for nuclear power plant 1 :



Source Map : http://citymocha.com/wp-content/uploads/2013/01/indonesia-map-outline.gif

Map of possible location for nuclear power plant 2 :



Source Map : http://citymocha.com/wp-content/uploads/2013/01/indonesia-map-outline.gif

Based on this 2 solution we can cross out the area that are not colored. For solution 1 the most hard area to create power plant is in NTT because the area is not very well developed. For solution number 2 however it is goint to be hard to implement the 1st row nuclear power plant because it will be located in the remote island or even built in the sea.

If in the future Indonesia is going to create more nuclear power plant (N > 4) then the number of possible solution also may increase. However it is not necessarly linear. For example in N = 5 there will be 10 possible solution. For N = 6 there will be 4 possible solution.

Increasing the amount of nuclear power plant will also create a smaller box for each table. Different with chess board that will expand according to NxN, Indonesia territory is not going to expand. Because of this reason the position is going to be more specific. This can become a good thing and a bad thing. Good thing because we will easier to make decision where the location of nuclear power plant and a bad thing because exact location might not be possible to be used as nuclear power plant (e.g. : in the middle of residential area, in the sea, outside Indonesia territory, etc.)

V. CONCLUSION

Backtracking Algorithm can be used to deduce Nuclear Power Plant Location. In order for the algortihm to work we need to make sure that some condition are being abstracted as the paper suggest. The solution we get from this method can give us the guidance / illustration on where we should put the nuclear power plant location, but cannot give an excat location of nuclear power plant location.

VI. THANKS

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DECLARATION

I hereby declare that this paper is written by Satria Priambada. This paper is not a translation and plagiarism from other paper

Bandung, 4 May 2015

Satria Priambada - 13513034