Forest fire spread simulation algorithm based on cellular automata

issam najah[1], walid arjouan[2] and Oumnia Ba Ahmed[3]

Mathematics, Computer Sciences and Applications Team (ERMIA)
ENSA of Tangier, University of AbdelMalek Essaadi, Morocco
issam.najah2802@gmail.com, walid.arj@gmail.com, oumniabaahmed9@gmail.com

Abstract. Fire models are used in different aspect of fire management to predict , understand and to define possible fire behavior without getting burned.
The increase in the number of forest fires in the last few years has forced pays to take precautions. Also the early intervention has an important role to fight against forest fire. Sometimes , If we know where the fire will be in it would be easier for us to stop or limit the fire. Therefore a big need for simulating the fire behavior exists.this paper we present can predict the spreading of fire in forests and can easily incorporate weather conditions and land topography. An algorithm has been constructed based on cellular automata . This algorithm is very fast and can run efficiently on a personal computer.The results have shown that this approach is fast and satisfactory enough for practical use. Shape of the fire front achieved in the simulation is similar to shape of fire front developed.

Keywords: Forest fire spread simulation. Cellular automata. Forest fire disaster. Fire point identification.

1 Introduction

A forest fire is a fire that spreads over a wooded area. It can be of natural origin (due to lightning or a volcanic eruption) or human (intentional and criminal or unintentional and accidental from agricultural fires or lit for "maintenance" of transits or areas open for hunting. for example).Each year, more than 60,000 forest fires occur in Europe. Globally 350 million hectares are affected per year (six times the size of France; twice as many as thirty years earlier, despite increased means of control).

Today, virtually all forest fires have been created intentionally or accidentally. Computer-based tools are making progress in simulating wildfires. As an attempt to calculate fire ignition and assess fire behavior on complex regions and unconventional forest fuel systems.The purpose of this work is to investigate the possibility of using CA in forest fire modeling. a model based on CA was developed. This model can easily accommodate all the factors affecting the spread of wildfires. An algorithm was developed with python using this model, and was used to determine the firefront in several imaginary forests. This algorithm is very fast and can run efficiently on a personal computer.The paper is arranged as follows: Section 2 provides a description of the relevant work. Section 3 presents Materials and methods. Section 4 presents Results and discussion Finally , Conclusion and perspectives are given in Section 5.

2 Related work

Over the past 50years, several scientists researched into the spread of fire; proper understanding of this issue is the most important factor for successful simulation of forest fires [1].

In 1950 Cellular automata was first employed for forest fire modeling [2]. This method was proposed by ULAM so as to optimize modeling forest fire and more essentially in order to present dynamic phenomena. a general modeling framework was proposed by him based on cellular spatial models in discrete times [3]. Kourtz, P.H. and O'Regan are the first researchers who studied this issue[4,5]. Van Wagner CE developed the first fire model in canada [6] later by Van Wagner CE in the United states worked on similar subject [7].

An improved model was constructed by Xiaoping Rui, Shan Hui, Xuetao Yu, Guangyuan Zhang and Bin Wu, to ensure better temporal accuracy of forest fire propagation. this model couples cellular automata with an existing forest fire model [8]. It provides an optimal time step value in consideration of the impact of time steps on the precision of the simulation. The results of a test of this model which was done in 2006 at Daxing'an Mountain using a case study of forest fire propagation show that the optimal time step for the simulation algorithm of Geographic cellular automata of forest fire propagation is 1/8 of the time taken for cellular material to be completely burned.

In Algarve (south of Portugal) in July 2012 a cellular automaton was presented by Joana Gouveia Freire and Carlos Castro DaCamara designed to simulate a severe wild fi re episode [9]. The results obtained show that when introducing a wind propagation rule in which the fire is allowed to spread to non-adjacent cells depending on the wind speed. the explosive stage is correctly modeled.

A new method of modeling the spread of fire using Cellular Automata based on 3D mesh was presented by Jaroslaw Was , Artur Karp, Szymon Lukasik, and Dariusz Palka [10]. The models based on different heat transport mechanisms were used in the study, including conductivity, convection and thermal radiation. General mechanisms of fire spread are exemplified by a fire inside a building. The tests of the created simulator for fire in rooms were conducted, and the reference point was the known simulator based on CFD, namely FDS Fire Dynamics Simulator.

we try to apply in this work a model of cellular automata Among the input parameters, only the temperature and wind conditions are taken into account.

3 Materials and methods

3.1 Cellular automata

Cellular Automata were invented by the mathematician Stanislaw Ulam and were used by J. von Neumann, followed by A.W. Burks and E. F. Codd, to solve problem of the non-trivial self-reproduction in a logical system .
A cellular automaton can be seen as an infinity of small identical machines: cells, distributed on a regular graph (discrete space). Cells only have a finite memory, that is, they do not can be that in a finite number of possible states and that they carry no other information than their state. At each time step, each cell changes its current state according to its state and that of its neighbors only. Formally, we have the following definition :
A cellular automaton (CA) is a 4-tuple A = (S, d, N, f) where:
• S is a nonempty finite set of automaton states. Each cell can take on only one state at any one time from a set of states, s S. Strict CA also requires state variables to be discrete.
• d is the dimension of the automaton, its network is then Z^d, the discrete space of dimension d.
• N neighborhood Template N - the state of any cell depends on the states and configurations of other cells in the neighborhood n of that cell. In two-dimensional space, there are two well-known templates, von Neumann or 5 cell neighborhood [10].

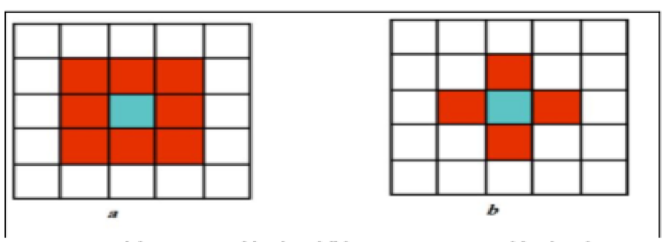


Fig 1. (a) Moore neighborhood (b) Von Neumann neighborhood

• f est la fonction de transition : f : $S^{|N|} \rightarrow$ S, avec $|N|$ le cardinal de N.
La fonction de transition locale f : $S^{|N|} \rightarrow$ S, $S^{|N|}$ représente l'ensemble de tous les états possibles que le voisinage peut avoir, Chaque valeur de $S^{|N|}$ a la forme $(s_0, s_1, \ldots, s|N| - 1)$ avec $s_i \in$ S.

3.2 Simulation of Fire Propagation Using the CA Model

• The proposed model takes into account the characteristics of the relevant materials, because each material has different self-ignition and ignition temperatures. If the temperature received by a cell is suitable for a given type of material (such as wood 250∘C, carpet 100∘C, fabric 170∘C), and an adjacent cells continues to catch fire for long enough, it may catch fire.

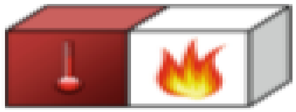


FIG 3: Explanation of cell ignition. White blood cells are cells with ignition temperature, and red blood cells are adjacent cells that burn within an appropriate time.

If (T>Tignition and burning time > ignition time) set in the cell ”fire” (red) state.

• The only condition for autoignition is to reach a sufficiently high temperature (e.g. wood 2000 ∘C, carpet 500 ∘C, fabrics 650 ∘C). Calculate the linear fire spread rate for each material. By converting the formula to account for speed, we calculated how long the battery must burn (to ignite its neighbors) .

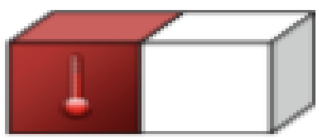


FIG 4: Explanation of cell spontaneous combustion. Red blood cells-self-ignited cells (not burning neighbors).

If (T >Tautoignition) set in the cell ”fire” (red) state.

4 Results and discussion

4.1 Rule set

The simulation realised in python in its simplest form accounts for: temperature of neighboring cells and the wind direction/power. The model used is the Von Neuhman Neighborhood.

```
def neighboring(i,j,n,m,Tab,d,p):

    S= neighborE(i,j,n,Tab)
    N= neighborW(i,j,n,Tab)
    W=neighborN(i,j,m,Tab)
    E=neighborS(i,j,m,Tab)

    (E,W,N,S)=windInfluence(d,p,E,W,S,N)


    return( E + W + N + S)
```

The temperature of the center cell will change accordingly to the temperature of its neighbors (1st law of thermodynamics), until it reaches a certain temperature of ignition (250 °C in this case). The cells can only be in one of these two states: burning or not burning. Cells will proceed in a thermal exchange with their neighbors, so they can get hotter or colder, but if the cell is already burning it cannot get any colder than 250°C or any hotter than 600°C, and if it's already on fire, it will increase by 20°C on each iteration. This is the preestablished convention that we decided to partake.

```
def isOnFire(T):
    n=len(T[0][:])
    m=len(T[:][0])
    Tab = [[0 for x in range(m)] for y in range(n)]
    for i in range(n):
        for j in range(m):
            if T[i][j]>=250:
                Tab[i][j]=1
    return(Tab)

def burningCell(T1,T2):

    n=len(T1[0][:])
    m=len(T1[:][0])
    for i in range(n):
        for j in range(m):
            if T2[i][j]==1 and T1[i][j]<600:
                T1[i][j]+=20
    return(T1)
```

4.2 Wind Influence

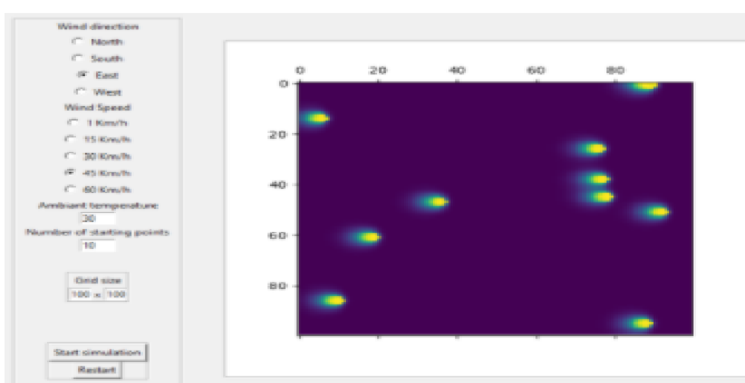
The wind is to change the values of thermal exchange between neighboring cells, by taking into account the wind power and direction it makes the thermal exchange between certain neighbors more favored than others.

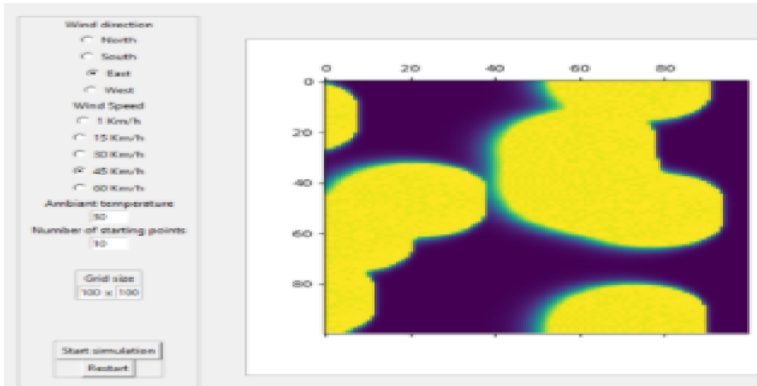
```
def windInfluence(d,p,E,W,S,N):
    p=p/60
    if d == "S":
        S=S-S*p
        N=N+N*p
    elif d == "N":
        N=N-N*p
        S=S+S*p
    elif d == "E":
        E=E-E*p
        W=W+W*p
    elif d == "W":
        W=W-W*p
        E=E+E*p

    return (E,W,N,S)
```

A southern or northern wind will only influence the thermal exchanges between northern or southern cells relative to each other. The same goes for west and east.

4.3 Graphical UI

The tool set is now programmed, all that's left to do is to set up a Graphical User Interface. The user should be able to choose the parameters that will affect the progress of the simulation, such as: wind direction and speed, ambient temperature, number of points that are already on fire at the start and finally the grid size.





Pressing “Next step” will allow the user to advance in the simulation. However the “Restart” button will allow him to reset the simulation and start it over with new parameters.

5 Conclusion and perspectives

Million hectares of worldwide forests fall victim to disasters either natural or man-made. Providing effective strategies to prevent and manage this complex phenomenon has been an ideal for environmental managers.an integration of Cellular Automata (CA)is used for modeling the forest fire spread Fire . In this paper cellular automata model has been applied . Among input parameters, only the temperature and wind conditions are taken into account. The results have shown that this approach is fast and satisfactory enough for practical use. Shape of the fire front achieved in the simulation is similar to shape of fire front developed. Considering that the fire behavior is a complex process controlled by many parameters, such as air temperature and humidity, fuel bed, and fuel humidity, it is possible to expand the input parameters in the future. only temperature and wind conditions are considered here. The combination of cellular automata model and other calculation methods will provide more accurate results .

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