# A STUDY on FOREST FIRE SPREADING ALGORITHM with CALCULATED WIND DISTRIBUTION

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## ABSTRACT

There are many parameters in prediction of forest fire spread. The variables such as fuel moisture, fuel loading, wind velocity, wind direction, relative humidity, slope, and solar aspect have important effects on fire. Particularly, wind and slope factors are considered to be the most important parameters in propagation of forest fire. Generally, slope effect cause different wind distribution in mountain area. However, this effect is disregarded in complex geometry. In this paper, wind is estimated by applying computational fluid dynamics to the forest geometry. Wind velocity data is obtained by using CFD code with Newtonian model and slope is calculated with geometrical data. These data are applied for 2-dimentional forest fire spreading algorithm with Korean ROS(Rate Of Spread). Finally, the comparison between the simulation and the real forest fire is made. The algorithm spread of forest fire will help fire fighter to get the basic data for fire suppression and the prediction to behavior of forest fire.

## INTRODUCTION

There is a long history of analysis of the forest fire behavior. The forest fire prediction techniques are covered in Richard C. Rothermal's(1983) "How to predict the Spread and Intensity of Forest and Range Fires."[1] Later a new ROS equation of Korean Forests was developed by Yeun Ha Joung(1992) [2]. A study of forest fire needs to combine geometry to large environmental data. In Canada, the CFFDRS(Canadian Forest Fire Danger Rating System ) was proposed in 1987 and has been promoted and ameliorated independently [3]. Besides, David Weistein developed an applied program called "FIRE" in 1995 [4], which is used to predict forest fire. This program was applied in the GIS environment and contained the forest fire prediction algorithm. In Korea, the major part of national territory is woodland and then forest fire is of frequent occurrence, however the study of forest fire behavior modeling has been extremely insufficient from a forest fire prevention point of view. In the United States and Canada, Forest fire spread modeling is applied to a gentle change of slope at local-scale topography. In case of Korea the studies of spread modeling are concerned with combustible rate, a sudden change of behavior and an unexpected flying sparks which are influenced by steep slopes and a lot of hills. However, the study of the different distribution of wind velocity between an open field and among hill has been extremely rare. We have focused wind velocity and direction among others parameters in forest fire.

In this paper, real forest fire is investigated and then the burnt area is divided with each of 50m × 50m of square cell. Wind velocity is calculated by CFD code and is applied in the newly proposed spreading algorithm. Both real forest fire and results are compared for the proof of efficiency.

## CALCULATION of FLOW FIELD

The whole flow field over the mountain was calculated numerically by the famous commercial code, CFX4.1c, which was developed at AEA Technology. The flow field is 3-dimensional, incompressible, turbulent, steady flow. Solved equations are continuity equation, momentum equation, and then the applied turbulent model is standard k-ε model ($C\mu = 0.09$, $\sigma_k = 1.0$). However, energy equation is not solved by assuming constant temperature field. The geometrical size of computational domain is shown in Figure 1. The dimension of the geometry is 3,300m long(x), 1,650m wide(y), and 1,000m high (z). The number of grid is 33(x)×66(y)×10(z), which equal to 18,720blocks

## BOUNDARY CONDITIONS

Initially, the bottom in the domain is set to be wall condition and inlet wind velocity is set to 3.70m/sec(x-direction), 1.53m/sec(y-direction) which is shown to be faces of 1 and 6 in Fig. 1. The outlet boundary conditions of the domain are given with constant atmospheric pressure, which are 2 and 4 faces in Fig. 1. The boundary of top is set to be zero of gradient of all physical properties, i.e. $\partial\phi/\partial x = \partial\phi/\partial y = \partial\phi/\partial z = 0$, where $\phi$ is any variable for 3 face. Table 1 shows the real meteorological data of investigated area and the wind velocity is inlet value. In this paper, only meteorological data of 28, march, 1997. were used as inlet value. Fig. 2 shows the distribution of streamline.

Table 1 Daily Meteorological Data of investigated area (March, 1997)

| Date | Air Temperature | | | R. H. | | Wind | | |
|---|---|---|---|---|---|---|---|---|
| | Mean (°C) | Max.(°C) | Min.(°C) | Mean (%) | Min. (%) | Mean W.S. (m/s) | Max. Speed(m/s) | Dir.(16) |
| 27 | 7.3 | 17.7 | -1.8 | 58 | 32 | 0.9 | 4.6 | W |
| 28 | 9.9 | 20.7 | 0.9 | 51 | 21 | 1.4 | 4.0 | WSW |
| 29 | 8.1 | 18.7 | 2.8 | 60 | 29 | 2.5 | 6.3 | WSW |
| 30 | 2.4 | 6.5 | -1.4 | 41 | 30 | 3.6 | 6.3 | WNW |

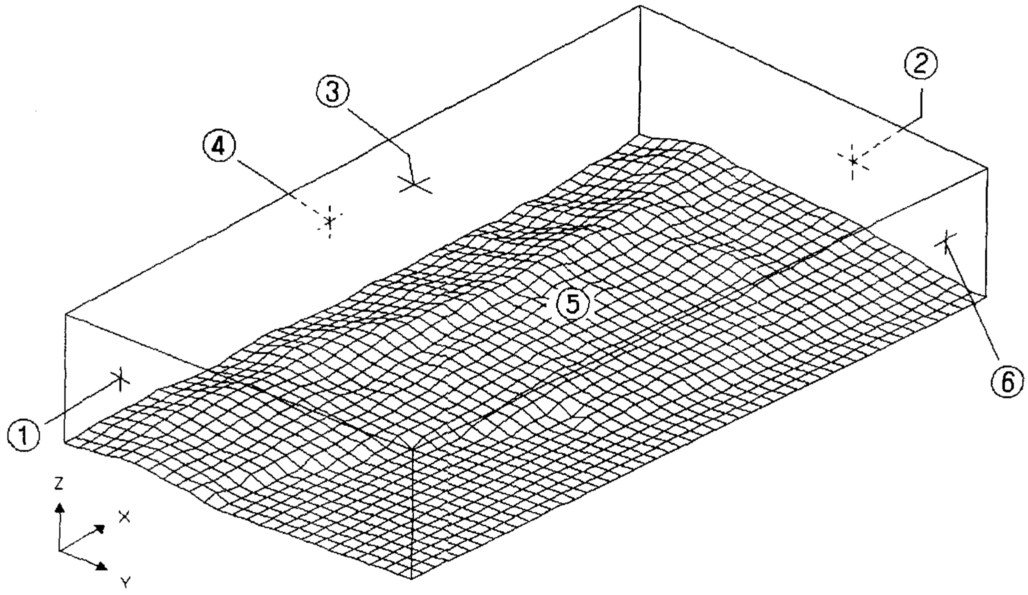


Fig. 1 Boundary Condition

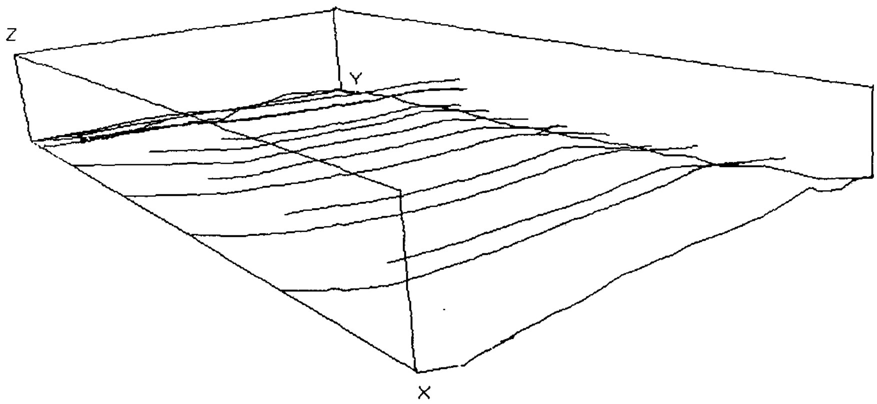


Fig. 2 The distribution of flow streamline

GEOMETRY

The experimental data acquired from the real forest fire, from 28 to 29, March, 1997, was selected to compare with computational results. It's located in Sechul-Ri, BaeBang-Myun, Asan, and ChungNam Province, Korea. The fire types of this area consist of surface fire and crown fire. The forest types of this area are conifer forest and mixed foliage. The mean of forest height is about 3 - 4m and the density is low. The altitude of cell was formed by its 4 corner points which was extracted on the base of 5m interval of contour line. The used map is one which has 5,000 vs 1 scale published by a National Geographic Institute.

Fig. 3 shows the real burnt area in Taehwa Mountain. And this area was reconstructed with 3-dimentional data for the analysis of velocity field. Fig .4 shows the grid system of geometry on Taehaw Mountain. The number of grid is 66 in width and 33 in depth. A real distance of interval is 50m. Therefore, investigated total area would be about 520 hectare and the portion of burnt area took 449 cells about 21.59% of the total 2080 cells.

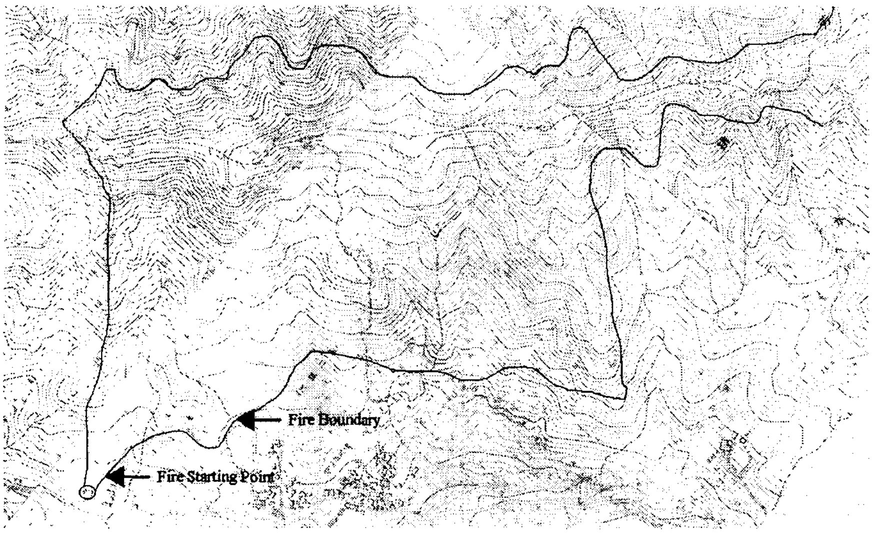


Fig .3 A map of Real forest fire on model Mountain

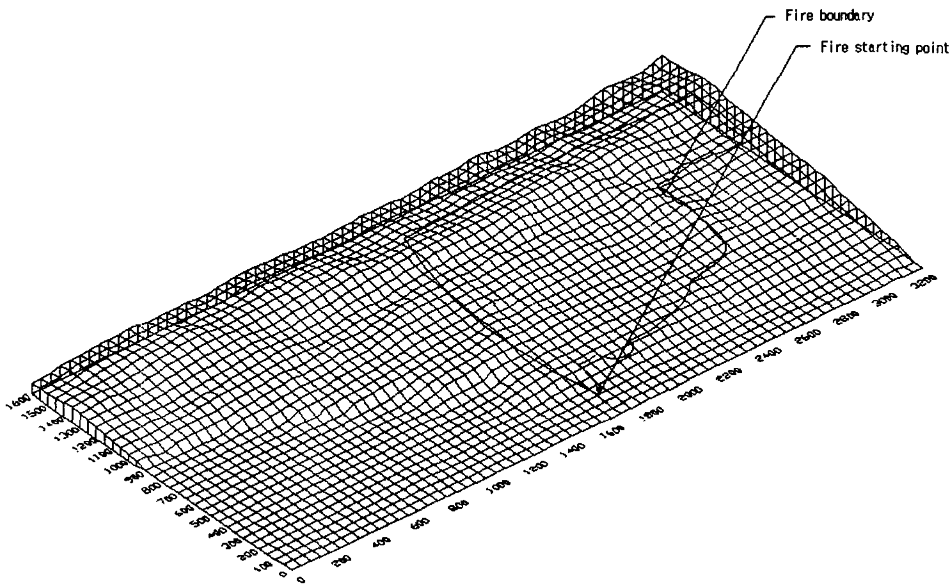


Fig. 4 A Geometry

## 2-DIMENSIONAL SPREADING ALGORITHM

In this study, we adapted the Korean ROS experimental equation by Yeon Ha Cheong [2].

$$ROS(4cm, R2=0.91^{**})\ [m/min] = -0.21H + 0.20S + 1.07W + 0.59F - 1.56$$

| | |
|---|---|
| S : slop angle | W : wind velocity |
| H: humidity | F: forest types. |

Because the application of the referred equation was confined to upward slope, we calculated and showed only positive slope region. The proposed algorithm is as follow.

(1) A standard unit is cell and the each cell is surrounded by 8 cells. The cells on fire are checked simultaneously whether is burnt out or not with time interval.
(2) The wind data given by CFD code and other data of each cell are applied to ROS.
(3) When fire occurred at one cell, the ROS value is transformed into the reciprocal number which expresses duration time. (If a ROS value is large, the duration time is short and forest fire propagates rapidly.)

The algorithm is developed using C language and ROS equation with experimental data by Yeon Ha Cheong[2] is applied to simulation. Comparison was made for the verification of effectiveness between real burnt area and simulated results. Fig. 5-Fig. 8 shows the behavior of forest fire and total burning time is about 115 minutes.

## CONCLUSION

This paper proposes 2 dimensional spreading algorithm of forest fire. Having actual meteorological data of the region where real forest fire happened. It is suitable to predict the propagation of forest fire in Korean topography. The shape and time are accord with the real forest fire. According to the wind distribution and forest type, the regions of surface fire and crown fire are divided. The averages of forest height and forest density are to be considered as important parameters and further study of them is necessary.

## REFERENCES

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4. David Weinstein, Kass Green, Jeff Campbell, and Mark Finney, 1995, "Fire Growth Modeling in an Integrated GIS Environment", Proceedings, ESRI User Conference.

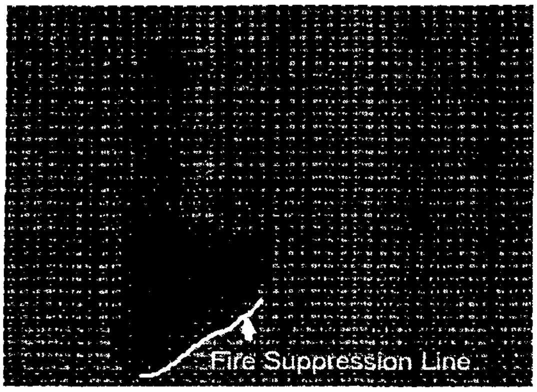


Fig. 5 Spread of fire as time passages
(after 30 minutes)

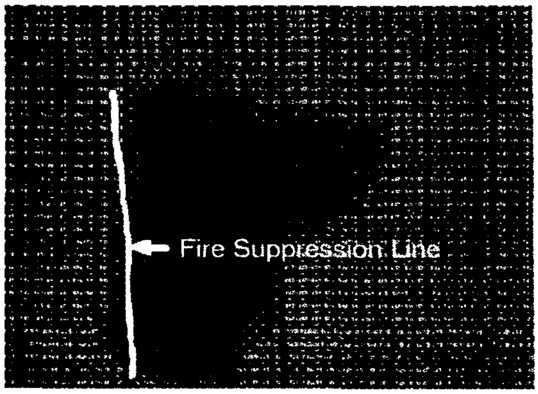


Fig. 6 Spread of fire as time passages
(after 60 minutes)

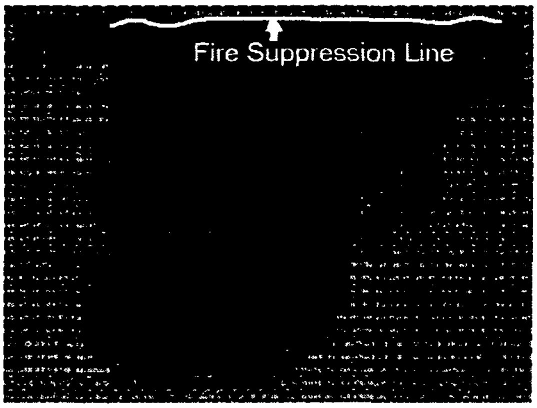


Fig. 7 Spread of fire as time passages
(after 80 minutes)

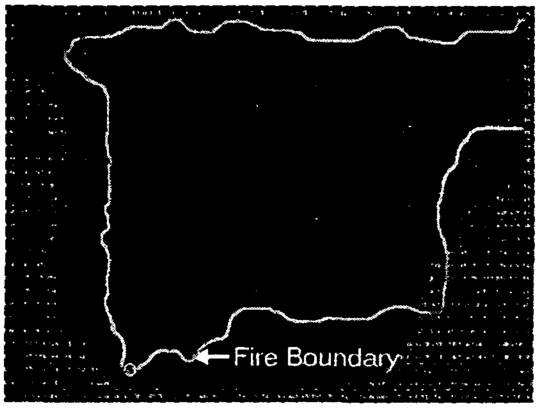


Fig. 8 Spread of fire as time passages
(after 115 minutes)