EXPERT AND GRAPHICAL SYSTEMS FOR SURFACE WILDLAND FIRES

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ABSTRACT

The expert system of wildland surface fires is established based on the code of BEHAVE of Andrews (1986), using the C and FORTRAN languages. By expanding the mathematical model of the code to fuels, terrain, and environmental conditions that vary with space and time, the graphical display system for the spread of wildland fires is also established. These two systems have been successfully turned to the Chinese display.

Key Words: Wildland Fires, Fire Behavior, Expert System

INTRODUCTION

Forest managers as well as those engaged in research involving in forests, brush fields, and grasslands need a consistent method for predicting fire spread and intensity in these fuels. Frandsen (1971)[1] and Rothermel (1972)[2] established a mathematical model for predicting rate of fire spread and intensity applicable to uniform bed and environmental conditions, and Andrews (1986),[3] etc. formulated the relative code of BEHAVE.

But the user's screen of the BEHAVE code is backward. The BEHAVE code consists of thousands input & output sentences, the code initializes values by answering every questions the program gives. It makes the operation tedious and difficult, and demands the user to possess the specialized knowledge and complicated operation technique. In this paper, the BEHAVE code has been converted and developed into a expert system. An expert system means that after properly program designing, the computer possesses some intellect behavior. In a limited field, it can make the function of the computer arrive to a specialist's level. A common user can easy to master the present expert system and to operate it. He can also get a overall perception of the running process and easy to change from a kind of task to another.

Meanwhile the graphical system for the spread of wildland surface fires on the curved ground is established. When the distribution of fuel, ground height and environmental conditions are known, the fire spread procedure can be simulated and shown on the computer screen using the system.

EXPERT SYSTEM

The expert system is composed of system instruction, input & output, and calculation. Because of the advantage of the C language in system designing, the C language is used in both of the system instruction and input & output parts. The FORTRAN language is used in calculation part. Thus, this system is constructed by mixing FORTRAN and C languages together.

Mixing compiling is a complicated and high level skill. The key problem is the data communication among different modules. Three methods are used in data transmission: near quotation, far quotation, and value quotation. It is related with the special knowledge of computer science, and the details are omitted here.

User's screen

This system possesses the most friendly user screen by developing a dialog box environment. The data windows are used for data input. Instructions will be given in the data window, such as the kind and limit of the data. The output is listed as tables on screen. If the content of the output data outvalues the capability of the screen, the display will be divided into several pages. In the process of performing, this system will display a list of menus, which guide the user to perform the system. The only task of user is to choose the items. The screen has a horizontal menu bar which is displayed at the top of the screen. After moving the cursor by the "RIGHT KEY" and "LEFT KEY" to the item selected on the horizontal menu bar, and pressing the "ENTER KEY", a vertical menu bar related will prompt. The "UP KEY" and "DOWN KEY" can be used to move the cursor to choose the sub-item on the vertical menu bar. When unexpected error occurs during the process of the program running, there will be enough information to tell user what kind of error and how to solve it.

This system adopts different level performance. It is most important thing to tell the user which level is in. A merit of this system is that it will tell you the level when needed.

The system can put the input data and the calculated results into the file the user named. It is helpful for the user to save the important and typical examples into archives. The system also provides the DOSSHELL function. This function enables the user to return to DOS environment when other operations need to be performed.

Function of major modules

The system consists of two parts, FIRE1 and NEWMDL.

The FIRE1 part consists of three modules which are Direct, Size and Contain modules. The SITE and DIRECT modules of the FIRE1 allow you to predict rate of spread, heat per unit area, fire line intensity, flame length, reaction intensity, effective wind speed, and direction of maximum spread. Although both modules predict the same values, their inputs are at a different level of resolution and they are designed for different applications. The SITE module aides the user in estimating fine dead fuel moister, wind, and slope. Its major feature is the estimation of fine dead fuel moisture from weather and shading information. The SITE module is used to make fire behavior predictions in cases where detailed site-specific information is available. On the other hand, the DIRECT module requires direct inputs of the basic input values (for example, 1-h fuel moisture). The DIRECT module may be more useful for general fire behavior prediction and "what if" questions. The CONTAIN module is used to estimate requirements for fire suppression activities. The CONTAIN module predicts final fire size, give forward rate of spread, initial fire size, fire shape length-to-width ratio, and control-line construction rate. It can also be used to find the line construction rate needed to hold the burned area to a fixed value.

The NEWMDL part is used for construction of a new site-specific fuel model. The NEWMDL part defines initial values for fuel model parameters under user control. The NEWMDL part is especially helpful if extensive fuel information is not available and permits construction of a "composite" fuel model containing any combination of litter, grass, shrub, or slash.

GRAPHICAL DISPLAY OF FIRE SPREAD PROCEDURE

Mathematical model

Frandsen (1971) established a mathematical model for predicting rate of surface fire spread and intensity applicable to homogeneous fuel bed and environmental conditions. The base of his model is that the spread speed R is the ratio of the heat flux I_p received from the source to the heat required for ignition by the potential fuel

$$R = I_p / \rho_{be} Q_{ig}, \qquad (1)$$

where ρ_{be} is the effective bulk density (the amount of fuel per unit volume of the fuel bed raised to ignition ahead of the advancing fire), Q_{ig} the heat of preignition (the heat required to bring a unit weight of fuel to ignition).

Wind and slope change the propagation heat flux I_p by exposing the potential fuel to additional convective and radiant heat, Rothermel (1972) given an approximate formula to calculate the effects

$$I_P=(I_P)_0(I+\phi_w+\phi_s), \qquad (2)$$

where $(I_P)_0$ is of the no-wind heat flux from the source on plane ground, the dimensionless coefficients ϕ_w and ϕ_s represent the additional propagating flux produced by wind and slope, which are evaluated from experimental data. This model is applicable to a wide range of wildland fuels, such as litter, grass, logging slash, and brush fields. The model is complete in the sense that no prior knowledge of a fuel's burning characteristics is required.

In most cases, the relative variances of the input data of the fuel, the ground undulation, and the environmental conditions are small quantities in the range of the length and time scales of the fire behavior. For these cases, Frandsen's model can be used to the first-order approximation, using the local linearization method. Therefore the fire spread procedure can be simulated with the inputs changed as the distributions of fire loading, depth, particle surface-area-to-volume ratio, particle heat content, and the moisture content at which extinction can be expected; the local wind velocity and ground height.

Graphical display of fire spread procedure

The graphical display system is built by using the VGA (video graphics array) showing code. The VGA has high ability to display graphics. It has more than 128KB visual screen memory. Its standard display mode has two main characteristics: First, it has the 640x350 high resolving power and can display 16 kinds of colors. Secondly, it has two display pages, each has 64KB visual memory. The address of page 0 is A000:0000, and the page 1 A000:8000.

This system uses VGA display mode to realize the high display quality of the VGA, with the following functions of the C language. The function initgraph (&graph—driver, &graph—mode," ") is used to initialize the graphics display mode, with the graph—driver defined as the VGA and the graph—mode as the Middle. The function setvisualpage() is used to set up the visual page with the choice 0 or 1. The function setactivepage() is used to set up the active visual page with the choice 0 or 1. Now dots and lines can be drawn on the active page. When graphics drawings are completed and dynamic display are needed, quick display on the screen can be achieved by alternatively defining the visual page and the active page.

As an illustration, the fire spread procedure is displayed in fig. 1, for

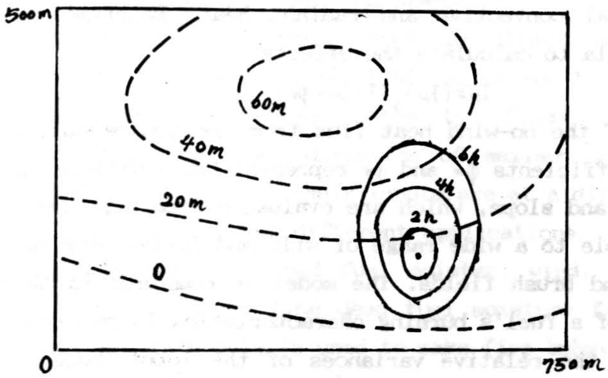

Fig. 1 The spread of a forest fire on a curved ground, with the solid line being perimeter of the fire field, the dotted line being the contour line of ground.

the case of the fuel model 12,[3] with the 1, 10, and 100 hours fuel moisture being 21%, 11%, and 5% respectively.

DISPLAY IN CHINESE CHARACTER

Two kinds of methods are generally used to make a system display in Chinese character, character display mode and graphics mode. The Character display mode has the advantage of high speed, but it can only display a limited number of Chinese character and also has to be related directly with the low level BIOS of computer. Thus, graphics mode is adopted in this system.

In order to realize displaying in Chinese character, several problems have to be solved. First, how to display Chinese characters on the screen, a function is specially devised to make it possible. In the function, the self-defined line style is used to put out the needed dot information. Secondly, because the cursor does not show on the screen under graphics mode, a self-devised cursor has to be made to let it display on the proper site of the screen. Special keys are used to control the cursor, the "BACKSPACE KEY" to delete the previous character and "UP KEY" and "DOWN KEY" to move the cursor. These functions are all in the self-devised inword() function. Third, under graphics mode, only the BIOSKEY function can accept keyboard input. A self-devised function has to be designed to make out whether the inputs are characters or data. It is also able to convert the individual digits into a mathematics data. These functions are in the self-designed inword() function. Usually, the capacity of standard Chinese character generator is very big, and this make the speed of reading a Chinese character from the character generator very slowly. A smaller Chinese character generator has been built, which raises the display speed greatly.

The graphics mode is easy to modify and supplement Chinese windows. It also has not the limitation of the number of Chinese characters. When a Chinese character is needed in a program. It can just be read from the standard Chinese character generator into the self-made small generator. The graphics mode is specially useful for designing a system which has a lot of Chinese windows and Chinese characters.

CONCLUSION

The expert system of wildland fires is established based on the BEHAVE code, using the C and FORTRAN languages. The system can be used to predict rate of spread, heat per unit area, fire line intensity, flame length, reaction intensity, effective wind speed, and direction of maximum spread; to estimate requirements for fire suppression activities; to construct new site-specific fuel model.

Applying mathematical model of Frandsen (1971) and Rothermel (1972) to include nonuniform fuels, curved ground and environmental conditions that vary with space and time, the graphical system for the fire spread is established also. When the distribution of fuel, ground height and environmental conditions are known, the fire spread procedure can be simulated and shown on the computer screen using the system.

These two systems have reasonable structure, friendly user's screen, and efficient display in Chinese. It is expected to be widely used in prevention and suppression of surface wildland fires in China.

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