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AN ALGORITHM TO HELP DESIGN FIRE SIMULATION AND OTHER DATA BASE WORK

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The simulation of fire behavior has become a valuable tool in wildland fire control. To support the simulation, large quantities of data representing local fire conditions must be developed, along with computer programs to manipulate the data and make them available for use. Both the data and the associated programs are usually referred to as the *data base.*

This report describes an algorithm that can be used in simulation models and may also prove helpful in related data base work. The method proposed is an application of well-known principles to the problem of computer simulation. Elements of the method have been successfully used in other areas of computer applications (Merrill 1973).

In a computer simulation run, the efficient and correct location of fires within certain types of boundaries, such as fuel, damage class potential, seen areas of a lookout or aircraft patrol, and equipment "exclusion" area, is essential. Information on the relation of the fire location to fuelbreak or area of modified fuels is also necessary. If, during the simulation, the fire location is found to be inside the modified fuel area, parameters of modified fuel and fire spread must be used to continue the simulation.

For illustration, we may assume that the aim is to determine the relation of the fire location to fuel type. A National Forest can be divided into fuel zones, as shown by letters A, B, C, D, and E in *figure 1.* In the forest being considered, some of the fuel zones are entirely contained within others. As a fire spreads through a given area during a simulation, the problem is to

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The data necessary for fire simulation may be made available through an algorithm based on tracing of boundaries composed of straight-line segments. Useful assumptions are that if a closed boundary does not contain a given point, then any other closed boundary contained within the former one does not contain the location; and that a given location will be contained in a closed boundary if the number of intersections of a finite line segment, drawn from the location to a known point inside the closed boundary, is even. The method described is similar in accuracy to existing alternative methods, and may have advantages. It may also be useful in other types of data base work.

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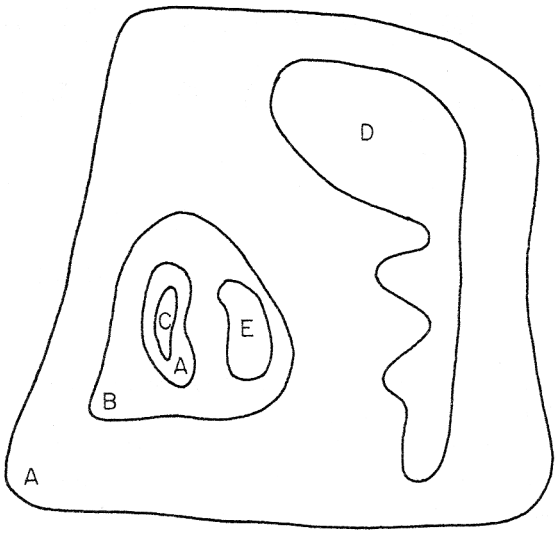

Figure 1—Fuel zones A, B, C, D, and E on a National Forest.

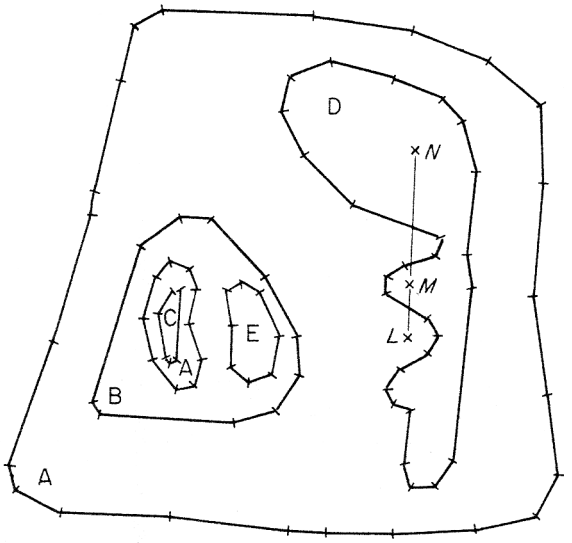

Figure 2—Digitized fuel boundaries.

determine the initial location of the fire and selected points of the expanding fire perimeter within the various fuel zones and to determine the fuel type and other associated parameters as a function of fire location.

The initial step in recording the data consists of associating the variable interest (fuel type) with location by digitizing (recording) grid points (X, Y) and the associated variable Z, to form the triplet (X, Y, and Z), in which X represents the longitude, Y the latitude, and Z the value of the variable.

At this point, two options are available:

1. Record enough grid points (X, Y, and Z), and write the associated computer programs to interpolate between grid points.

2. Trace the boundary of each zone and record points (X, Y, and Z) at selected intervals along the boundary, which is thus approximated by consecutive straight-line segments.

The same linear error is inherent in both methods, unless an interpolation scheme of a higher order is used in the first method. The choice between the two methods in a particular situation will depend on the amount and kind of data to be handled. Both methods have advantages and both have their place in simulation and data base work.

The fuel boundaries *(fig. 1)* can be digitized *(fig. 2)*. Each line segment is represented by two (X, Y, and Z) triplets, and (N + 1) points are needed to describe a boundary consisting of N sides.

To determine if a fire location is in or outside a given fuel zone *(fig. 2)*, apply these principles:

1. If a closed boundary does not contain a given fire location, then any other closed boundary contained within the former one does not contain the fire location. Use of this fact in procedures for both storage and access of data on any computer system can minimize computation and access time.

2. A given fire location will be contained in a closed boundary made up of line segments if the number of intersections of a finite line segment, drawn from the fire location to a known point inside the closed boundary, is even. If the total number of intersections is odd, the location in question will be outside the boundary enclosing the area of interest. For example, if a known point N is inside the fuel area D *(fig. 2)*, the number of intersections with the boundary of area D would be 2 for the point M and 3 for point L.

Computer programs based on the above two principles have been combined with the output of a digitizer at the Pacific Southwest Forest and Range Experiment Station's Forest Service Fire Laboratory, Riverside, California and one used to support data base work for the FOCUS program. FOCUS (Fire Operational Characteristics Using Simulation) is a model being developed at the laboratory to predict probable consequences of available alternatives in fire planning (Storey 1972).

The computer programs are written in Fortran for operation on the IBM 360 computer and are independent of the type of digitizer used. Copies of the programs are available upon request from the Director, Pacific Southwest Forest and Range Experiment

Station, P.O. Box 245, Berkeley, California 94701, Attention: Computer Services Librarian.

The following examples serve to clarify the application of the algorithm and indicate its accuracy.

For the example illustrated in *figure 3,* 10 zones of interest, composing a square, were established. If all 10 types are considered as a unit square, then the area of each zone is:

	Area	*Percentage*
Zones:		
A	0.33984	0.33545
B	.15234	.1531
C	.07421	.0731
D	.01953	.0191
E	.15234	.1535
F	.11718	.1191
G	.02343	.0238
H	.00390	.0035
I	.08593	.08729
J	.03107	.0320

A random set of 20,000 (X and Y) points ($0 \leqslant X \leqslant 1$, $0 \leqslant Y \leqslant 1$) was generated. Each point was then determined to be in one of the 10 zones, using the algorithm described here, and many of these points were checked individually for accuracy. As a further check on the algorithm, the percentage of points falling within each zone was computed.

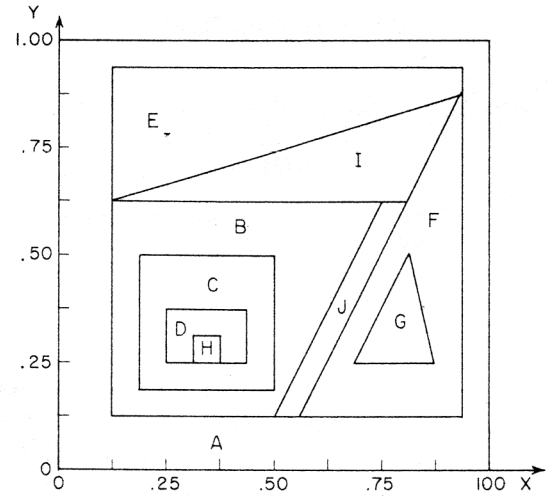

Figure 3—A unit square consisting of 10 distinct zones.

In an application of the technique *(fig. 4),* the 30 closed boundaries represent the seen areas of a lookout on a National Forest. Illustrated are the location of the lookout, a known inside point within each closed boundary, and the fires found inside the seen areas of the lookout.

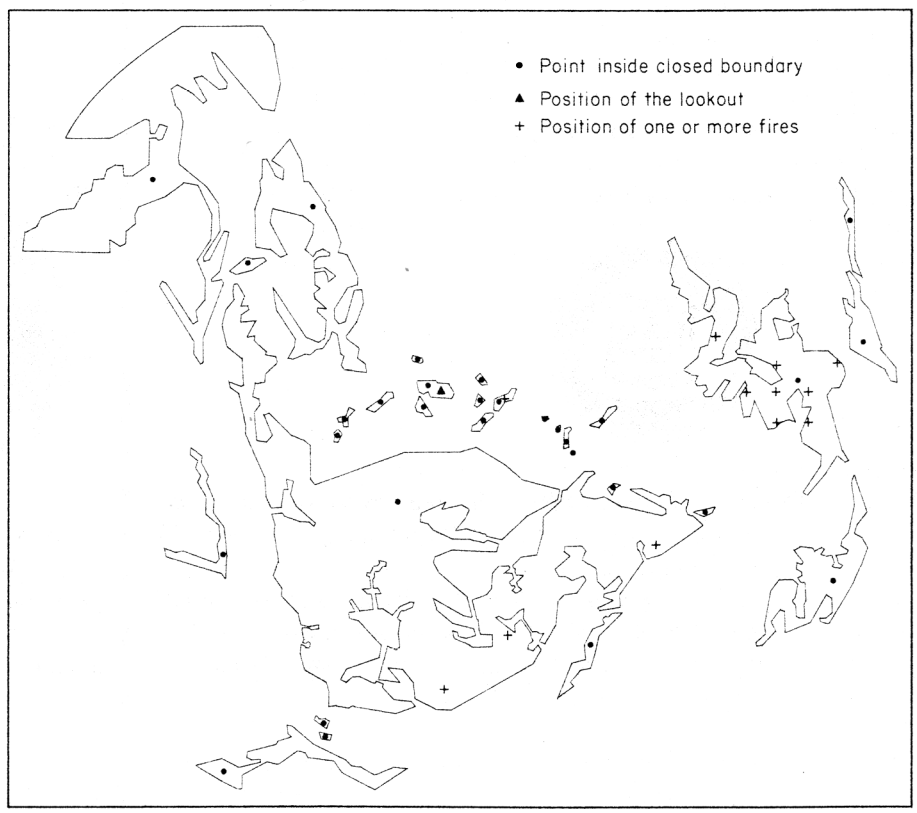

Figure 4—Seen areas of a lookout on a National Forest illustrate the application of a data base program in computer simulation.

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