PROGRAM ABSTRACTS/ALGORITHMS

PRS1 and PRS2: FORTRAN programs for the analysis of animal spatial data

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The spatial positions adopted at any one time by members of a discrete population of animals reflect the influence of one, or more often, the cumulative influence of a number of factors (Bovbjerg, 1975). The measurement and analysis of the spatial and temporal interactions between individuals in a group and between groups and the influence of social or environmental factors on their distribution are areas of growing interest. Coordinate data have been used to characterize rat gregariousness and positional preferences in the development of social theory (Barefoot, Aspey, & Olson, 1975; Latané, Schneider, Waring, & Zweigenhaft, 1971; Syme & Syme, 1973). Other applications are seen in the relationship between social dominance rankings among dairy cattle and territorial behavior (Beilharz & Mylrea, 1967; Friend & Polan, 1974; Syme, Syme, Waite, & Pearson, 1975) and the factors affecting sheep distribution (Arnold & Pahl, 1974; Kilgour, Pearson, & de Langen, 1975; Lynch, 1974; Nicholls, Fowler, & Kearins, 1976). Before the environmental and social cues affecting position can be investigated, there is a need to define the placement of a population on site and to compute simple parameters such as occupancy by individuals and interpair distances.

A major problem confronting animal spatial analysis is the means of data collection. To date, investigators have used both photography (Syme et al., 1975) and visual sightings (Kilgour et al., 1975). The problems involved in aerial photography of sheep grazing over large ranges in open country have been discussed in detail (Dudziński & Arnold, 1967; Dudziński, Pahl, & Arnold, 1969). Automatic radio tracking (Cochran, Warner, Tester, & Kuechle, 1965), optical (Lappalainen & Lahtinen, 1975; Wilcox & Garthe, 1977), and electronic (Hirao, Shinozaki, Furuya, & Ishikawa, 1975) devices have been built capable of interfacing with a computer via some form of data storage.

However, even small numbers of subjects generate large quantities of coordinate data over a short period, and automated analysis is essential. Computer programs designed to analyze the positional behavior of animals monitored with a radio-tracking system (Siniff & Tester,

1965) of children (Herron & Frobish, 1969) and of two subjects in a rectangular (Aspey, 1977b) or circular (Aspey, 1977a) field have been published. A more complex program is that of Stricklin, Graves, and Wilson (1977) (DISTANGLE), which is capable of calculating the spatial variates for up to 50 subjects including results based on the orientation of the subjects in the field.

The family of programs described in this report produce 10 different variates for up to 30 individually identified subjects or for a larger group of unidentified subjects, in any observation area. Experiments that include separate sessions of observations for comparison and groups of animals containing identified subgroups are readily handled. These programs have been developed and modified over several years in response to the requirements of 10 different experiments involving sheep (Kilgour et al., 1975), dairy cows (Syme et al., 1975), pigs, deer, bulls, and steers.

Description. PRS1 is a FORTRAN IV program (Table 1) to analyze sequential coordinate data and to produce information about the movement and interaction of subjects in behavioral studies. A structure diagram is shown in Figure 1.

Observation Field. The observation field is divided into squares, and the position of the subjects with respect to the grid is recorded for each observation. A four-digit number is used to describe the appropriate square; the first two digits to describe the X coordinate and the second pair the Y coordinate. The observation field is not required to be rectangular, but only such that a suitable grid may be placed over it and the edge distortion (where the squares are intersected by the field boundary) is negligible (Figure 2). If the square side length is entered as an input parameter, then all calculated distances are scaled accordingly. Otherwise, the results are in terms of unit-square side lengths. A maximum of 12 squares along the X axis and 20 along the Y axis is permitted in the current version of PRS1.

Observations. The basic unit of any experiment is the uniquely identified observation. Instantaneous or scan observations are taken throughout an experiment at defined intervals. Observations are then grouped into sessions (or summaries) for the computation of

Table 1
PRS1 Specifications

Language;	FORTAN IV
Lines:	1,279
Computer:	ICL 2980
Peripherals:	Direct-access files, card reader, line printer

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Figure 1. Structure diagram of PRS1.

mean results and standard deviations. A mean and standard deviation are also computed for each parameter over the entire experiment. A session may be defined arbitrarily or may correspond to a natural division of the observation period. While a maximum of 30 observations per session is permitted, the number of observations per session need not be constant and may vary to suit the experimental design.

Input. The input consists of three types of card. First, the optional comment cards are used to describe the experiment. Second, the parameter cards define the experimental structure and its bounds. Up to 82 parameters that control the processing of an experiment may be altered using the subroutine OPTION prior to the input of the coordinate data. Except for three essential parameters (number of sessions, maximum number of observations per session, and number of subjects), all have default values. Finally, the observation data cards are subdivided into sessions and contain the experiment number, the observation number, the card number, and a string of four-figure digits describing, in a fixed order, the coordinates of each subject.

Output. In addition to any comments and the input coordinate data, the output is any or all of the following: (1) the mean group coordinate position; (2) the subject density, calculated as the area of the occupied squares divided by the total number of subjects; (3) aggregation of the group about the mean position (the sum of the distances from each subject to the mean position divided by the total subject number, i.e., mean deviation); (4) aggregation of the group about specified points (up to four different fixed

Figure 2. Grid system superimposed on observation field, showing topography and numbering of X and Y axes.

points may be specified by the user and the measure is calculated as the sum of the distances from each subject to the specified point divided by the total subject number); (5) distance moved by the mean coordinate between observations; (6) frequency of occupation of the observational squares by all subjects; (7) frequency of occupation of the observational squares by individual subjects; (8) distance between each pair of subjects; (9) distance moved by individual subjects per observation; (10) proximity of other subjects to each individual (up to three different user-specified radii are possible and the frequency with which other subjects appear within the radius from each individual subject is calculated).

For Parameters 1-6 the results are tabulated for each observation, each session, and over the entire experiment, while for Parameters 7-10 only mean session and experiment values are presented. Clearly, some calculated results, such as subject density and the mean aggregation about the mean coordinate, are related. Nevertheless, each parameter has proved useful in at least one field experiment and, when not required, may be easily suppressed using **OPTION**. Typical output results are shown in Tables 2 and 3 for interpair distances and the aggregation about the mean coordinate.

Subgroups. Some experiments involve the presence of one or more defined subgroups among the main group (e.g., adult males within a female group). Using **OPTION** it is possible to identify the members of up

to five subgroups and to carry out a specified analysis of each subgroup. It is necessary to supply the following data: (1) the number of subgroups, (2) the number of subjects in each subgroup, and (3) the position among the input coordinates of each subject forming the subgroup.

Missing Data. Practical difficulties in the design of an experiment or in the collection of the coordinate data sometimes result in unbalanced or missing data. Where a subject is absent or its coordinate not determined for some reason, then the value 9999 is entered into the input data. When experimental parameters are calculated, such values are ignored and means and standard deviations are derived only from the remaining coordinates. Provision is also made for observations that are missing, or for sessions with a differing number of observations.

Data Checking. A special program PRSA has been developed to check the PRS1 input deck for internal self-consistency and freedom from gross errors.

PRS2. The FORTRAN program PRS2 with its associated data-checking program PRSB is designed for experiments where individual identification of subjects is not made. Here, the number of subjects is limited only by the requirement that not more than 120 observation squares are simultaneously occupied. The coordinate data for each observation are comprised of a string of six-figure digits defining the occupied squares and the number of subjects in each one. Essentially, the output of PRS2 is a subset of the PRS1

Table 2
Interpair Distances (in meters) Between Subject 1 and All Other Subjects

Subject 1 Pair	Session								Mean	SD
	1	2	3	4	5	6	7	8		
1/2	2.0	4.0	1.5	2.2	.9	1.8	3.0	1.3	2.1	1.0
1/3	4.5	8.6	.2	7.6	2.0	1.1	4.9	5.7	4.3	3.0
1/4	4.7	4.1	1.3	.5	5.4	1.3	2.3	4.5	3.0	1.9
1/5	3.7	5.1	1.3	7.7	2.0	1.3	3.7	4.3	3.6	2.2
1/6	7.6	4.4	2.1	4.6	8.7	3.5	2.6	2.3	4.5	2.5
1/7	4.5	4.2	1.5	4.7	8.1	3.7	2.7	2.0	3.9	2.1
1/8	8.1	3.7	1.6	4.6	8.6	3.7	2.5	4.2	4.6	2.5
1/9	5.2	9.5	1.7	4.3	9.0	5.6	2.6	2.8	5.1	2.9
1/10	5.4	6.3	3.0	4.7	9.2	4.7	4.2	3.2	5.1	2.0
Mean	5.1	5.5	1.6	4.5	6.0	3.0	3.2	3.4	4.0	1.5
SD	1.9	2.1	.7	2.3	3.5	1.7	.9	1.4	1.0	

Table 3
Group Aggregation About the Mean Coordinate (in meters)

Observation	Session								Mean	SD
	1	2	3	4	5	6	7	8		
1	1.2	1.8	1.1	1.2	1.4	1.3	2.4	.8	1.4	.5
2	1.7	3.8	.7	4.7	4.0	3.0	3.1	3.8	3.1	1.3
3	6.7	7.3	1.1	5.0	8.7	3.0	2.5	2.8	4.6	2.7
4	2.9	6.5	1.4	4.7	1.7	2.9	1.9	3.2	3.1	1.7
5	7.0	5.9	2.0	4.4	8.5	3.0	3.2	4.0	4.7	2.2
Mean	3.9	5.1	1.2	4.0	4.9	2.6	2.6	2.9	3.4	1.3
SD	2.8	2.2	.5	1.6	3.5	.8	.5	1.2	1.4	

Table 4
PRS1 and PRS2 Restrictions

	PRS1	PRS2
Maximum number of sessions	12	12
Maximum number of observations per session	30	30
Maximum number of subjects	30	
Maximum number of occupied squares		120
Maximum number of squares along X axis	12	12
Maximum number of squares along Y axis	20	20
Maximum number of subgroups	5	5

output (Parameters 1-6) plus the mean interpair distance for each observation.

Program Restrictions. Overall current limits of PRS1 and PRS2 are given in Table 4. Most of these restrictions can be relaxed with little reprogramming effort, and experiments involving a large number of observations can be split into conveniently sized blocks for processing.

Final Comments. Objective and repeated spatial data, while valuable in their own right, are of more significance accompanied by simultaneous behavioral information, perhaps collected with computer-compatible event recorders (Fernald & Heinecke, 1974; Gass, 1977). Another area needing investigation is the incorporation of subject orientation into data collection. Clearly, in many circumstances, bearing is as important as position.

Since the observation techniques used to collect spatial information are a type of instantaneous or scan sampling as defined by Altmann (1974), the frequency of changes in positional states and the rate of such changes are only crudely estimated (depending on the observational frequency) as a lower bound. However, with the judicious choice of observation interval for each experiment, the data derived have been consistent and significant, and small observation intervals appear unnecessary in most instances. The use of continuous electronic monitoring would permit more exact estimates of each parameter, especially in situations where animal movement is rapid.

In conclusion, while animal positional studies have now become feasible with the use of electronic computers in data analysis, much remains to be explored in the interpretation of the results in terms of social theory, in devising new, more useful, spatial measures of the interactions between individuals and their environment, and in the application of statistics to this data.

Availability. Source listings of PRS1, PRS2, PRSA, and PRSB, together with detailed manuals for their use, are available at no charge from the author.

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