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AUTOMATED ACQUISITION OF DECISION RULES: THE PROBLEMS OF ATTRIBUTE CONSTRUCTION AND SELECTION

BY

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THESIS

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Dedication

To LJH now LHB for still thinking I was worth the wait...

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This paper describes a system which seeks to relieve the domain expert of the burden of analyzing his own methods. He uses his knowledge to reach expert determinations (classifications) for examples from his domain of expertise. Once the expert has classified each sample case, the system uses techniques patterned on a general model of the expertise development process to attempt to discover the relationships prevalent in each class used by the expert, and formulates general rules for classifying future examples. This approach, termed *learning from examples* minimizes the need for the expert to codify his technical knowledge. The system consists of three programs which are described in detail later in the paper. The first, CONVART, computes attributes of the time-varying characteristics of examples. The second, VARSEL, selects the "most relevant" attributes for formulating classification rules from those produced by CONVART and those initially available. The third program, GEM, uses the attributes identified by VARSEL to formulate classification rules for each of the classes represented by the set of examples. VARSEL was devised and written by the author, while CONVART and GEM were written by others [John Davis, and Robert Stepp, et. al., respectively].

1.1 Current Expert System Development Techniques

1.1.1 Knowledge Encoding

One traditional approach to the creation of expert systems is shown in Figure 1. A *knowledge engineer* works in concert with a domain expert to characterize the process used by the expert to reach decisions [Hayes-Roth,1980]. Unfortunately, domain experts are often unable to describe their own mental processes clearly enough to enable the production of efficient, complete and reliable systems. This problem makes many iterations through the development loop necessary. The knowledge engineer encodes the expert's knowledge, applies the resulting system to sample cases, uncovers insufficiencies or inconsistencies, and returns to the expert to overcome these difficulties. This iterative process strains the knowledge representation scheme and the process control structure until the system becomes unwieldy and difficult to use and maintain.

1. INTRODUCTION

Expert systems are computer programs which contain and are capable of applying expert knowledge of a particular problem domain to solving problems within the domain. Examples of such systems are Mycin [Shortliffe,1982], used for medical diagnosis, and Plant/ds [Michalski,1982a], used for diagnosing soybean plant diseases. Each system identifies a given input example as belonging to a particular class within the system's domain of expertise. The Plant/ds system, for example, arrives at the most plausible diagnosis for an afflicted soybean plant based on the symptoms the plant exhibits. In this case, the domain of soybean diseases has been divided into a number of categories (classes) each representing a different disease. The task of the expert system is to identify which class (disease category) a given plant's symptomology represents.

Traditional expert system development techniques require an expert in the domain of interest to specify the important factors he uses to arrive at expert determinations. In the Mycin system, the experts were required to formulate a set of rules to apply to test cases to determine a plausible course of treatment for each case. The experts found that while they were capable of reaching determinations easily, they were less able to articulate the process they used to arrive at them. This approach requires the expert to analyze his own methodology from a perspective to which he is unaccustomed. The systems which result are often inefficient because they use unnecessary data in the process of analyzing a test case, and unreliable because contingencies not previously encountered may result in faulty or indeterminate results [Clancey,1981] [Hayes-Roth,1980]. To repair these shortcomings, the system designer resorts to iterative development methods in which the expert is presented with the faulty results and asked to augment the current system so that correct results are produced. When further testing uncovers new flaws, the development loop is repeated.

between data-set size and processing time required [Rabin,1974]. This causes a problem termed *combinatorial explosion* where the processing time for a large data set is often far too lengthy to be of practical value. Modern inductive learning systems, e.g., AQ11 or ID3 are able to avoid this problem by applying appropriate heuristic methods. However, the task of looking for patterns of interaction and interdependency within data is so complex, and since the amount of data should be large if the results are to be reliable, the modern systems must use some means of further *data-reduction* if the processing time for the learning programs is to be acceptable. Traditionally, system designers rely on domain experts to tell them which data are relevant and which should be ignored. Consequently, expert system development using automated methods is also prone to iterative development because the domain experts frequently misjudge which data are important or relevant. This produces systems with the same basic flaws encountered in knowledge engineered systems: inefficiency and unreliability.

1.2 Requirements for Better Expert System Development

The major shortcoming of current expert system development techniques is the continued dependency on domain experts to provide information they are normally unprepared to provide. System development techniques requiring the aid of domain experts for initial development are doomed to inadequate performance unless new insights can be gained into the ways in which domain expertise arises and is implemented. This paper describes a data-driven system which is largely domain independent and can operate without the explicitly stated *a priori* knowledge of the problem domain usually needed by system developers [Buchanan,1979]. Assuming that the necessary knowledge is contained in the pairing of sample events with expert determinations, sufficiently powerful methods for extracting the knowledge are needed [Tunstall,1974] [Shapiro,1981]. The ability to do this requires a method which can assess the relevance of attributes reliably while remaining so computationally efficient that extensive pre-selection of attributes by a domain expert is not required [Chen,1974]. Hence, the role played by the domain expert in ordinary automated system development paradigms is now also largely automated. The system can

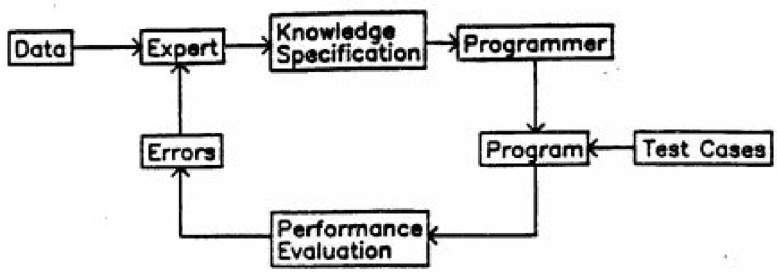


Figure 1. The traditional expert system development loop

A second failing of the knowledge encoding approach arises from the necessity of having a domain expert in the development process. This requirement precludes the possibility of expert-system development in domains in which no experts have developed because the area is too new or obscure. The development of domain expertise is a slow process because of the tremendous difficulties inherent in discovering relevant avenues of inquiry into the underlying processes and structures within the domain.

1.1.2 Automated Inductive Inference

A relatively new approach toward expert system development involves *inductive learning* systems which use empirical evidence, in the form of examples, to derive rules by which determinations may be made for data presented to the system. Such systems use *automated inductive inference*, a method whereby rules for classifying events are derived using computer programs which systematically process the data to discover patterns and interelationships which may be useful for distinguishing each class from the others [Michalski, 1972, 1980, Angluin,1982]. The failing of these systems arises from the limitations inherent in dealing with statistically valid populations of sample data. For some automated inductive inference methods, an exponential relationship exists

2 A MODEL OF THE EXPERTISE DEVELOPMENT PROCESS

The following definitions will be used throughout the discussion which follows:

- An *exemplar* or *example* is an object which exemplifies a given decision class.
- An *attribute* is a measurable characteristic of an exemplar within the problem domain. Examples are color, height, and annual rainfall. Attributes fall into two categories: static attributes measure characteristics which have a constant value while dynamic attributes measure characteristics whose values vary relative to some other variable such as time, for a given exemplar.
- A *selector* is a relation between a given attribute and the value of that attribute. Examples include color$\neq$ red, height=1.75m, and weight$\leq$ 95kg.
- An *event* is a vector of attribute values characterizing a given exemplar. An event may be represented by a conjunction of selectors.
- A *decision class* or *class* represents the membership of one or more exemplars in a category characterized by some common denotation.
- An *event set* is a set of events which are members of known decision classes.

An example of an event set is given in Figure 2. The event set is comprised of two classes of two events each and one class of one event. Each event is in the form of a conjunction of four selectors. A Dodge-Dart, for example, weighs 6000lb, is twelve feet long, and can carry six passengers.

A model of the expertise development process, patterned after one in [Dietterich,1981], is presented in Figure 3. The sequential model of expertise development presented here has four major processing steps and feedback from any step to any previous step [Kanal,1978]. Each of the four processing steps– attribute construction, attribute selection, rule formation, and rule implementation– are described in detail below.

deal with large amounts of data and indicate promising avenues of exploration for researchers in the problem domain and expert system implementors alike.

2.1 Attribute Construction

Once an initial set of attributes have been selected by the expert as potentially relevant, the first processing step involves the construction of derived attributes. Derived attributes are produced by applying a variety of logical, statistical, or mathematical operations to the initial attributes. For example, a derived attribute may be a mathematical product of some numerical attributes or a logical expression of propositional attributes (properties that are true or false).

Additional attributes may be derived by first noting that some attributes change over time. Rainfall would be one example of such an attribute. The rainfall on a given field could be given as a series of values representing "rainfall" on each day for a given time interval. New attributes can be constructed from this type of attribute using statistical operations such as averaging (e.g. "the average rainfall per week"). Arithmetic operators can be applied to numeric attributes. For example, if we have the attributes length, width, and height, we might apply the multiplication operator to construct the attribute "volume." Neither mathematical nor statistical operators can be applied to non-numeric (i.e., *symbolic*) attributes such as "blood type" or "eye color."

To perform attribute construction, operators are applied to the attribute values in the hope of discovering new attributes which have greater class-differentiating abilities than the original attributes. This process is termed *constructive induction* [Michalski,1982b] [Davis,1981].

2.2 Attribute Selection

After attribute construction is completed, the set of constructed attributes is joined to the set of initial attributes and each attribute is evaluated in terms of its potential *relevance* (i.e., its potential utility for differentiating classes based on its value for a given exemplar) [Kodratoff,1982]. This is the process of attribute selection in which unusable or less informative attributes are discarded and only those attributes which best distinguish the classes are retained.

2.3 Rule Formation

The third processing step is rule formation. Rule formation entails characterizing the classes by logic expressions involving selectors. The most interesting expressions are those which most compactly capture the knowledge necessary to classify a new event reliably. The two basic conditions that a set of such expressions (rules) must meet are *consistency* and *completeness*. Completeness requires that each exemplar must satisfy some rule from the rule set, and consistency requires that each exemplar satisfy *at most* one class from the set of classes.

A set of simple discriminant rules for the event set of Figure 2 is shown in Figure 4. The first rule reads: "If the length is less than 20 feet, the vehicle is a car." The second rule reads: "If the length is greater than 20 feet and the vehicle can carry less than four passengers, then it is a truck."

Rule 1:	[length$<$ 20ft] ::> car
Rule 2:	[length$\geq$ 20ft]$\wedge$[passengers$\leq$ 3] ::> truck
Rule 3:	[length$\geq$ 20ft]$\wedge$[passengers$>$ 3] ::> bus

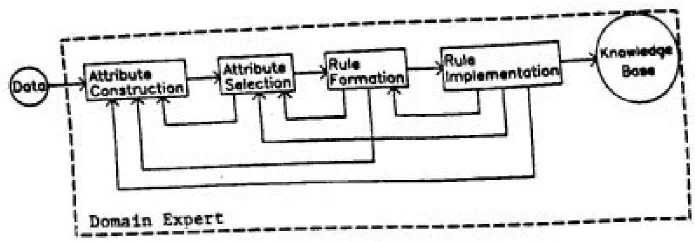
Figure 4. A set of discriminant rules derived from the event set in Figure 2.

2.4 Rule Implementation

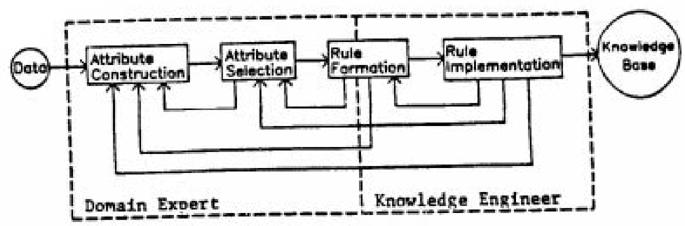
The final processing step is rule implementation. This is the encoding of the rules generated in the previous step in such a fashion that they may be applied to new events supplied by a user. Although implementing the rules is a simple process, designing the user interface is not. The most important characteristics of an expert system which will be used by people who are not intimately familiar with the software are: easy data entry, comprehensive presentation of results including measures of how confident the system is in its analysis, and the ability to explain the reasoning processes which led to the result presented.

2.5 Conventional Methods in Terms of the Model

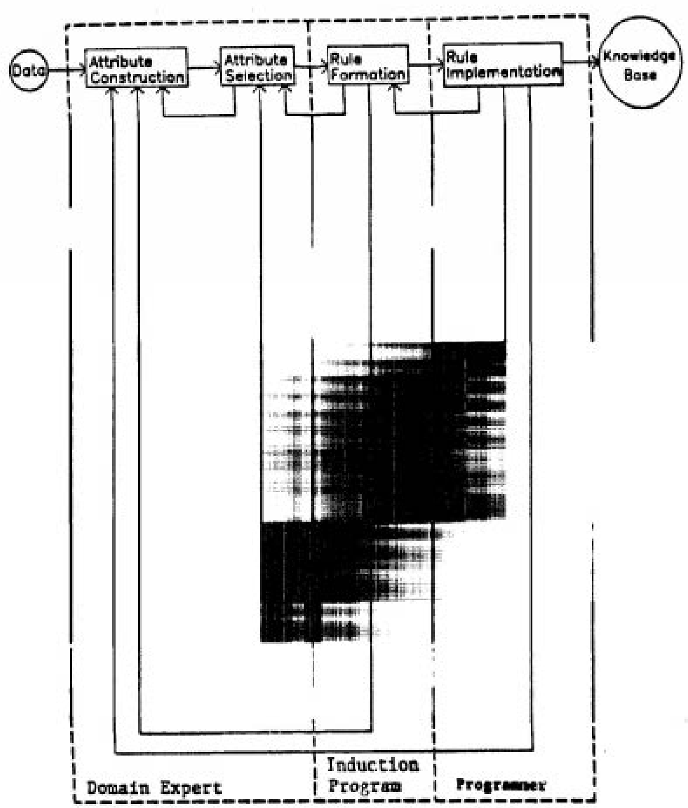
Figures 5a-c show the model of Figure 2 configured to correspond to its application to human expertise development, the knowledge engineering approach to expert system development, and the automated induction method respectively. In Figure 5a, human expertise development, we see that the human expert is responsible for all processing, implementation, and application of the resulting expertise. In Figure 5b, the knowledge engineering approach, the expert is still responsible for all attribute processing but now the knowledge engineer must share the task of rule generation and becomes responsible for implementing the rules on a computer. Figure 5c shows the automated inductive inference method in terms of the general model. The human expert is now responsible only for deciding which attributes are relevant. The data is then presented to an inference program in terms of the specified attributes, and the program develops rules which characterize the data. The software engineer must then implement the rule set on the computer. Figure 5d shows the software described below as it relates to the model.


Data
Attribute Construction
Attribute Selection
Rule Formation
Rule Implementation
Knowledge Base
Domain Expert

(a)


Data
Attribute Construction
Attribute Selection
Rule Formation
Rule Implementation
Knowledge Base
Domain Expert
Knowledge Engineer

(b)


Data
Attribute Construction
Attribute Selection
Rule Formation
Rule Implementation
Knowledge Base
Domain Expert
Induction Program
Programmer

3 AN IMPLEMENTATION OF THE MODEL

3.1 Attribute Construction Using the Program CONVART

3.1.1 A Rationale for Attribute Construction

Time-dependent attributes are those that capture the value of some characteristic of an event as it changes with time. Such attributes are, therefore, useful for describing procedures or processes. If such attributes could be used by an inference engine, a broader range of problem domains would be approachable by expert systems. Current inference engines, however, are only capable of processing so-called static attributes which have only a single value for each event. If inductive inference techniques are to be applied to these problem domains, some method for representing dynamic (time-dependent) attributes by static attributes is needed. Two ways of describing dynamic attributes statically may be employed. The first involves characterizing the progression of values for the attribute over time as a polynomial or other functional entity. This is the method used in the series of Bacon programs [Langley,1982].

The second method is the computation of fundamental descriptive quantities for the set of measured values. Examples of such quantities for numeric attributes (i.e., attributes whose possible values have a natural partial-ordering) are maximum, minimum, average, etc. Examples of quantities for nominal attributes (i.e., attributes whose possible values have no inherent partial-ordering such as color or shape) are most-common-value and least-common-value. This is the method used by CONVART [Davis,1981]. CONVART is composed of a number of routines which compute such measures for dynamic attributes. It is implemented in Pascal on a Vax 11/780.

Another problem found in both dynamic and static attributes is the use of continuous variables which may take on any real value within some range of values. Interpreting the meaning of a given value for such an attribute is often difficult, and applying inductive inference techniques to them often produces unwieldy results. The solution CONVART applies to continuous attributes is *discretization*. Discretization is the process of dividing the range of possible values for an attribute into a manageable set of discrete values based on the distribution of the observed values throughout the range of possible values. CONVART uses a nearest-neighbor algorithm to arrive at plausible discrete ranges.

3.1.2 Using CONVART in An Expertise Development System

Given that CONVART produces many derived attributes from each dynamic attribute and adds them to the original static attributes, the burden falls on the inference engine to weed out the bad attributes and use only the relevant ones. Although a rudimentary relevancy evaluator was incorporated in CONVART, the developer admits that it is far from sufficient for the task [Davis,1981]. Therefore, the rule constructor is still faced with the task of dealing with many attributes measured (or computed) for many events. Because of the complexity of the algorithms on which inductive inference programs are based, the processing required for event sets containing many attributes is unacceptable. Attribute selection is needed to make the process of expert system development practical for "real" event sets.

3.2 The Attribute Selection Program VARSEL

The program VARSEL performs the task of attribute selection based on a measure of attribute relevancy for class discrimination calculated using the method described below. It is implemented in Pascal on a Vax 11/780. The program evaluates each attribute individually and then compiles a subset of attributes which completely differentiates each class from the others. The user may select one of two ways in which the compilation is to proceed. The first method is an adaptation of a procedure proposed by [Lbov,1965] in which attributes are chosen randomly using a weighted selection scheme in which more relevant attributes are more likely to be chosen. The method described here uses this principle of *random adaptive search*, modified so that small subsets of attributes are evaluated and the individual relevancy measure of each constituent attribute is improved or degraded based on the performance of the selected subset as a whole

[Smith,1980] [Bethke,1981]. If the process converges, the most relevant attributes are then indicated by high relevancy measure.

The second method involves what has been termed a *greedy* search scheme in which attributes are added to a subset of attributes until a sufficiently discriminatory attribute set has been found. Both methods are described in detail below.

3.2.1 A Rationale for Attribute Selection

Attributes may be of three types. Numeric attributes have real or integer values which represent measured quantities directly. Examples of numeric attributes are "temperature" and "number of legs." Ordinal attributes have integer values which capture a true partial ordering present in the attribute values. An example of such an attribute is "quality" which may have the values "very bad", "bad", "acceptable", "good", and "excellent." The third type of attribute is a symbolic attribute. The values of symbolic attributes have no inherent partial ordering. One example of such an attribute is "shape." Another term often applied to symbolic and ordinal attributes is *nominal*.

The problem of selecting the most relevant set of attributes to describe objects for the purpose of inductive learning is traditionally approached using various methods of attribute selection such as factor analysis, multidimensional scaling, and linear transformation, developed in the fields of pattern recognition and statistical decision theory. These methods involve statistical or information-theoretic measures which identify the principal attributes in the event set [Andrews,1972] [Harmon,1960] [Lawley,1963]. These methods are most effective for numeric attributes when the size of the event set is statistically significant. When attributes are symbolic (categorical or propositional) and the event set is small, these methods are not adequate [Stearns,1976] [Zadeh,1981]. In fact, using the methods mentioned above, "it is almost impossible to formulate general guidelines regarding the selection of physical [attributes] and structural [attributes]" [Tou,1974]. To analyze such *nominal* attributes mathematically, numeric values must be assigned to each possible value of the attribute (e.g., color might be encoded as: red=1, yellow=2, blue=3, etc.). When statistical methods are applied to such attributes, the results from the statistical methods may vary if the ordering of the values changes (e.g., red=2 and yellow=1). Thus, although the actual values of the attribute have not changed, the measures derived from them have. This is clearly erroneous. Therefore, there is a need for new methods applicable to multivalued or propositional symbolic attributes and for small numbers of events.

3.2.2 A Relevancy Measure

The difficulty of performing satisfactory attribute selection using statistically-based methods may be overcome by analyzing the observed values of the attributes using a method based on heuristic knowledge of the properties of attribute values typically found in event sets of interest. Such a system could deal effectively with symbolic and ordinal attributes since these attributes do not behave statistically in the same way that numeric attributes do.

The computation time necessary to process a set of events is large when the event set contains many attributes. A computationally inexpensive means of rapidly eliminating irrelevant attributes would reduce the computation time required. The method described below accomplishes all of these goals.

Classical information theory has been used to attack the problem of attribute relevancy measurement by modeling decision trees as information sources and attribute values as "messages." The information contained in a message "M" depends on the probability of the message and is expressed by:

$$I = \log_x \left(\frac{1}{P(M)} \right) \quad (1)$$

where: P(M) is the probability of message "M."

In event sets of interest, a given value (message) may occur in events representing more than one class. If we can assume that the message is *correct* for only one of the classes in which it occurs, then the information provided by the message depends not only on the probability of the message, but on the probability that the message is correct P(c∩M):

$$I = \log_x \left(\frac{1}{P(c \cap M)} \right) \quad (2)$$

Others have postulated that the information in such a "questionable" message is [Quinlan,1982]:

$$I = \log_x \left(\frac{1}{p^+} \right) + \log_x \left(\frac{1}{p^-} \right) \quad (3)$$

where: p^+ is the probability of the correct occurence of the message.

p^- is the probability of the incorrect occurence of the message.

The derivation of this expression relies on one fundamental assumption. The correct and incorrect messages are probabilistically independent. This, however, is incorrect. The two messages are, in fact, mutually exclusive by their very nature. This invalidates the expression. We might then hypothesize that, given the information measure in equation 2, that for "v" possible values (messages) for a given attribute:

$$I_{tot} = \log_x \left(\frac{1}{P(c \cap M_1)} \right) + \log_x \left(\frac{1}{P(c \cap M_2)} \right) + \cdots + \log_x \left(\frac{1}{P(c \cap M_v)} \right) \quad (4)$$

holds if the messages are independent. Unfortunately, the most frequent case is that the different messages are not necessarily independent and such an assumption has an associated risk. In addition, these measures effectively assume that we are interested in viewing the messages as "correct" or "incorrect." While such a binary view is sometimes useful, the multi-class nature of event sets of interest calls for a more robust measure. Therefore, we require a measure which retains the multi-class view of the world and is immune to the vagaries of data collection and random occurrence of events which often produce widely disparate class sizes within an event set.

We approach this problem by first making a simple assumption: since we wish to measure a characteristic of the data (which, hopefully, reflects the nature of the domain of interest) we may take advantage of the fact that for a given attribute, for a given event, only one value may be observed in the data. This assumption allows us to further assume that the possible messages (values) for a given event are not independent, but mutually exclusive. Unlike the case of equation 3 above, we realize that dealing with such messages by combining their information contents can be misleading. Instead, we will manipulate their probabilities directly. The total probability of all possible messages given mutual exclusivity is:

$$P_{tot} = P(M_1) + P(M_2) + \cdots + P(M_v) \tag{5}$$

If each of the terms is further divided into probability of correctness $P(c \cap M_i)$ and error $P(e \cap M_i)$, the total probability is:

$$P_{tot} = P(c \cap M_1) + P(e \cap M_1) + P(c \cap M_2) + P(e \cap M_2) + \cdots + P(c \cap M_v) + P(e \cap M_v) \tag{6}$$

This equation may be separated into two:

$$P_c = P(c \cap M_1) + P(c \cap M_2) + \cdots + P(c \cap M_v) \tag{7a}$$

$$P_e = P(e \cap M_1) + P(e \cap M_2) + \cdots + P(e \cap M_v) \tag{7b}$$

capturing the probability of correctness or incorrectness for all messages (values). Each term in Equation 7b may be expanded into:

$$P(e \cap M) = \frac{n_{e_1} + n_{e_2} + \cdots + n_{e_{(m-1)}}}{N_{tot}} \tag{8}$$

where: m is the number of classes in the event set.

n_{e_i} is the number of occurrences of the message in error class "i" of which there are (m-1) since one of the classes is "correct," not in error.

N_{tot} is the total number of events in the event set.

We see that this value is sensitive only to the *relative sizes* of the class for which the value is correct and the remaining classes in the event set. Since this is not desirable as mentioned above, we introduce normalization factors into each term to remove this size bias. Since this will change our result into something other than a pure probability, we will designate our new result the *likelyhood of error for a given message (value)* $l_{e,M}$:

$$l_{e,M} = \frac{1}{m-1}\left(\frac{n_{e_1}}{N_{e_1}} + \frac{n_{e_2}}{N_{e_2}} + \cdots + \frac{n_{e_{(m-1)}}}{N_{e_{(m-1)}}}\right) \tag{9}$$

where: N_{e_i} is the total number of events in error class "i."

Given the likelyhood that each possible value will be interpreted incorrectly, the total likelyhood of error is:

$$L_{e,a} = \sum_{M=1}^{v} l_{e,M} \tag{10}$$

since the number of possible messages equals the number of possible values "v" of the attribute. The value of this measure is between 0 and 1 but the range is inverted in meaning (i.e., the best attribute has likelyhood of error of 0). The final step is to invert the range to arrive at a measure we will call the *relevance* of an attribute denoted by ρ:

$$\rho = 1 - L_{e,a} \tag{11}$$

Which has value 0 for worst-case attributes and value 1 for perfectly discriminant attributes. The final consideration is the determination of which class is the "correct" one for a value which appears in more than one class. We have assumed, for the purposes of this study, that the class for which the value is most likely is the correct class. In practice, this is the class for which the value of the term $n_{m_{class}} / N_{class}$ is greatest for a given attribute value "m."

An example will show the application of equation 11. In Figure 6a, a event set of three attributes measured for three classes is given. Figure 6b shows that, for attribute x_2, the normalized probabilities of occurrence in each class of the value "1" is 1.0, 0.0, and 0.0 respectively. Since there are 3 out of 4 events with value 1 in class 1 (0.75), 0 out of 2 events with value 1 in class 2 (0.0), and 0 out of 1 events with value 1 in class 3 (0.0). The same analysis for the other messages (values) completes the table. Figure 6c shows the calculation of likelyhood of error for each of the values. For example, assuming the "correct" class for value 2 is class 2 since the term in Figure 6b for value 2 is greatest for class 2, The calculation is the sum of the remaining 2 "error" classes times 1/(m-1) which is 1/2. Finally, Figure 6d gives the remaining calculation of relevance.

Three experiments were performed to examine the performance of equation 11 using the program PROMISE which calculates the value of ρ for attributes in a given event set. The inductive inference engine was the program AQ11 [Michalski,1978]. Both PROMISE and AQ11 were implemented in Pascal on a Cyber 175 computer.

	x_1	x_2	x_3
c_1	1	1	1
	1	1	1
	1	1	4
	1	2	2
c_2	2	2	2
	2	4	2
c_3	3	3	2

(a)

$\frac{n_{M,class}}{N_{class}}$		Class 1	Class 2	Class 3
Message	1	0.75	0.00	0.00
	2	0.25	0.50	0.00
	3	0.00	0.00	1.00
	4	0.00	0.50	0.00

(b)

$$l_{e,1} = \frac{1}{2}\left(\frac{0}{2} + \frac{0}{1}\right) = 0.000$$

$$l_{e,2} = \frac{1}{2}\left(\frac{1}{4} + \frac{0}{1}\right) = 0.125$$

$$l_{e,3} = \frac{1}{2}\left(\frac{0}{4} + \frac{0}{2}\right) = 0.000$$

$$l_{e,4} = \frac{1}{2}\left(\frac{0}{4} + \frac{0}{1}\right) = 0.000$$

(c)

$$L_{e,x_2} = 0 + 0.125 + 0 + 0 = 0.125$$

$$\rho = 1 - 0.125 = 0.875$$

(d)

Figure 6. Calculating relevance:

(a) A sample event set

(b) A chart showing the number of events with a given value in each class divided by the total number of events in the class for each of the possible values of x_2

(c) The calculations of likelyhood of error for each the possible values of x_2

(d) The final steps in the calculation of the relevance of x_2

3.2.2.1 Experiment I

The relevance ρ for more than one attribute at a time may be calculated by considering the values of several attributes in an event as a single *compound* attribute. To test the behavior of ρ for this type of processing, the "Animals" event set, described in [Michalski,1975], was processed by PROMISE. The Animals event set is shown in Figure 7. The data and a set of rules for Animals are given in Appendix D. The protozoan creatures in each of the fourteen classes may be described by thirteen attributes:

- x_1 is the number of black circles on the body.
- x_2 is the number of tails.
- x_3 is the number of crossmarks on tails.
- x_4 is the number of easily distinguished extremities.
- x_5 is the body texture.
- x_6 is the number of empty circles on the body.
- x_7 is the number of empty squares on the body.
- x_8 is the number of empty triangles on the body.
- x_9 is the type of tail.
- x_{10} is the shape of the body.
- x_{11} is the number of sharp or straight angles.
- x_{12} is the number of "eyes" (half-black circles).
- x_{13} is the number of black squares on the body.

First, the relevance of the individual attributes were evaluated by PROMISE, and the attributes were arranged in order of increasing value of relevance. Next, all projections on pairs of attributes were evaluated and the results were analyzed as follows: The combinations were ranked by increasing value of ρ and the range of observed values of ρ was divided into 10 equal-sized sub-ranges. The number of occurrences of a particular attribute in the set of pairs with relevance values in a sub-range is expressed as a percentage of the total number of occurrences of all

Figure 7. An event set showing fourteen species of "Animals."

		x_1	x_2	x_3	x_4
c_1		1	1	1	1
		1	1	1	1
		1	1	1	1
		1	2	3	1
c_2		2	2	2	2
		2	2	2	2
		2	2	2	2
c_3		3	2	3	2
		3	2	3	2
		3	3	3	3

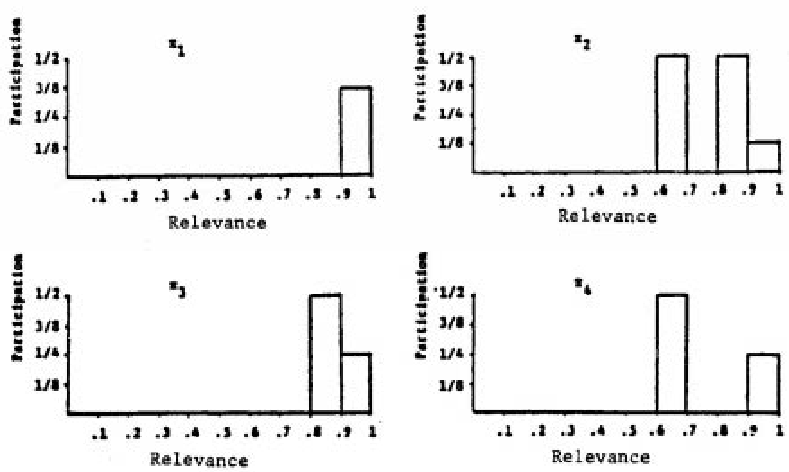
(a)

Pair	ρ
x_1x_2	1.00
x_1x_3	1.00
x_1x_4	1.00
x_3x_4	1.00
x_2x_3	0.87
x_2x_4	0.67

(b)

Attribute	Frequency of appearence of attributes from table above by relevance value.				
	0- <.6	.6- <.7	.7- <.8	.8- <.9	.9-1.0
x_1	0	0	0	0	3/8
x_2	0	1/2	0	1/2	1/8
x_3	0	0	0	1/2	2/8
x_4	0	1/2	0	0	2/8

(c)



(d)

Figure 8. Sample analysis of attribute groups for determining individual attribute relevance:

(a) Sample event set

(b) Value of ρ for all distinct pairs of attributes

(c) Table of counts of the number of times each attribute appears in each subrange of promise, divided by the total number of attributes appearing in the range

(d) Histogram plots of the values from the table in (c)

attributes in the subrange and plotted as a histogram. An example of such an analysis is presented in Figure 8. A relevant attribute should exhibit greater participation in the high-valued sub-ranges and irrelevant attributes should exhibit greater participation in low-valued sub-ranges. When linear regression analysis is applied to these plots, relevant attribute "profiles" should have more positive slopes and lesser y-intercepts and irrelevant attribute profiles should have more negative slopes and greater y-intercepts. Such an analysis was performed for all combinations of three and four attributes as well. The histogram plots for all of the analyses are given in Appendix D. The resulting attribute rankings are shown in Figure 9. Actual values from the analyses are not given since values computed for different size groupings of attributes are not directly comparable. The table shows that the relevance value measured for each attribute is independent of the interactions between attributes in this event set because the rankings are fundamentally the same independent of the size of the groupings used. Therefore, the values indicated by PROMISE for individual attributes are independent of the interactions between attributes in this experiment, and can be used to order the attributes.

Combinations	Best ——————————————— Worst
Single Attributes	x_1 x_9 x_6 x_{10} x_3 x_2 x_4 x_8 x_{13} x_5 x_{11} x_{12} x_7
Pairs	x_1 x_9 x_6 x_{10} x_4 x_{13} x_3 x_2 x_8 x_{11} x_5 x_{12} x_7
Triples	x_1 x_9 x_6 x_{10} x_2 x_3 x_4 x_8 x_{13} x_{11} x_5 x_{12} x_7
Quadruples	x_1 x_9 x_6 x_{10} x_4 x_{13} x_2 x_3 x_8 x_{11} x_5 x_7 x_{12}

Figure 9. Attributes ranked by their relevance when evaluated interdependently in pairs, triples, and quadruples. A sample of such an analysis is given in Figure 7 and all of the analyses are given in Appendix D

3.2.2.2 Experiment II

The event set used for experiment II is given in Figure 10. It includes attributes with widely varying degrees of relevance. The values of one attribute were arranged so that the classes could be distinguished by the value of that attribute alone. Another attribute had the same value in all events. Two more attributes were pseudo-random, and the rest differentiated the classes to varying degrees. The data comprised five classes (3 with 8 events, 2 with 5 events). The result of the analysis of the attributes individually is shown in Figure 11. The ordering of the attributes by ρ-value (Figure 11) matches the order of attribute relevancy designed into the event set. The results show that PROMISE evaluates attributes based on their ability to distinguish classes in the event set. This indicates that a set of attributes which uniquely characterizes each class in an event set and contains few extraneous variables can be obtained by examining attributes beginning with the most relevant attributes and adding more attributes in order of decreasing relevance until the projection of the event set on the attributes has $\rho=1$. For example, when the most relevant attribute is excluded, the next three attributes can distinguish the classes uniquely (two of them comprise the minimum number that do so in this event set when the best attribute is excluded).

3.2.2.3 Experiment III

Experiment three was undertaken to determine the magnitude of the computational advantage, if any, realized by removing as many extraneous attributes as possible using PROMISE before the data is processed by AQ11.

The data for the third experiment were the same data used in experiment II but with the most-relevant attribute removed and a number of pseudo-random attributes added (42 in this experiment) to simulate the common occurrence of event sets which include no perfect attributes and many irrelevant ones. The attributes were processed by PROMISE and ordered by increasing relevance value. Because the three most relevant attributes are not distinguished by different ρ-values, they were all accepted initially and the projection of the data onto those three attributes was

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
	0	0	0	0	0	1	0	1	2	3
	0	0	0	0	0	1	0	1	3	4
	0	0	0	0	0	1	0	1	3	0
c_1	0	0	0	0	0	1	0	2	0	1
	0	0	0	0	0	1	0	3	4	1
	0	0	0	0	0	1	0	2	4	2
	0	0	0	0	0	1	0	1	1	2
	0	0	0	0	0	1	0	3	3	0
	1	0	0	0	0	2	0	2	5	3
	1	0	0	0	0	2	0	4	5	3
	1	0	0	0	0	2	0	4	5	2
c_2	1	0	0	0	0	2	0	3	5	1
	1	0	0	0	0	2	0	3	5	3
	1	0	0	0	0	2	0	1	5	2
	1	0	0	0	0	2	0	4	5	4
	1	0	0	0	0	2	0	3	5	3
	2	1	0	0	0	3	0	2	0	2
	2	1	0	0	0	3	0	3	2	0
	2	1	0	0	0	3	0	3	0	0
c_3	2	1	0	0	0	3	0	1	0	0
	2	1	0	0	0	3	0	1	1	3
	2	1	0	0	0	3	0	1	1	1
	2	1	0	0	0	3	0	0	0	4
	2	1	0	0	0	3	0	2	2	3
	2	2	1	1	0	4	0	4	6	3
	2	2	1	1	0	4	0	0	6	3
c_4	2	2	1	1	0	4	0	2	6	1
	2	2	1	1	0	4	0	1	6	0
	2	2	1	1	0	4	0	4	6	3
	2	2	2	0	1	5	0	3	3	4
	2	2	2	0	1	5	0	2	1	0
c_5	2	2	2	0	1	5	0	0	4	3
	2	2	2	0	1	5	0	2	1	1
	2	2	2	0	1	5	0	1	0	3

Figure 10. An event set containing attributes with a wide range of relevance used to test the performance of equation 11

Best ——————— Worst

x_6 x_1 x_2 x_3 x_4 x_5 x_8 x_9 x_7

Figure 11. Attributes from the test event set ranked by individual relevance

evaluated by PROMISE and found to have $\rho=1$. Next, the projected event set was processed by the inductive-learning program AQ11 which derived rules to discriminate the classes. The rules derived from the projected event set were identical to those derived from the entire event set. Figure 12 shows a comparison of the time needed to derive the same set of rules using AQ11 on the entire event set versus running the program using only the three best attributes determined by PROMISE. In this instance, the computation time required to filter the data using PROMISE and derive rules using AQ11 was approximately one tenth the time required using AQ11 alone.

3.2.3 The Random Adaptive Search Algorithm

The relevance measure is intended for the analysis of single attributes independently of other attributes to find those that are most relevant. If such evaluation is not sufficient due to a high degree of interdependency between attributes, the Randomized Adaptive Search (RAS) algorithm may be used.

	Using PROMISE	Not Using PROMISE
PROMISE	0.319 CPU sec.	-
AQ11	0.227 CPU sec.	4.576 CPU sec.
Total	0.546 CPU sec.	4.576 CPU sec.

Figure 12. A comparison of CPU time required to formulate identical rule sets using and not using PROMISE to process the data before processing by inductive learning program AQ11

The algorithm iteratively evaluates groups of attributes and continuously updates an indicator of the relevancy of the individual attributes based on the performance of the groups. First, the relevance of each of the attributes is evaluated and stored as the initial *relevance index* (so-called because the values will no longer be based on ρ as the algorithm progresses) for that attribute. A user-specified number of attributes is then chosen by weighted random selection based on these values. Attributes with better relevancy values are more likely to be chosen. The relevance of the group of attributes is then computed as a whole. Based on a comparison between the value for this group and a reference value (0.5 initially), the relevance index for each of the constituent attributes in the group is increased by a small, fixed amount (0.05 for this study) if the group performed better than the reference, or decreased by the same amount if the the group score was worse than the reference. The individual values are kept within the 0 to 1 range of ρ. The reference value is then set to the new group's relevance. The attributes are re-ordered by the new values of their relevance indices and a new group is chosen by weighted random selection. The process iterates until the reference value converges to a constant value or until a specified number of iterations have transpired.

The object of RAS is to find interdependent groupings of attributes and promote their selection as a group, even if one or more of them has a low value of ρ when evaluated independently. As the algorithm progresses, groups of attributes which perform well are promoted and groups which perform poorly are suppressed. When the algorithm converges (if it does), a stable, high-relevance group of attributes has risen to the top of the list of indices and the poor attributes have fallen to the bottom.

3.2.4 The Greedy Attribute Selection Algorithm

A second method for applying the relevance measure to attributes is Greedy Attribute Selection (GAS). When attribute interdependency is not a problem, GAS may be an effective way to arrive at a quasi-minimal set of attributes in a less computationally intensive way than RAS.

The GAS algorithm begins with the independent evaluation of the relevance of each of the attributes. The list of attributes is rank-ordered by decreasing relevance. The first two (those two with the highest relevance) are chosen and evaluated as a group. If the relevance of the pair is greater than the relevance of the most relevant attribute alone, the second most-relevant attribute is deemed to have added useful information (as measured through the increased relevance) and is kept. If no improvement is noted, the second attribute is discarded since it added no information to that from the first attribute. The third most relevant attribute is then added and the group evaluated. The third attribute is also kept or discarded based on whether it contributes to an improvement in relevance score for the group. The scheme continues until a group of attributes is found which is perfectly discriminatory (*i.e.*, $\rho=1$) or the list of attributes is exhausted.

The Greedy Attribute Selection scheme is based on the assumption that the relevance measure is a good indicator of the value an attribute has for discrimination and its ability to evaluate groups of attributes in a way that yields results which can be compared meaningfully.

3.3 The Rule Generation Program GEM

3.3.1 The A^q Algorithm for Rule Generation

The A^q algorithm is a method for generating generalized descriptions which *cover* all of the positive events (*i.e.*, those within the class to be described) and none of the negative events (*i.e.*, those within the other classes) [Michalski,1978]. The process of developing a cover involves partially computing the complement of the set of negative events and selecting logical conjunctions of selectors, called *complexes*, which cover positive events. The final cover may be a single complex or a disjunction of complexes. The algorithm proceeds depth-first using the method of *disjoint stars*. A positive event, e_1, is chosen and an approximation of the set of all prime implicants which cover e_1 and are in the compliment of the set of all negative events is developed. This set is called a *star*. The best complex in the star, *lq*, is chosen using a lexicographic evaluation functional (see [Diettrich,1980]). The events covered by *lq* are removed from further consideration. The process is then repeated but each new event, e_1 is chosen so that it has not been covered by any element of any previous star. This ensures that disjoint, well-separated stars are built. The process is repeated until all events have been covered by at least one star.

3.3.2 Using GEM in an Expertise Development System

The A^q algorithm is implemented in a program called GEM written in Pascal on a Vax 11/780. The A^q algorithm (and, consequently, GEM) is an attractive choice for an inductive inference engine because of its flexibility. GEM is domain dependent only within the confines of the data structures used. Any problem domain which can be described by events that can be characterized using acceptable data structures can be processed using GEM. The data structures used required for input to GEM are patterned after relational tables. This structure has proven to be very flexible.

4 EXPERIMENTATION

4.1 Experiment 1: Black-Cutworm Damage Prediction

4.1.1 Problem Domain

Black Cutworms are insect larvae which damage between two and ten percent of the corn acreage in the Midwest annually. The name derives from the effect of cutworm action on corn plants: the severing of the stalk just above the soil line. In mid-April, Black Cutworm (BCW) moths are carried into Illinois by southerly winds and they land in the fields they find most attractive and lay their eggs. The growth cycle of the cutworm is short enough to allow three generations of worms to mature each growing season. Because more mature plants are more resistant to the ravages of the larvae, only the first generation of worms typically causes damage to field corn. Two major factors have been identified by corn entomologists in explaining damage mechanisms. The first is the attractiveness of a given field for the moths. A more attractive field will be the target of more moths' egg-laying. One of the most commonly postulated factors in field attractiveness is weediness at the time of moth flight. The second factor has been termed *synchrony* or the correspondence in time between corn maturation and cutworm maturation. Both corn and cutworm larvae mature at rates proportional to temperature. When the corn is young and the larvae are large, damage will be severe. When the corn is mature before the larvae mature, damage is slight. Also, if the larvae mature into pupae before the corn emerges from the soil, the damage will be slight [Boulanger, 1983]. Many factors may effect the rate of cutworm development and the size of cutworm populations. The difficulty of identifying the most important factors lies in the lack of sufficient quantities of high quality data due to both the rarity of cutworm damage and the lack of sufficient manpower for data collection. The system described in this paper was applied to a selected subset of the data to attempt to uncover some of the important factors.

4.1.2 Data

The data for this experiment consists of seventeen static attributes and two dynamic attributes as well as time and cutworm damage percentage figures for each of 210 events (given in Appendix D) recorded for the 1978 growing season. A sample event is shown in Figure 13. The breakdown

```
Static Portion

   [fieldowner=smith][year=1978][previous crop=clover]&
   [bcw history=yes][adjacent water=no][surface slope=north]&
   [surface character=level][fall tillage=plow][spring till=disc]&
   [manure used=no][fertilizer regimen=none][insecticide=none]&
   [planting date=june 1]&

Dynamic Portion

   [date=mar 24]=> [weed species=horseweed][weed density=heavy]
   [date=mar 24]=> [weed species=smartweed][weed density=light]
   [date=apr 15]=> [weed species=smartweed][weed density=heavy]
   [date=may 1 ]=> [weed species=weedkill ][weed density=none ]

                                        ::> [damage= 75%]
```

Figure 13. A sample event for the black cutworm damage data showing static and dynamic attributes

of the data by damage percentage is shown in Figure 14. The zero number of fields damaged between 45 and 50% was thought to be a logical class division. CONVART used the original two dynamic attributes to construct 10 new attributes which characterize the behavior of the dynamic attributes over time. The attributes (both original and constructed) are given in Appendix A, with the range of possible values each may have. The original values for some of the attributes in some of the events were missing so values deemed plausible by an expert corn entomologist were inserted where appropriate. If no plausible value was apparent, the value was left as "unknown". The final event set is missing approximately 20% of the data values and many of the events have limited time-dependent data. These factors combined to complicate the experiment considerably.

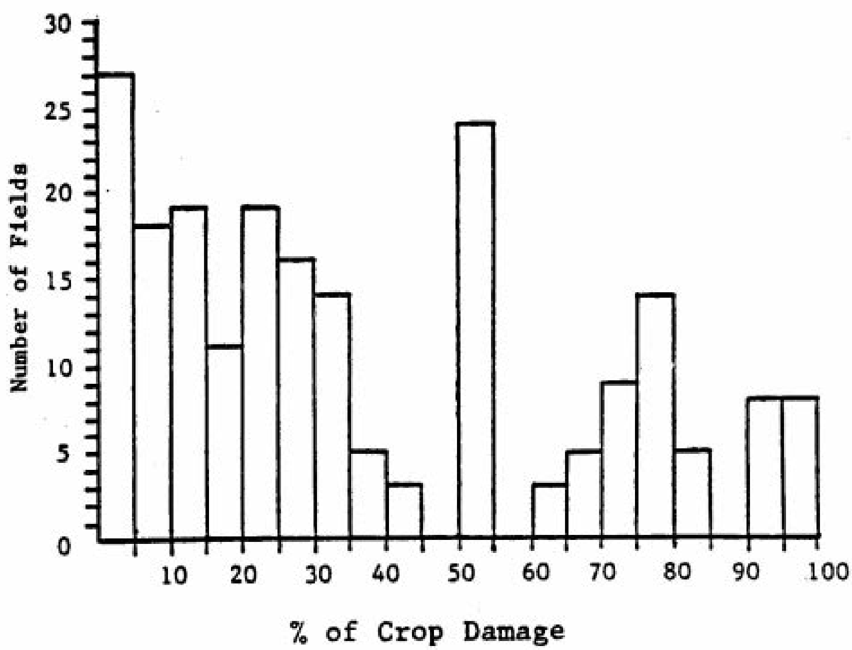


Figure 14. Histogram of the relative frequency of occurrence of different ranges of damage percentage in the 210 events used for this study

4.1.3 Results

Rules generated by applying GEM to this data are given in Appendix B. As the sparsity of the data could inject a significant amount of noise into the data, a corn entomologist was asked to identify those complexes which might be extraneous or unnecessarily convoluted. A comparison of the performance of the random adaptive search method and the greedy method is given in Figure 15. The output of the test runs is given in Appendix D. The lists of attributes were comparable with only minor differences among the least relevant attributes.

Search Scheme	No. Attributes Per Sample	CPU Time	No. Iterations	No. Attributes Finally Chosen
Greedy	-	34 sec	1	11
Random	5	46	18	10
"	10	48	48	12
"	15	45	7	13

Figure 15. A comparison between different search schemes and varying search parameters for selecting a quasi-minimal set of attributes

4.1.4 Analysis

A comparison between the rules generated and the model outlined in 4.1.1 shows substantial agreement between the factors considered most important by corn entomologists and those identified by the processing. For example, factors such as planting date, several weediness measures, and tillage regimens reflect considerations of field attractiveness and synchrony presented earlier. Insecticide usage effects the survival of larvae during periods of low availability of food and during other periods of adverse conditions. The value of CONVART for this processing was considerable since it was required for the production of the attributes which capture the weed population trends that indicate both synchrony and field attractiveness.

Comparison between the performance of random adaptive search and greedy search show that, for this event set, the differences in results in terms of attribute set size is small and the penalty for processing using the random adaptive search scheme is large. The results of the random search shows that no highly synergistic combinations of attributes are contained within the event set since RAS (designed to find such interaction) provided the same results as greedy search.

4.2 Experiment 2: Craniostenosis Syndrome Identification

4.2.1 Problem Domain

The study and classification of medical syndromes is a well established field of medicine and medical diagnosis. The task of diagnosing these syndromes is increasingly difficult due to the growing number of rare genetic disorders and poorly understood patterns of malformation and malfunction. In addition, the problem is compounded by disease symptomes and hereditary traits which resemble the indications of many of the disorders of interest. A genetics clinic must be capable of reliably diagnosing approximately 8000 disorders on a day to day basis.

One of the fundamental problems in this field has been the rarity of most of the syndromes. With only a few (sometimes only one or two) examples of a given disorder reported, it is difficult to differentiate true indications of the syndrome from individual peculiarities of the patients. This problem has been approached in the past by the merging of the findings of several geographically separate observers of the same findings to recognize patterns in the data.

The class of syndromes studied in Experiment 2 is named *Craniostenosis*. The cranium of an infant is composed of bony plates joined at their edges by flexible joints or sutures. When these joints ossify (become bony), the skull assumes its final shape and size. The now-hard joints are known as synostes and occur normally during the course of growth and development. If a suture should harden before or after the others, the skull will develop abnormally, leading to asymmetry of the skull and face or abnormalities such as unusually limited cranial size. Due to the large number of observable anomalies of the face and skull and the sparseness of the available data, the methods described in this paper were applied in an attempt to pinpoint the most definitive anomalies for differentiating the syndromes in this class of disorders.

4.2.2 Data

The data consists of 231 observed cranio-facial anomalies for 80 patients diagnosed as having craniostenosis (the data may be found in Appendix D). Craniostenosis may be divided into four major syndromes with many patients undiagnosable due to the large overlap between the indications of the syndromes. Despite this overlap, doctors have characterized each syndrome according to certain individual tendencies [Spackman,1983]:

- *Crouzon's Syndrome* patients exhibit premature craniosynostosis, shallow orbits and frontal bossing, and maxillary hypoplasia with or without a parrot-like nose. About a quarter of the reported cases appear to be fresh mutations.
- *Saethre-Chotzen Syndrome* is highly variable in almost all of its features. Among the more common abnormalities are: synostes of the coronal sutures, low-set hairline, facial asymmetries, shallow orbits, ptosis (drooping eyelid), small ears, and partial webbing of two or more fingers or toes.
- *Apert's Syndrome* includes both craniosynostosis and severe syndactly (fusion of two or more fingers).
- *Pfeiffer's Syndrome* also involves craniosynostosis and syndactly, although it is milder in almost every similar feature.

Among the 81 patients, many were not diagnosed as to individual syndrome. When a single "normal" patient is added as a sixth control class, the data may be broken down as shown in Figure 16. A sample event is shown in Figure 17. A list of the 231 anomalies is given in Appendix C.

Syndrome	# Patients
Apert	16
Crouzon	24
Saethre-Chotzen	8
Pfeiffer	1
Undiagnosed	31

Figure 16. Breakdown of data for craniostenosis patients by syndrome

4.2.3 Results

The attributes were all binary (*i.e.*, syndrome present=1, not present=0), VARSEL identified a set of 20 attributes, among the original 231 in the event set, which successfully characterized each of the syndromes without characterizing any of the patients of indeterminate diagnosis or the normal patient. The chosen attributes are given in Figure 18. GEM then analyzed the new event set and used 16 of the twenty attributes to produce the rules shown in Figure 19. A physician who had been attempting to perform the same task manually, had invested approximately 4 man-months in the job. He also discovered twenty attributes but had only succeeded in characterizing about 75% of the patients successfully. These attributes are also given in Figure 18. The rules he derived using GEM and these attributes are given in Appendix D. The total real-time required for the computer processing was less than an hour.

If we compare the generated rules in Figure 19, with the clinical profiles presented earlier, we may note close correspondence between the rules for each class and the clinical findings. An important consideration is that the clinical profiles presented have a great deal of overlap so they are not a perfect "benchmark" for deciding rule validity. In addition, the data collected by different clinicians often varies as to quality and scope.

```
[patient number=000][date=1/1/81][flat forehead=present][syndactly=present]&
                    [craniosynostosis=absent] ... 228 other anomalies

                              ::> [syndrome=Pfeiffer]
```

Figure 17. A sample event from the craniostenosis event set

Chosen by VARSEL	Chosen by Expert
Craniosynostosis	Craniosynostosis-General
Craniosynostosis-Coronal	Ear Malformations
Craniosynostosis-Saggital	Impaired Hearing
Facial Assymetry	Facial Assymetry
Flat Forehead	Flat Forehead
Assymetric Forehead	Beaked Nose
Ptosis-Eye	Ptosis
Shallow Orbit	Hypertelorism
Exophthalmos/Proptosis-L Eye	Proptosis
Exophthalmos/Proptosis-R Eye	Hallux Valgus
Byzantine Palate	Byzantine Palate
Midface Hypoplasia	Maxillary Hypoplasia
Cutaneous Syndactly-Hand	Syndactly of Fingers
Syndactly-Foot	Syndactly of Toes
Partial Syndactly-Foot	Webbing of Toes
Hypertonia	Webbing of Fingers
Plagiocephaly	Strabismus
Pyloric Stenosis	Cleft Palate
Position Anomolies-Digits	Tear Duct Stenosis
Undescended Testes	Proptosis

Figure 18. A comparative listing of the attributes chosen as most relevant by VARSEL and by a human expert for the discrimination of craniostenosis syndromes from the data used in this study

```
R1: [syndactly_foot=absent][craniosynostosis=present]&          (NEW,IND,COV)
    [exophthalmos_eye=present][flat_forehead=absent]             (18,16,18)
        v
    [syndactly_foot=absent][byzantine_palate=present][ptosis_eye=absent]     (1,1,3)
        v
    [syndactly_foot=absent][exophthalmos_eye=present][plagiocephaly=present] (1,1,1)
        v
    [craniosynostosis=absent][craniosynostosis_coronal=absent]&
    [midface_hypoplasia=present][cutaneous_syndactly_hand=absent]   (2,2,2)
        v
    [shallow_orbit=absent][craniosynostosis_coronal=absent]&
    [midface_hypoplasia=absent][flat_forehead=present][plagiocephaly=absent]  (1,1,1)

            ::> [syndrome=Crouzon]


R2: [cutaneous_syndactly_hand=present]                               (5,3,5)
        v
    [midface_hypoplasia=present][flat_forehead=present]&
    [byzantine_palate=absent]                                        (3,3,5)

            ::> [syndrome=Sathre-Chotzen]


R3: [syndactly_foot=present]                                         (16,16,16)

            ::> [syndrome=Apert]


R4: [pyloric_stenosis=present]                                       (1,1,1)

            ::> [syndrome=Pfeiffer]
```

Figure 19. A set of discriminant rules for the craniostenosis event set (the numbers in parentheses are the number of events first covered by this complex, the number of events only covered by this complex, and the total number of events covered by this complex)

Random adaptive search failed to converge for this event set, probably due to the low likelyhood of synergistic interaction since the minimum number of binary attributes required to differentiate six classes would be three and 16 were actually required. The system has clearly operated cost-effectively on this event set, producing plausible rules within the limitations of the event set in a computationally attractive amount of time. The resulting data reduction from the use of VARSEL as a preprocessor was over 91% since only 20 of the original 231 attributes were needed.

5 CONCLUSIONS

A model has been presented which describes the process of domain expertise development in terms of the sequential application of four sub-processes with multiple feedback paths. The subprocesses include attribute construction (implemented in CONVART), attribute selection (implemented in SELECT), rule formation (implemented in GEM), and rule implementation (left for the system builder).

A system has been constructed which is capable of applying the model for the purpose of deriving expert decision rules from data using a minimum of explicitly stated domain knowledge and minimal iterative processing. The system contains modules for: the construction of attributes which describe time-dependent behavior of other attributes so that time-varying processes can be analyzed, the selection of most relevant attributes for class discrimination using a recently developed measure of attribute relevancy, and inductive rule inference based on established methods of automated inductive inference. The rule implementation process in which a set of rules is embedded in a program which can apply the rules to new events, remains as a task for the programmer.

5.1 System Performance

The constructive induction program CONVART was vitally important in the processing of Black-Cutworm damage data because cutworm damage is closely tied to time-dependent processes. It was of not used for Craniostenosis data since the attributes present were all static. The variable selection program VARSEL was useful in both cases but different search strategies were of different utility. Random adaptive search showed explicitely the lack of synergistic interaction between attributes in the BCW data since the attribute sets chosen by RAS were the same as those chosen by greedy search (these results are given in Appendix D). RAS failed to produce useful results of any sort for the craniostenosis data because of the poor discriminatory value of binary attributes for multi-class event sets. Greedy search was effective in both cases since significant data reduction was achieved in both cases and appropriate experts favorably evaluated the resulting attribute sets. The inductive inference engine GEM produced good rules from the pre-processed event sets which were thought to be reasonable and consistent with the input data when examined by experts from within the problem domains.

5.2 Indicated Future Directions of Inquiry

The potential for significant future inquiry exists throughout the processing chain used in this system. Specific avenues of study for the concepts embodied in CONVART and GEM are described in detail elsewhere [Michalski,1982b] [Davis,1981]. Future directions for applying and studying the measure of relevancy presented earlier include exploring its use as an indicator of potentially relevant groups of attributes for constructive induction purposes, and further refinement of the measure to enhance its resolution. In addition, new implementations of the greedy and random adaptive search schemes may overcome the limitations of the current implementations, and new search schemes may prove more effective than either.

APPENDICES

Appendix A: Attributes in BCW Damage Event-Set

The following is a list of the attributes, both original and constructed, used for the analysis of black cutworm damage in the state of Illinois.

* means this attribute was chosen by RAS.

** means this attribute was chosen by GAS.

*** means this attribute was chosen by both RAS and GAS.

	No.	Attribute	Possible Values (domain)
Initial Attributes		**Static Attributes**	
	1.	Damage	=<50%, >50%
	2.	Field Owner	too numerous to list
	3.	Growing Year	1978
	***4.	Previous Crop	Corn, Beans, Weeds, Sorghum
	5.	BCW History	Yes, No
	***6.	Permanent Border Vegetation	Yes, No
	***7.	Permanent Border Water	Yes, No
	***8.	Surface Direction	North, South, East, West, None
	9.	Surface Character	Level, Rolling, Bottomland
	***10.	Fall Tillage	None, Plow, Chisel, Disc
	***11.	Spring Tillage	None, Plow, Chisel, Disc
	12.	Manure Usage	Yes, No
	13.	Fertilizer Usage	Yes, No
	***14.	Insecticide	None, Yes (nonspecific), Preventative, Rescue Treatment
	*15.	Planting Date	Jan1-Apr10, Apr11-Apr20, Apr21-May15, May16-Jun9, After Jun9
	16.	Planting Rate	<100%, 100%
		Dynamic Attributes	
	17.	Weed Species	None, Weeds (nonspecific), Very Few Weeds, Onion, Grass, Legume, Winter Annual, Other Broadleaf, Weedkill
	18.	Weed Density	None, Light, Heavy, Heavy Patches
Constructed Attributes		**Static Attributes**	
	*19.	Most Common Weed Species	None, Weeds (nonspecific), Very Few Weeds, Onion, Grass, Legume, Winter Annual, Other Broadleaf, Weedkill
	20.	Least Common Weed Species	None, Weeds (nonspecific), Very Few Weeds, Onion, Grass, Legume, Winter Annual, Other Broadleaf, Weedkill
	21.	Number Of Observations Of Same Weed Species	1, 2
	***22.	Number Of Different Weed Species	0, 1, 2. 3, >3
	*23.	Average Density	None, Light, Heavy, Heavy Patches
	*24.	Intercept of Density vs Time	
	*25.	Slope Of Density vs Time	-.057, -.047, -.044, -.040, -.036, -.034, -.032, -.030, -.029, -.028, -.024, -.020, -.018, -.015, >0
	***26.	Maximum Weed Density	None, Light, Heavy, Heavy Patches
	27.	1st Time Of Max.	Before Mar24, Mar24-Apr13
	*28.	Minimum Weed Density	None, Light, Heavy, Heavy Patches
	***29.	1st Time of Min.	Apr5-Apr18, Apr19-22, Apr23-Apr27, Apr28-Apr30, May1-May2, May3-May7, May8-May12, May13-May19, May20-May21, May22-May26, May27-Jun3

Appendix B: BCW Damage Estimation Rules

The following two pages give rules for predicting black cutworm damage severity derived by GEM from 1978 BCW data after new attributes were constructed by CONVART and selection was performed by VARSEL. Each rule is quite complicated in that each has many complexes. The reason for this becomes clear when one examines the parameters on the right-hand side of the page:

- NEW - The first number is the number of events covered by this complex which were not covered by previous complexes in the list.
- IND - The second is the number of events covered by this complex alone of all complexes.
- COV - The third is the total number of events covered by this complex.

Examination of the numbers shows that the rules reveal a subtle and complex interaction between three factors: weediness, synchrony, and pesticide use. The interaction is suggested by the coverage numbers. Note that each complex covers several events but covers very few uniquely. Therefore, the complexes have significant overlap in coverage but each one accounts for a slight variation on one or more of these themes.

```
                                                                          (NEW,IND,COV)
R1:  [previous crop=corn,weeds,sorghum][permanent vegetation=no]&
     [adjacent water=yes][terrain=level,rolling]&
     [fall tillage=none,chisel,disc][planting date=after may15]
                                  v                                          (5,3,5)
     [previous crop=soybeans,weeds,sorghum][fall tillage=plow,disc]&
     [spring tillage=none,plow,disc]&
     [number of diff. weed species<=3][maximum weedensity=heavy..heavy patches]
                                  v                                          (7,2,7)
     [spring tillage=none,disc][planting date=after may15]&
     [number of diff. weed species=3][maximum weedensity not=heavy patches]&
     [1st minimum weedensity=after may2]
                                  v                                          (9,2,10)
     [permanent vegetation=yes][terrain=level][fall tillage=none,disc]&
     [planting date=jan1..may15][maximum weedensity=heavy patches]
                                  v                                          (2,1,2)
     [terrain=level,bottomland][fall tillage=plow][spring tillage=none,plow,disc]&
     [planting date=after may15][number of diff. weed species=3]
                                  v                                          (5,3,9)
     [adjacent water=no][fall tillage=none,chisel][spring tillage=none,chisel]&
     [number of diff. weed species=3..>3][maximum weedensity=heavy]
                                  v                                          (3,1,3)
     [previous crop=corn,weeds,sorghum][permanent vegetation=yes]&
     [fall tillage=chisel][planting date= after may15]
                                  v                                          (3,3,3)
     [permanent vegetation=no][1st minimum weedensity=aftjun3]
                                  v                                          (1,1,4)
     [adjacent water=yes][maximum weedensity=heavy patches]&
     [1st minimum weedensity=may19..may21]
                                  v                                          (1,0,1)
     [previous crop=corn,weeds,sorghum][terrain=level][fall tillage=disc]&
     [number of diff. weed species=<3]
                                  v                                          (1,1,2)
     [permanent vegetation=yes][fall tillage=chisel,disc][insecticide=no]&
     [number of diff. weed species>2][maximum weedensity not= heavy patches]
                                  v                                          (2,1,6)
     [permanent vegetation=yes][terrain=level,bottomland]&
     [fall tillage=chisel,disc][insecticide=no][maximum weedensity=heavy]
                                  v                                          (2,2,4)
     [permanent vegetation=yes][adjacent water=no][fall tillage=chisel]&
     [spring tillage=none,plow,disc][planting date=after apr30]&
     [maximum weedensity=no..lt][1st minimum weedensity=before may2]
                                  v                                          (1,1,3)
     [permanent vegetation=yes][terrain=level][fall tillage=none,chisel,disc]&
     [spring tillage=none,disc][insecticide=preventive][maximum weedensity=heavy]
                                  v                                          (1,1,1)
     [permanent vegetation=no][terrain=level,bottomland]&
     [fall tillage=none,plow,disc]&
     [spring tillage=none,disc][planting date=after may15]&
     [number of diff. weed species=3]
                                  v                                          (3,1,8)
     [previous crop=corn,weeds,sorghum][terrain=level,rolling]&
     [fall tillage=none,chisel]&
     [spring tillage=none,chisel,disc][planting date=after may15]&
     [maximum weedensity=no..lt][1st minimum weedensity=before apr30]
                                  v                                          (2,2,3)
     [permanent vegetation=no][fall tillage=chisel]&
     [spring tillage=none,plow,chisel][maximum weedensity=heavy..heavy patches]
                                  v                                          (1,1,3)
     [permanent vegetation=yes][fall tillage=none,disc]&
     [insecticide=no,rescue treatment][number of diff. weed species=3]
                                  v                                          (1,1,5)
     [permanent vegetation=no][adjacent water=no][terrain=level,bottomland]&
     [spring tillage=none,disc][planting date=after may15]&
     [number of diff. weed species=3]
                                                                             (1,1,7)

                         ::> [damage >= 50%]
```

```
                                                                                     (NEW,IND,COV)
R2: [previous crop=soybeans,weeds,sorghum][fall tillage=none,plow]&
    [spring tillage=none,chisel,disc][insecticide=preventive,rescue treatment]&
    [number of diff. weed species=<3]                                                  (12,2,12)
                                   v
    [terrain=rolling][fall tillage=plow,chisel]&
    [maximum weedensity not= heavy patches][1st minimum weedensity=before apr30]       (10,5,11)
                                   v
    [previous crop=soybeans,sorghum][adjacent water=yes]&
    [terrain=level,rolling][insecticide=preventive,rescue treatment]                   (13,4,16)
                                   v
    [permanent vegetation=yes][fall tillage=none,plow,disc]&
    [spring tillage=none,disc]&
    [number of diff. weed species=>3][1st minimum weedensity=before may21]             (4,1,6)
                                   v
    [permanent vegetation=yes][fall tillage=plow,chisel,disc]&
    [spring tillage=none,chisel][insecticide=preventive,rescue treatment]              (6,2,7)
                                   v
    [adjacent water=yes][terrain=level,bottomland][fall tillage=none,plow]&
    [spring tillage=none,plow,disc][number of diff. weed species<3]                    (7,5,7)
                                   v
    [terrain=level,bottomland][planting date=before apr30]                             (9,4,18)
                                   v
    [previous crop=corn,soybeans,sorghum][permanent vegetation=yes]&
    [insecticide=preventive,rescue treatment][maximum weedensity=heavy patches]        (4,1,10)
                                   v
    [permanent vegetation=yes][terrain=level,rolling][fall tillage=none,chisel]&
    [insecticide=no,rescue treatment][number of diff. weed species<3]&
    [maximum weedensity=no..lt]                                                        (4,1,4)
                                   v
    [previous crop=soybeans,sorghum][fall tillage=plow,disc]&
    [insecticide=preventive,rescue treatment][planting date=after may15]               (4,3,8)
                                   v
    [permanent vegetation=yes][fall tillage=none,chisel,disc]&
    [insecticide=no,rescue treatment][number of diff. weed species<3]&
    [maximum weedensity=heavy]                                                         (1,1,1)
                                   v
    [previous crop=soybeans,sorghum][permanent vegetation=no]&
    [terrain=level,rolling][fall tillage=chisel,disc]&
    [insecticide=preventive,rescue treatment][number of diff. weed species>2]&
    [1st minimum weedensity=before may26]                                              (2,1,6)
                                   v
    [permanent vegetation=yes][fall tillage=none,chisel]&
    [insecticide=preventive,rescue treatment][number of diff. weed species<4]&
    [maximum weedensity=heavy]                                                         (1,1,6)
                                   v
    [permanent vegetation=no][terrain=level,bottomland]&
    [spring tillage=none,plow,chisel][maximum weedensity=no..lt]                       (5,0,15)
                                   v
    [permanent vegetation=yes][terrain=level,bottomland][fall tillage=none]&
    [maximum weedensity=no..heavy]                                                     (2,2,12)
                                   v
    [permanent vegetation=no][adjacent water=no][terrain=rolling]                      (2,1,11)
                                   v
    [adjacent water=no][fall tillage=disc]&
    [insecticide=preventive,rescue treatment][number of diff. weed species>2]          (1,1,7)
                                   v
    [permanent vegetation=no][adjacent water=yes][terrain=bottomland]&
    [fall tillage=plow,chisel]                                                         (2,2,4)
                                   v
    [permanent vegetation=yes][number of diff. weed species=<3]&
    [1st minimum weedensity=may2..may21]                                               (2,2,4)
                                   v
    [previous crop=soybeans,sorghum][permanent vegetation=yes]&
    [terrain=level,bottomland][insecticide=preventive,rescue treatment]&
    [number of diff. weed species>2]                                                   (1,1,5)
                                   v
    [previous crop=soybeans,weeds,sorghum]&
    [insecticide=preventive,rescue treatment]&
    [number of diff. weed species=>3][maximum weedensity=heavy patches][1,3]           (1,1,3)
                                   v
    [previous crop=corn,weeds,sorghum][planting date=apr30]                            (1,1,12)
                                   v
    [terrain=level][spring tillage=none,chisel][maximum weedensity=no..lt]             (1,1,16)
                                   v
    [permanent vegetation=no][adjacent water=no][fall tillage=disc]                    (1,1,10)

                              ::> [damage < 50%]
```

Appendix C: Attributes for Craniostenosis Event Set

The following list gives the anomalies present in the original craniostenosis data-set grouped by body system effected. See Figure 18 for lists of which attributes were chosen by VARSEL and which were chosen by a human expert.

Palate
- Incomplete Median Cleft
- Median Cleft
- Submucous Cleft (3 varieties)

Skull
- General
- Assymetric
- Macrocephaly
- Craniosynostosis
- Craniosynostosis-Coronal
- Craniosynostosis-Sagittal
- Faulty Sutures
- Shape Anomalies
- Brachycephaly
- Cloverleaf Skull
- Plagiocephaly
- Trigonocephaly
- Prominent Coronal Suture

Forehead
- General
- Assymetric
- Large
- Typical Aperts
- Bossing
- Prominent/Bulging
- Elongated
- Flat
- Midline Defect
- Typical Crouzons
- Supraorbital Ridge Anomalies

Midface
General
Facial Assymetry
Midface Hypoplasia
Hypertelorism
Hypotelorism
Assymetric Orbital Placement (Right Higher)
Hypoplasia (Left Side)

Jaw
General
Assymetric
Micrognathia/Hypoplasia
Antegonial Notching
Prognathia
Wide Gonial Angle

Left Eye
General
Anophthalmia
Microphthalmia
Exophthalmos/Proptosis
Prominent/Protruding
Setting Sun Sign
Devil's Eye
Shallow Orbit
Small Orbit
Malpositioned Orbit
Blepharitis
Ptosis
Antimongoloid Slant
Epicanthal Fold
Synoche of the Lids
Esotropia
Strabismus
Nystagmus

Right Eye
General
Anophthalmia
Microphthalmia
Exophthalmos/Proptosis
Prominent/Protruding
Orbit Anomalies
Devil's Eye
Shallow Orbit
Small Orbit
Blepharitis
Ptosis
Lids Fail To Close
Antimongoloid Slant
Epicanthal Fold
Syneche of the Lids
Esotropia
Strabismus
Nystagmus

Left Ear
- Small
- Preauricular Pit/Sinus
- EAC Atresia
- Low Set
- Posteriorly Set
- Ossicular Anomalies
- Cupped
- Lopped/Protruding

Right Ear
- Small
- Preauricular Tag
- Rotated
- Low Set
- Cupped
- Lopped/Protruding

Nose
- General
- Assymetric
- Bifid
- Narrow
- Broad/Bulbous
- Alae Anomalies
- Cleft Nostrils/Alae
- Pinched Nares
- Beaked
- Saddle Shaped/No Bridge/Flat Bridge
- Choanal Atresia/Stenosis
- Deviated Bridge/Nose
- Deviated Septum

Oral Cavity
- High Arched Palate
- Byzantine Palate
- Torus Paltinus
- Narrow Palate
- Maxillary Assymetry
- Commissural Lip Pits
- Macrostomia

Tongue
- Short Frenulum/Tongue Tie
- Dry

Dentition
- Open Bite
- Crossbite
- Dental Crowding
- Missing Teeth
- Typical Aperts

Mimetic Musculature
- Motor Problem
- Paresis

Muscles of Mastication
Motor Problem
Paresis

Neck
General
Torticollis
Short

Abdominal Wall
Hernia, Unspecified
Umbilical Hernia
Inguinal Hernia

Chest Wall
General
Asymmetry
Prominent
Pectus Excavatum

Back
General
Scoliosis
Kyphosis/Kyphoscoliosis

Respiratory System
Chronic URI or Other Respiratory Disease

Cardiovascular System
Cardiac Anomalies
Valve Anomalies
Rythm Anomalies
Aortic Arch Anomalies

GI System
Liver,Spleen
Pyloric Stenosis

Genital
General
Hypospadias
Undescended Testes
Scrotal Anomalies
Uterine Anomalies
Kidney Anomalies

Skin and Adnexia
Alopecia/Bald
Thin/Sparse Hair
Echzema

Left Arm
General

Upper Arm Anomalies
Joint -
Dislocation/Subluxation
Contractures

Right Arm
General
Upper Arm Anomalies
Joint
Contractures

Left Hand
General
Arachnodactly
Contractures
Syndactly
Complete Syndactly
Cutaneous Syndactly
Dermatoglyphics
Simian Crease
Phalangeal Anomalies
Position Anomalies/Digits

Right Hand
General
Arachnodactly
Contractures
Syndactly
Complete Syndactly
Cutaneous Syndactly
Simian Crease
Position Anomalies

Left Leg
Contractures
Joint
Knee

Right Leg
Contractures
Joint
Knee
Overlapping Toes

Left Foot
Overlapping Toes
Bifid Toe
Broad/Large Digits
Syndactly
Partial Syndactly

Cutaneous Syndactly
Clubbing
Abnormal Position
Cleft/Seperation, Toes
Abnormal Postion/Foot

Right Foot
Broad/Large Toes
Syndactly
Partial Syndactly
Cutaneous Syndactly
Clubbing
Abnormal Position
Overlapping Toes
Cleft/Seperation, Toes
Abnormal Postition/Foot

Nervous System
General
Facial Nerves
Retardation
Developmental Retardation
Epilepsy/Seizure Disorder
EEG Abnormal
Hyperactive
Reflexes Hyperactive
Cerebral Anomalies
Corpus Collosum Anomalies
Aplusia/Speech Problems

Skeletal (Primary Axial)
General
Cervical
Cervical Fusions
C-1 Anomalies
Occipitalization, C-1
Basilar Invagination
Scoliosis
Hip Anomalies
Hip Dislocations
Joint Anomalies, Generalized
Spina Abifida

Muscular System
General
Hypotomia
Hypertonia
Contractures

Appendix D: Data and Miscellaneous Information of Interest

The following pages contain all of the data used in this work that has not been presented earlier, as well as certain other analyses and information that may be of interest.

```
bcwdom
!bcw_damag real 0.0 47.5 57.5
!farm_code key
        mussel  skaer talbot  helms wenzel   solt   fams herter schleu
        dannel briggs finfro  albin   lock carrol muelle muelle wetzel
        wetzel wiebur hisson zindar blacke dalton gregor lightl goodin
        dufren gebhar    poe  wirth  wirth   ruff montgo rincke henton
        jeffco dasche thoren patter groezi ostrum  nagel buchan  ivers
        bunsel  leigh beeler gustaf winkel fricke johnso hampto

  schaef  crowly  ccline  blkbrn  blkbrn  vnrdhm  steder  steder
  slnskr  vnlnkn  rokers  rokers   stein  seifrd   short   sturm  willms
  willms  borden  aschmn  bauman  drsler    fehr  bgrstf  bryant  carter
    curd  hammel  lamont  martin  sailer   white  stcklr  nelson  edward
  holman  holman  ranwtr  staggs   vaugh  moobry  rowell  saader  scwrtg
  sprngr  boldmn    imig   kilby   kiley   acton  antaze   spain  wenard
  hoffmn  kelsey  kelsey  kelsey  gruenl  vander   nolte  ferrer   woods
   woods  brande    burt  cornwe  kitloy  leonar  newton  rogers  templi
  weiler   baker   furry  halsey  whalen   clark  huddle  swinge   brown
  fombel   evans  mckinz    reid  gaibel  klitzi    lidy  miller   mundt
  schmid  uthell   cleer  toncra    hall  lingmi    fals   melby    frey
  weaver  jorgen  bixler  elmore  poehle    wolf    cain    goss  simkin
  pierso  hoxsey   logan    myer  stephe  warren  buchan  finely  henert
    zapf   alvey  bertsc   flint  mcbroo  sancke  thorne  thorso  klenke
   malau   malau  martin  gaines  vandev   walsh   young   young   buser
  fiedle  laible  lasswe  stange  benedi  mackma   james    cole   drake
   drake  rosent    ross  schrue   smith  travis  walqui  alliso  mcmill
   myers    wolf  miller   dixon  langle  mercer   green  lafeve   evans
   blair  mcfarl  graden  justis  lawler   manke  redeke   rovey  rupert
  tucker    webb  wemsin  montco  montco   white  steven  steven  steven
  alexan  gucker   olson   walsh   walsh  wilkin  davids  twordo  campbe
  deterd  eggeme  hersch   welge  kermic  klingl  r_runy  ethert   frank
  mcclel  osterm   stone   stout  bridge  bugenh   gregg  hampto  montgo
    ruff  schmit   addis   addis  elliot    gray   tracy  webste  wilson


  schwen  reusch  shaffe  jenkin  ecthte  ecthte  fordha  fordha  stoner
  gullet  rosebl  roseb2  roseb3  roseb4  roseb5  roseb6  roseb7    peal
   eiten  schnei  ludwig  erlwin  arnull   ester  custin    lane  niemey
  granch  tompio  thurma  johnso  larkin  rohrer  rohrer  robert  mccorm
  schmid  bluffd    kins  guetin  thomps  everet  stineb  thomps  perkin
  hofbau   nobis  landmi  nesher   flint    shaw  larson  graves   adams
   zabel   harms  zigler    ruff   asper   sousy   kelly  frelan   pitts
  boitno   jones  gibben  gibben  gulley  zindor  carrol  prohil  engelh
  engelh   cress   cress   cress  vasque  kessle  schult   gress  adkins
  syfert     cox  dustin  pedige  mcmill  fehien  jackso   shane  stalle
   sager    gill    meng   skaer    yong    moll   boyce  devrie   runte
   drake  desutt   frahm  schmid    good  staher  rowell  weyhrl  weyhr2
   green  bauman  herman  schert  kennel  wiegan  schert  bowald
```

1978 Black Cutworm Data for the State of Illinois

The following two pages list the attributes and their possible values for this data. The data follows with each new event preceeded by a "!." Each event has one line consisting of the static attributes in order, followed by zero or more lines of dynamic data consisting of time in days followed by weed species followed by weed density.

cutworm data 1978. THIS DATA HAS BEEN HEAVILY EDITTED TO FILL IN MANY MISSING VALUES WITH PLAUSIBLE ONES. IT SHOULD NOT BE USED AS NATURAL DATA.

```
! 75 schaef 78 weeds ? no yes ? lev chisel disc
  ?        ? counter 148 ? 1 1
    83   pigweed     hy
    83   smartweed   hy
    83   velvetleaf  hy

! 90 crowly 78 beans ? yes no ? rol disc disc
  ?        ? ramrod 128 ? 1 1
    83   peppergrass hy

! 27 ccline 78 beans ? yes no ? rol plow disc
  ?        ? counter 147 ? 1 1
    83   smartweed   lt

! 75 blkbrn 78 beans ? no yes ? bld none disc
  ?        ? lorsban 157 ? 1 1
    83   smartweed   lt
   156   d_weedkill  no

! 80 blkbrn 78 beans ? no yes ? bld none disc
  ?        ? lorsban 161 ? 1 1
    83   smartweed   lt
   156   d_weedkill  no

! 35 vnrdhm 78 beans ? no no ? lev disc fldclt
  ?        ? no 147 ? 1 1
    83   smartweed   hyps
    83   foxtail     hyps

! 10 steder 78 corn ? yes no ? rol plow disc
  ?        ? counter 147 ? 1 1
    83   ?   lt

! 33 steder 78 corn ? no no ? lev none plow
  ?        ? counter 152 ? 1 1
    83   ?   lt

! 25 slnskr 78 beans ? yes yes ? lev none plow
  ?        ? lorsban 170 ? 1 1
    83   peppergrass hyps
   138   p_weedkill  no

! 25 vnlnkn 78 beans ? yes yes ? rol chisel fldclt
  ?        ? no 142 ? 1 1
    83   smartweed   hy
```

```
!year n/a   75 76 77 78 79 80
!prev_crop char corn beans bewh whbe pasture bromegr  weeds blugras
                wheat oats whcl whmi whco clover hay  sod  pasture
                whsor
!bcw_hist n/a yes no
!perm_veg char yes no
!brdr_water char yes no
!surfacedir n/a n e s w
!surface char lev rol bld
!fall_till char none plow chisel disc cult fldclt harrow roter edisc ldisc
!sprngtill char none plow chisel disc cult fldclt harrow roter edisc ldisc
!manure n/a yes no
!fertilizer n/a fall complete anhydrous
!insecticid char yes no counter furadan thimit diazinon mocap
                     ramrod  lorsban  dyfonate r_lorsban
                     thimet  aldrin  isotox_dia heptachlor
                     rescue_trt r_penncap r_sevin belt
!plantdate integer 0 100 110 120 135 160
!plantrate n/a 0 100
!risk_index integer 0 10 15 20 25
!dyn_count n/a 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
$eos
!date integer 0 71 82 95 101 104 112 118 123 129 136 140
!weed_species struc
    none weeds very_few_wds onion
  # weedkill d_weedkill f_weedkill h_weedkill p_weedkill
  # grass  grsssod rye quackgrass h_grass foxtail volntercorn peppergrass
           watergrass orchardgrass giantfoxtail nutgrass hay johnsongrass
           ticklegrass sod barley wild_millet crab_grass bluegrass
           foxweed
  # legume   redclover peavine alfalfa h_alfalfa sweetclover clover
  # winter_annl chickweed winterweed shephrdpurse blwinterweed mustard
              wmustard  purslnespdwl spdwl yellowrocket vines
  # otherbroad dandelion smartweed pigweed lambsquarter ragweed
              horseweed dock velvetweed wstrawberry milkweed ironweed
              cocklebur d_few velvetleaf chickweed giantragweed
              fall_panicum can_thistle jimson butterprint bull_thistle
              horseradish morningglory sourdock nutsedge button_weed
              sandbur henbit garlic fishscale hutsedge spineysida
              spurge
!weedensity lchar no lt hy hyps
```

```
!   3  bauman  78   beans   ?   no   no   ? rol   none   disc
  ?         ?          no  150   ?   1    1
    83      foxtail    hy
    83    smartweed    hy
   148   d_weedkill    no

!  50  drsler  78    corn   ?   no  yes   ? lev   none   plow
  ?         ?   counter  138   ?   1    1
    83      foxtail  hyps
    83    cocklebur  hyps
    83  butterprint  hyps

!  11    fehr  78    corn   ? yes  yes   ? rol  chisel   disc
  ?         ?    thimet  123   ?    1    1
    83      foxtail    lt

!  90  bgrstf  78   beans   ?   no  yes   ? rol   disc  chisel
  ?         ?          no  142   ?   1    1
    83            ?    lt
   135   f_weedkill    no

!   4  bryant  78    corn   ? yes   no   ? lev   plow  chisel
  ?         ? r_lorsban  155   ?    1    1
    83    smartweed     ?
    83    horseweed     ?

!  80  carter  78   beans   ? yes   no   ? bld   plow   disc
  ?         ?          no  149   ?    1    1
    83    chickweed  hyps

!  75    curd  78   beans   ? yes  yes   ? bld  chisel fldclt
  ?         ?          no  150   ?    1    1
    83            ?    lt
   150   f_weedkill    no

!   2  hammel  78    corn   ?   no  yes   ? bld   plow   disc
  ?         ?         yes  142   ?   1    1
    83    chickweed    lt

!  70  lamont  78    corn   ? yes   no   ? lev   plow   disc
  ?         ?   furadan  146   ?    1    1
    83    chickweed     ?
    83   otherbroad     ?

!  50  martin  78   beans   ?   no   no   ? bld  chisel   disc
  ?         ?   furadan  138   ?   1    1
    83 johnsongrass    lt
```

```
! 3 rokers 78 beans ? yes yes ? lev none fldclt
  ? ? dyfonate 152 ? 1 1
    83 foxtail hy

! 95 stein 78 beans ? no no ? lev chisel disc
  ? ? no 156 ? 1 1
    83 ? hy

! 91 seifrd 78 corn ? no yes ? lev chisel disc
  ? ? furadan 153 ? 1 1
    83 ? lt
    135 d_weedkill no

! 75 short 78 beans ? yes no ? lev none disc
  ? ? no 147 ? 1 1
    83 pigweed lt
    83 foxtail hyps

! 1 sturm 78 beans ? yes no ? rol none plow
  ? ? diazinon 140 ? 1 1
    83 smartweed hy
    121 p_weedkill no

! 60 willms 78 beans ? yes no ? bld disc disc
  ? ? no 146 ? 1 1
    83 smartweed hy
    140 d_weedkill no

! 100 willms 78 beans ? yes yes ? bld plow disc
  ? ? no 146 ? 1 1
    83 horseweed hyps
    83 smartweed hyps

! 50 borden 78 pasture ? yes no ? rol none plow
  ? ? counter 148 ? 1 1
    83 ? lt

! 33 aschmn 78 beans ? yes no ? lev none disc
  ? ? no 151 ? 1 1
    83 foxtail hy
    83 vines hy
    83 cocklebur hy
```

```
?            ?    counter  148    ?    1     1
   83              ?    lt
  121    p_weedkill     no

!  10   rowell  78    beans    ? yes     no    ? lev    none  fldclt
?            ?     thimet  123    ?    1     1
   83              ?    lt

!  12   saader  78    beans    ?    no     no    ? lev    none  fldclt
?            ?   dyfonate  117    ?    1     1
   83         foxtail   lt

!  50   scwrtg  78    beans    ?    no    yes    ? lev    none    disc
?            ?              no   148    ?    1     1
   83     smartweed     hy
   83     horseweed     hy

!  25   sprngr  78    beans    ? yes     no    ? rol    none    disc
?            ?    counter  121    ?    1     1
   83     smartweed     lt
  118    d_weedkill     no

!   3   boldmn  78     corn    ? yes     no    ? lev    plow    disc
?            ?    counter  149    ?    1     1
   83    velvetleaf  hyps
   83       pigweed  hyps

!  30     imig  78     corn    ? yes     no    ? rol    plow    disc
?            ?     thimet  145    ?    1     1
   83  lambsquarter     lt

!  30    kilby  78    beans    ? yes    yes    ? rol    none  fldclt
?            ?    counter  149    ?    1     1
   83     smartweed     lt
  149    f_weedkill     no

!  35    kiley  78     oats    ? yes     no    ? lev    none    plow
?            ?   dyfonate  145    ?    1     1
   83  lambsquarter     hy
  145    p_weedkill     no

!  75    acton  78    beans    ?    no     no    ? lev    none    disc
?            ?              no   145    ?    1     1
   83              ? hyps
  140    d_weedkill     no
```

```
! 25   woods  78   beans    ? yes   no  ? lev       chisel  disc
  ?           ?            no   147    ?   1     1
    83     chickweed     hy

! 20   woods  78    corn    ? yes   no  ? lev chisel    disc
  ?           ?    counter  117    ?   1     1
    83              ?   lt

! 50  brande  78   beans    ? yes   no  ? lev chisel    disc
  ?           ?            no   159    ?   1     1
    83     smartweed     hy

! 50    burt  78   beans    ? yes   no  ?   lev   none    disc
  ?           ?            no   151    ?   1     1
    83       ragweed     hy
    83      nutgrass     hy

! 75  cornwe  78   beans    ?  no   no  ? lev   none    disc
  ?           ?            no   154    ?   1     1
    83     chickweed     hy
    83   ticklegrass     hy
    83       foxtail     hy

! 20  kitloy  78   beans    ? yes   no  ? rol   none        disc
  ?           ?    furadan  152    ?   1     1
    83     chickweed     hy
    83   winter_annl     hy
    83         grass     hy
   150    d_weedkill     no

! 10  leonar  78   beans    ? yes   no  ? lev chisel    disc
  ?           ?            no   152    ?   1     1
    83       foxtail  hyps

! 20  newton  78   beans    ? yes   no  ? lev   disc    disc
  ?           ?    counter  152    ?   1     1
    83     chickweed     lt

! 80  rogers  78    whbe    ? yes   no  ? lev chisel    disc
  ?           ?            no   154    ?   1     1
    83     chickweed     lt
    83     smartweed     lt

! 40  templi  78   beans    ?  no   no  ? lev chisel    disc
  ?           ?    counter  152    ?   1     1
    83       foxtail     lt
    83       ragweed     lt
```

```
      83  giantragweed     lt

 !   50   sailer  78     corn    ? yes    no   ? bld   plow    disc
     ?          ?          yes  147    ?     1     1
      83     smartweed    lt
     135    d_weedkill    no

 !   90   stcklr  78    beans    ? yes    no   ? rol    none  chisel
     ?          ?    furadan  147    ?     1     1
      83     chickweed    hy
      83     smartweed    hy
      83       foxtail    hy
      83  giantragweed    hy

 !   37   nelson  78     corn    ? yes    no   ? lev       none  plow
     ?          ?    furadan  143    ?     1     1
      83       foxtail    lt
     121    p_weedkill    no

 !  100   edward  78    beans    ?  no    no   ? bld   plow    disc
     ?          ?          no   152    ?     1     1
      83     smartweed    lt
      83     chickweed    lt

 !   50   holman  78     corn    ?  no    no   ? lev  chisel   disc
     ?          ?          yes  158    ?     1     1
      83              ?   lt

 !   50   holman  78    beans    ?  no    no   ? lev  chisel   disc
     ?          ?          no   149    ?     1     1
      83              ?   lt

 !   70   ranwtr  78     corn    ? yes   yes   ? bld  chisel   disc
     ?          ?          yes  145    ?     1     1
      83              ?   lt

 !   90   staggs  78    beans    ? yes   yes   ? bld   disc    disc
     ?          ?          no   141    ?     1     1
      83       foxtail    lt
     141    d_weedkill    no

 !   75    vaugh  78    beans    ?  no    no   ? bld  chisel   disc
     ?          ?          no   152    ?     1     1
      83     cocklebur    lt

 !   50   moobry  78     corn    ? yes    no   ? lev   disc    plow
```

```
      115    f_weedkill     no
      146    f_weedkill     no

!  25   fombel  78    beans    ?   no   no   ?  lev  chisel  fldclt
   ?           ?           no   156   ?   1    1
     83  very_few_wds      lt
    105    f_weedkill     no

!  15    evans  78    beans    ?  yes   no   ?  lev   plow    disc
   ?           ?           no   148   ?   1    1
     83     chickweed     lt
     83       ragweed   hyps
    124    d_weedkill     no
    147    d_weedkill     no

!  70   mckinz  78    beans    ?  yes   no   ?  rol  chisel   disc
   ?           ?     furadan   148   ?   1    1
     83     smartweed     lt
    125    d_weedkill     no

!  67     reid  78    beans    ?   no  yes   ?  rol  chisel   disc
   ?           ?           no   141   ?   1    1
     83  morningglory     lt
    125    d_weedkill     no

!  30   gaibel  78     whbe    ?   no   no   ?  lev  chisel   disc
   ?           ?    dyfonate   154   ?   1    1
     83       foxtail     hy
     83     smartweed     hy
     83       ragweed     hy

!  50   klitzi  78     corn    ?  yes   no   ?  lev   plow    disc
   ?           ?  isotox_dia   156   ?   1    1
     83     chickweed     hy
    150    d_weedkill     no

!  35     lidy  78    beans    ?   no  yes   ?  lev   plow    disc
   ?           ?     furadan   155   ?   1    1
     83       foxtail   hyps
     83       ragweed   hyps
     83     smartweed   hyps
    151    d_weedkill     no
    155    d_weedkill     no

!  12   miller  78    beans    ?   no   no   ?  lev  chisel   disc
   ?           ?           no   152   ?   1    1
     83       ragweed     hy
     83       foxtail     hy
```

```
! 77 antaze 78 corn ? no no ? lev plow disc
  ? ? thimet 150 ? 1 1
    83 velvetweed 1t
    83 foxtail 1t

! 50 spain 78 beans ? no no ? rol none disc
  ? ? no 140 ? 1 1
    83 ? 1t

! 3 wenard 78 beans ? yes no ? lev none fldclt
  ? ? no 140 ? 1 1
    83 grass 1t

! 99 hoffmn 78 corn ? no yes ? bld disc disc
  ? ? yes 141 ? 1 1
    83 sourdock 1t

! 20 kelsey 78 beans ? no yes ? lev chisel disc
  ? ? furadan 150 ? 1 1
    83 ? 1t

! 20 kelsey 78 whbe ? yes no ? rol disc disc
  ? ? furadan 147 ? 1 1
    83 ragweed 1t

! 20 kelsey 78 corn ? no yes ? lev plow disc
  ? ? furadan 140 ? 1 1
    83 morningglory 1t

! 20 gruenl 78 whbe ? yes no ? rol chisel disc
  ? ? furadan 152 ? 1 1
    83 smartweed hy

! 25 vander 78 whbe ? no no ? lev none chisel
  ? ? no 151 ? 1 1
    83 smartweed hyps

! 10 nolte 78 whcl ? no no ? rol none plow
  ? ? counter 131 ? 1 1
    83 ? hy

! 50 ferrer 78 beans ? no no ? lev chisel fldclt
  ? ? furadan 147 ? 1 1
    83 smartweed hy
```

```
! 10 melby 78 beans ? yes no ? lev none disc
  ? ? no 140 ? 1 1
    83 ? hy

! 50 frey 78 beans ? yes no ? lev chisel disc
  ? ? no 146 ? 1 1
    83 smartweed lt
    83 ticklegrass lt
    140 d_weedkill no

! 75 weaver 78 beans ? yes yes ? bld plow fldclt
  ? ? no 143 ? 1 1
    83 foxtail lt

! 7 jorgen 78 beans ? no no ? rol none disc
  ? ? no 149 ? 1 1
    83 smartweed lt

! 20 bixler 78 corn ? no no ? lev chisel disc
  ? ? furadan 157 ? 1 1
    83 chickweed lt
    83 foxtail hy
    83 smartweed hy

! 15 elmore 78 beans ? no no ? lev disc disc
  ? ? furadan 149 ? 1 1
    83 chickweed hy
    83 smartweed hy
    83 ragweed hy

! 16 poehle 78 beans ? yes yes ? lev chisel disc
  ? ? r_sevin 160 ? 1 1
    83 ? hy
    153 d_weedkill no
    156 d_weedkill no
    159 d_weedkill no

! 99 wolf 78 whbe ? no yes ? lev chisel disc
  ? ? no 155 ? 1 1
    83 chickweed hyps
    83 smartweed hyps
    145 d_weedkill no

! 66 cain 78 corn ? yes yes ? bld plow disc
  ? ? thimet 149 ? 1 1
    83 chickweed hy
```

```
! 50 weiler 78 corn ? yes no ? rol chisel disc
  ? ? furadan 146 ? 1 1
    83 chickweed hy
    83 ragweed hy
    145 d_weedkill no

! 27 baker 78 beans ? yes no ? lev chisel disc
  ? ? furadan 148 ? 1 1
    83 smartweed hyps
    143 d_weedkill no

! 40 furry 78 corn ? yes no ? rol disc fldclt
  ? ? yes 149 ? 1 1
    83 chickweed hy
    83 lambsquarter hy
    83 ragweed hy
    125 f_weedkill no

! 1 halsey 78 beans ? no yes ? lev none fldclt
  ? ? lorsban 130 ? 1 1
    83 foxtail lt

! 30 whalen 78 corn ? no no ? lev plow fldclt
  ? ? counter 150 ? 1 1
    83 smartweed ?
    123 f_weedkill no

! 15 clark 78 beans ? no yes ? lev chisel disc
  ? ? no 151 ? 1 1
    83 chickweed hy
    83 smartweed hy
    83 cocklebur hy
    144 d_weedkill no

! 95 huddle 78 beans ? no yes ? lev chisel disc
  ? ? no 156 ? 1 1
    83 smartweed lt
    155 d_weedkill no

! 20 swinge 78 beans ? yes no ? lev chisel disc
  ? ? furadan 157 ? 1 1
    83 grass hy

! 2 brown 78 beans ? no yes ? lev chisel fldclt
  ? ? no 146 ? 1 1
    83 foxtail lt
```

```
!  15  buchan  78  beans   ?  no  yes  ? bld chisel  disc
 ?          ?       no  151   ?   1   1
   83      foxtail    lt
   83    smartweed    lt

!   2  finely  78   corn   ?  no  yes  ? bld chisel  disc
 ?          ?   furadan 152   ?   1   1
   83             ?   lt

!  15  henert  78    sod   ?  no  no   ? lev   none  disc
 ?          ?       no  121   ?   1   1
   83           sod   hy

!   1   zapf  78   beans   ? yes  no   ? rol   none  disc
 ?          ? heptachlor 124  ?   1   1
   83      foxtail hyps

!  30   alvey  78  beans   ?  no  no   ? rol   none  disc
 ?          ?  r_lorsban 135  ?   1   1
   83 lambsquarter    lt

!   3  bertsc  78  beans   ? yes  no   ? lev chisel fldclt
 ?          ?  diazinon 147   ?   1   1
   83 giantfoxtail    ?

!  15   flint  78  beans   ?  no  no   ? lev   disc fldclt
 ?          ? rescue_trt 142  ?   1   1
   83       clover    lt
   83    smartweed    lt
  142   f_weedkill    no

!  12  mcbroo  78  beans   ?  no  no   ? lev   disc  disc
 ?          ?       no  119   ?   1   1
   83    smartweed    lt
  115   d_weedkill    no

!   5  sancke  78   corn   ? yes  yes  ? bld   plow fldclt
 ?          ?   furadan 146   ?   1   1
   83    smartweed hyps
   83       clover hyps

!   5  thorne  78  beans   ? yes  no   ? rol   none fldclt
 ?          ?       no  145   ?   1   1
   83    smartweed hyps
   83     nutsedge hyps
  144   f_weedkill    no
```

```
      83      smartweed     hy

!  70    mundt  78     whbe    ? yes    no   ? lev    plow    disc
  ?          ?           no   157    ?     1     1
      83       foxtail    hy
      83     smartweed    hy
     153    d_weedkill    no
     156    d_weedkill    no

!  60   schmid  78    beans    ?    no    no   ? lev  chisel    disc
  ?           ?       aldrin  156    ?     1     1
      83       foxtail    hy
      83     chickweed    hy
      83       pigweed    hy
     153    d_weedkill    ?
     155    d_weedkill    no

!   4   uthell  78    whcl    ?   no    no   ?    lev    plow    disc
  ?           ?           no   156    ?     1     1
      83       foxtail  hyps
      83     smartweed  hyps
      83       ragweed  hyps

!   3    cleer  78    beans    ?   no    no   ?  lev    plow  fldclt
  ?           ?           no   147    ?     1     1
      83       foxtail    hy
      83      milkweed    hy

!   5   toncra  78    beans    ?   no    yes    ? lev    none    disc
  ?           ?       thimet  122    ?     1     1
      83       foxtail    lt
     118    d_weedkill    no
     121    f_weedkill    no

!   9     hall  78    beans    ? yes   yes    ? rol    disc  fldclt
  ?           ?           no   148    ?     1     1
      83     smartweed     ?
      83        clover  hyps
     147    f_weedkill    no

!  28   lingmi  78    beans    ? yes    no   ? rol    none    disc
  ?           ?           no   147    ?     1     1
      83  morningglory    lt

! 100     fals  78    beans    ?   no    no   ? lev  chisel  fldclt
  ?           ?           no   145    ?     1     1
      83     smartweed    hy
     135    f_weedkill    no
```

```
    83            ?    1t

!   2  fiedle  78     corn     ? yes  yes    ? rol    none    disc
  ?            ?    counter  150    ?     1      1
     83    chickweed    hy
     83      foxtail    hy
     83     sourdock    hy
     83  button_weed    hy

!  25   laible  78     corn     ? yes  yes    ? rol    disc    disc
  ?            ?    counter  134    ?     1      1
     83      foxtail  hyps
    116   d_weedkill    no
    133   f_weedkill    no

!   6   lasswe  78     corn     ? yes    no   ? rol    none    disc
  ?            ?    counter  144    ?     1      1
     83      foxtail    1t
     83    smartweed    1t
    124   d_weedkill    no
    140   d_weedkill    no
    144   f_weedkill    no

!  50   stange  78     corn     ?    no   yes    ? rol    none    disc
  ?            ?    furadan  142    ?     1      1
     83    smartweed    1t

!   7   benedi  78    beans     ?    no    no    ? rol  chisel    disc
  ?            ?            ?  146    ?     1      1
     83  sweetclover    hy
     83      foxtail    hy

!  15   mackma  78    beans     ?    no    no    ? lev    none      disc
  ?            ?          no   115    ?     1      1
     83 lambsquarter    1t

!  12    james  78    beans     ?    no   yes    ? bld    none      disc
  ?            ?          no   147    ?     1      1
     83    smartweed    1t

!  50     cole  78    beans     ?    no    no    ? lev  chisel    disc
  ?            ?          no   153    ?     1      1
     83    chickweed    hy
     83    smartweed    hy
    152   d_weedkill    no

!  25    drake  78     whbe     ? yes    no    ? lev  chisel    disc
```

```
     83          grass    hy

!    5     goss  78     corn    ? yes    no   ? rol     disc  fldclt
   ?             ?      counter  120    ?     1     1
     83                 ?    lt
    119     f_weedkill     no

!    4    simkin  78     corn    ? yes  yes     ?    lev    none    plow
   ?             ?     dyfonate  142    ?    1     1
     83         foxtail     lt
     83      velvetleaf     lt
     83       smartweed     lt
    135      p_weedkill     no

!    3    pierso  78     corn     ?    no    no   ?  lev    plow    disc
   ?             ?      counter  121    ?     1     1
     83      quackgrass     lt
    106      d_weedkill     no
    120      d_weedkill     no

!    0    hoxsey  78     beans    ? yes    no   ?  lev    none    disc
   ?             ?      thimet  135    ?     1     1
     83      velvetleaf     lt
     83           grass     lt
    115      d_weedkill     no
    135      d_weedkill     no

!    5     logan  78     beans    ? yes    no   ?  rol    plow    disc
   ?             ?          no   146    ?     1     1
     83      velvetleaf     lt
    118      d_weedkill     no
    146      f_weedkill     no

!    4      myer  78     beans    ?    no   yes    ?  lev    none  fldclt
   ?             ?      furadan  140    ?    1     1
     83                 ?    hy

!    33   stephe  78     beans    ?    no   yes    ?  rol    none    disc
   ?             ?      furadan  147    ?    1     1
     83           grass     lt
    121      d_weedkill     no

!    7    warren  78     corn    ? yes    no   ?  lev    disc    disc
   ?             ?      counter  142    ?    1     1
     83      velvetleaf     lt
     83       smartweed     lt
```

```
      83      chickweed  hyps
      83      smartweed  hyps
      83        foxtail  hyps

!  75     wolf  78    beans    ?  yes    no   ?  lev  chisel   disc
   ?            ?    counter  145    ?     1      1
     83                ?    1t

!  33   miller  78    beans    ?  yes    no   ?  lev  fldclt  harrow
   ?            ?     thimet  138    ?     1      1
     83                ?    1t
    137    h_weedkill      no

!   4    dixon  78     corn    ?   no    no   ?  lev   plow    plow
   ?            ?    counter  127    ?     1      1
     83     smartweed     1t
    110    p_weedkill     no

!   4   langle  78     corn    ?  yes    no   ?  rol   none    disc
   ?            ?    counter  130    ?     1      1
     83                ?    1t

!   5   mercer  78     corn    ?  yes    no   ?  bld   plow    disc
   ?            ?     thimet  125    ?     1      1
     83       pigweed     1t
     83    velvetleaf     1t
     83     smartweed     1t

!  75    green  78    beans    ?  yes   yes   ?  lev   plow    disc
   ?            ?          no  140    ?     1      1
     83       sandbur     1t
     83         grass     1t

!  10   lafeve  78     corn    ?  yes    no   ?  rol   plow    disc
   ?            ?   dyfonate  138    ?     1      1
     83                ?    1t

!  90    evans  78    beans    ?   no    no   ?  lev   plow    disc
   ?            ?          no  142    ?     1      1
     83    smartweed  hyps

!   1    blair  78    beans    ?   no   yes   ?  lev   none    disc
   ?            ?          no  155    ?     1      1
     83     chickweed  hyps
     83     smartweed  hyps
    153    d_weedkill     no
```

```
! 25   thorso  78   beans    ? yes   no   ? bld  chisel   disc
  ?           ?     thimet  143   ?    1    1
    83            ?   lt
   130   d_weedkill   no

! 50   klenke  78   beans    ?   no   no   ? lev  chisel   disc
  ?           ?          no   153   ?    1    1
    83           grass    lt

! 70   malau  78    corn     ? yes   no   ? lev   disc    disc
  ?           ?     furadan  151   ?    1    1
    83           grass    lt

! 30   malau  78    beans    ? yes   no   ? lev   none    disc
  ?           ?     furadan  153   ?    1    1
    83           grass    lt

! 75   martin  78    whbe    ? yes   no   ? lev  chisel  chisel
  ?           ?          no   156   ?    1    1
    83           grass    lt
    83       chickweed    lt

! 20   gaines  78   beans    ?   no   yes   ? lev  chisel  fldclt
  ?           ?  r_penncap  130   ?    1    1
    83       chickweed    lt
    83          barley    lt

! 90   vandev  78   beans    ? yes   no   ? lev  chisel   disc
  ?           ?          no   142   ?    1    1
    83       chickweed  hyps

! 70   walsh  78    beans    ? yes   no   ? lev  chisel   disc
  ?           ?          no   156   ?    1    1
    83            ?   hy

! 65   young  78    bewh     ?   no   yes   ? lev   disc    disc
  ?           ?          no   151   ?    1    1
    83            ?   lt

! 25   young  78    beans    ?   no   yes   ? lev   none    disc
  ?           ?          no   152   ?    1    1
    83        foxtail    hy

! 10   buser  78    beans    ? yes   no   ? lev   disc    disc
  ?           ?     thimet  144   ?    1    1
```

```
! 33 wemsin 78 beans ? no no ? lev disc fldclt
? ? no 156 ? 1 1
83 smartweed hyps
83 pigweed hyps

! 50 montco 78 beans ? yes no ? lev disc disc
? ? no 157 ? 1 1
83 smartweed lt

! 5 montco 78 beans ? no no ? lev chisel fldclt
? ? no 150 ? 1 1
83 smartweed lt
83 grass lt

! 60 white 78 beans ? no no ? lev none disc
? ? counter 140 ? 1 1
83 cocklebur lt
83 jimson lt

! 80 steven 78 corn ? no no ? lev none disc
? ? thimet 152 ? 1 1
83 pigweed ?
83 lambsquarter ?

! 50 steven 78 beans ? no no ? lev chisel disc
? ? thimet 152 ? 1 1
83 pigweed ?
83 lambsquarter ?

! 50 steven 78 wheat ? no no ? lev plow disc
? ? thimet 152 ? 1 1
83 pigweed ?
83 lambsquarter ?

! 20 alexan 78 corn ? no no ? rol disc disc
? ? counter 118 ? 1 1
83 lambsquarter lt
83 giantfoxtail lt
83 smartweed lt

! 3 gucker 78 beans ? yes no ? lev none disc
? ? no 145 ? 1 1
83 foxtail lt

! 10 olson 78 corn ? no no ? rol disc disc
```

```
?          ?   furadan  154   ?   1   1
  83   smartweed   lt
  83     ragweed   lt

!  70   drake  78   clover   ?  yes   no   ?  lev  chisel      disc
?          ?   furadan  154   ?   1   1
  83   smartweed  hyps
  83     ragweed  hyps

!  50   rosent  78   beans   ?  yes   no   ?  lev   plow   disc
?          ?        no  154   ?   1   1
  83     ragweed    hy

!  80    ross  78   beans   ?  yes   no   ?  rol  chisel   disc
?          ?        no  153   ?   1   1
  83             ?  hyps

!  25   schrue  78   beans   ?  yes   no   ?   lev   chisel  fldclt
?          ?     mocap  154   ?   1   1
  83   watergrass   lt

!  17   smith  78    corn   ?  yes   no   ?  bld   none   disc
?          ?   furadan  135   ?   1   1
  83             ?   lt

!  20   travis  78   beans   ?  yes  yes   ?  bld   plow   disc
?          ?        no  145   ?   1   1
  83   smartweed   lt

!  20   walqui  78   beans   ?  yes   no   ?  rol  chisel   disc
?          ?   furadan  140   ?   1   1
  83    nutgrass  hyps
  83   cocklebur  hyps
  83       grass  hyps

!  35   alliso  78   beans   ?  yes   no   ?  rol   none  fldclt
?          ?   furadan  147   ?   1   1
  83   smartweed   lt

!  20   mcmill  78   beans   ?   no   no   ?  lev   none   disc
?          ?    thimet  148   ?   1   1
  83             ?   lt
 144   d_weedkill   no

!  20   myers  78   beans   ?   no   no   ?  lev   none   disc
?          ?   furadan  151   ?   1   1
```

```
!  25   welge  78    corn    ? yes  yes   ? bld    none    disc
 ?          ?         yes   143    ?     1     1
    83      nutsedge  hyps

!   0  kermic  78    wheat   ? yes   no   ? rol    none    plow
 ?          ?    furadan  151    ?     1     1
    83     hutsedge      ?
    83        clover     ?

!  17  klingl  78    beans   ?  no   no   ? lev    disc    disc
 ?          ?         no   152    ?     1     1
    83    chickweed     lt

!  42  r_runy  78    beans   ? yes  yes   ? rol  chisel    disc
 ?          ?    furadan  149    ?     1     1
    83              ?   lt

!  20  ethert  78     corn   ?  no   no   ? rol    disc  fldclt
 ?          ?    counter  147    ?    1     1
    83       foxtail  hyps
    83    velvetleaf  hyps

!  33   frank  78    beans   ? yes   no   ? lev  chisel    disc
 ?          ?    counter  119    ?    1     1
    83    chickweed  hyps
    83       foxtail  hyps

!  50  mcclel  78    beans   ? yes   no   ? lev  chisel  fldclt
 ?          ?         no   147    ?    1     1
    83   peppergrass  hyps

!  30  osterm  78    beans   ? yes  yes   ? lev  chisel  harrow
 ?          ?    counter  122    ?    1     1
    83              ?   lt
   122    h_weedkill     no

!  10   stone  78     corn   ? yes  yes   ? lev    plow    disc
 ?          ?    counter  144    ?    1     1
    83       foxtail    hy

!   3   stout  78    beans   ?  no   no   ? lev  chisel  fldclt
 ?          ?         no   149    ?    1     1
    83        spurge    lt
    83     smartweed    lt
    83         grass    lt
```

```
!   5   mcfarl  78   beans    ?  yes   no   ?  lev  chisel  fldclt
  ?            ?           no   140   ?    1    1
    83     chickweed    lt
    83       foxtail    lt

!   6   graden  78   beans    ?  yes   no   ?  lev  chisel  fldclt
  ?            ?           no   154   ?    1    1
    83       foxtail    lt

!   5   justis  78    corn    ?   no   no   ?  rol   disc  fldclt
  ?            ?          yes   140   ?    1    1
    83               ?    lt

!  65   lawler  78   beans    ?   no   yes   ?  lev  chisel   disc
  ?            ?           no   145   ?    1    1
    83       foxtail    lt
   143    d_weedkill    no

!  70    manke  78   beans    ?  yes  yes   ?  lev  chisel   disc
  ?            ?           no   156   ?    1    1
    83     chickweed    hy
    83       pigweed    hy
    83     smartweed    hy

!  30   redeke  78   beans    ?   no   yes   ?  lev  chisel  fldclt
  ?            ?  dyfonate  156   ?    1    1
    83     smartweed    lt

!  10    rovey  78   beans    ?   no   yes   ?  lev  chisel   disc
  ?            ?     mocap  146   ?    1    1
    83     smartweed  hyps
    83       foxtail  hyps

!  20   rupert  78   beans    ?  yes   no   ?  lev  chisel  fldclt
  ?            ?           no   151   ?    1    1
    83  lambsquarter  hyps
    83     smartweed  hyps
   149    f_weedkill    no

!  75   tucker  78   beans    ?  yes   no   ?  lev  chisel   disc
  ?            ?  heptachlor  154   ?    1    1
    83     smartweed    hy

!  35     webb  78   beans    ?   no   yes   ?  lev  chisel   disc
  ?            ?   counter  148   ?    1    1
    83     smartweed    hy
```

!	13	wilson	78	beans	?	no	no	?	lev	none	disc
	?		?	thimet	130	?	1	1			
	83			?	lt						

```
?         ?     counter  123   ?    1     1
  83   wild_millet      lt
 122     d_weedkill     no

!  10   walsh  78  pasture   ?   no   no   ?  lev    none    plow
 ?          ?     counter  146   ?    1     1
  83              ?     lt

!  10   walsh  78    beans   ?   no   no   ?  rol    none  fldclt
 ?          ?           no   140   ?    1     1
  83     smartweed     lt
 122     f_weedkill    no
 146     f_weedkill    no

!  65   wilkin  78    corn   ?  yes  yes   ?  rol    disc    disc
 ?          ?     counter  116   ?    1     1
  83      milkweed     lt
  83     smartweed     lt

!  85   davids  78    corn   ?  yes   no   ?  rol    none    disc
 ?          ?           yes  148   ?    1     1
  83       ragweed     lt
  83    crab_grass     lt

!  17   twordo  78    corn   ?  yes   no   ?  rol    none    disc
 ?          ?     counter  123   ?    1     1
  83              ?     lt
 122     d_weedkill     no

!  17   campbe  78    whbe   ?  yes   no   ?  rol  chisel    disc
 ?          ?           no   136   ?    1     1
  83     chickweed   hyps

!   3   deterd  78  clover   ?   no  yes   ?  bld    plow  fldclt
 ?          ?     furadan  111   ?    1     1
  83     chickweed     lt
  83        henbit     lt
 110     h_weedkill    no

!  20   eggeme  78   beans   ?   no   no   ?  lev    none    disc
 ?          ?     furadan  121   ?    1     1
  83        garlic     lt

!   3   hersch  78    corn   ?  yes   no   ?  bld    none    disc
 ?          ?           yes  110   ?    1     1
  83        henbit     ?
  83     fishscale     ?
```

Results after VARSEL using Greedy Attribute Search.

domaintypes

name	type	levels
prev_crop	nom	18
perm_veg	nom	2
brdr_water	nom	2
surface	nom	3
fall_till	nom	10
sprngtill	nom	10
insecticid	nom	19
plantdate	lin	6
nbrnotsame_of_weed_s	nom	4
maxvalue_of_weedensi	lin	4
lstmintim_of_weedens	lin	13

variables

#	name
1	var2.prev_crop
2	var4.perm_veg
3	var5.brdr_water
4	var7.surface
5	var8.fall_till
6	var9.sprngtill
7	var12.insecticid
8	var13.plantdate
9	var20.nbrnotsame_of_weed_s
10	var24.maxvalue_of_weedensi
11	var27.lstmintim_of_weedens

class1-events

#	var12	var9	var13	var8	var7	var27	var20	var2	var24	var5	var4
1	2	3	4	1	1	0	1	1	1	1	0
2	1	5	4	3	0	0	2	1	3	1	1
3	2	3	4	1	1	0	?	0	1	1	0
4	2	1	4	0	0	0	?	0	1	1	1
5	8	1	5	0	0	8	2	1	3	0	0
6	1	5	4	2	1	0	1	1	2	0	0
7	9	5	4	0	0	0	1	1	2	0	0
8	5	1	4	0	1	5	2	1	2	1	0
9	1	3	4	0	0	0	3	1	2	1	0
10	1	3	4	0	1	11	3	1	2	1	1
11	11	3	3	2	1	0	1	0	1	0	0
12	10	2	4	1	0	?	2	0	?	1	0
13	0	3	4	1	2	0	1	0	1	0	1
14	3	1	4	0	0	5	2	0	1	1	0
15	11	5	3	0	0	0	?	1	1	1	0
16	9	5	2	0	0	0	1	1	1	1	1
17	2	3	3	0	1	4	2	1	1	1	0
18	2	3	4	1	0	0	2	0	3	1	0
19	11	3	4	1	1	0	1	0	1	1	0
20	2	5	4	0	1	11	2	1	1	0	0
21	9	1	4	0	0	10	2	9	2	1	0
22	1	5	4	0	0	0	1	1	1	1	0
23	3	3	4	2	0	0	?	1	1	0	1
24	3	3	4	3	1	0	1	3	1	1	0
25	3	3	4	1	0	0	1	0	1	0	1
26	3	3	4	2	1	0	1	3	2	1	0

```
    119    h_weedkill    no
    149    f_weedkill    no

! 100  bridge  78   beans   ?  no  no  ?  lev  chisel  fldclt
  ?            ?            no  155  ?  1  1
     83    chickweed    lt
     83    smartweed    hy

! 90  bugenh  78   beans   ?  yes  yes  ?  lev  disc  disc
  ?            ?            no  152  ?  1  1
     83          grass    lt

! 50  gregg  78   beans   ?  no  no  ?  lev  chisel  disc
  ?            ?            no  149  ?  1  1
     83    smartweed    lt

! 25  hampto  78   beans   ?  yes  no  ?  lev  plow  fldclt
  ?            ?  diazinon  150  ?  1  1
     83    smartweed  hyps

! 50  montgo  78   beans   ?  yes  no  ?  lev  none  fldclt
  ?            ?            no  157  ?  1  1
     83    smartweed  hyps

! 8   ruff  78   beans   ?  no  no  ?  lev  chisel  fldclt
  ?            ?            no  152  ?  1  1
     83    chickweed    lt
     83    spineysida   lt
    150    f_weedkill   no

! 75  schmit  78   whbe   ?  yes  no  ?  rol  disc  disc
  ?            ?            no  151  ?  1  1
     83    peppergrass  hyps
    150    d_weedkill   no

! 22  elliot  78   corn   ?  no  no  ?  rol    none  plow
  ?            ?  furadan  147  ?  1  1
     83    velvetleaf   lt

! 12  gray  78  pasture   ?  no  yes  ?  rol  none  disc
  ?            ?  counter  123  ?  1  1
     83          grass    hy

! 5   webste  78   corn   ?  yes  yes  ?  rol    plow  disc
  ?            ?          yes  147  ?  1  1
     83    smartweed    lt
```

83	?	3	4	2	1	0	2	1	2	1	1
84	1	3	2	0	0	0	1	1	1	1	1
85	1	3	4	0	2	0	1	1	1	0	1
86	3	3	4	2	0	0	2	3	1	1	0
87	6	5	4	2	0	0	1	1	1	1	0
88	3	3	4	0	2	0	?	0	1	1	0
89	1	3	4	1	2	0	1	1	1	0	0
90	3	3	4	2	1	0	3	1	3	1	0
91	3	5	4	0	1	0	1	1	1	1	0
92	11	3	4	0	0	10	1	1	1	1	1
93	3	3	4	0	0	0	3	1	3	1	1
94	11	6	4	5	0	8	1	1	1	1	0
95	2	1	3	1	0	2	2	0	1	1	1
96	2	3	3	0	1	0	?	0	1	1	0
97	11	3	3	1	2	0	3	0	1	1	0
98	9	3	4	1	1	0	?	0	1	1	0
99	1	3	4	0	0	11	3	1	3	0	1
100	1	5	4	2	0	0	2	1	1	1	0
101	1	5	4	2	0	0	1	1	1	1	0
102	0	5	4	3	1	0	?	0	1	1	1
103	9	5	4	2	0	0	1	1	1	0	1
104	6	3	4	2	0	0	2	1	3	0	1
105	1	5	4	2	0	11	3	1	3	1	0
106	2	3	4	2	0	0	1	1	2	0	1
107	1	5	4	3	0	0	2	1	3	1	1
108	1	5	4	2	0	0	2	1	1	1	1
109	2	3	2	3	1	0	3	0	1	1	1
110	1	3	4	0	0	0	1	1	1	1	0
111	2	3	3	3	1	6	2	0	1	1	1
112	2	1	4	0	0	0	?	4	1	1	1
113	1	5	4	0	1	6	2	1	1	1	1
114	2	3	3	0	1	6	1	0	1	1	0
115	1	3	4	2	1	0	1	3	3	1	0
116	3	5	2	1	2	2	3	13	1	0	1
117	3	3	3	0	0	0	1	1	1	1	1
118	0	3	2	0	2	?	2	0	?	1	0
119	0	3	4	0	2	0	1	0	3	0	0
120	3	1	4	0	1	?	2	8	?	1	0
121	1	3	4	3	0	0	1	1	1	1	1
122	3	3	4	2	1	0	?	1	1	0	0
123	2	5	4	3	1	0	2	0	3	1	1
124	2	3	2	2	0	0	2	1	3	1	0
125	2	6	3	2	0	6	1	1	1	0	0
126	2	3	4	1	0	0	1	0	2	0	0
127	1	5	4	2	0	4	3	1	1	1	1
128	5	5	4	1	0	0	1	1	3	1	0
129	1	5	4	2	0	11	3	1	1	1	1
130	3	1	4	0	1	0	1	0	1	1	1
131	2	3	3	0	1	0	1	4	2	0	1
132	0	3	4	1	1	0	1	0	1	0	0
133	11	3	3	0	0	0	?	1	1	1	1

class2-events

#	var12	var9	var13	var8	var7	var27	var20	var2	var24	var5	var4
1	2	3	4	2	0	0	3	6	2	0	1
2	7	3	3	3	1	0	1	1	2	1	0

Results from processing 1978 BCW data with CONVART and VARSEL so as to compare RAS to GAS

The following pages give the input tables suitable for use with GEM, produced by VARSEL after CONVART. Results of greedy search and random adaptive search for sample sizes of 5, 10, and 15 are given.

59	2	3	4	2	0	0	?	1	1	1	0
60	1	3	4	1	0	0	2	1	1	0	0
61	1	3	4	1	0	0	1	1	3	1	1
62	1	3	4	2	0	10	2	1	1	0	1
63	1	3	4	2	0	0	3	1	2	0	0
64	14	3	4	2	0	0	1	1	2	1	0
65	1	3	4	3	0	0	1	1	1	1	0
66	2	3	4	0	0	0	2	1	1	1	1
67	11	3	4	0	0	?	2	0	?	1	1
68	11	3	4	2	0	?	2	1	?	1	1
69	11	3	4	1	0	?	2	8	?	1	1
70	2	3	2	3	1	0	2	0	1	0	0
71	0	3	4	0	1	0	2	0	1	1	0
72	1	5	4	2	0	0	1	1	3	1	0
73	1	5	4	2	0	0	2	1	2	1	1
74	1	3	4	3	0	0	1	1	1	0	0
75	1	3	4	2	0	0	1	1	1	1	1
76	1	5	4	0	0	0	1	1	3	1	0
77	1	3	4	3	1	11	2	3	3	1	0

27	1	2	4	0	0	0	1	3	3	1	1
28	2	1	3	0	1	0	?	10	2	1	1
29	1	3	4	2	0	0	1	1	2	1	0
30	2	3	2	2	0	0	?	0	1	1	0
31	3	3	4	0	1	11	3	1	2	1	0
32	1	3	4	2	0	0	1	1	3	1	0
33	2	3	4	3	0	0	1	1	1	1	0
34	2	3	4	2	0	0	2	1	1	1	1
35	3	3	4	2	0	10	2	1	3	1	0
36	0	5	4	3	1	6	3	0	2	1	0
37	8	5	3	0	0	0	1	1	1	0	1
38	2	5	4	1	0	6	2	0	0	1	1
39	1	3	4	2	0	10	3	1	2	0	1
40	3	3	4	2	0	0	1	1	2	1	0
41	1	5	4	2	0	3	2	1	1	0	1
42	1	5	4	2	0	1	2	1	1	1	1
43	1	3	4	1	0	6	3	1	3	1	0
44	9	3	4	2	0	0	3	3	2	1	1
45	3	3	4	1	0	11	3	1	3	0	1
46	1	3	4	2	0	0	3	1	2	1	1
47	1	3	4	1	0	0	3	10	3	1	1
48	1	5	4	1	0	0	2	1	2	1	1
49	11	3	3	0	0	4	2	1	1	0	1
50	1	5	4	3	1	11	3	1	3	0	0
51	1	3	4	0	1	0	1	1	1	1	0
52	1	3	4	0	0	0	?	1	2	1	0
53	1	3	4	0	1	0	1	1	1	1	1
54	3	3	4	2	0	0	3	0	2	1	1
55	3	3	4	3	0	0	3	1	2	1	1
56	17	3	5	2	0	11	1	1	2	0	0
57	2	5	3	3	1	4	1	0	1	1	0
58	9	1	4	0	0	8	3	0	1	0	0
59	2	3	3	1	0	1	2	0	1	1	1
60	11	3	4	0	0	3	3	1	1	1	0
61	1	3	4	1	1	4	2	1	1	1	0
62	3	5	4	0	0	0	?	1	2	0	1
63	3	3	4	0	1	5	2	1	1	0	1
64	2	3	4	3	0	0	2	0	1	1	0
65	1	3	4	2	2	0	2	1	1	0	1
66	3	3	4	2	2	0	?	0	1	0	1
67	1	3	3	0	0	0	1	15	2	1	1
68	14	3	3	0	1	0	1	1	3	1	0
69	10	3	4	0	1	0	1	1	1	1	1
70	5	5	4	2	0	?	1	1	?	1	0
71	15	5	4	3	0	10	3	1	1	1	1
72	1	3	2	3	0	3	2	1	1	1	1
73	3	5	4	1	2	0	2	0	3	0	0
74	1	5	4	0	1	10	3	1	3	1	0
75	11	3	4	2	2	7	1	1	1	1	0
76	3	3	4	0	0	0	1	1	1	1	0
77	16	5	3	2	0	0	2	1	1	0	1
78	1	3	4	0	0	0	1	1	2	0	1
79	11	3	4	3	0	0	?	1	1	1	0
80	2	3	4	0	1	0	3	0	2	0	0
81	2	3	3	3	1	3	2	0	3	0	0
82	2	3	4	0	1	6	3	0	1	1	0

25	3	1	1	3	0	4	0	1	0	0	9	1
26	3	2	1	3	0	4	3	0	1	1	9	2
27	1	0	1	2	0	4	3	1	0	1	9	3
28	2	0	?	1	0	3	10	1	1	1	?	2
29	1	2	1	3	0	4	1	0	0	1	9	2
30	2	2	?	3	0	2	0	0	0	1	?	1
31	3	0	3	3	11	4	1	0	1	1	9	2
32	1	2	1	3	0	4	1	0	0	1	9	3
33	2	3	1	3	0	4	1	0	0	1	9	1
34	2	2	2	3	0	4	1	1	0	1	9	1
35	3	2	2	3	10	4	1	0	0	1	9	2
36	0	3	3	5	6	4	0	0	1	1	9	2
37	8	0	1	5	0	3	1	1	0	0	9	1
38	2	1	2	5	6	4	0	1	0	1	9	0
39	1	2	3	3	10	4	1	1	0	0	9	2
40	3	2	1	3	0	4	1	0	0	1	5	2
41	1	2	2	5	3	4	1	1	0	0	9	0
42	1	2	2	5	1	4	1	1	0	1	2	1
43	1	1	3	3	6	4	1	0	0	1	9	1
44	9	2	3	3	0	4	3	1	0	1	9	2
45	3	1	3	3	11	4	1	1	0	0	9	2
46	1	2	3	3	0	4	1	1	0	1	9	2
47	1	1	3	3	0	4	10	1	0	1	9	3
48	1	1	2	5	0	4	1	1	0	1	9	2
49	11	0	2	3	4	3	1	1	0	0	9	0
50	1	3	3	5	11	4	1	0	1	0	9	2
51	1	0	1	3	0	4	1	0	1	1	9	1
52	1	0	?	3	0	4	1	0	0	1	?	2
53	1	0	1	3	0	4	1	1	1	1	9	1
54	3	2	3	3	0	4	0	1	0	1	9	2
55	3	3	3	3	0	4	1	1	0	1	9	2
56	17	2	1	3	11	5	1	0	0	0	9	1
57	2	3	1	5	4	3	0	0	1	1	9	1
58	9	0	3	1	8	4	0	0	0	0	9	1
59	2	1	2	3	1	3	0	1	0	1	9	0
60	11	0	3	3	3	4	1	0	0	1	9	1
61	1	1	2	3	4	4	1	0	1	1	9	0
62	3	0	?	5	0	4	1	1	0	0	?	2
63	3	0	2	3	5	4	1	1	1	0	5	1
64	2	3	2	3	0	4	0	0	0	1	9	1
65	1	2	2	3	0	4	1	1	2	0	9	1
66	3	2	?	3	0	4	0	1	2	0	?	1
67	1	0	1	3	0	3	15	1	0	1	9	2
68	14	0	1	3	0	3	1	0	1	1	9	3
69	10	0	1	3	0	4	1	1	1	1	9	1
70	5	2	1	5	?	4	1	0	0	1	9	?
71	15	3	3	5	10	4	1	1	0	1	9	1
72	1	3	2	3	3	2	1	1	0	1	9	1
73	3	1	2	5	0	4	0	0	2	0	9	3
74	1	0	3	5	10	4	1	0	1	1	9	2
75	11	2	1	3	7	4	1	0	2	1	9	1
76	3	0	1	3	0	4	1	0	0	1	5	1
77	16	2	2	5	0	3	1	1	0	0	9	1
78	1	0	1	3	0	4	1	1	0	0	9	2
79	11	3	?	3	0	4	1	0	0	1	?	1
80	2	0	3	3	0	4	0	0	1	0	9	2

3	8	3	4	0	2	12	2	1	1	0	1
4	8	3	5	0	2	12	2	1	1	0	1
5	1	3	4	2	0	0	?	1	2	1	1
6	3	3	4	2	0	8	1	0	1	0	1
7	1	3	4	0	0	0	2	1	3	1	0
8	1	3	4	3	2	9	2	1	2	1	0
9	1	3	4	1	2	0	2	1	3	0	0
10	2	1	4	0	1	0	?	4	1	1	0
11	2	1	4	0	0	0	3	0	3	0	1
12	1	2	4	3	1	8	1	1	1	0	1
13	1	3	4	1	2	0	1	1	3	1	0
14	1	5	4	2	2	11	1	1	1	0	0
15	3	3	4	1	0	?	2	0	?	1	0
16	3	3	4	2	2	0	2	1	1	1	1
17	0	3	4	1	2	8	2	0	1	1	0
18	3	2	4	0	1	0	3	1	2	1	0
19	1	3	4	1	2	0	2	1	1	1	1
20	0	3	4	2	0	0	?	0	1	1	1
21	1	3	4	2	0	0	?	1	1	1	1
22	0	3	4	2	2	0	?	0	1	0	0
23	1	3	4	3	2	10	2	1	1	0	0
24	1	3	4	2	2	0	1	1	1	1	1
25	2	1	4	3	0	5	1	0	1	1	0
26	1	3	4	0	0	0	2	1	2	0	1
27	1	3	4	0	0	9	1	1	3	1	1
28	11	3	4	1	0	0	2	0	1	1	1
29	1	3	4	0	1	0	?	1	1	1	1
30	0	3	4	3	2	0	1	0	1	0	1
31	3	5	4	2	0	0	1	1	2	1	1
32	1	3	4	2	0	0	1	1	2	1	0
33	1	3	4	0	0	0	2	1	2	1	0
34	1	3	4	0	0	0	3	1	2	1	1
35	1	3	4	2	0	0	2	3	1	1	0
36	3	3	4	2	1	10	3	0	2	1	0
37	1	3	4	2	0	12	2	1	1	0	1
38	3	3	4	2	1	6	2	1	1	1	0
39	1	3	4	2	1	6	2	1	1	0	1
40	13	3	4	1	0	11	2	0	2	1	0
41	1	3	4	1	0	11	3	3	2	1	0
42	12	3	4	2	0	12	3	1	2	1	1
43	1	5	4	2	0	8	2	1	2	1	1
44	1	3	4	2	0	9	3	1	1	1	0
45	1	5	4	1	2	0	1	1	1	0	0
46	1	3	4	2	0	10	3	3	3	0	1
47	11	3	4	1	2	0	2	0	2	0	0
48	1	3	4	2	0	0	1	1	1	1	1
49	3	3	4	3	0	0	1	0	1	1	0
50	1	2	4	2	0	0	2	3	1	1	0
51	1	3	4	2	0	0	1	1	3	1	0
52	1	3	4	2	0	0	?	1	2	1	0
53	1	3	4	3	0	0	?	2	1	0	1
54	3	3	4	0	1	0	1	0	1	0	1
55	1	3	4	2	0	11	3	1	2	1	1
56	3	3	4	2	0	0	2	13	3	1	0
57	1	3	4	1	0	0	1	1	2	1	0
58	1	3	4	2	1	0	?	1	3	1	0

1	2	2	3	3	0	4	6	1	0	0	9	2
2	7	3	1	3	0	3	1	0	1	1	9	2
3	8	0	2	3	12	4	1	1	2	0	9	1
4	8	0	2	3	12	5	1	1	2	0	9	1
5	1	2	?	3	0	4	1	1	0	1	?	2
6	3	2	1	3	8	4	0	1	0	0	9	1
7	1	0	2	3	0	4	1	0	0	1	9	2
8	1	3	2	3	9	4	1	0	2	1	9	1
9	1	1	2	3	0	4	1	0	2	0	9	3
10	2	0	?	1	0	4	4	0	1	1	?	1
11	2	0	3	1	0	4	0	1	0	0	9	3
12	1	3	1	2	8	4	1	1	1	0	9	1
13	1	1	1	3	0	4	1	0	2	1	9	3
14	1	2	1	5	11	4	1	0	2	0	9	1
15	3	1	2	3	?	4	0	0	0	1	9	?
16	3	2	2	3	0	4	1	1	2	1	9	1
17	0	1	2	3	8	4	0	0	2	1	9	1
18	3	0	3	2	0	4	1	0	1	1	9	2
19	1	1	2	3	0	4	1	1	2	1	9	1
20	0	2	?	3	0	4	0	1	0	1	?	1
21	1	2	?	3	0	4	1	1	0	1	?	1
22	0	2	?	3	0	4	0	0	2	0	?	1
23	1	3	2	3	10	4	1	0	2	0	9	1
24	1	2	1	3	0	4	1	1	2	1	9	1
25	2	3	1	1	5	4	0	0	0	1	9	1
26	1	0	2	3	0	4	1	1	0	0	9	2
27	1	0	1	3	9	4	1	1	0	1	9	2
28	11	1	2	3	0	4	0	1	0	1	9	1
29	1	0	?	3	0	4	1	1	1	1	?	1
30	0	3	1	3	0	4	0	1	2	0	9	1
31	3	2	1	5	0	4	1	1	0	1	9	2
32	1	2	1	3	0	4	1	0	0	1	9	2
33	1	0	2	3	0	4	1	0	0	1	9	2
34	1	0	3	3	0	4	1	1	0	1	9	2
35	1	2	2	3	0	4	3	0	0	1	9	1
36	3	2	3	3	10	4	0	0	1	1	9	1
37	1	2	2	3	12	4	1	1	0	0	9	1
38	3	2	2	3	6	4	1	0	1	1	9	1
39	1	2	2	3	6	4	1	1	1	0	9	1
40	13	1	2	3	11	4	0	0	0	1	9	1
41	1	1	3	3	11	4	3	0	0	1	9	1
42	12	2	3	3	12	4	1	1	0	1	9	2
43	1	2	2	5	8	4	1	1	0	1	9	1
44	1	2	3	3	9	4	1	0	0	1	9	1
45	1	1	1	5	0	4	1	0	2	0	9	1
46	1	2	3	3	10	4	3	1	0	0	9	2
47	11	1	2	3	0	4	0	0	2	0	9	2
48	1	2	1	3	0	4	1	1	0	1	5	1
49	3	3	1	3	0	4	0	0	0	1	5	1
50	1	2	2	2	0	4	3	0	0	1	5	1
51	1	2	1	3	0	4	1	0	0	1	9	3
52	1	2	?	3	0	4	1	0	0	1	?	2
53	1	3	?	3	0	4	2	1	0	0	?	1
54	3	0	1	3	0	4	0	1	1	0	9	1
55	1	2	3	3	11	4	1	1	0	1	9	1
56	3	2	2	3	0	4	13	0	0	1	9	3

Results after VARSEL using
Random Adaptive Search
Sample size = 5

domaintypes

name	type	levels
prev_crop	nom	18
perm_veg	nom	2
brdr_water	nom	2
surface	nom	3
fall_till	nom	10
sprngtill	nom	10
insecticid	nom	19
plantdate	lin	6
mostcomval_of_weed_s	nom	9
nbrnotsame_of_weed_s	nom	4
averageval_of_weeden	lin	4
1stmintim_of_weedens	lin	13

variables

#	name
1	var2.prev_crop
2	var4.perm_veg
3	var5.brdr_water
4	var7.surface
5	var8.fall_till
6	var9.sprngtill
7	var12.insecticid
8	var13.plantdate
9	var17.mostcomval_of_weed_s
10	var20.nbrnotsame_of_weed_s
11	var21.averageval_of_weeden
12	var27.1stmintim_of_weedens

class1-events

#	var12	var8	var20	var9	var27	var13	var2	var4	var7	var5	var17	var21
1	2	1	1	3	0	4	1	0	1	1	9	1
2	1	3	2	5	0	4	1	1	0	1	9	3
3	2	1	?	3	0	4	0	0	1	1	?	1
4	2	0	?	1	0	4	0	1	0	1	?	1
5	8	0	2	1	8	5	1	0	0	0	9	2
6	1	2	1	5	0	4	1	0	1	0	9	2
7	9	0	1	5	0	4	1	0	0	0	9	2
8	5	0	2	1	5	4	1	0	1	1	9	1
9	1	0	3	3	0	4	1	0	0	1	9	2
10	1	0	3	3	11	4	1	1	1	1	9	1
11	11	2	1	3	0	3	0	0	1	0	9	1
12	10	1	2	2	?	4	0	0	0	1	9	?
13	0	1	1	3	0	4	0	1	2	0	9	1
14	3	0	2	1	5	4	0	0	0	1	9	1
15	11	0	?	5	0	3	1	0	0	1	?	1
16	9	0	1	5	0	2	1	1	0	1	9	1
17	2	0	2	3	4	3	1	0	1	1	9	1
18	2	1	2	3	0	4	0	0	0	1	9	3
19	11	1	1	3	0	4	0	0	1	1	9	1
20	2	0	2	5	11	4	1	0	1	0	9	1
21	9	0	2	1	10	4	9	0	0	1	9	1
22	1	0	1	5	0	4	1	0	0	1	5	1
23	3	2	?	3	0	4	1	1	0	0	?	1
24	3	3	1	3	0	4	3	0	1	1	9	1

Results after VARSEL using
Random Adaptive Search
Sample size = 10

domaintypes

name	type	levels
prev_crop	nom	18
perm_veg	nom	2
brdr_water	nom	2
surface	nom	3
fall_till	nom	10
sprngtill	nom	10
insecticid	nom	19
plantdate	lin	6
nbrnotsame_of_weed_s	nom	4
yintercept_of_weeden	lin	15
maxvalue_of_weedensi	lin	4
minvalue_of_weedensi	lin	4
lstmintim_of_weedens	lin	13

variables

#	name
1	var2.prev_crop
2	var4.perm_veg
3	var5.brdr_water
4	var7.surface
5	var8.fall_till
6	var9.sprngtill
7	var12.insecticid
8	var13.plantdate
9	var20.nbrnotsame_of_weed_s
10	var23.yintercept_of_weeden
11	var24.maxvalue_of_weedensi
12	var26.minvalue_of_weedensi
13	var27.lstmintim_of_weedens

class1-events

#	var12	var8	var9	var20	var13	var26	var27	var23	var24	var7	var2	var5	var4
1	2	1	3	1	4	1	0	?	1	1	1	1	0
2	1	3	5	2	4	3	0	?	3	0	1	1	1
3	2	1	3	?	4	1	0	?	1	1	0	1	0
4	2	0	1	?	4	1	0	?	1	0	0	1	1
5	8	0	1	2	5	0	8	?	3	0	1	0	0
6	1	2	5	1	4	2	0	?	2	1	1	0	0
7	9	0	5	1	4	2	0	?	2	0	1	0	0
8	5	0	1	2	4	0	5	?	2	1	1	1	0
9	1	0	3	3	4	2	0	0	2	0	1	1	0
10	1	0	3	3	4	0	11	8	2	1	1	1	1
11	11	2	3	1	3	1	0	?	1	1	0	0	0
12	10	1	2	2	4	?	?	?	?	0	0	1	0
13	0	1	3	1	4	1	0	?	1	2	0	0	1
14	3	0	1	2	4	0	5	?	1	0	0	1	0
15	11	0	5	?	3	1	0	?	1	0	1	1	0
16	9	0	5	1	2	1	0	?	1	0	1	1	1
17	2	0	3	2	3	0	4	?	1	1	1	1	0
18	2	1	3	2	4	3	0	?	3	0	0	1	0
19	11	1	3	1	4	1	0	?	1	1	0	1	0
20	2	0	5	2	4	0	11	?	1	1	1	0	0
21	9	0	1	2	4	0	10	?	2	0	9	1	0
22	1	0	5	1	4	1	0	?	1	0	1	1	0

81	2	3	2	3	3	3	0	0	1	0	9	1
82	2	0	3	3	6	4	0	0	1	1	9	0
83	7	2	2	3	0	4	1	1	1	1	9	2
84	1	0	1	3	0	2	1	1	0	1	9	1
85	1	0	1	3	0	4	1	1	2	0	9	1
86	3	2	2	3	0	4	3	0	0	1	9	1
87	6	2	1	5	0	4	1	0	0	1	9	1
88	3	0	?	3	0	4	0	0	2	1	?	1
89	1	1	1	3	0	4	1	0	2	0	9	1
90	3	2	3	3	0	4	1	0	1	1	9	3
91	3	0	1	5	0	4	1	0	1	1	9	1
92	11	0	1	3	10	4	1	1	0	1	9	1
93	3	0	3	3	0	4	1	1	0	1	9	3
94	11	5	1	6	8	4	1	0	0	1	9	1
95	2	1	2	1	2	3	0	1	0	1	9	1
96	2	0	?	3	0	3	0	0	1	1	?	1
97	11	1	3	3	0	3	0	0	2	1	9	1
98	9	1	?	3	0	4	0	0	1	1	?	1
99	1	0	3	3	11	4	1	1	0	0	9	2
100	1	2	2	5	0	4	1	0	0	1	9	1
101	1	2	1	5	0	4	1	0	0	1	9	1
102	0	3	?	5	0	4	0	1	1	1	?	1
103	9	2	1	5	0	4	1	1	0	0	9	1
104	6	2	2	3	0	4	1	1	0	0	9	3
105	1	2	3	5	11	4	1	0	0	1	9	2
106	2	2	1	3	0	4	1	1	0	0	9	2
107	1	3	2	5	0	4	1	1	0	1	9	3
108	1	2	2	5	0	4	1	1	0	1	9	1
109	2	3	3	3	0	2	0	1	1	1	9	1
110	1	0	1	3	0	4	1	0	0	1	9	1
111	2	3	2	3	6	3	0	1	1	1	9	1
112	2	0	?	1	0	4	4	1	0	1	?	1
113	1	0	2	5	6	4	1	1	1	1	9	0
114	2	0	1	3	6	3	0	0	1	1	9	1
115	1	2	1	3	0	4	3	0	1	1	9	3
116	3	1	3	5	2	2	13	1	2	0	9	1
117	3	0	1	3	0	3	1	1	0	1	9	1
118	0	0	2	3	?	2	0	0	2	1	9	?
119	0	0	1	3	0	4	0	0	2	0	9	3
120	3	0	2	1	?	4	8	0	1	1	9	?
121	1	3	1	3	0	4	1	1	0	1	9	1
122	3	2	?	3	0	4	1	0	1	0	?	1
123	2	3	2	5	0	4	0	1	1	1	9	3
124	2	2	2	3	0	2	1	0	0	1	9	3
125	2	2	1	6	6	3	1	0	0	0	9	1
126	2	1	1	3	0	4	0	0	0	0	9	2
127	1	2	3	5	4	4	1	1	0	1	9	1
128	5	1	1	5	0	4	1	0	0	1	9	3
129	1	2	3	5	11	4	1	1	0	1	9	1
130	3	0	1	1	0	4	0	1	1	1	9	1
131	2	0	1	3	0	3	4	1	1	0	5	2
132	0	1	1	3	0	4	0	0	1	0	9	1
133	11	0	?	3	0	3	1	1	0	1	?	1

class2-events

#	var12	var8	var20	var9	var27	var13	var2	var4	var7	var5	var17	var21

79	11	3	3	?	4	1	0	?	1	0	1	1	0
80	2	0	3	3	4	2	0	0	2	1	0	0	0
81	2	3	3	2	3	0	3	14	3	1	0	0	0
82	2	0	3	3	4	0	6	3	1	1	0	1	0
83	?	2	3	2	4	2	0	?	2	1	1	1	1
84	1	0	3	1	2	1	0	?	1	0	1	1	1
85	1	0	3	1	4	1	0	?	1	2	1	0	1
86	3	2	3	2	4	1	0	?	1	0	3	1	0
87	6	2	5	1	4	1	0	?	1	0	1	1	0
88	3	0	3	?	4	1	0	?	1	2	0	1	0
89	1	1	3	1	4	1	0	?	1	2	1	0	0
90	3	2	3	3	4	3	0	0	3	1	1	1	0
91	3	0	5	1	4	1	0	?	1	1	1	1	0
92	11	0	3	1	4	0	10	?	1	0	1	1	1
93	3	0	3	3	4	3	0	0	3	0	1	1	1
94	11	5	6	1	4	0	8	?	1	0	1	1	0
95	2	1	1	2	3	0	2	?	1	0	0	1	1
96	2	0	3	?	3	1	0	?	1	1	0	1	0
97	11	1	3	3	3	1	0	0	1	2	0	1	0
98	9	1	3	?	4	1	0	?	1	1	0	1	0
99	1	0	3	3	4	0	11	11	3	0	1	0	1
100	1	2	5	2	4	1	0	?	1	0	1	1	0
101	1	2	5	1	4	1	0	?	1	0	1	1	0
102	0	3	5	?	4	1	0	?	1	1	0	1	1
103	9	2	5	1	4	1	0	?	1	0	1	0	1
104	6	2	3	2	4	3	0	?	3	0	1	0	1
105	1	2	5	3	4	0	11	12	3	0	1	1	0
106	2	2	3	1	4	2	0	?	2	0	1	0	1
107	1	3	5	2	4	3	0	?	3	0	1	1	1
108	1	2	5	2	4	1	0	?	1	0	1	1	1
109	2	3	3	3	2	1	0	0	1	1	0	1	1
110	1	0	3	1	4	1	0	?	1	0	1	1	0
111	2	3	3	2	3	0	6	?	1	1	0	1	1
112	2	0	1	?	4	1	0	?	1	0	4	1	1
113	1	0	5	2	4	0	6	3	1	1	1	1	1
114	2	0	3	1	3	0	6	?	1	1	0	1	0
115	1	2	3	1	4	3	0	?	3	1	3	1	0
116	3	1	5	3	2	0	2	7	1	2	13	0	1
117	3	0	3	1	3	1	0	?	1	0	1	1	1
118	0	0	3	2	2	?	?	?	?	2	0	1	0
119	0	0	3	1	4	3	0	?	3	2	0	0	0
120	3	0	1	2	4	?	?	?	?	1	8	1	0
121	1	3	3	1	4	1	0	?	1	0	1	1	1
122	3	2	3	?	4	1	0	?	1	1	1	0	0
123	2	3	5	2	4	3	0	?	3	1	0	1	1
124	2	2	3	2	2	3	0	?	3	0	1	1	0
125	2	2	6	1	3	0	6	?	1	0	1	0	0
126	2	1	3	1	4	2	0	?	2	0	0	0	0
127	1	2	5	3	4	0	4	3	1	0	1	1	1
128	5	1	5	1	4	3	0	?	3	0	1	1	0
129	1	2	5	3	4	0	11	2	1	0	1	1	1
130	3	0	1	1	4	1	0	?	1	1	0	1	1
131	2	0	3	1	3	2	0	?	2	1	4	0	1
132	0	1	3	1	4	1	0	?	1	1	0	0	0
133	11	0	3	?	3	1	0	?	1	0	1	1	1

57	1	1	1	3	0	4	1	0	0	1	9	2
58	1	2	?	3	0	4	1	0	1	1	?	3
59	2	2	?	3	0	4	1	0	0	1	?	1
60	1	1	2	3	0	4	1	0	0	0	9	1
61	1	1	1	3	0	4	1	1	0	1	9	3
62	1	2	2	3	10	4	1	1	0	0	9	1
63	1	2	3	3	0	4	1	0	0	0	9	2
64	14	2	1	3	0	4	1	0	0	1	9	2
65	1	3	1	3	0	4	1	0	0	1	9	1
66	2	0	2	3	0	4	1	1	0	1	9	1
67	11	0	2	3	?	4	0	1	0	1	9	?
68	11	2	2	3	?	4	1	1	0	1	9	?
69	11	1	2	3	?	4	8	1	0	1	9	?
70	2	3	2	3	0	2	0	0	1	0	9	1
71	0	0	2	3	0	4	0	0	1	1	9	1
72	1	2	1	5	0	4	1	0	0	1	9	3
73	1	2	2	5	0	4	1	1	0	1	9	2
74	1	3	1	3	0	4	1	0	0	0	5	1
75	1	2	1	3	0	4	1	1	0	1	9	1
76	1	0	1	5	0	4	1	0	0	1	9	3
77	1	3	2	3	11	4	3	0	1	1	9	2

55	1	2	3	3	4	0	11	8	2	0	1	1	1
56	3	2	3	2	4	3	0	?	3	0	13	1	0
57	1	1	3	1	4	2	0	?	2	0	1	1	0
58	1	2	3	?	4	3	0	?	3	1	1	1	0
59	2	2	3	?	4	1	0	?	1	0	1	1	0
60	1	1	3	2	4	1	0	?	1	0	1	0	0
61	1	1	3	1	4	3	0	?	3	0	1	1	1
62	1	2	3	2	4	0	10	?	1	0	1	0	1
63	1	2	3	3	4	2	0	0	2	0	1	0	0
64	14	2	3	1	4	2	0	?	2	0	1	1	0
65	1	3	3	1	4	1	0	?	1	0	1	1	0
66	2	0	3	2	4	1	0	?	1	0	1	1	1
67	11	0	3	2	4	?	?	?	?	0	0	1	1
68	11	2	3	2	4	?	?	?	?	0	1	1	1
69	11	1	3	2	4	?	?	?	?	0	8	1	1
70	2	3	3	2	2	1	0	?	1	1	0	0	0
71	0	0	3	2	4	1	0	?	1	1	0	1	0
72	1	2	5	1	4	3	0	?	3	0	1	1	0
73	1	2	5	2	4	1	0	?	2	0	1	1	1
74	1	3	3	1	4	1	0	?	1	0	1	0	0
75	1	2	3	1	4	1	0	?	1	0	1	1	1
76	1	0	5	1	4	3	0	?	3	0	1	1	0
77	1	3	3	2	4	0	11	?	3	1	3	1	0

23	3	2	3	?	4	1	0	?	1	0	1	0	1
24	3	3	3	1	4	1	0	?	1	1	3	1	0
25	3	1	3	1	4	1	0	?	1	0	0	0	1
26	3	2	3	1	4	2	0	?	2	1	3	1	0
27	1	0	2	1	4	3	0	?	3	0	3	1	1
28	2	0	1	?	3	2	0	?	2	1	10	1	1
29	1	2	3	1	4	2	0	?	2	0	1	1	0
30	2	2	3	?	2	1	0	?	1	0	0	1	0
31	3	0	3	3	4	0	11	8	2	1	1	1	0
32	1	2	3	1	4	3	0	?	3	0	1	1	0
33	2	3	3	1	4	1	0	?	1	0	1	1	0
34	2	2	3	2	4	1	0	?	1	0	1	1	1
35	3	2	3	2	4	0	10	?	3	0	1	1	0
36	0	3	5	3	4	0	6	10	2	1	0	1	0
37	8	0	5	1	3	1	0	?	1	0	1	0	1
38	2	1	5	2	4	0	6	?	0	0	0	1	1
39	1	2	3	3	4	0	10	9	2	0	1	0	1
40	3	2	3	1	4	2	0	?	2	0	1	1	0
41	1	2	5	2	4	0	3	2	1	0	1	0	1
42	1	2	5	2	4	0	1	?	1	0	1	1	1
43	1	1	3	3	4	0	6	9	3	0	1	1	0
44	9	2	3	3	4	2	0	0	2	0	3	1	1
45	3	1	3	3	4	0	11	11	3	0	1	0	1
46	1	2	3	3	4	2	0	0	2	0	1	1	1
47	1	1	3	3	4	3	0	0	3	0	10	1	1
48	1	1	5	2	4	2	0	?	2	0	1	1	1
49	11	0	3	2	3	0	4	6	1	0	1	0	1
50	1	3	5	3	4	0	11	?	3	1	1	0	0
51	1	0	3	1	4	1	0	?	1	1	1	1	0
52	1	0	3	?	4	2	0	?	2	0	1	1	0
53	1	0	3	1	4	1	0	?	1	1	1	1	1
54	3	2	3	3	4	1	0	0	2	0	0	1	1
55	3	3	3	3	4	2	0	0	2	0	1	1	1
56	17	2	3	1	5	0	11	8	2	0	1	0	0
57	2	3	5	1	3	0	4	?	1	1	0	1	0
58	9	0	1	3	4	0	8	4	1	0	0	0	0
59	2	1	3	2	3	0	1	6	1	0	0	1	1
60	11	0	3	3	4	0	3	5	1	0	1	1	0
61	1	1	3	2	4	0	4	2	1	1	1	1	0
62	3	0	5	?	4	2	0	?	2	0	1	0	1
63	3	0	3	2	4	0	5	?	1	1	1	0	1
64	2	3	3	2	4	1	0	?	1	0	0	1	0
65	1	2	3	2	4	1	0	?	1	2	1	0	1
66	3	2	3	?	4	1	0	?	1	2	0	0	1
67	1	0	3	1	3	2	0	?	2	0	15	1	1
68	14	0	3	1	3	3	0	?	3	1	1	1	0
69	10	0	3	1	4	1	0	?	1	1	1	1	1
70	5	2	5	1	4	?	?	?	?	0	1	1	0
71	15	3	5	3	4	0	10	3	1	0	1	1	1
72	1	3	3	2	2	0	3	?	1	0	1	1	1
73	3	1	5	2	4	3	0	?	3	2	0	0	0
74	1	0	5	3	4	0	10	13	3	1	1	1	0
75	11	2	3	1	4	0	7	?	1	2	1	1	0
76	3	0	3	1	4	1	0	?	1	0	1	1	0
77	16	2	5	2	3	1	0	?	1	0	1	0	1
78	1	0	3	1	4	2	0	?	2	0	1	0	1

29	1	3	4	2	0	0	2	1	1	0
30	2	3	2	2	0	0	1	0	?	0
31	3	3	4	0	1	11	2	1	3	0
32	1	3	4	2	0	0	3	1	1	0
33	2	3	4	3	0	0	1	1	1	0
34	2	3	4	2	0	0	1	1	2	1
35	3	3	4	2	0	10	3	1	2	0
36	0	5	4	3	1	6	2	0	3	0
37	8	5	3	0	0	0	1	1	1	1
38	2	5	4	1	0	6	0	0	2	1
39	1	3	4	2	0	10	2	1	3	1
40	3	3	4	2	0	0	2	1	1	0
41	1	5	4	2	0	3	1	1	2	1
42	1	5	4	2	0	1	1	1	2	1
43	1	3	4	1	0	6	3	1	3	0
44	9	3	4	2	0	0	2	3	3	1
45	3	3	4	1	0	11	3	1	3	1
46	1	3	4	2	0	0	2	1	3	1
47	1	3	4	1	0	0	3	10	3	1
48	1	5	4	1	0	0	2	1	2	1
49	11	3	3	0	0	4	1	1	2	1
50	1	5	4	3	1	11	3	1	3	0
51	1	3	4	0	1	0	1	1	1	0
52	1	3	4	0	0	0	2	1	?	0
53	1	3	4	0	1	0	1	1	1	1
54	3	3	4	2	0	0	2	0	3	1
55	3	3	4	3	0	0	2	1	3	1
56	17	3	5	2	0	11	2	1	1	0
57	2	5	3	3	1	4	1	0	1	0
58	9	1	4	0	0	8	1	0	3	0
59	2	3	3	1	0	1	1	0	2	1
60	11	3	4	0	0	3	1	1	3	0
61	1	3	4	1	1	4	1	1	2	0
62	3	5	4	0	0	0	2	1	?	1
63	3	3	4	0	1	5	1	1	2	1
64	2	3	4	3	0	0	1	0	2	0
65	1	3	4	2	2	0	1	1	2	1
66	3	3	4	2	2	0	1	0	?	1
67	1	3	3	0	0	0	2	15	1	1
68	14	3	3	0	1	0	3	1	1	0
69	10	3	4	0	1	0	1	1	1	1
70	5	5	4	2	0	?	?	1	1	0
71	15	5	4	3	0	10	1	1	3	1
72	1	3	2	3	0	3	1	1	2	1
73	3	5	4	1	2	0	3	0	2	0
74	1	5	4	0	1	10	3	1	3	0
75	11	3	4	2	2	7	1	1	1	0
76	3	3	4	0	0	0	1	1	1	0
77	16	5	3	2	0	0	1	1	2	1
78	1	3	4	0	0	0	2	1	1	1
79	11	3	4	3	0	0	1	1	?	0
80	2	3	4	0	1	0	2	0	3	0
81	2	3	3	3	1	3	3	0	2	0
82	2	3	4	0	1	6	1	0	3	0
83	?	3	4	2	1	0	2	1	2	1
84	1	3	2	0	0	0	1	1	1	1

class2-events

#	var12	var8	var9	var20	var13	var26	var27	var23	var24	var7	var2	var5	var4
1	2	2	3	3	4	2	0	0	2	0	6	0	1
2	7	3	3	1	3	2	0	?	2	1	1	1	0
3	8	0	3	2	4	0	12	?	1	2	1	0	1
4	8	0	3	2	5	0	12	?	1	2	1	0	1
5	1	2	3	?	4	2	0	?	2	0	1	1	1
6	3	2	3	1	4	0	8	?	1	0	0	0	1
7	1	0	3	2	4	1	0	?	3	0	1	1	0
8	1	3	3	2	4	0	9	?	2	2	1	1	0
9	1	1	3	2	4	3	0	?	3	2	1	0	0
10	2	0	1	?	4	1	0	?	1	1	4	1	0
11	2	0	1	3	4	3	0	0	3	0	0	0	1
12	1	3	2	1	4	0	8	?	1	1	1	0	1
13	1	1	3	1	4	3	0	?	3	2	1	1	0
14	1	2	5	1	4	0	11	?	1	2	1	0	0
15	3	1	3	2	4	?	?	?	?	0	0	1	0
16	3	2	3	2	4	1	0	?	1	2	1	1	1
17	0	1	3	2	4	0	8	?	1	2	0	1	0
18	3	0	2	3	4	2	0	0	2	1	1	1	0
19	1	1	3	2	4	1	0	?	1	2	1	1	1
20	0	2	3	?	4	1	0	?	1	0	0	1	1
21	1	2	3	?	4	1	0	?	1	0	1	1	1
22	0	2	3	?	4	1	0	?	1	2	0	0	0
23	1	3	3	2	4	0	10	?	1	2	1	0	0
24	1	2	3	1	4	1	0	?	1	2	1	1	1
25	2	3	1	1	4	0	5	?	1	0	0	1	0
26	1	0	3	2	4	2	0	?	2	0	1	0	1
27	1	0	3	1	4	0	9	?	3	0	1	1	1
28	11	1	3	2	4	1	0	?	1	0	0	1	1
29	1	0	3	?	4	1	0	?	1	1	1	1	1
30	0	3	3	1	4	1	0	?	1	2	0	0	1
31	3	2	5	1	4	2	0	?	2	0	1	1	1
32	1	2	3	1	4	2	0	?	2	0	1	1	0
33	1	0	3	2	4	2	0	?	2	0	1	1	0
34	1	0	3	3	4	2	0	0	2	0	1	1	1
35	1	2	3	2	4	1	0	?	1	0	3	1	0
36	3	2	3	3	4	0	10	9	2	1	0	1	0
37	1	2	3	2	4	0	12	?	1	0	1	0	1
38	3	2	3	2	4	0	6	?	1	1	1	1	0
39	1	2	3	2	4	0	6	?	1	1	1	0	1
40	13	1	3	2	4	0	11	?	2	0	0	1	0
41	1	1	3	3	4	0	11	8	2	0	3	1	0
42	12	2	3	3	4	0	12	8	2	0	1	1	1
43	1	2	5	2	4	0	8	?	2	0	1	1	1
44	1	2	3	3	4	0	9	3	1	0	1	1	0
45	1	1	5	1	4	1	0	?	1	2	1	0	0
46	1	2	3	3	4	0	10	13	3	0	3	0	1
47	11	1	3	2	4	2	0	?	2	2	0	0	0
48	1	2	3	1	4	1	0	?	1	0	1	1	1
49	3	3	3	1	4	1	0	?	1	0	0	1	0
50	1	2	2	2	4	1	0	?	1	0	3	1	0
51	1	2	3	1	4	3	0	?	3	0	1	1	0
52	1	2	3	?	4	2	0	?	2	0	1	1	0
53	1	3	3	?	4	1	0	?	1	0	2	0	1
54	3	0	3	1	4	1	0	?	1	1	0	0	1

5	1	3	4	2	0	0	2	1	?	1
6	3	3	4	2	0	8	1	0	1	1
7	1	3	4	0	0	0	3	1	2	0
8	1	3	4	3	2	9	2	1	2	0
9	1	3	4	1	2	0	3	1	2	0
10	2	1	4	0	1	0	1	4	?	0
11	2	1	4	0	0	0	3	0	3	1
12	1	2	4	3	1	8	1	1	1	1
13	1	3	4	1	2	0	3	1	1	0
14	1	5	4	2	2	11	1	1	1	0
15	3	3	4	1	0	?	?	0	2	0
16	3	3	4	2	2	0	1	1	2	1
17	0	3	4	1	2	8	1	0	2	0
18	3	2	4	0	1	0	2	1	3	0
19	1	3	4	1	2	0	1	1	2	1
20	0	3	4	2	0	0	1	0	?	1
21	1	3	4	2	0	0	1	1	?	1
22	0	3	4	2	2	0	1	0	?	0
23	1	3	4	3	2	10	1	1	2	0
24	1	3	4	2	2	0	1	1	1	1
25	2	1	4	3	0	5	1	0	1	0
26	1	3	4	0	0	0	2	1	2	1
27	1	3	4	0	0	9	3	1	1	1
28	11	3	4	1	0	0	1	0	2	1
29	1	3	4	0	1	0	1	1	?	1
30	0	3	4	3	2	0	1	0	1	1
31	3	5	4	2	0	0	2	1	1	1
32	1	3	4	2	0	0	2	1	1	0
33	1	3	4	0	0	0	2	1	2	0
34	1	3	4	0	0	0	2	1	3	1
35	1	3	4	2	0	0	1	3	2	0
36	3	3	4	2	1	10	2	0	3	0
37	1	3	4	2	0	12	1	1	2	1
38	3	3	4	2	1	6	1	1	2	0
39	1	3	4	2	1	6	1	1	2	1
40	13	3	4	1	0	11	2	0	2	0
41	1	3	4	1	0	11	2	3	3	0
42	12	3	4	2	0	12	2	1	3	1
43	1	5	4	2	0	8	2	1	2	1
44	1	3	4	2	0	9	1	1	3	0
45	1	5	4	1	2	0	1	1	1	0
46	1	3	4	2	0	10	3	3	3	1
47	11	3	4	1	2	0	2	0	2	0
48	1	3	4	2	0	0	1	1	1	1
49	3	3	4	3	0	0	1	0	1	0
50	1	2	4	2	0	0	1	3	2	0
51	1	3	4	2	0	0	3	1	1	0
52	1	3	4	2	0	0	2	1	?	0
53	1	3	4	3	0	0	1	2	?	1
54	3	3	4	0	1	0	1	0	1	1
55	1	3	4	2	0	11	2	1	3	1
56	3	3	4	2	0	0	3	13	2	0
57	1	3	4	1	0	0	2	1	1	0
58	1	3	4	2	1	0	3	1	?	0
59	2	3	4	2	0	0	1	1	?	0
60	1	3	4	1	0	0	1	1	2	0

Results after VARSEL using
Random Adaptive Search
Sample size = 15

domaintypes

name	type	levels
prev_crop	nom	18
perm_veg	nom	2
surface	nom	3
fall_till	nom	10
sprngtill	nom	10
insecticid	nom	19
plantdate	lin	6
nbrnotsame_of_weed_s	nom	4
maxvalue_of_weedensi	lin	4
lstmintim_of_weedens	lin	13

variables

#	name
1	var2.prev_crop
2	var4.perm_veg
3	var7.surface
4	var8.fall_till
5	var9.sprngtill
6	var12.insecticid
7	var13.plantdate
8	var20.nbrnotsame_of_weed_s
9	var24.maxvalue_of_weedensi
10	var27.lstmintim_of_weedens

class1-events

#	var12	var9	var13	var8	var7	var27	var24	var2	var20	var4
1	2	3	4	1	1	0	1	1	1	0
2	1	5	4	3	0	0	3	1	2	1
3	2	3	4	1	1	0	1	0	?	0
4	2	1	4	0	0	0	1	0	?	1
5	8	1	5	0	0	8	3	1	2	0
6	1	5	4	2	1	0	2	1	1	0
7	9	5	4	0	0	0	2	1	1	0
8	5	1	4	0	1	5	2	1	2	0
9	1	3	4	0	0	0	2	1	3	0
10	1	3	4	0	1	11	2	1	3	1
11	11	3	3	2	1	0	1	0	1	0
12	10	2	4	1	0	?	?	0	2	0
13	0	3	4	1	2	0	1	0	1	1
14	3	1	4	0	0	5	1	0	2	0
15	11	5	3	0	0	0	1	1	?	0
16	9	5	2	0	0	0	1	1	1	1
17	2	3	3	0	1	4	1	1	2	0
18	2	3	4	1	0	0	3	0	2	0
19	11	3	4	1	1	0	1	0	1	0
20	2	5	4	0	1	11	1	1	2	0
21	9	1	4	0	0	10	2	9	2	0
22	1	5	4	0	0	0	1	1	1	0
23	3	3	4	2	0	0	1	1	?	1
24	3	3	4	3	1	0	1	3	1	0
25	3	3	4	1	0	0	1	0	1	1
26	3	3	4	2	1	0	2	3	1	0
27	1	2	4	0	0	0	3	3	1	1
28	2	1	3	0	1	0	2	10	?	1

Craniostenosis Data

The following pages give the original data for the Craniostenosis event set used in this study. The next page details the data format for each patient entry. For reference, the following are the syndrome codes for the patients in this event set:

Syndrome	Code
Apert's	15
Crouzon's	16
Pfeiffer's	152
Saethre-Chotzen	57
Other Descriptive Classes	
Brachycephaly	96
Plagiocephaly	80
Scaphacephaly	84
Other Craniostenoses	18

85	1	3	4	0	2	0	1	1	1	1
86	3	3	4	2	0	0	1	3	2	0
87	6	5	4	2	0	0	1	1	1	0
88	3	3	4	0	2	0	1	0	?	0
89	1	3	4	1	2	0	1	1	1	0
90	3	3	4	2	1	0	3	1	3	0
91	3	5	4	0	1	0	1	1	1	0
92	11	3	4	0	0	10	1	1	1	1
93	3	3	4	0	0	0	3	1	3	1
94	11	6	4	5	0	8	1	1	1	0
95	2	1	3	1	0	2	1	0	2	1
96	2	3	3	0	1	0	1	0	?	0
97	11	3	3	1	2	0	1	0	3	0
98	9	3	4	1	1	0	1	0	?	0
99	1	3	4	0	0	11	3	1	3	1
100	1	5	4	2	0	0	1	1	2	0
101	1	5	4	2	0	0	1	1	1	0
102	0	5	4	3	1	0	1	0	?	1
103	9	5	4	2	0	0	1	1	1	1
104	6	3	4	2	0	0	3	1	2	1
105	1	5	4	2	0	11	3	1	3	0
106	2	3	4	2	0	0	2	1	1	1
107	1	5	4	3	0	0	3	1	2	1
108	1	5	4	2	0	0	1	1	2	1
109	2	3	2	3	1	0	1	0	3	1
110	1	3	4	0	0	0	1	1	1	0
111	2	3	3	3	1	6	1	0	2	1
112	2	1	4	0	0	0	1	4	?	1
113	1	5	4	0	1	6	1	1	2	1
114	2	3	3	0	1	6	1	0	1	0
115	1	3	4	2	1	0	3	3	1	0
116	3	5	2	1	2	2	1	13	3	1
117	3	3	3	0	0	0	1	1	1	1
118	0	3	2	0	2	?	?	0	2	0
119	0	3	4	0	2	0	3	0	1	0
120	3	1	4	0	1	?	?	8	2	0
121	1	3	4	3	0	0	1	1	1	1
122	3	3	4	2	1	0	1	1	?	0
123	2	5	4	3	1	0	3	0	2	1
124	2	3	2	2	0	0	3	1	2	0
125	2	6	3	2	0	6	1	1	1	0
126	2	3	4	1	0	0	2	0	1	0
127	1	5	4	2	0	4	1	1	3	1
128	5	5	4	1	0	0	3	1	1	0
129	1	5	4	2	0	11	1	1	3	1
130	3	1	4	0	1	0	1	0	1	1
131	2	3	3	0	1	0	2	4	1	1
132	0	3	4	1	1	0	1	0	1	0
133	11	3	3	0	0	0	1	1	?	1

class2-events

#	var12	var9	var13	var8	var7	var27	var24	var2	var20	var4
1	2	3	4	2	0	0	2	6	3	1
2	7	3	3	3	1	0	2	1	1	0
3	8	3	4	0	2	12	1	1	2	1
4	8	3	5	0	2	12	1	1	2	1

1125			4/ 6/59 1 1	96	10
1125	7	21	CRANIOSYNOSTOSIS, CORONAL SUTURE	96	10
1125	9	4	MILD HYPOPLASIA	96	10
1125	11	0	SWELLING ALONG UPPER LATERAL PART OF ORBIT	96	10
1125	11	75	PTOSIS	96	10
1125	11	78	SLIGHT ANTIMONGOLOID SLANT	96	10
1125	12	75	PTOSIS	96	10
1125	12	78	SLIGHT ANTIMONGOLOID SLANT	96	10
1125	13	31	LOW SET	96	10
1125	14	31	LOW SET	96	10
1125	17	23	SHORT FRENULUM	96	10
1125	27	24	PECTUS EXCAVATUM	96	10
1125	36	41	SIMIAN CREASE	96	10
1125	37	41	SIMIAN CREASE	96	10
1125	42	31	SLOW RATE OF DEVELOPMENT	96	10
2223			10/28/64 1 2	96	10
2223	7	21	CRANIOSYNOSTOSIS, CORONAL SUTURE	96	10
3730			12/ 3/57 1 1	96	10
3730	7	21	CRANIOSYNOSTOSIS, CORONAL SUTURE	96	10
4124			11/26/60 2 1	84	10
4124	7	20	CRANIOSYNOSTOSIS, SAGITTAL & LAMBDOIDAL SUTURES	84	10
4124	32	23	UNDESCENDED TESTES	84	10
5738			5/28/57 1 2	84	10
5738	7	24	CRANIOSYNOSTOSIS, SAGITAL SUTTURE	84	10
5738	42	41	FOCAL JACKSONIAN SEIZURES	84	10
5931			12/23/69 1 2	84	10
5931	7	24	STENOSIS OF SAGGITAL SUTURE	84	10
5931	8	21	FRONTAL BOSSING	84	10
5931	9	0	PROTRUDING	84	10
5931	10	4	SMALL	84	10
5931	11	20	PROPTOSIS	84	10
5931	12	20	PROPTOSIS	84	10
5931	13	31	LOW SET	84	10
5931	14	31	LOW SET	84	10
5931	15	4	SMALL	84	10
5931	16	21	HIGH ARCHED PALATE	84	10
5931	16	27	NARROW PALATE	84	10
5931	20	21	ANTERIOR OPEN BITE	84	10
5931	21	11	MOTOR PROBLEM?	84	10
5931	22	10	MOTOR PROBLEM?	84	10
5931	42	0	CNS PROBLEM?	84	10
7124			4/13/62 1 1	84	10
7124	7	24	CRANIOSYNOSTOSIS, SAGITTAL SUTURE	84	10
7124	8	21	BOSSING	84	10
9532			1/ 4/68 1 1	84	10
9532	7	24	CRANIOSYNOSTOSIS, SAGITTAL SUTURE	84	10
9532	32	22	MILD HYPOSPADIAS	84	10
9532	43	80	SPINA BIFIDA, L-5	84	10
143			11/11/59 1 1	15	3
143	2	66	SURGERY MEDIAN	15	3
143	7	45	PLAGIOCEPHALY	15	3
143	9	31	HYPOPLASTIC R)L	15	3
143	11	20	PROPTOSIS	15	3
143	12	20	PROPTOSIS	15	3
143	25	0	L TIGHTNESS	15	3
143	26	20	HERNIA	15	3
143	27	21	PROMINENCE L SIDE	15	3
143	30	41	SINUS ARRHYTHMIA	15	3
143	30	41	SLOW HEART RATE	15	3
143	36	30	SYNDACTYLY	15	3
143	37	30	SYNDACTYLY	15	3
143	40	30	SYNDACTYLY	15	3
143	41	30	SYNDACTYLY	15	3

61	1	3	4	1	0	0	3	1	1	1
62	1	3	4	2	0	10	1	1	2	1
63	1	3	4	2	0	0	2	1	3	0
64	14	3	4	2	0	0	2	1	1	0
65	1	3	4	3	0	0	1	1	1	0
66	2	3	4	0	0	0	1	1	2	1
67	11	3	4	0	0	?	?	0	2	1
68	11	3	4	2	0	?	?	1	2	1
69	11	3	4	1	0	?	?	8	2	1
70	2	3	2	3	1	0	1	0	2	0
71	0	3	4	0	1	0	1	0	2	0
72	1	5	4	2	0	0	3	1	1	0
73	1	5	4	2	0	0	2	1	2	1
74	1	3	4	3	0	0	1	1	1	0
75	1	3	4	2	0	0	1	1	1	1
76	1	5	4	0	0	0	3	1	1	0
77	1	3	4	3	1	11	3	3	2	0

743			12/25/74 1 1	15 10
743	7	21	CRANIOSYNOSTOSIS-CORONAL SUTURE	15 10
743	8	2	FLAT L SIDE	15 10
743	9	2	ASYMMETRY, L<R	15 10
743	9	4	HYPOPLASIA?	15 10
743	11	34	LOW SET	15 10
743	16	22	BYZANTINE PALATE	15 10
743	36	32	SYNDACTYLY, COMPLETE	15 10
743	37	32	SYNDACTYLY, COMPLETE	15 10
743	40	30	SYNDACTYLY	15 10
743	41	30	SYNDACTYLY	15 10
749			10/16/75 1 1	15 10
749	7	20	CRANIOSYNOSTOSIS	16 10
749	7	43	CLOVERLEAF SKULL	16 10
749	8	0	BILATERAL INDENTATIONS	16 10
749	8	22	PROMINENT	16 10
749	9	4	HYPOPLASIA?	16 10
749	11	20	PROPTOSIS	16 10
749	11	75	PTOSIS	16 10
749	12	20	PROPTOSIS	16 10
749	12	75	PTOSIS	16 10
749	15	32	OBSTRUCTION R CHOANAE	16 10
749	25	35	SHORT	16 10
926			2/10/51 5 2	16 10
926	7	20	CRANIOSYNOSTOSIS?	18 10
926	8	23	HIGH	18 10
926	9	4	HYPOPLASIA	18 10
926	11	31	MILD DEVIL'S EYE	18 10
926	12	31	MILD DEVIL'S EYE	18 10
947			3/ 3/32 1 1	18 10
947	7	20	CRANIOSYNOSTOSIS	57 10
947	8	24	FLAT	57 10
947	9	4	HYPOPLASIA	57 10
947	10	41	PROGNATHISM	57 10
947	11	20	PROPTOSIS, MILD	57 10
947	11	122	CONSTANT TEARING	57 10
947	12	30	POSTERIORLY SET	57 10
947	40	34	CUTANEOUS SYNDACTYLY	57 10
947	41	34	CUTANIOUS SYNDACTYLY	57 10
1120			10/ 4/56 1 1	57 10
1120	7	20	CRANIOSYNOSTOSIS	80 10
1120	8	21	BOSSING, L SIDE	80 10
1120	9	2	ASYMMETRY, L<R	80 10
1120	12	93	SLIGHT EXTERNAL STRABISMUS	80 10
1124			8/23/61 1 1	80 10
1124	7	21	CRANIOSYNOSTOSIS, L CORONAL SUTURE	80 10
1124	9	2	ASYMMETRY	80 10
1124	12	31	MILD DEVIL'S EYE ANOMALY	80 10
1124	16	32	ASYMMETRY MAXILLA, L>R	80 10
1434			3/16/60 1 1	80 10
1434	7	20	CRANIOSYNOSTOSIS	18 10
1434	9	4	HYPOPLASIA	18 10
1434	44	23	CONTRACTURES, CORRECTED BY PHYSICAL THERAPY	18 10
2244			12/ 2/42 1 1	18 10
2244	7	20	CRANIOSYNOSTOSIS	16 10
2244	9	4	HYPOPLASTIC	16 10
2244	11	20	EXOPHTHALMUS	16 10
2244	12	20	EXOPHTHALMUS	16 10
2244	15	25	BIFID RADIZ NASII	16 10
2633			12/25/48 1 2	16 10
2633	7	20	CRANIOSYNOSTOSIS	15 10
2633	8	21	BOSSING	15 10
2633	9	4	HYPOPLASIA	15 10
2633	13	28	ATRETIC CANAL	15 10
2633	13	40	HYPOPLASTIC INCUS	15 10
2633	16	22	BYZANTINE PALATE	15 10

Card Layout - First for Each Patient

Columns	1/4	CCFA Number	
	5/11	Blank	
	12/20	Birthdate	
	21	Race	1=white
			2=black
			3=oriental
			4=other
			5=uknown
	22	Blank	
	23	Sex	1=male
			2=female
	24/80	Blank	
	81/83	Syndrome	0=no known syndrome
	84/86	Diagnostic Category	

Card Layout - Others

Columns	1/4	CCFA Number	
	5	Blank	
	6/7	System Number	1=lip cleft description
			2=palate cleft description
	8/10	Code Number	
	11	Blank	
	12/80	Description of Findings	
	81/83	Syndrome	0=no known syndrome
	84/86	Diagnostic Category	

2945	39	30	CONTRACTURE HIP JOINT	16	10
2945	39	40	ANKYLOSIS HIP JOINT	16	10
2945	39	42	ANKYLOSIS KNEE JOINT	16	10
2945	42	74	APHASIA	16	10
2945	44	20	HYPOTONIA	16	10
3022			8/29/58 1 2	15	3
3022	2	66	SURGERY MEDIAN	15	3
3022	7	20	CRANIOSYNOSTOSIS	15	3
3022	8	2	ASYMMETRY	15	3
3022	9	2	ASYMMETRY	15	3
3022	9	4	HYPOPLASIA	15	3
3022	11	0	CANTHAL DYSTROPIA	15	3
3022	11	20	PROPTOSIS	15	3
3022	12	0	CANTHAL DYSTROPIA	15	3
3022	12	20	PROPTOSIS	15	3
3022	27	2	ASYMMETRY, L PROMINENCE	15	3
3022	34	50	ANKYLOSED	15	3
3022	34	60	HUMERUS DISLOCATED ANTERIORLY?	15	3
3022	36	30	SYNDACTYLY	15	3
3022	37	30	SYNDACTYLY	15	3
3022	40	30	SYNDACTYLY	15	3
3022	41	30	SYNDACTYLY	15	3
3023			11/21/49 1 2	16	10
3023	7	20	CRANIOSYNOSTOSIS	16	10
3023	9	4	HYPOPLASIA	16	10
3023	11	20	PROPTOSIS	16	10
3023	12	20	PROPTOSIS	16	10
3023	16	26	TORUS PALATINI	16	10
3036			8/11/67 2 2	15	10
3036	7	20	CRANIOSYNOSTOSIS	15	10
3036	9	4	HYPOPLASTIC	15	10
3036	9	21	HYPOTELORISM	15	10
3036	11	20	PROPTOSIS	15	10
3036	12	20	PROPTOSIS	15	10
3036	16	22	BYZANTINE PALATE	15	10
3036	36	30	SYNDACTYLY	15	10
3036	37	30	SYNDACTYLY	15	10
3036	40	30	SYNDACTYLY	15	10
3036	41	30	SYNDACTYLY	15	10
3128			9/11/64 1 1	15	4
3128	2	86	SUBMUCOUS (U)	15	4
3128	7	20	CRANIOSYNOSTOSIS, CORONAL & ?LAMBDOID SUTURES	15	4
3128	8	20	TYPICAL APERTS	15	4
3128	9	4	HYPOPLASIA	15	4
3128	9	20	HYPERTELORISM	15	4
3128	13	31	LOW SET	15	4
3128	14	31	LOW SET	15	4
3128	15	31	SADDLE DEFORMITY	15	4
3128	15	32	UNILATERAL CHOANAL ATRESIA	15	4
3128	16	22	BYZANTINE PALATE	15	4
3128	20	21	OPEN BITE	15	4
3128	36	30	SYNDACTYLY	15	4
3128	37	30	SYNDACTYLY	15	4
3128	40	30	SYNDACTYLY	15	4
3128	40	41	CLUBBED	15	4
3128	41	30	SYNDACTYLY	15	4
3128	41	41	CLUBBED	15	4
3128	42	55	ABNORMAL EEG	15	4
3128	42	59	HYPOTONIC	15	4
3144			2/25/73 1 2	80	10
3144	7	21	PARTIAL CRANIOSYNOSTOSIS, CORONAL SUTURE, L	80	10
3144	8	2	L FLATTENING	80	10
3144	25	30	TORTICOLLIS	80	10
3144	38	40	DISLOCATED HIP	80	10
3144	39	40	DISLOCATED HIP	80	10

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227          9/23/44 1 2
227   7 40 HIGH VAULT
227   7 42 SHORT A-P DIAMETER
227   8 24 RECEDING FRONTAL BONES
227   9  4 HYPOPLASIA
227  16 27 NARROW HARD PALATE
227  36 34 WEBBING
227  37 34 WEBBING
227  40 63 GAP BETWEEN 1ST & 2ND TOES
227  41 63 GAP BETWEEN 1ST & 2ND TOES
241          1/27/74 2 1
241   7  2 ASYMMETRY
241   7 27 SAGITTAL SUTURE VERY WIDE
241   7 59 PROMINENT R CORONAL SUTURE
241   8  2 FLATTENED R SIDE
241  11 20 MILD PROPTOSIS
241  11 34 R EYE HIGHER THAN LEFT
241  12 20 MILD PROPTOSIS
241  12 91 EXOTROPIA
241  26 21 UMBILICAL HERNIA
241  36 41 SIMIAN CREASE
241  37 41 SIMIAN CREASE
243          5/ 3/74 4 1
243   7 20 CRANIOSYNOSTOSIS
243   9  4 HYPOPLASIA, MILD
243  11 32 SHALLOW ORBIT
243  12 32 SHALLOW ORBIT
243  31 22 PYLORIC STENOSIS
243 36400 INCURVED 4TH DIGIT
243 36500 INCURVED 5TH DIGIT
243 36560 OVERLAPPING 5TH DIGIT
243 37400 INCURVED 4TH DIGIT
243 37500 INCURVED 5TH DIGIT
243 37500 OVERLAPPING 5TH DIGIT
243  40 31 SYNDACTYLY, 2,3,4 TOES
243 40124 BROAD 1ST TOE
243  41 31 SYNDACTYLY, 2,3,4 TOES
243 41124 BROAD 1ST TOE
634          1/14/65 1 1
634   7 47 TRIGONCEPHALY
634   8 21 BOSSING
634   9 21 HYPOTELORISM
634  10 40 ANTEGONIAL NOTCHING
634  10 43 WIDE GONIAL ANGLE
634  13 31 LOW SET
634  13 62 LOP EARS
634  14 31 LOW SET
634  14 62 LOP EARS
634  33 23 ALOPECIA
634 36160 THUMBS HIGH SET
634 37160 THUMBS HIGH SET
634  39 62 TOES OVERLAP
634  40 62 TOES OVERLAP
637          8/20/65 2 2
637   7 20 CRANIOSYNOSTOSIS
637   8 29 TYPICAL CROUZONS
637   9  4 HYPOPLASIA
637   9 20 HYPERTELORISM
637  11 20 PROPTOSIS
637  11 33 SMALL ORBIT
637  11 86 SYNECHE OF LID
637  12 20 PROPTOSIS
637  12 33 SMALL ORBIT
637  12 86 SYNECHE OF LID
637  16 21 HIGH ARCHED
637  33 24 SPARSE HAIR
637  42 65 AGENESIS POSTERIOR PORTION OF CORPUS CALLOSUM
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4125	12	78	ANTIMONGOLOID SLANT	15	10
4125	13	61	CUPPED	15	10
4125	13	62	LOPPED	15	10
4125	14	61	CUPPED	15	10
4125	14	62	LOPPED	15	10
4125	16	22	BYZANTINE PALATE, MODERATE	15	10
4125	20	21	ANTERIOR OPEN BITE	15	10
4125	36	30	SYNDACTYLY	15	10
4125	37	30	SYNDACTYLY	15	10
4125	40	30	SYNDACTYLY	15	10
4125	41	30	SYNDACTYLY	15	10
4139			11/20/69 2 2	16	3
4139	2	63	INCOMPLETE MEDIAN	16	3
4139	7	20	CRANIOSYNOSTOSIS	16	3
4139	9	4	HYPOPLASTIC	16	3
4139	11	20	EXORBITISM	16	3
4139	12	20	EXORBITISM	16	3
4222			4/ 3/66 1 1	15	10
4222	7	20	CRANIOSYNOSTOSIS	15	10
4222	9	4	HYPOPLASIA	15	10
4222	16	22	BYZANTINE PALATE	15	10
4222	32	23	UNDESCENDED TESTES	15	10
4222	32	31	DOUBLE COLLECTING SYSTEM, L KIDNEY	15	10
4222	36	30	SYNDACTYLY	15	10
4222	37	30	SYNDACTYLY	15	10
4222	40	30	SYNDACTYLY	15	10
4222	41	30	SYNDACTYLY	15	10
4248			7/10/74 2 2	16	10
4248	7	20	CRANIOSYNOSTOSIS, R	16	10
4248	8	2	FLATTENED R	16	10
4248	11	20	PROPTOSIS	16	10
4248	12	20	PROPTOSIS	16	10
4248	13	25	MICROTIA I, PREAURICULAR SINUS	16	10
4248	14	24	MICROTIA I, EAR TAG	16	10
4248	44	21	SLIGHTLY HYPERTONIC	16	10
4323			8/19/49 2 1	18	10
4323	7	20	CRANIOSYNOSTISIS	18	10
4323	11	21	PROTRUDING	18	10
4323	11	94	NYSTAGMUS, AT REST	18	10
4323	12	21	PROTRUDING	18	10
4323	12	94	NYSTAGMUS, AT REST	18	10
4323	15	41	SEPTUM DEVIATES TO L	18	10
4323	42	30	RETARDATION	18	10
4323	43	23	OCCIPITALIZATION, ATLAS	18	10
4348			8/ 4/56 1 1	16	10
4348	7	45	PLAGIOCEPHALY, L	16	10
4348	8	2	FLATTENED ON L	16	10
4348	11	20	PROPTOSIS, MILD	16	10
4348	12	20	PROPTOSIS, MILD	16	10
4348	13	4	SMALLER THAN R	16	10
4348	13	31	LOW SET	16	10
4348	13	32	POSTERIORLY SET	16	10
4348	15	34	DEVIATED TO L	16	10
4440			3/ 5/52 1 2	16	4
4440	2	86	SUBMUCOUS (U)	16	4
4440	9	4	HYPOPLASTIC	16	4
4440	11	20	PROPTOSIS	16	4
4440	12	20	PROPTOSIS	16	4
4440	18	20	SLIGHTLY DRY	16	4
4838			10/21/61 1 1	80	10
4838	7	45	PLAGIOCEPHALY	80	10
4838	8	2	R EYEBROW LOWER THAN L	80	10
4838	9	20	HYPERTELORISM	80	10
4838	11	31	DEVIL'S EYE	80	10
4838	11	80	EPICANTHAL FOLD	80	10
4838	12	80	EPICANTHAL FOLD	80	10
4838	15	2	ASYMMETRY	80	10

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                                                   15 10
2633 36 30 SYNDACTYLY                              15 10
2633 37 30 SYNDACTYLY                              15 10
2633 40 30 SYNDACTYLY                              15 10
2633 41 30 SYNDACTYLY                              15 10
2637         3/ 4/64 1 1                           16 10
2637  7 20 CRANIOSYNOSTOSIS                        16 10
2637  8 22 BULGING                                 16 10
2637  8 23 HIGH                                    16 10
2637  9  4 HYPOPLASIA                              16 10
2637 11 20 EXOPHTHALMOS                            16 10
2637 12 20 EXOPHTHALMOS                            16 10
2637 26 22 R INDIRECT INGUINAL HERNIA              16 10
2637 42  0 L CNS DAMAGE                            16 10
2637 42 30 RETARDED                                16 10
2637 43 23 UNILATERAL OCCIPITALIZATION C-1?        16 10
2734         7/ 4/64 1 1                           15 10
2734  7 20 CRANIOSYNOSTOSIS                        15 10
2734  9  4 HYPOPLASIA                              15 10
2734  9 20 HYPERTELORISM                           15 10
2734 11 93 INTERNAL STRABISMUS                     15 10
2734 12 80 EPICANTHAL FOLD                         15 10
2734 16 22 BYZANTINE PALATE                        15 10
2734 20 61 TYPICAL APERTS                          15 10
2734 36 30 SYNDACTYLY                              15 10
2734 37 30 SYNDACTYLY                              15 10
2734 40 30 SYNDACTYLY                              15 10
2734 41 30 SYNDACTYLY                              15 10
2936         5/10/64 1 2                           18 10
2936  7 20 CRANIOSYNOSTOSIS                        18 10
2936  9 20 HYPERTELORISM                           18 10
2936 20 22 L MOLAR CROSSBITE                       18 10
2936 21 13 R PARESIS?                              18 10
2936 22 13 R PARESIS?                              18 10
2945         3/10/58 1 1                           16 10
2945  7  5 MACROCEPHALY                            16 10
2945  7 20 CRANIOSYNOSTOSIS                        16 10
2945  8 24 FLAT                                    16 10
2945  9  4 HYPOPLASIA                              16 10
2945  9 20 HYPERTELORISM                           16 10
2945 10 41 PROGNATHISM                             16 10
2945 11 20 PROPTOSIS                               16 10
2945 12 20 PROPTOSIS                               16 10
2945 13  4 SMALL                                   16 10
2945 13 31 LOW SET                                 16 10
2945 14  4 SMALL                                   16 10
2945 14 31 LOW SET                                 16 10
2945 15  0 UPTURNED                                16 10
2945 15  5 BROAD                                   16 10
2945 16 22 BYZANTINE PALATE                        16 10
2945 25 35 SHORT                                   16 10
2945 27  0 PECTUS DEFORMITY                        16 10
2945 28  0 GIBBONS DEFORMITY, THORACIC AREA        16 10
2945 28 21 KYPHOSCOLIOSIS, THORACIC AREA           16 10
2945 30 21 MITRAL VALVE PROLAPSE                   16 10
2945 30 51 AORTIC ROOT DILATION                    16 10
2945 34 72 CONTRACTURE, ELBOW JOINT                16 10
2945 35 72 CONTRACTURE, ELBOW JOINT                16 10
2945 36 22 LONG FINGERS                            16 10
2945 36 26 CONTRACTURE OF HAND                     16 10
2945 37 22 LONG FINGERS                            16 10
2945 37 26 CONTRACTURE INTERPHALANGEAL JOINTS      16 10
2945 38 30 CONTRACTURE KNEE JOINT                  16 10
2945 38 30 CONTRACTURE HIP JOINT                   16 10
2945 38 40 ANKYLOSIS HIP JOINT                     16 10
2945 38 42 ANKYLOSIS KNEE JOINT                    16 10
2945 39 30 CONTRACTURE KNEE JOINT                  16 10
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6139			1/ 9/55 2 2	16	10
6139	7	20	CRANIOSYNOSTOSIS, POST OP	16	10
6139	9	20	HYPERTELORISM	16	10
6139	11	20	PROPTOSIS	16	10
6139	12	20	PROPTOSIS	16	10
6246			9/14/69 1 1	57	10
6246	7	20	SYNOSTOSIS	57	10
6246	11	80	EPICANTHAL FOLD	57	10
6246	12	80	EPICANTHAL FOLD	57	10
6246	13	31	LOW SET	57	10
6246	14	31	LOW SET	57	10
6246	32	23	UNDESCENDED L TESTICLE	57	10
6246	36	34	WEBBING BETWEEN 1ST & 2ND FINGERS	57	10
6246	37	34	WEBBING BETWEEN 1ST & 2ND FINGERS	57	10
6434			5/23/41 1 2	15	10
6434	7	20	CRANIOSYNOSTOSIS	15	10
6434	8	21	BOSSING	15	10
6434	11	78	ANTIMONGOLOID SLANT	15	10
6434	12	78	ANTIMONGOLOID SLANT	15	10
6434	15	2	ASYMMETRIC	15	10
6434	16	22	BYZANTINE PALATE	15	10
6434	20	43	CROWDING	15	10
6434	36	30	SYNDACTYLY	15	10
6434	37	30	SYNDACTYLY	15	10
6434	40	30	SYNDACTYLY	15	10
6434	41	30	SYNDACTYLY	15	10
6437			3/ 9/40 1 2	16	10
6437	7	0	BEATEN SILVER APPEARANCE	16	10
6437	7	20	CRANIOSYNOSTOSIS	16	10
6437	9	4	HYPOPLASIA, MILD	16	10
6437	11	20	EXOPHTHALMOS	16	10
6437	12	20	EXOPHTHALMOS	16	10
6634			1/ 9/72 1 2	18	10
6634	7	20	CRANIOSYNOSTOSIS	18	10
6730			5/10/72 1 2	80	10
6730	7	45	PLAGIOCEPHALY, CORONAL, LEFT	80	10
6730	11	0	DEEPER SET	80	10
6730	33	51	ECHZEMA	80	10
6741			11/ 9/74 1 1	18	10
6741	7	45	PLAGIOCEPHALY	18	10
6741	8	2	FLATTENED L	18	10
6741	11	1	ENOPHTHALMIA	18	10
6741	11	75	PTOSIS	18	10
6741	16	45	MACROSTOMIA	18	10
6741	42	27	L FACIAL PARESIS	18	10
7121			8/ 8/60 1 1	16	10
7121	7	42	SHORTENED A-P DIAMETER	16	10
7121	8	24	FLATTENED LOWER PART	16	10
7121	10	2	ASYMMETRY	16	10
7121	11	1	ANOPHTHALMIA	16	10
7121	11	75	PTOSIS	16	10
7121	12	1	ANOPHTHALMIA	16	10
7121	12	75	PTOSIS	16	10
7121	40	62	OVERLAP 1ST & 2ND TOES	16	10
7121	40	70	CALCANEOVALGUS	16	10
7121	40	160	HALLUX VALGUS	16	10
7121	41	62	OVERLAP 1ST & 2ND TOES	16	10
7121	41	70	CALCANEOVALGUS	16	10
7121	41	160	HALLUX VALGUS	16	10
7121	43	51	REDUCTION ROTATION & ADDUCTION R HIP	16	10
7121	43	52	CONGENITAL HIP DISLOCATION, L	16	10
7228			6/26/65 1 2	80	10
7228	7	20	CRANIOSYNOSTOSIS	80	10
7228	7	45	PLAGIOCEPHALY	80	10
7228	8	24	FLATTENED	80	10
7228	11	91	ESOTROPIA	80	10

				16	10
3236			2/22/70 1 1	16	10
3236	7	20	CRANIOSYNOSTOSIS	16	10
3236	9	4	HYPOPLASTIC	16	10
3236	11	20	PROPTOSIS	16	10
3236	12	20	PROPTOSIS	80	10
3245			3/24/74 1 2	80	10
3245	7	45	PLAGIOCEPHALY	80	10
3245	8	2	FLATTENED L	80	10
3245	9	2	ASYMMETRY, R>L	80	10
3245	11	34	LOW SET	80	10
3245	13	31	LOWSET	80	10
3245	42	27	FACIAL PALSY, L	16	10
3437			4/ 4/59 1 1	16	10
3437	7	20	CRANIOSYNOSTOSIS	16	10
3437	9	4	HYPOPLASIA	16	10
3437	11	20	PROPTOSIS	16	10
3437	12	20	PROPTOSIS	16	10
3437	15	30	PARROT BEAKED	16	10
3437	34	40	PROMINENT LATERAL EPICONDYLE, HUMERUS	16	10
3437	35	40	PROMINENT LATERAL EPICONDYLE, HUMERUS	16	10
3437	43	0	HYPOPLASTIC OCCIPITAL CONDYLES	16	10
3437	43	20	ANOMALOUS ODONTOID	16	10
3437	43	21	FUSIONS, C-2,3,4 & C-5,6	16	10
3437	43	22	ENLARGED LATERAL MASSES, C-1	16	10
3437	43	24	BASILAR INVAGINATION	16	4
3439			11/ 3/63 1 1	16	4
3439	2	86	SUBMUCOUS (U)	16	4
3439	7	20	CRANIOSYNOSTOSIS	16	4
3439	9	4	HYPOPLASIA	16	4
3439	11	20	EXOPHTHALMOS	16	4
3439	12	20	EXOPHTHALMOS	16	4
3439	13	31	LOW SET	16	4
3439	14	31	LOW SET	16	4
3439	20	45	MISSING TEETH	16	4
3439	32	26	BIFID SCROTUM	16	4
3439	40	31	INCOMPLETE SYNDACTYLY	16	4
3439	41	31	INCOMPLETE SYNDACTYLY	16	4
3439	42	55	ABNORMAL EEG	18	10
3446			3/27/74 1 1	18	10
3446	7	24	CRANIOSYNOSTOSIS, SAGITTAL SUTURE	35	30
3841	41124		LARGE BIG TOE	80	10
3935			10/26/71 1 2	80	10
3935	7	45	PLAGIOCEPHALY R	80	10
3935	8	2	FLATTENED, R	80	10
3935	8	21	BOSSING, L	80	10
3935	9	24	R EYE HIGHER THAN L	18	10
4021			2/20/47 1 2	18	10
4021	7	20	CRANIOSYNOSTOSIS, CORONAL & SAGITTAL SUTURES	18	10
4021	8	23	HIGH	18	10
4021	11	31	DEVIL'S EYE	18	10
4021	12	31	DEVIL'S EYE	18	10
4022			5/20/55 1 1	18	10
4022	7	20	CRANIOSYNOSTOSIS?	18	10
4022	8	5	LARGE	18	10
4022	8	21	HYPEROSTOSIS FRONTALIS	18	10
4022	8	23	HIGH	18	10
4022	11	93	INTERNAL ALTERNATING STRABISMUS	18	10
4022	12	93	INTERNAL ALTERNATING STRABISMUS	15	10
4125			4/ 9/63 1 1	15	10
4125	7	20	CRANIOSYNOSTOSIS	15	10
4125	8	22	BULGING	15	10
4125	8	23	HIGH	15	10
4125	9	4	HYPOPLASIA	15	10
4125	10	40	BILATERAL ANTEGONIAL NOTCHING	15	10
4125	11	32	SHALLOW ORBITS	15	10
4125	11	78	ANTIMONGOLOID SLANT	15	10
4125	12	32	SHALLOW ORBITS		

				15	10
8434	11	78	ANTIMONGOLOID SLANT	15	10
8434	12	78	ANTIMONGOLOID SLANT	15	10
8434	20	43	CROWDING	15	10
8434	36	30	SYNDACTYLY	15	10
8434	37	30	SYNDACTYLY	15	10
8434	40	30	SYNDACTYLY	15	10
8434	41	30	SYNDACTYLY	15	10
8437			7/ 6/65 1 2	16	10
8437	7	20	CRANIOSYNOSTOSIS	16	10
8437	9	4	HYPOPLASIA	16	10
8437	11	20	EXOPHTHALMOS	16	10
8437	12	20	EXOPHTHALMOS	16	10
8946			10/15/72 4 2	57	4
8946	2	86	SUBMUCOUS (U)	57	4
8946	7	20	CRANIOSYNOSTIS	57	4
8946	8	24	FLAT	57	4
8946	9	4	HYPOPLASIA	57	4
8946	10	41	PROGNATHISM	57	4
8946	11	20	MILD PROPTOSIS	57	4
8946	11	73	CHRONIC BLEPHARITIS	57	4
8946	12	20	MILD PROPTOSIS	57	4
8946	12	73	CHRONIC BLEPHARITIS	57	4
8946	13	31	LOW SET	57	4
8946	14	31	LOW SET	57	4
8946	16	42	COMMISSURAL LIP PIT, LEFT	57	4
8946	40	34	CUTANEOUS SYNDACTYLY 2ND & 3RD TOES	57	4
8946	41	34	CUTANEOUS SYNDACTYLY 2ND & 3RD TOES	57	4
9126			6/15/63 1 2	15	4
9126	2	83	SUBMUCOUS (S-U)	15	4
9126	7	0	MIDLINE DEFECT	15	4
9126	8	25	MIDLINE DEFECT	15	4
9126	11	21	PROMINENT	15	4
9126	12	21	PROMINENT	15	4
9126	30	20	HYPERTROPHIC CARDIAC STENOSIS	15	4
9126	36	30	SYNDACTYLY	15	4
9126	37	30	SYNDACTYLY	15	4
9126	40	30	SYNDACTYLY	15	4
9126	41	30	SYNDACTYLY	15	4
9126	42	30	SEVERE RETARDATION	15	4
9126	42	64	HYPOPLASIA CEREBRAL WHITE MATTER	15	4
9129			7/ 2/64 1 2	16	10
9129	9	2	ASYMMETRY	16	10
9129	9	4	HYPOPLASIA	16	10
9129	9	20	HYPERTELORISM	16	10
9129	11	4	MICROPHTHALMIA	16	10
9129	11	31	DEVIL'S EYE	16	10
9129	11	33	ORBIT SMALL	16	10
9129	11	75	PTOSIS	16	10
9129	11	94	NYSTAGMUS	16	10
9129	12	4	MICROPHTHALMIA	16	10
9129	12	31	DEVIL'S EYE	16	10
9129	12	33	SMALL ORBIT	16	10
9129	12	75	PTOSIS	16	10
9129	12	94	NYSTAGMUS	16	10
9129	14	31	LOW SET	16	10
9129	15	3	BIFID	16	10
9129	28	20	SCOLIOSIS	16	10
9129	32	20	ANOMALOUS GENITALIA	16	10
9129	36	34	CUTANEOUS SYNDACTYLY 3RD & 4TH DIGITS	16	10
9129	36	53	DOUBLE PHALANGES, MID & DISTAL ZONE 4TH DIGIT	16	10
9129	40403		BIFID 4TH TOE	16	10
9129	41	31	2ND & 3RD DIGITS FUSED PROXIMALLY	16	10
9129	42	62	SUPERFICIAL ABDOMINAL REFLEXES ABSENT	16	10
9226			2/14/67 1 2	57	3
9226	2	63	INCOMPLETE MEDIAN	57	3
9226	7	20	CRANIOSTENOSIS	57	3

4839			4/15/71 1 1	15	4
4839	2	87	SUBMUCOUS (U)	15	4
4839	7	20	CRANIOSYNOSTOSIS	15	4
4839	9	4	HYPOPLASIA	15	4
4839	11	20	PROPTOSIS	15	4
4839	12	20	PROPTOSIS	15	4
4839	16	22	BYZANTINE PALATE	15	4
4839	36	30	SYNDACTYLY	15	4
4839	37	30	SYNDACTYLY	15	4
4839	40	30	SYNDACTYLY	15	4
4839	41	30	SYNDACTYLY	15	4
5024			9/14/54 1 2	80	10
5024	7	21	SYNOSTOSIS R CORONAL SUTURE	80	10
5024	8	2	ASYMMETRY	80	10
5024	10	2	ASYMMETRY	80	10
5024	11	31	DEVIL'S EYE	80	10
5430			5/ 5/42 1 1	57	10
5430	7	21	SYNOSTOSIS, CORONAL SUTURE	57	10
5430	8	23	HIGH	57	10
5430	8	24	FLAT	57	10
5430	11	75	PTOSIS	57	10
5430	12	75	PTOSIS	57	10
5430	15	41	DEVIATED SEPTUM	57	10
5430	16	22	BYZANTINE PALATE	57	10
5430	36	34	WEBBING BETWEEN 1ST & 2ND FINGERS	57	10
5430	37	34	WEBBING BETWEEN 1ST & 2ND FINGERS	57	10
5437			8/ 5/64 1 1	16	10
5437	7	20	CRANIOSYNOSTOSIS	16	10
5437	9	4	HYPOPLASIA	16	10
5437	11	20	EXOPHTHALMOS	16	10
5437	12	20	EXOPHTHALMOS	16	10
5437	16	22	BYZANTINE PALATE	16	10
5437	20	43	CROWDING	16	10
5531			10/26/69 1 1	80	10
5531	7	21	CRANIOSYNOSTOSIS, RT CORONAL SUTURE	80	10
5531	8	32	DEPRESSION OVER R BROW	80	10
5531	9	2	ASYMMETRY	80	10
5531	11	34	LOWER THAN R	80	10
5531	12	76	INABILITY TO CLOSE COMPLETELY	80	10
5639			5/31/72 1 1	15	4
5639	2	86	SUBMUCOUS (U)	15	4
5639	7	20	CRANIOSYNOSTOSIS	15	4
5639	9	4	HYPOPLASIA	15	4
5639	11	20	PROPTOSIS	15	4
5639	11	91	SOME EXOTROPIA	15	4
5639	12	20	PROPTOSIS	15	4
5639	12	91	SOME EXOTROPIA	15	4
5639	15	21	CONSTRICTED NARES	15	4
5639	16	22	BYZANTINE PALATE	15	4
5639	28	21	KYPHOSIS, LOWER BACK	15	4
5639	36	30	SYNDACTYLY	15	4
5639	37	30	SYNDACTYLY	15	4
5639	40	30	SYNDACTYLY	15	4
5639	41	30	SYNDACTYLY	15	4
5639	43	32	SCOLIOSIS?	15	4
6125			2/24/60 1 1	80	10
6125	7	21	CRANIOSYNOSTOSIS, R CORONAL SUTURE	80	10
6125	8	2	FLATTENED R SIDE	80	10
6125	10	2	ASYMMETRY	80	10
6125	11	31	DEVIL'S EYE	80	10
6125	32	23	UNDESCENDED TESTES	80	10
6127			2/12/52 1 2	16	10
6127	7	20	CRANIOSYNOSTOSIS	16	10
6127	8	2	ASYMMETRY	16	10
6127	9	4	HYPOPLASIA	16	10
6127	11	20	MILD PROPTOSIS	16	10
6127	12	20	MILD PROPTOSIS	16	10

Histogram Analyses of Groups of Attributes as described in the text

The following pages give the histograms for the attributes in the Animals event set when taken in pairs, triples, and quadruples. The hand-written numbers are the least squares fit line (in the form mx+b) calculated for each histogram.

7321			6/ 4/53 1 2	18	10
7321	7	20	CRANIOSYNOSTOSIS	18	10
7321	8	23	HIGH	18	10
7321	8	24	DEPRESSIONS ABOVE EYEBROWS	18	10
7321	8	24	FLAT	18	10
7321	11	32	SHALLOW ORBIT	18	10
7321	12	32	SHALLOW ORBIT	18	10
7321	40	70	PES VALGUS	18	10
7321	41	70	PES VALGUS	18	10
7321	43	60	HYPERELASTICITY ALL JOINTS	18	10
7340			6/26/66 4 1	57	10
7340	7	20	CRANIOSYNOSTOSIS	57	10
7340	8	24	FLATTENED	57	10
7340	9	4	HYPOPLASTIC	57	10
7340	9	20	HYPERTELORIC	57	10
7340	36	34	WEBBING	57	10
7340	37	34	WEBBING	57	10
7340	43	20	WIDENING ATLANTO-AXIAL JOINT	57	10
7340	43	22	FIXATION ANTERIOR ARCH C1	57	10
7434			5/23/41 1 1	15	4
7434	2	86	SUBMUCOUS (U)	15	4
7434	7	20	CRANIOSYNOSTOSIS	15	4
7434	8	21	BOSSING	15	4
7434	9	2	ASYMMETRIC	15	4
7434	9	4	HYPOPLASIA	15	4
7434	10	2	ASYMMETIC	15	4
7434	11	20	PROPTOSIS	15	4
7434	11	75	PTOSIS	15	4
7434	12	20	PROPTOSIS	15	4
7434	12	75	PTOSIS	15	4
7434	13	62	LOPPED	15	4
7434	14	62	LOPPED	15	4
7434	16	22	BYZANTINE PALATE	15	4
7434	36	30	SYNDACTYLY	15	4
7434	37	30	SYNDACTYLY	15	4
7434	40	30	SYNDACTYLY	15	4
7434	41	30	SYNDACTYLY	15	4
7437			1/17/68 1 1	16	4
7437	2	86	SUBMUCOUS (U)	16	4
7437	7	20	CRANIOSYNOSTOSIS	16	4
7437	9	4	HYPOPLASIA	16	4
7437	10	0	BYZANTINE PALATE, MILD	16	4
7437	11	20	EXOPHTHALMOS	16	4
7437	12	20	EXOPHTHALMOS	16	4
7437	20	43	CROWDING	16	4
8226			5/25/45 1 1	16	10
8226	7	20	CRANIOSYNOSTOSIS	16	10
8226	9	4	HYPOPLASIA	16	10
8226	11	20	PROPTOSIS	16	10
8226	12	20	PROPTOSIS	16	10
8429			4/25/55 1 2	16	10
8429	7	20	CRANIOSYNOSTOSIS, CORONAL & SAGITTAL SUTURES	16	10
8429	8	23	BULGING	16	10
8429	8	24	HIGH	16	10
8429	11	31	DEVIL'S EYE	16	10
8429	12	31	DEVIL'S EYE	16	10
8429	13	31	LOW SET	16	10
8429	14	30	ROTATED	16	10
8429	14	31	LOW SET	16	10
8429	29	55	EMPHYSEMA	16	10
8429	31	21	2 ACCESSORY SPLEENS	16	10
8429	32	28	UTERUS DUPLEX BICORNIS	16	10
8434			1/ 8/54 1 1	15	10
8434	7	20	CRANIOSYNOSTOSIS	15	10
8434	8	22	BULGING	15	10
8434	8	23	HIGH	15	10

```
VARIABLE:     3
     0    0    5   11   11    3    7    0

              5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1 [
  1 [
  1 [
  2 [
  2 [
  2 [                                                      -0.4x+9.4
  3 [*****
  3 [*****
  3 [*****
  4 [***********
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  5 [***********
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  6 [***
  6 [***
  6 [***
  7 [*******
  7 [*******
  7 [*******
  8 [
  8 [
  8 [
```

```
VARIABLE:     4
     0    0   16    5    8    7    7    0

              5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1 [
  1 [
  1 [
  2 [
  2 [
  2 [
  3 [****************
  3 [****************                                  -1.6x+16.6
  3 [****************
  4 [*****
  4 [*****
  4 [*****
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  8 [
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```

				57	3
9226	9	20	HYPERTELORISM	57	3
9226	15	31	DEPRESSED NASAL BRIDGE	57	3
9226	36	34	WEBBING	57	3
9226	37	34	WEBBING	57	3
9534			6/ 8/67 1 2	15	10
9534	7	20	CRANIOSYNOSTOSIS	15	10
9534	8	24	FLATTENING	15	10
9534	9	4	HYPOPLASIA	15	10
9534	11	20	PROPTOSIS	15	10
9534	12	20	PROPTOSIS	15	10
9534	13	31	LOW SET	15	10
9534	14	31	LOW SET	15	10
9534	15	26	PINCHED	15	10
9534	16	22	BYZANTINE PALATE	15	10
9534	34	0	WIDE CARRYING ANGLE	15	10
9534	34	50	PROMINENT ACROMIO-CLAVICULAR JOINT	15	10
9534	35	0	WIDE CARRYING ANGLE	15	10
9534	35	50	PROMINENT ACROMIO-CLAVICULAR JOINT	15	10
9534	36	30	SYNDACTYLY	15	10
9534	37	30	SYNDACTYLY	15	10
9534	40	30	SYNDACTYLY	15	10
9534	41	30	SYNDACTYLY	15	10
9534	42	30	RETARDATION	15	10
9534	42	57	HYPERACTIVITY	15	10
9538			9/ 9/61 1 1	16	10
9538	7	20	CRANIOSYNOSTOSIS	16	10
9538	8	29	TYPICAL CROUZON	16	10
9538	9	4	HYPOPLASIA	16	10
9538	11	20	EXOPHTHALMOS	16	10
9538	12	20	EXOPHTHALMOS	16	10
9538	16	22	BYZANTINE PALATE	16	10
9925			0/ 0/ 0 5 2	18	10
9925	7	20	CRANIOSYNOSTOSIS?	18	10
9925	8	23	HIGH	18	10
9925	9	4	HYPOPLASIA	18	10
9946			5/15/74 4 2	57	4
9946	2	86	SUBMUCOUS (U)	57	4
9946	7	20	CRANIOSYNOSTOSIS	57	4
9946	8	24	FLAT	57	4
9946	9	4	HYPOPLASIA	57	4
9946	10	41	PROGNATHISM	57	4
9946	11122		CHRONIC TEARING	57	4
9946	12	30	POSTERIORLY SET	57	4
9946	12	30	LOW SET	57	4
9946	13	31	LOW SET	57	4
9946	14	31	LOW SET	57	4
9946	16	42	COMMISSURAL LIP PITS	57	4
9946	40	34	CUTANEOUS SYNDACTYLY	57	4
9946	41	34	CUTANEOUS SYNDACTYLY	57	4

```
VARIABLE:   7
   0    0    0    0    5    7   25   50

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
   1 [
   1 [
   1 [
   2 [                                                 15.3x-77.7
   2 [
   2 [
   3 [
   3 [
   3 [
   4 [
   4 [
   4 [
   5 [*****
   5 [*****
   5 [*****
   6 [*******
   6 [*******
   6 [*******
   7 [*************************
   7 [*************************
   7 [*************************
   8 [**************************************************
   8 [**************************************************
   8 [**************************************************
```

```
VARIABLE:   8
   0    0   11    2    8   14    7    0

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
   1 [
   1 [                                                     0.4x+6.4
   1 [
   2 [
   2 [
   2 [
   3 [***********
   3 [***********
   3 [***********
   4 [**
   4 [**
   4 [**
   5 [********
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   6 [**************
   7 [*******
   7 [*******
   7 [*******
   8 [
   8 [
   8 [
```

```
RANGE TOTALS
    2    8   18   34   36   28   28    2
VARIABLE:     1
   50   25   16   11    5    0    0    0

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1 [ **************************************************
  1 [ **************************************************
  1 [ **************************************************
  2 [ *************************
  2 [ *************************
  2 [ *************************                  -10.4+52.6
  3 [ ****************
  3 [ ****************
  3 [ ****************
  4 [ ***********
  4 [ ***********
  4 [ ***********
  5 [ *****
  5 [ *****
  5 [ *****
  6 [
  6 [
  6 [
  7 [
  7 [
  7 [
  8 [
  8 [
  8 [


VARIABLE:     2
    0    0    5    8   13    3    7    0
          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1 [
  1 [
  1 [                                            -0.1x+7.7
  2 [
  2 [
  2 [
  3 [ *****
  3 [ *****
  3 [ *****
  4 [ ********
  4 [ ********
  4 [ ********
  5 [ *************
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  6 [ ***
  6 [ ***
  6 [ ***
  7 [ *******
  7 [ *******
  7 [ *******
  8 [
  8 [
  8 [
```

```
VARIAELE:   11
  0    0    5    5    8   14    7    0

           5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
      1 [
      1 [
      1 [
      2 [
      2 [
      2 [                                              1.3x+1.3
      3 [*****
      3 [*****
      3 [*****
      4 [*****
      4 [*****
      4 [*****
      5 [********
      5 [********
      5 [********
      6 [**************
      6 [**************
      6 [**************
      7 [*******
      7 [*******
      7 [*******
      8 [
      8 [
      8 [

VARIABLE:   12
  0    0    0    0    5    7   25   50

           5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
      1 [
      1 [
      1 [                                              15.3x-77.7
      2 [
      2 [
      2 [
      3 [
      3 [
      3 [
      4 [
      4 [
      4 [
      5 [*****
      5 [*****
      5 [*****
      6 [*******
      6 [*******
      6 [*******
      7 [*************************
      7 [*************************
      7 [*************************
      8 [**************************************************
      8 [**************************************************
      8 [**************************************************
```

```
VARIABLE:  5
 0   0    0    5    8   17    7    0

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
 1 [
 1 [
 1 [
 2 [
 2 [
 2 [                                            1.5x+1
 3 [
 3 [
 3 [
 4 [ *****
 4 [ *****
 4 [ *****
 5 [ ********
 5 [ ********
 5 [ ********
 6 [ *****************
 6 [ *****************
 6 [ *****************
 7 [ *******
 7 [ *******
 7 [ *******
 8 [
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```

```
VARIABLE:  6
 0   37    5   14    2    7    0    0

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
 1 [                                                 -6.3x +38.2
 1 [
 1 [
 2 [ *************************************
 2 [ *************************************
 2 [ *************************************
 3 [ *****
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 7 [
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 7 [
 8 [
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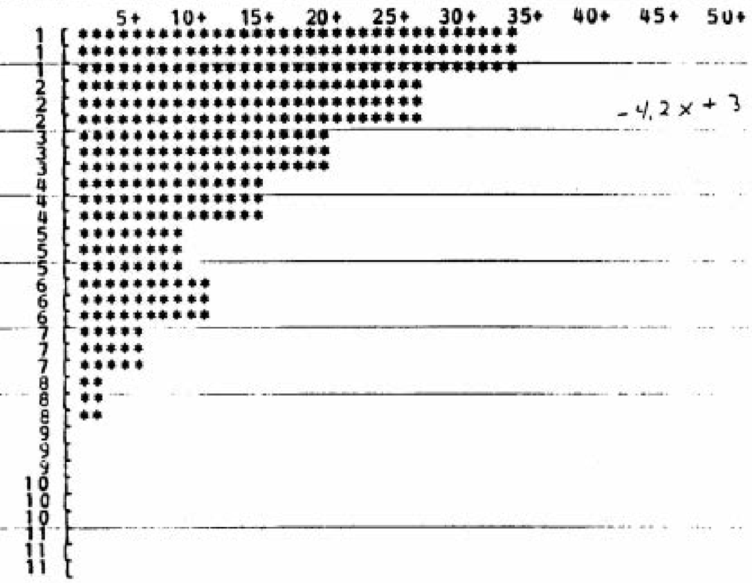
 8 [
```

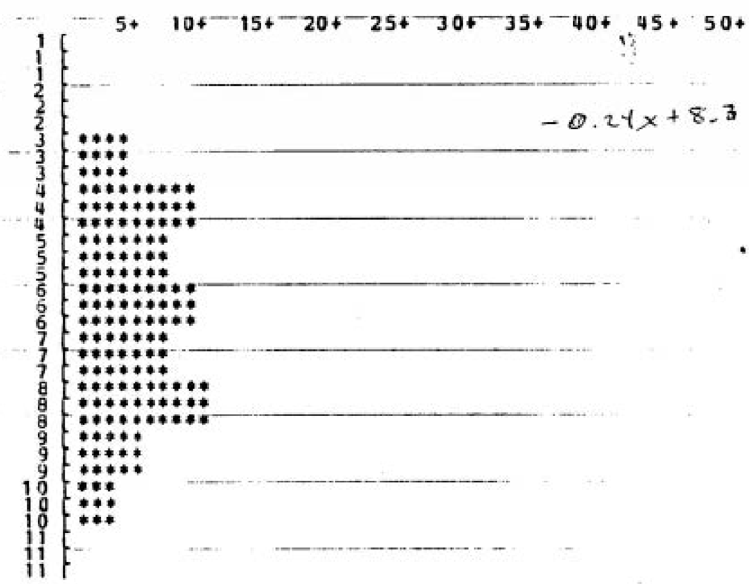
RANGE TOTALS
3 15 42 87 105 177 171 126 93 33 6

VARIABLE:
33 26 19 14 8 10 5 2 0 0 0



$-4.2x + 33.6$

VARIABLE:
0 0 4 2 9 7 9 7 10 5 3 0



$-0.24x + 8.3$

```
VARIABLE:   9
 50   12   22   11    5    0    0    0

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1  [ **************************************************
  1  [ **************************************************
  1  [ **************************************************
  2  [ ************
  2  [ ************
  2  [ ************
  3  [ **********************
  3  [ **********************
  3  [ **********************
  4  [ ***********
  4  [ ***********
  4  [ ***********
  5  [ *****
  5  [ *****
  5  [ *****
  6  [
  6  [
  6  [
  7  [
  7  [
  7  [
  8  [
  8  [
  8  [
```

$-9.1x + 47.3$

```
VARIABLE:   10
  0   25   11    8    5   10    0    0

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1  [
  1  [
  1  [
  2  [ *************************
  2  [ *************************
  2  [ *************************
  3  [ ***********
  3  [ ***********
  3  [ ***********
  4  [ ********
  4  [ ********
  4  [ ********
  5  [ *****
  5  [ *****
  5  [ *****
  6  [ **********
  6  [ **********
  6  [ **********
  7  [
  7  [
  7  [
  8  [
  8  [
  8  [
```

$-3.6x + 26.2$

```
VARIABLE:    5
   0    0    2    0    6    6    9   11   10   12   16
          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
 1 [
 1 [
 1 [
 2 [
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 3 [**
 3 [**
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 9 [**********
10 [************
10 [************
10 [************
11 [****************
11 [****************
11 [****************
```

$1.6x - 2.5$

```
VARIABLE:    6
  33   13   16   12   12    8    5    4    1    0    0
          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
 1 [*********************************
 1 [*********************************
 1 [*********************************
 2 [*************
 2 [*************
 2 [*************
 3 [****************
 3 [****************
 3 [****************
 4 [************
 4 [************
 4 [************
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 7 [*****
 8 [****
 8 [****
 8 [****
 9 [*
 9 [*
 9 [*
10 [
10 [
10 [
11 [
11 [
11 [
```

$-3.0x + 26.6$

```
VARIABLE:   13
   0    0    0   11   11    7    7    0

          5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
 1 [
 1 [
 1 [
 2 [
 2 [                                          -1.6x+17.8
 2 [
 3 [
 3 [
 3 [
 4 [ ***********
 4 [ ***********
 4 [ ***********
 5 [ ***********
 5 [ ***********
 5 [ ***********
 6 [ *******
 6 [ *******
 6 [ *******
 7 [ *******
 7 [ *******
 7 [ *******
 8 [
 8 [
 8 [
```

```
VARIABLE:  9
   33  26  19  13  12  6  7  2  0  0  0

        5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
   1 [*********************************
   1 [*********************************
   1 [*********************************
   2 [**************************
   2 [**************************
   2 [**************************
   3 [*******************
   3 [*******************
   3 [*******************
   4 [*************
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   4 [*************
   5 [************
   5 [************
   5 [************
   6 [******
   6 [******
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   8 [**
   8 [**
   8 [**
   9 [
   9 [
   9 [
  10 [
  10 [
  10 [
  11 [
  11 [
  11 [
```

-4.2 x+33.6

```
VARIABLE:  10
    0  20  11  12  10  7  6  6  3  3  0

        5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
   1 [
   1 [
   1 [
   2 [********************
   2 [********************
   2 [********************
   3 [***********
   3 [***********
   3 [***********
   4 [************
   4 [************
   4 [************
   5 [**********
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   6 [*******
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   8 [******
   8 [******
   9 [***
   9 [***
   9 [***
  10 [***
  10 [***
  10 [***
  11 [
  11 [
  11 [
```

-1.8x 19.5

```
VARIABLE:   3
  0   0   4   6   4  11   8   6   9   3   0

        5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1 [
  1 [
  1 [
  2 [
  2 [
  2 [
  3 [****
  3 [****
  3 [****
  4 [******
  4 [******
  4 [******
  5 [****
  5 [****
  5 [****
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  6 [***********
  6 [***********
  7 [********
  7 [********
  7 [********
  8 [******
  8 [******
  8 [******
  9 [*********
  9 [*********
  9 [*********
 10 [***
 10 [***
 10 [***
 11 [
 11 [
 11 [
```

0.13 x + 5.5

```
VARIABLE:   4
  0   6  11   8  10   7   7   7   4   6  16

        5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1 [
  1 [
  1 [
  2 [******
  2 [******
  2 [******
  3 [***********
  3 [***********
  3 [***********
  4 [********
  4 [********
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  5 [**********
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  8 [*******
  8 [*******
  9 [****
  9 [****
  9 [****
 10 [******
 10 [******
 10 [******
 11 [****************
 11 [****************
 11 [****************
```

0.16x + 7.2

```
VARIABLE:   13
   0   0   2   8   8   9   7   9   6   9   0

              5+  10+  15+  20+  25+  30+  35+  40+  45+  50+
   1 [
   1 [
   1 [
   2 [
   2 [
   2 [
   3 [**
   3 [**
   3 [**
   4 [*********
   4 [*********
   4 [*********
   5 [*********
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   7 [********
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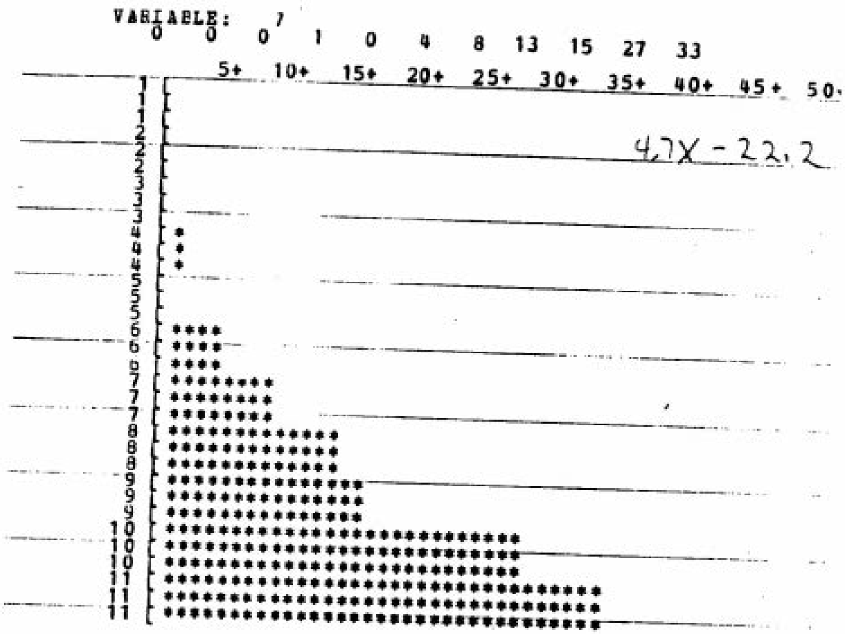
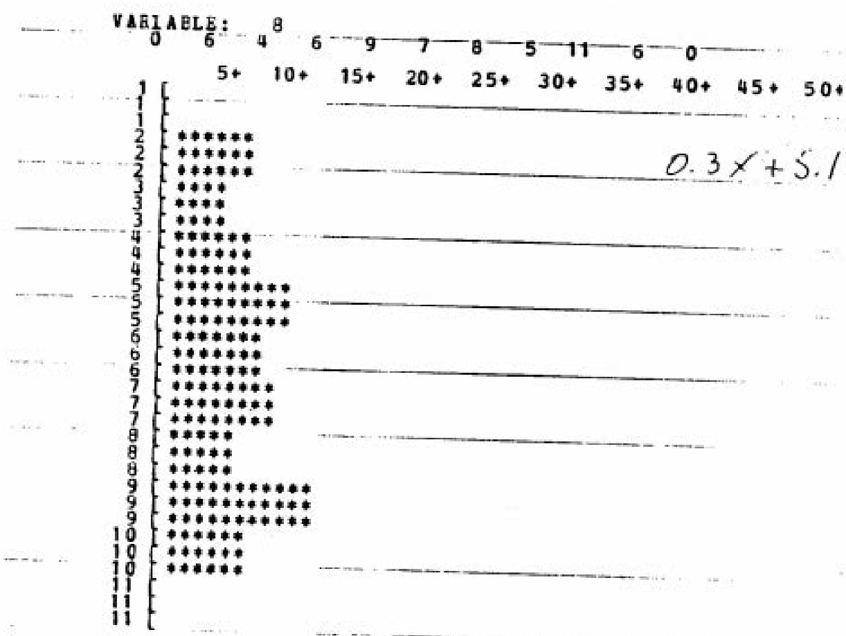
   9 [*******
   9 [*******
   9 [*******
  10 [**********
  10 [**********
  10 [**********
  11 [
  11 [
  11 [
```

0.45x+4.2


VARIABLE: 7
0 0 0 1 0 4 8 13 15 27 33
5+ 10+ 15+ 20+ 25+ 30+ 35+ 40+ 45+ 50+
4.7X - 22.2


VARIABLE: 8
0 6 4 6 9 7 8 5 11 6 0
5+ 10+ 15+ 20+ 25+ 30+ 35+ 40+ 45+ 50+
0.3X + 5.1

```
VARIABLE:    3
     0    0    2    4    7    5    9    7    9    8    8    4    0
                5+  10+  15+  20+  25+  30+  35+  40+  45+  50+
   1 [
   1 [
   1 [
   2 [
   2 [
   2 [
   3 [ **
   3 [ **
   3 [ **
   4 [ ****
   4 [ ****
   4 [ ****
   5 [ *******
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   6 [ *****
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   7 [ *********
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   7 [ *********
   8 [ *******
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   9 [ *********
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  10 [ ********
  11 [ ********
  11 [ ********
  11 [ ********
  12 [ ****
  12 [ ****
  12 [ ****
  13 [
  13 [
  13 [
```

0.37x +3.5

```
VARIABLE:    4
     0   18    8   12    9   10    6    8    5    7    4    5   10
                5+  10+  15+  20+  25+  30+  35+  40+  45+  50+
   1 [
   1 [
   1 [
   2 [ ******************
   2 [ ******************
   2 [ ******************
   3 [ ********
   3 [ ********
   3 [ ********
   4 [ ************
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  10 [ *******
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  11 [ ****
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  11 [ ****
  12 [ *****
  12 [ *****
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  13 [ **********
  13 [ **********
  13 [ **********
```

-.68 + 13.6

```
VARIABLE:  11
   0   0   2   4   7   7   7   8  13   6   0

            5+  10+  15+  20+  25+  30+  35+  40+  45+  50+
 1 [
 1 [
 1 [
 2 [
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 3 [ **
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 9 [ *************
10 [ ******
10 [ ******
10 [ ******
11 [
11 [
11 [
```

0.9x+ 0.9

```
VARIABLE:  12
   0   0   0   1   0   3   9  11  18  24  33

            5+  10+  15+  20+  25+  30+  35+  40+  45+  50
 1 [
 1 [
 1 [
 2 [
 2 [
 2 [
 3 [
 3 [
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 4 [ *
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10 [ ************************
10 [ ************************
10 [ ************************
11 [ *********************************
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11 [ *********************************
```

4.6x−22.0

```
VARIABLE:    7
     0    0    0    0    2    2    4    6    9   12   14   22   25

          5+   10+  15+  20+  25+  30+  35+  40+  45+  50+
  1 [
  1 [
  1 [
  2 [
  2 [
  2 [
  3 [
  3 [
  3 [
  4 [
  4 [
  4 [
  5 [ **
  5 [ **
  5 [ **
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 12 [ **********************
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 13 [ *************************
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```

3.0x − 16.0

```
VARIABLE:    8
     0    6    8    5    7    8    7    7    8    6    6   10   15

          5+   10+  15+  20+  25+  30+  35+  40+  45+  50+
  1 [
  1 [
  1 [
  2 [ ******
  2 [ ******
  2 [ ******
  3 [ ********
  3 [ ********
  3 [ ********
  4 [ *****
  4 [ *****
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  5 [ *******
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0.42+4.6

```
RANGE TOTALS
    4   16   48  108  236  284  468  512  460  352  244  108   20
VARIABLE:
   25   25   18   14   13   10   10    7    5    4    0    0    0

           5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
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$-2.4x+26.4$

```
VARIABLE:       2
    0    0    4    4    6    9    8    7   10    7    6    5    0

           5+   10+   15+   20+   25+   30+   35+   40+   45+   50+
  1 [
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$0.18x+5.2$

```
VARIABLE:  1-1
     0    0    4    2    6    6    6    7    8    8   11    8    5
          5+  10+  15+  20+  25+  30+  35+  40+  45+  50+
  1 [
  1 [
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  5 [******
  6 [******                               0.45+2.8
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```
VARIABLE:  12
     0    0    0    0    1    1    4    6    9   12   16   20   25
          5+  10+  15+  20+  25+  30+  35+  40+  45+  50+
  1 [
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  1 [                                  3.05 - 17.0
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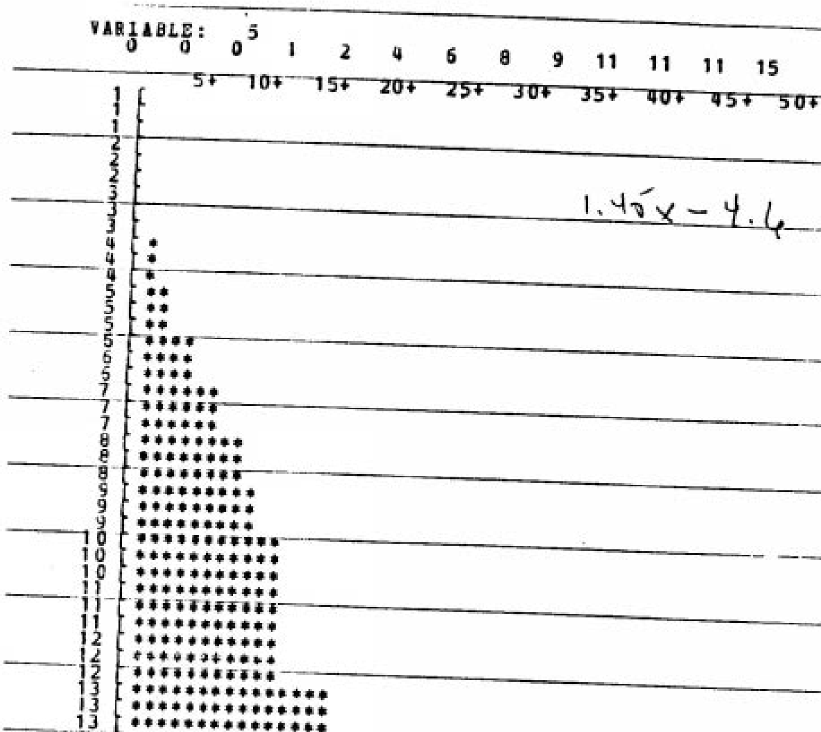
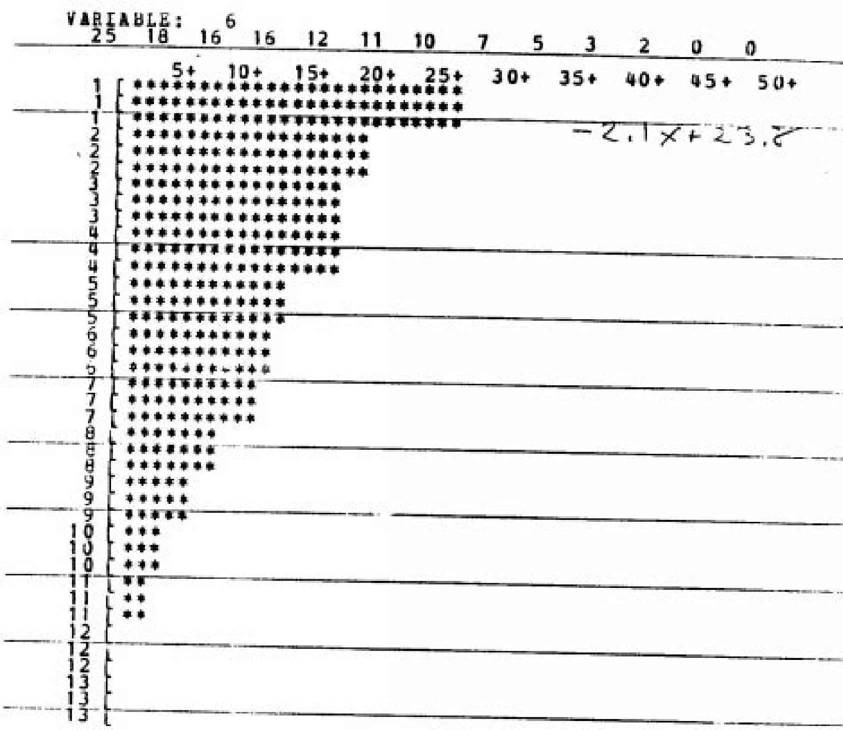
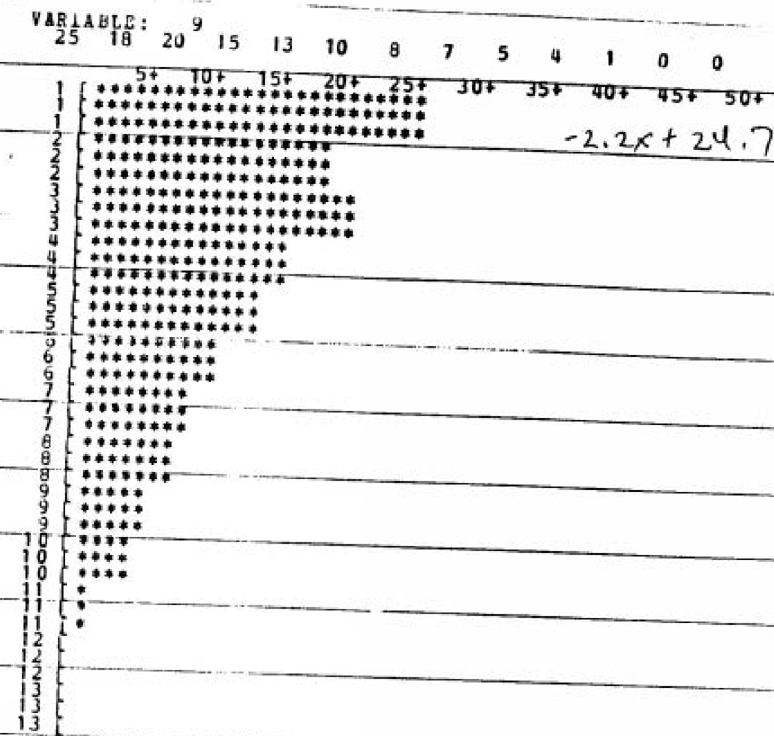

VARIABLE: 5
0 0 0 1 2 4 6 8 9 11 11 11 15
5+ 10+ 15+ 20+ 25+ 30+ 35+ 40+ 45+ 50+
1.45x − 4.6


VARIABLE: 6
25 18 16 16 12 11 10 7 5 3 2 0 0
5+ 10+ 15+ 20+ 25+ 30+ 35+ 40+ 45+ 50+
−2.1x+23.8

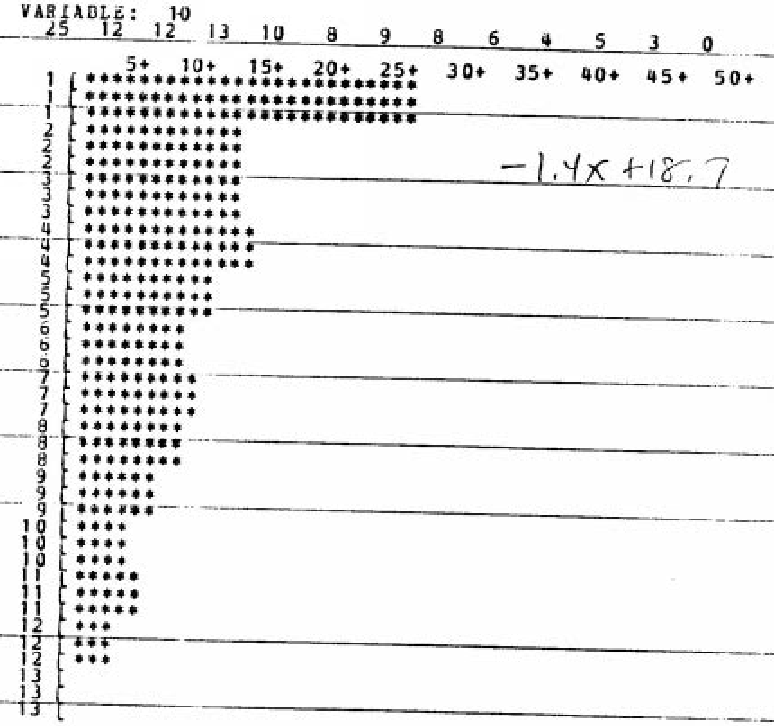
Rules for the Animals Event Set
Derived Using AQ11

VARIABLE: 9



-2.2x + 24.7

VARIABLE: 10



-1.4x + 18.7

```
LINE  12:   0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0,
LINE  13:   0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0,
LINE  14:   0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0,
LINE  15:   0, 0, 0, 1, 0, 2, 0, 1, 0, 0, 0, 0, 0,
LINE  16:   0, 1, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0,
LINE  17:   0, 0, 0, 0, 0, 1, 0, 0, 0, 3, 1, 0, 0,
LINE  18:   0, 0, 0, 1, 0, 2, 0, 0, 0, 0, 0, 0, 1,
LINE  19:   0, 0, 0, 1, 0, 2, 0, 0, 0, 0, 1, 0, 1,
LINE  20:   0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0,
LINE  21:   0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0,
LINE  22:   0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  23:   0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  24:   0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0,
LINE  25:   0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0,
LINE  26:   0, 1, 0, 0, 0, 0, 0, 0, 1, 3, 1, 0, 0,
LINE  27:   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
LINE  28:   0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  29:   0, 1, 0, 0, 6, 0, 0, 0, 1, 0, 0, 0, 0,
LINE  30:   0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  31:   0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  32:   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
LINE  33:   1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0,
LINE  34:   1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0,
LINE  35:   1, 1, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  36:   1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0,
LINE  37:   1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  38:   1, 1, 0, 0, 0, 0, 0, 0, 1, 3, 1, 0, 0,
LINE  39:   0, 0, 0, 0, 0, 0, 0, 1, 0, 2, 0, 0, 0,
LINE  40:   1, 1, 0, 0, 0, 0, 0, 0, 1, 3, 1, 0, 0,
LINE  41:   0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0,
LINE  42:   1, 0, 0, 0, 0, 0, 0, 0, 0, 3, 1, 0, 0,
LINE  43:   0, 1, 0, 1, 0, 0, 0, 1, 1, 3, 1, 0, 0,
LINE  44:   0, 1, 0, 0, 0, 0, 0, 0, 2, 1, 1, 0, 1,
LINE  45:   0, 1, 0, 0, 0, 0, 0, 0, 2, 1, 0, 0, 1,
LINE  46:   0, 1, 0, 0, 0, 0, 1, 0, 2, 0, 0, 0, 1,
LINE  47:   0, 1, 0, 0, 0, 2, 0, 0, 2, 2, 0, 0, 1,
LINE  48:   0, 1, 0, 0, 2, 0, 0, 0, 2, 3, 1, 0, 1,
LINE  49:   0, 1, 0, 0, 5, 0, 0, 0, 2, 0, 0, 0, 1,
LINE  50:   0, 1, 0, 0, 5, 0, 0, 0, 1, 0, 1, 0, 1,
LINE  51:   0, 1, 0, 0, 0, 0, 0, 0, 0, 3, 1, 0, 1,
LINE  52:   0, 1, 0, 0, 0, 0, 0, 0, 2, 0, 1, 0, 0,
LINE  53:   0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 1,
LINE  54:   0, 1, 0, 0, 0, 0, 1, 0, 2, 0, 1, 0, 1,
LINE  55:   0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1,
LINE  56:   2, 1, 2, 0, 0, 0, 0, 0, 1, 3, 1, 0, 0,
LINE  57:   2, 1, 2, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  58:   2, 1, 2, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0,
LINE  59:   2, 1, 2, 1, 0, 0, 0, 0, 0, 3, 1, 0, 0,
LINE  60:   2, 1, 2, 1, 0, 2, 0, 0, 0, 0, 0, 0, 0,
LINE  61:   2, 1, 2, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0,
LINE  62:   1, 1, 2, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0,
LINE  63:   2, 1, 2, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0,
LINE  64:   2, 1, 1, 0, 0, 2, 0, 0, 1, 0, 0, 0, 0,
LINE  65:   1, 1, 2, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0,
LINE  66:   2, 1, 2, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0,
LINE  67:   1, 1, 2, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0,
LINE  68:   1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
LINE  69:   1, 0, 0, 1, 4, 0, 0, 0, 0, 0, 0, 0, 0,
LINE  70:   0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0,
LINE  71:   0, 0, 0, 1, 0, 0, 0, 0, 0, 2, 0, 0, 0,
LINE  72:   0, 0, 0, 1, 0, 0, 0, 0, 0, 2, 0, 0, 0,
LINE  73:   0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0,
LINE  74:   0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0,
LINE  75:   0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0,
LINE  76:   0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0,
LINE  77:   0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0,
LINE  78:   0, 0, 0, 1, 3, 0, 0, 0, 0, 0, 1, 0, 0,
LINE  79:   0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,
0ECHO OF INPUT FORMULAS
0 TIME OF DATA INPUT:        51.20  CENTISECONDS
1BEGINNING OF PASS 1.
0 FORMULAS FOR EACH CLASS:
         1:    NO FORMULAS.
         2:    NO FORMULAS.
         3:    NO FORMULAS.
         4:    NO FORMULAS.
         5:    NO FORMULAS.
         6:    NO FORMULAS.
         7:    NO FORMULAS.
         8:    NO FORMULAS.
         9:    NO FORMULAS.
        10:    NO FORMULAS.
        11:    NO FORMULAS.
        12:    NO FORMULAS.
```

```
VARIABLE:  13
   0    0    4    5    6    9    7    8    8    7    8    7    5
              5+   10+  15+  20+  25+  30+  35+  40+  45+  50+
  1 [
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0.15+5.6

```
Q* * * COVER OF CLASS  13 * * *
  CPX  1:(X 5= 1, 4)
  CPX  2:(X 4= 1)(X 6= 0) (X 8= 1) (X11= 0)
  CPX  3:(X 4= 1)(X10= 2)
  CPX  4:(X 2= 0)(X 7= 1)
Q* * * COVER OF CLASS  14 * * *
  CPX  1:(X 4= 1) (X 5= 0, 1, 2, 3, 5, 6) (X 6= 0) (X 7= 0) (X 8= 0) (X 9= 0, 2) (X10= 0)
  CRIT # 2 EVALUATED 2954 TIMES.
  CRIT # 1 EVALUATED 1300 TIMES.
Q TIME FOR THIS PASS:      570.20  CENTISECONDS
MAXIMUM SIZE OF COMPLEX STORAGE WAS:          200

PRINT (V9.1) REQUEST   82/03/25.   10.38.02.  RJE=LOCAL   UN=3IJJIG

* * * * * *
(   1, 1, 1, 2, 1,   1, 1, 2, 1,   1, 1, 2, 1)
(   6,   6,   6)
```

```
******* CFFA017  *** 112 ***** BIN  17 ***** ALLVARS(3IJOIGZ)      ***** BIN  17 ***** 10.40.48 AM * 25 MAR 82 ****** START
******* CFFA017  *** 112 ***** BIN  17 ***** ALLVARS(3IJOIGZ)      ***** BIN  17 ***** 10.40.48 AM * 25 MAR 82 ****** START
******* CFFA017  *** 112 ***** BIN  17 ***** ALLVARS(3IJOIGZ)      ***** BIN  17 ***** 10.40.48 AM * 25 MAR 82 ****** START
******* CFFA017  *** 112 ***** BIN  17 ***** ALLVARS(3IJOIGZ)      ***** BIN  17 ***** 10.40.48 AM * 25 MAR 82 ****** START
******* CFFA017  *** 112 ***** BIN  17 ***** ALLVARS(3IJOIGZ)      ***** BIN  17 ***** 10.40.48 AM * 25 MAR 82 ****** START

****************************************** H A S P  (3.1)  S Y S T E M   L O G ******************************************

$ 10.39.21 JOB 112           234 LINES TO BE PRINTED
$ 10.39.21 JOB 112 FROM THE CYBER 175
$ 10.40.48 JOB 112 CFFA017  ON PRINTER2 BIN=17

**************************** O S / M V T  (21.7)  S Y S T E M   M E S S A G E   B L O C K ****************************

RAJII PASCAL:  MULTI-STEP RULE DEDUCTION AND REFINEMENT - VERSION 2.0

0INITIALIZATION TIME:        0.60  CENTISECONDS
0  PARAMETERS THIS RUN:
0  NUMBER OF CLASSES:              14                    NTAU:      0
   NUMBER OF VARIALBLES:           13                  TAUINC:  0.02000000
   NUMBER OF EVENTS:               79                     TAU:  0.01900000
   MAXIMUM STAR SIZE:              10                     IRK:   2
   ALLOWABLE # OF EXCEPTIONS:       1                    PUNY:  0.02000000
   NUMBER OF PASSES:                1   INIT STRGE FOR CPXS:     200
0  MODE OF COVER SYNTHESIS:  INTERSECTING COVERS.
0  ECHO EVENTS?          TRUE
    ECHO COSTS?          TRUE
 RESTRICTIONS?           TRUE
     FORMULAS?           TRUE
   PARAMETERS?          FALSE
  TRANSLATION?          FALSE

          NCRIT:   2
0                    (1)    (2)    (3)    (4)    (5)    (6)
     CRITVALUES:      2      1      5      9      0      0
     TOLERANCES:  0.00   0.00   0.00   0.0C   C.00   0.00
0       STRATEGY:   1
0         TEST:   TEST COMPLEXES?              FALSE
           ORD:   ORDER COMPLEXES?              TRUE
         CPXEV:   EVALUATE COMPLEXES?           TRUE
         INDEP:   PRINT INDEPENDANTS?           TRUE
            TR:   TRACE FORMULATION?           FALSE
        STARTR:   TRACE STAR FORMATN?          FALSE
          SAVE:   SAVE COMPLEXES?              FALSE
      RESTRICT:   INPUT RESTRICTIONS?          FALSE
           OPT:   PRINT # COST FUNCS?           TRUE
           GEN:   TRIM CPXS FOR OUTPT?         FALSE
         RTEST:   APPLY RSTRS TO TEST?          TRUE
         TRANS:   TRANSLATE OUTPUT?            FALSE

                                   *******************************************************
                                                          ANIMALS, FROM (MICHALSKI '75)
                                   *******************************************************

OEVENT SPECIFICATIONS
       VARIABLE:     1     2     3     4     5     6     7     8     9    10    11    12    13
           TYPE:   LIN   NOM   LIN   NOM   NOM   LIN   NOM   NOM   NOM   NOM   NOM   NOM   NOM
  NUM OF LEVELS:     3     2     3     2     7     3     2     2     3     4     2     2     2
0 PERCENTAGE OF EVENTS TO USE PER PASS:    1.0000
0  ECHO OF INPUT EVENTS
   LINE   1:   0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0,
   LINE   2:   0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0,
   LINE   3:   0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0,
   LINE   4:   0, 0, 0, 0, 0, 1, 0, 0, 0, 2, 0, 0, 0,
   LINE   5:   0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0,
   LINE   6:   0, 1, 0, 0, 0, 2, 0, 0, 1, 0, 0, 0, 0,
   LINE   7:   0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 1, 0, 0,
   LINE   8:   0, 1, 0, 1, 0, 0, 0, 0, 0, 3, 1, 0, 0,
   LINE   9:   0, 0, 0, 0, 0, 2, 0, 0, 0, 1, 0, 0, 0,
   LINE  10:   0, 1, 0, 0, 0, 0, 0, C, 2, 1, 0, 0, 0,
   LINE  11:   0, 0, 0, 0, 0, 1, 0, 1, 0, 2, 0, 0, 0.
```

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```
14:      NO FORMULAS.
0NUMBER OF EVENTS IN EACH CLASS:
          CLASS # 1      5
          CLASS # 2      5
          CLASS # 3      5
          CLASS # 4      5
          CLASS # 5      6
          CLASS # 6      6
          CLASS # 7      5
          CLASS # 8      6
          CLASS # 9      6
          CLASS #10      6
          CLASS #11      6
          CLASS #12      7
          CLASS #13      5
          CLASS #14      6

0* * * COVER OF CLASS   1 * * *                                                * NEW * * IND *   COV
 CPX  1: (X 6= 1) (X 8= 0) (X10= 0, 2)                                         (    5,     5,      5)
0* * * COVER OF CLASS   2 * * *                                                * * * * * *
 CPX  1: (X 3= 0) (X 6= 1.. 2) (X 9= 1)                                        (    1,     1,      1)
 CPX  2: (X 2= 0) (X 4= 0) (X 6= 2)                                            (    2,     2,      2)
 CPX  3: (X 3= 0.. 1) (X 4= 1) (X 9= 0, 2) (X10= 3)                            (    1,     1,      1)
 CPX  4: (X 9= 1, 2) (X10= 1, 2) (X13= 0)                                      (    1,     1,      1)
0* * * COVER OF CLASS   3 * * *                                                * * * * * *
 CPX  1: (X 6= 1.. 2) (X 8= 1)                                                 (    5,     5,      5)
0* * * COVER OF CLASS   4 * * *                                                * * * * * *
 CPX  1: (X 2= 1) (X 3= 0.. 1) (X 6= 2) (X 9= 0)                               (    1,     1,      1)
 CPX  2: (X 6= 1) (X10= 3)                                                     (    1,     1,      1)
 CPX  3: (X 2= 0) (X13= 1)                                                     (    2,     2,      2)
 CPX  4: (X 4= 1) (X10= 1)                                                     (    1,     1,      1)
0* * * COVER OF CLASS   5 * * *                                                * * * * * *
 CPX  1: (X 1= 0) (X 5= 0, 1, 2, 3, 4, 5) (X 6= 0.. 1) (X 8= 0) (X 9= 1) (X11= 0)   (    3,     2,      3)
 CPX  2: (X 1= 0) (X 4= 1) (X 9= 1, 2) (X10= 0, 1, 2)                          (    2,     2,      3)
 CPX  3: (X 1= 0) (X 4= 0) (X 9= 1) (X10= 1, 2, 3)                             (    1,     1,      1)
0* * * COVER OF CLASS   6 * * *                                                * * * * * *
 CPX  1: (X 2= 0) (X 4= 0) (X 6= 0) (X10= 0, 1)                                (    2,     2,      2)
 CPX  2: (X 1= 0) (X 4= 0) (X 5= 0, 1, 2, 3, 4, 6) (X 9= 1) (X10= 0, 1, 2) (X11= 1)   (    3,     3,      3)
 CPX  3: (X 5= 1, 6)                                                           (    1,     1,      1)
0* * * COVER OF CLASS   7 * * *                                                * * * * * *
 CPX  1: (X 1= 1) (X 9= 1, 2) (X11= 0)                                         (    3,     0,      3)
 CPX  2: (X 1= 1.. 2) (X 4= 1) (X 9= 1, 2)                                     (    1,     0,      1)
 CPX  3: (X 1= 1.. 2) (X 3= 0) (X 9= 1, 2) (X10= 0, 1, 2)                      (    1,     1,      5)
0* * * COVER OF CLASS   8 * * *                                                * * * * * *
 CPX  1: (X 1= 1) (X10= 1, 2, 3)                                               (    3,     3,      3)
 CPX  2: (X 6= 0) (X 8= 1) (X10= 1, 2, 3)                                      (    2,     1,      2)
 CPX  3: (X 8= 1) (X 9= 1, 2)                                                  (    1,     1,      2)
0* * * COVER OF CLASS   9 * * *                                                * * * * * *
 CPX  1: (X 9= 2) (X10= 2, 3)                                                  (    3,     2,      3)
 CPX  2: (X 9= 1, 2) (X11= 0) (X13= 1)                                         (    3,     3,      4)
0* * * COVER OF CLASS  10 * * *                                                * * * * * *
 CPX  1: (X 5= 1, 2, 5) (X 9= 0, 1)                                            (    1,     0,      1)
 CPX  2: (X 6= 0.. 1) (X 9= 0, 1) (X13= 1)                                     (    3,     3,      4)
 CPX  3: (X 9= 2) (X10= 0, 1, 2) (X11= 1)                                      (    2,     2,      2)
0* * * COVER OF CLASS  11 * * *                                                * * * * * *
 CPX  1: (X 3= 1.. 2) (X10= 1, 2, 3)                                           (    3,     0,      3)
 CPX  2: (X 1= 2) (X 9= 1, 2) (X11= 1)                                         (    1,     1,      3)
 CPX  3: (X 3= 1.. 2) (X 4= 1)                                                 (    2,     2,      4)
0* * * COVER OF CLASS  12 * * *                                                * * * * * *
 CPX  1: (X 1= 0.. 1) (X 3= 1.. 2)                                             (    3,     1,      3)
 CPX  2: (X 1= 2) (X 4= 0) (X 9= 0, 2)                                         (    2,     2,      2)
 CPX  3: (X 3= 1)                                                              (    1,     1,      1)
 CPX  4: (X 1= 1) (X 2= 1) (X 9= 0, 2)                                         (    1,     1,      3)
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This thesis describes a set of three programs which perform constructive induction, attribute selection, and inductive inference, respectively. The first and last were developed by others. The attribute selection program is based on a method developed by the author which relies on an extension of information theory. Three experiments are described which were used to evaluate the selection method, and two experiments in the medical and agricultural domains, in which the program set was applied, are described.

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