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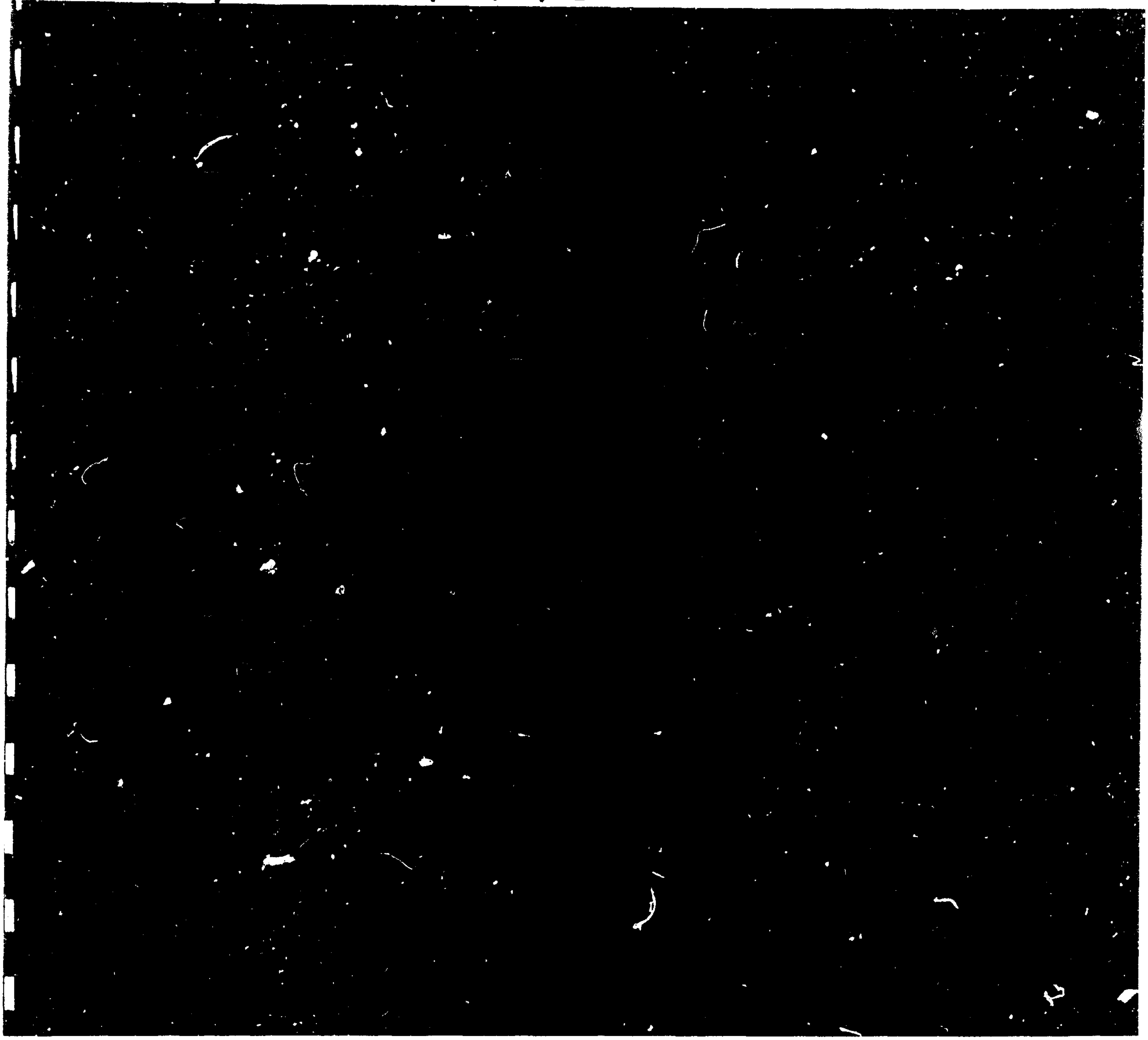

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13. ABSTRACT

This report documents the work accomplished during the fourth reporting period in applying the principles of pattern recognition technology to the analysis of EEG.

Several additional sleep scoring decision systems were investigated. Most classifications are performed satisfactorily. However, no reliable single channel frequency relationships have been discovered for separation of Stage 1 and REM. Also the transitional nature of Stage 3 patterns leads to confusing these patterns with Stage 2 or Stage 4.

Cluster analysis was applied to frequency indicators derived from an overnight sleep record. Selection of clusters independent of human scoring demonstrated well defined groupings for awake, Stage 1 and REM combined, Stage 2 and Stage 4. Stage 3 patterns were split between the Stage 2 and Stage 4 clusters.

Sleep scoring decision systems based upon frequency analysis of a single channel of EEG have been designed for each of two Tektite I aquanauts.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Sleep EEG						
Sleep						
EEG						
Sleep Stage Classification						
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Automatic Sleep Scoring						

FOREWORD

This report was prepared by the McDonnell Douglas Astronautics Company - West under ONR Contract N00014-68-C-1277. This work is sponsored by the Psychological Sciences Division, Office of Naval Research, Department of the Navy, Washington, D. C. Dr. Eugene E. Gloye, ONR Pasadena is Technical Coordinator of the contract. The studies began on May 15, 1968. This document is the fourth periodic technical report.

Work on the contract was performed by the Pattern Recognition Research Group under the direction of S. S. Viglione. The principal contributors to the program were W. B. Martin (Project Leader) and E. F. Carrison

This study is being performed in conjunction with the Sleep Research Program being conducted by Dr. L. Johnson and his staff at the Navy Medical Neuropsychiatric Research Unit (NMNPRU), San Diego. The sleep records have been provided by the NMNPRU who also perform the manual scoring of the records and assist in the technical evaluation of the classification results.

SUMMARY

This report documents the work accomplished during the fourth reporting period in applying the principles of pattern recognition technology to the analysis of EEG.

Several additional sleep scoring decision systems were investigated. Most classifications are performed satisfactorily. However, no reliable single channel frequency relationships have been discovered for separation of Stage 1 and REM. Also the transitional nature of Stage 3 patterns leads to confusing these patterns with Stage 2 or Stage 4.

Cluster analysis was applied to frequency indicators derived from an overnight sleep record. Selection of clusters independent of human scoring demonstrated well defined groupings for awake, Stage 1 and REM combined, Stage 2 and Stage 4. Stage 3 patterns were split between the Stage 2 and Stage 4 clusters.

Sleep scoring decision systems based upon frequency analysis of a single channel of EEG have been designed for each of two Tektite I aquanauts.

CONTENTS

1.0 INTRODUCTION 1

2.0 SUMMARY OF PROGRESS 4

- 2.1 Data Processing 4
- 2.2 Recognition System Design 4
- 2.3 Clustering 12
- 2.4 Tektite Recognition System Design 15
- 2.5 On Line Sleep Scoring 18

3.0 PROGRAM FOR NEXT REPORTING PERIOD 22

DISTRIBUTION LIST 23

FIGURES

1 Sleep Stage Classification System Block Diagram 2

2 Classification Performance of Decision Tree 1 (16 Sec., 1 Subj.) 5

3 Classification Performance of Decision Tree 2 (16 Sec., 6 Subj.) 7

4 Classification Performance of Decision Tree 3 (32 sec., 1 Subj.) 8

5 Classification Performance of Decision Tree 4 (32 Sec., 6 Subj.) 10

6 Classification Performance of Decision Tree 5 (32 Sec., 4 Hi Alpha Subjects) 11

7 Cluster Points Selected from Small Data Base (Subject 02S) 14

8 Confusion Matrix - 158 Patterns from Subject 02S 16

9 Clustering Results for Overnight Baseline, Subject 02S 17

10 Confusion Matrix (Tektite Decision Trees Tested on Base Line Data) 19

11 Confusion Matrices Comparing Off Line and On Line Performance for the Clifton 26 Indicator Decision System 21

1.0 INTRODUCTION

Researchers studying the relationships between sleep and psychological or physiological phenomena rely heavily upon the electroencephalograph (EEG) recording in categorizing various sleep periods of normal human subjects. The present method of visually classifying EEG records in the awake and various sleep categories requires a great deal of time on the part of a skilled encephalographer; also, the human scorers are not always consistent in interpreting the scoring rules for each sleep category. The objectives of this program include processing and analyzing EEG waveforms recorded from normal subjects during awake and sleep periods with the ultimate goal of establishing a method of scoring the records automatically.

Two broad approaches are being attempted. The first involves performing a frequency analysis of short time epochs of the EEG, and allowing a self-organizing pattern recognition system to associate the frequency information with correct decisions on a set of sample patterns previously classified by human scorers. If a representative sample of each sleep state may be obtained and sufficient information is retained in the spectrum of the EEG, no knowledge of sleep patterns is required. The recognition system will adaptively derive the appropriate correlations between the frequency information and the sleep state. This approach will demonstrate if frequency information alone, from one EEG channel, is sufficient for sleep scoring.

The second area of investigation, called "Known Property Extraction", requires detailed knowledge of the various EEG patterns associated with one or more stages of sleep. An attempt is made to develop detectors or indicators that highlight specific patterns such as K complexes or spindles. It is expected that these indicators will serve as useful inputs to augment the frequency information and increase the classification accuracy of the recognition system.

Each approach may be investigated, evaluated, and implemented separately or the two approaches may be combined in a single system. Figure 1 is the overall system block diagram in which both approaches are combined. Known properties may be extracted separately from the Fourier

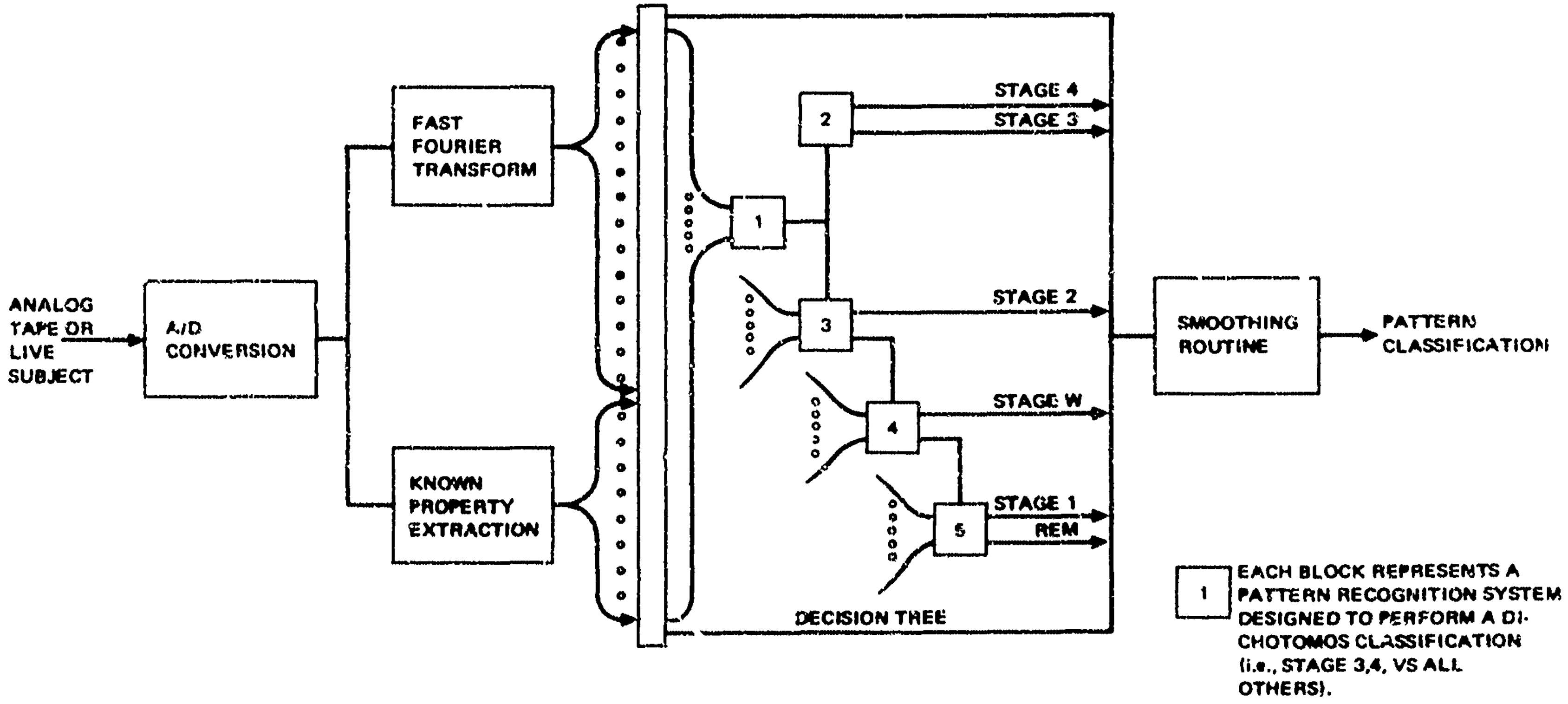


Figure 1. Sleep Stage Classification System Block Diagram

magnitudes but the recognition system is provided with all inputs pertaining to the epoch to be classified. The system operates on all indicators to determine the output classification.

Details concerning data collection, conversion and Fourier transformation as well as descriptions of the recognition systems and decision tree logic have been presented in previous technical reports.

2.0 SUMMARY OF PROGRESS

2.1 Data Processing

Since the inception of this program a library of sleep EEG recordings has been accumulated and has served as a rich source of data for testing signal transformation and pattern recognition techniques. These recordings are being generated by the Navy Medical Neuropsychiatric Research Unit (NMNPRU), San Diego, in the course of their sleep deprivation experiments. The first phase of their data collection effort resulted in normal overnight baseline recordings from 13 subjects plus selected portions from deprivation recovery nights. The data from six of these subjects were used as a design base for sleep stage classification systems. The remaining records were reserved as independent tests.

2.2 Recognition System Design

Four decision tree designs were accomplished during this reporting period. For the sake of completeness two previously reported designs will also be discussed. These designs used frequency information derived from the Fourier Transform of one channel of EEG. Spectral indicators covered the range from 0.2 Hz to 26 Hz. The results tabulated in this section do not represent performance averaged over subjects. It was believed that more insight into the usefulness of the decision systems and the nature of the disagreements with human scorers could be obtained by presenting individual examples for typical subjects. The format chosen was the confusion matrix (Figure 2). On the left of the matrix are listed the classes and number of patterns placed in each class by visual scoring of the EEG test record. The right portion details the categories into which these patterns were placed by the decision system. For example, in Figure 2a, 88.1 percent of the patterns visually classified as Stage 4 were correctly identified while 6.9 percent were placed in the Stage 3 category by the decision tree.

Class	No. of Samples	*	Percent of Samples Classified into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	217	*	99.5			.5		
Stage 1	18	*		11.1	77.8	11.1		
REM	63	*	4.8	7.9	74.6	12.7		
Stage 2	274	*	.7	1.1	1.1	77.0	11.3	8.8
Stage 3	42	*			2.4	16.7	23.8	57.1
Stage 4	159	*				5.0	6.9	88.1

Overall Performance = 81.0

a. Subject 02S Recovery Sleep (Independent Test)

Class	No. of Samples	*	Percent of Samples Classified into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	33	*	90.9			9.1		
Stage 1	26	*	3.8	42.3	46.2	7.7		
REM	122	*	16.4	13.1	43.4	27.0		
Stage 2	296	*	.3	1.7	3.0	92.6	2.4	
Stage 3	31	*				54.8	32.3	12.9
Stage 4	335	*				20.9	18.5	60.6

Overall Performance = 68.9

b. Subject 09C Baseline Sleep (Independent Test)

Figure 2. Classification Performance of Decision Tree 1
(16 Sec, One Subj)

Two such tables will be shown for each design indicating fairly typical performance on high alpha subjects. The first matrix represents an independent test on a subject whose sleep records were included in the design base. This data was recorded one week after the initial sleep record used in the system designs. The second matrix is associated with data from an independent high alpha subject whose patterns were never included in the design base.

Decision Tree 1 (Figure 2) was designed using spectra for 16.4-second epochs from a single night of sleep from one high alpha subject. Performance on Awake data is quite good. The failure to discriminate between Stage 1 and REM is characteristic of this and subsequent designs. The difficulty in matching human scoring of Stage 3 is also evident.

The second decision tree (Figure 3) used a data base derived from six people including high and low alpha subjects. There is a marginal improvement in Stage 3 performance, but overall percentage of correct classifications declined over those achieved with the single subject high alpha design.

Since the human scoring was based upon examination of 30-second segments of the EEG it seemed reasonable to allow the recognition system to look at longer epoch lengths to reduce the variability from one period to the next. It was found that better agreement with the human scorer was achieved either by smoothing the system output classifications or by smoothing the spectrum which served as input to the system. The desire for less variability in the output classifications led to the design of Decision Trees 3 and 4 (Figure 4). Decision Tree 3 was essentially a repeat of the Decision Tree 1 design using 31.4 seconds rather than 16.4 seconds for the epoch length. There was a noticeable decrease in per cent agreement for Awake and Stage 3 patterns. This can be attributed to the scarcity of training patterns for these stages. The other stages showed increased agreement over the system designed on short epochs, (including Stage 1, REM if taken as a single class).

Confusion Matrix for File 1

Class	No. of Samples	*	Percent of Samples Classified into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	217	*	98.6	.5		.9		
Stage 1	18	*		61.1	27.8	11.1		
REM	63	*	3.2	38.1	47.6	11.1		
Stage 2	274	*		1.8	.4	59.9	27.7	10.2
Stage 3	42	*				11.9	35.7	52.4
Stage 4	159	*				1.9	10.7	87.4

Overall Performance = 74.1

a. Subject 02S Recovery Sleep (Independent Test)

Confusion Matrix for File 3

Class	No. of Samples	*	Percent of Samples Classified into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	33	*	78.8	6.1		12.1	3.0	
Stage 1	26	*		26.9	15.4	57.7		
REM	122	*	.8	24.6	47.5	26.2	.8	
Stage 2	296	*		1.4	.7	93.9	3.7	.3
Stage 3	31	*				35.5	54.8	9.7
Stage 4	335	*				4.8	51.3	43.9

Overall Performance = 63.2

b. Subject 09C Baseline Sleep (Independent Subject)

Figure 3. Classification Performance of Decision Tree 2
(16 Sec, Six Subjects)

Class	No. of Samples	*	Percent of Samples Classified into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	103	*	92.2	6.8		1.0		
Stage 1	7	*			100.0			
REM	30	*		3.3	83.3	13.3		
Stage 2	134	*				83.6	6.0	10.4
Stage 3	19	*		5.3		21.1	15.8	57.9
Stage 4	78	*				2.6	1.3	96.2

Overall Performance = 83.6

a. Subject 02S Recovery Sleep (Independent Test)

Class	No. of Samples	*	Percent of Samples Classified into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	15	*	40.0	20.0		40.0		
Stage 1	12	*		16.7	58.3	25.0		
REM	58	*	13.8	10.3	53.4	20.7	1.7	
Stage 2	142	*		.7	2.1	93.0	2.8	1.4
Stage 3	14	*				64.3	14.3	21.4
Stage 4	166	*				20.5	3.0	76.5

Overall Performance = 73.7

b. Subject 09C Baseline Sleep (Independent Subject)

Figure 4. Classification Performance of Decision Tree 3
(32 Sec, One Subject)

The six subject design was also repeated using 31.4-second spectra and data from six subjects. This Decision Tree 4 (Figure 5) suffered a decrease in the percentage of Awake patterns correctly classified for which no reasonable explanation could be found. The system exhibited a general improvement for all other classes (except for a problem with Stage 3 on the independent subject).

It became apparent that amplitude variations from subject to subject were causing an undesirable overlap in spectral intensity for adjacent sleep stages. To effect a coarse screening of subjects, Decision Tree 5 (Figure 6) was designed using sleep recordings from four high alpha subjects. Disregarding the problem of discriminating between Stage 1 and REM, Decision Tree 5 showed improvement over Decision Tree 4 in every classification category, including separation of Stage 1 and REM patterns from the other stages of sleep. This improvement did not carry over to low alpha subjects.

Decision Tree 6 represented an attempt to improve the scoring performance on Stage 3 patterns by restructuring the decision tree. Several configurations were tried but improved identification of Stage 3 could not be achieved without sacrificing accuracy on Stage 2 or Stage 4.

The results to date provide some insight into the two most noticeable problems -- lack of separation between Stage 1 and REM and confusion of Stage 3 with Stages 2 and 4. In some cases the pattern recognition algorithm selected combinations of spectral components which allowed better than chance separation of Stage 1 from REM test patterns selected from the same nights of sleep used for the design base (70 percent to 75 percent correct classification). However, this performance was drastically degraded when applied to other nights of sleep from the same subject or to other subjects (average percent correct was about 50 percent). The Stage 1 versus REM discriminations based upon spectral analysis of one EEG channel do not provide sufficiently close agreement with human scorers to be useful in scoring sleep records. This may be due to the small number of Stage 1

Class	No. of Samples	*	Percent of Samples Classified Into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
Awake	103	*	96.1			3.9		
Stage 1	7	*		71.4	28.6			
REM	30	*		40.0	53.3	6.7		
Stage 2	134	*		1.5	.7	77.6	14.2	6.0
Stage 3	19	*				21.1	42.1	36.8
Stage 4	78	*				2.6	9.0	88.5

Overall Performance = 81.1

Subject 02S Recovery Sleep (Independent Test)

Class	No. of Samples	*	Percent of Samples Classified Into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
Awake	15	*	33.3	6.7		60.0		
Stage 1	12	*		41.7	16.7	41.7		
REM	58	*		15.5	50.0	34.5		
Stage 2	142	*		.7		96.5	2.1	.7
Stage 3	14	*				50.0	28.6	21.4
Stage 4	166	*				6.0	42.8	51.2

Overall Performance = 65.1

Subject 09C Baseline Sleep (Independent Subject)

Figure 5. Classification Performance of Decision Tree 4
(32 Sec, Six Subjects)

Class	No. of Samples	* * *	Percent of Samples Classified Into Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
Awake	103	*	100.0					
Stage 1	7	*			100.0			
REM	30	*		3.3	80.0	16.7		
Stage 2	134	*				84.3	11.2	4.5
Stage 3	19	*				10.5	47.4	42.1
Stage 4	78	*					5.1	94.9

Overall Performance = 87.1

a. Subject 02S Recovery Sleep (Independent Test)

Class	No. of Samples	* * *	Percent of Samples Classified Into Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
Awake	15	*	100.0					
Stage 1	12	*		16.7	58.3	25.0		
REM	58	*		1.7	72.4	25.9		
Stage 2	142	*		1.4	1.4	96.5	.7	
Stage 3	14	*				64.3	35.7	
Stage 4	166	*				3.6	4.2	92.2

Overall Performance = 87.0

b. Subject 09C Baseline Sleep (Independent Subject)

Figure 6. Classification Performance of Decision Tree 5
(32 Sec, Four High Alpha Subjects)

patterns available for system design from a typical night of sleep and it is possible that analysis of a larger data base may uncover discriminating relationships between frequencies. However, no reliable single channel frequency relationships have yet been discovered for separation of Stage 1 from REM.

As expected, frequency analysis provided excellent discrimination between Awake patterns and all other sleep stages for dominant alpha subjects. Stages 3 and 4 patterns were rarely confused with Stage 1, REM or Awake. The confusion between REM and Stage 2 patterns was somewhat greater but acceptable for sleep scoring on high alpha subjects.

The decision trees exhibited a strong tendency to confuse Stage 3 epochs with Stage 2 or Stage 4. The confusion was apparently due to three factors. First, Stage 3 is transitional in nature and contains features found in Stage 2 (k complexes, spindles) and Stage 4 (slow waves).

In addition, there are fewer Stage 3 patterns than Stage 2 or Stage 4 epochs providing only a marginal sample size for analysis. This may be compensated for by adjusting the design algorithms to place more emphasis on the Stage 3 patterns. However, this leads to a sharp reduction in performance for Stage 2 and 4 suggesting that a significant proportion of the Stage 2 and 4 spectral patterns lie within the Stage 3 distribution.

Examination of means and standard deviations accumulated for spectral indicators in the delta band reinforces this conclusion. For the two subjects presented in Figures 5 through 9, most of the Stage 3 spectral means are within one standard deviation of the Stage 2 mean or the Stage 4 mean. The cluster analysis reported in Section 2.3 also provides supporting evidence for the above conclusion.

2.3 Clustering

There has been considerable concern expressed among members of the sleep research community about the appropriateness of the adopted scoring criteria based upon six distinct stages of sleep (including awake).

For example, the specification for Stage 3 that EEG epochs contain more than 20 percent but less than 50 percent delta activity represented a somewhat arbitrary attempt to differentiate the transitional state between the low voltage, spindle sleep of Stage 2 and the full slow wave sleep of Stage 4. It might be possible to define a set of sleep stages more closely related to the underlying physiologic states of the subject.

To investigate this question, a clustering program adapted by McDonnell Douglas was applied to a small set of about 150 sleep patterns from one subject. The clustering algorithm is a simple one and to a certain extent is dependent on working with input indicators having as little extraneous noise as possible. The four indicators selected represented the strength of EEG activity in four clinical EEG bands (delta, theta, alpha, and sigma) and were derived using the Fourier transform. Initially each pattern is considered to be a cluster point with a weight of one. On each pass through the data, the two points with the minimum interpoint distance are merged into one cluster point with a weighting equal to the sum of the two individual cluster point weights.

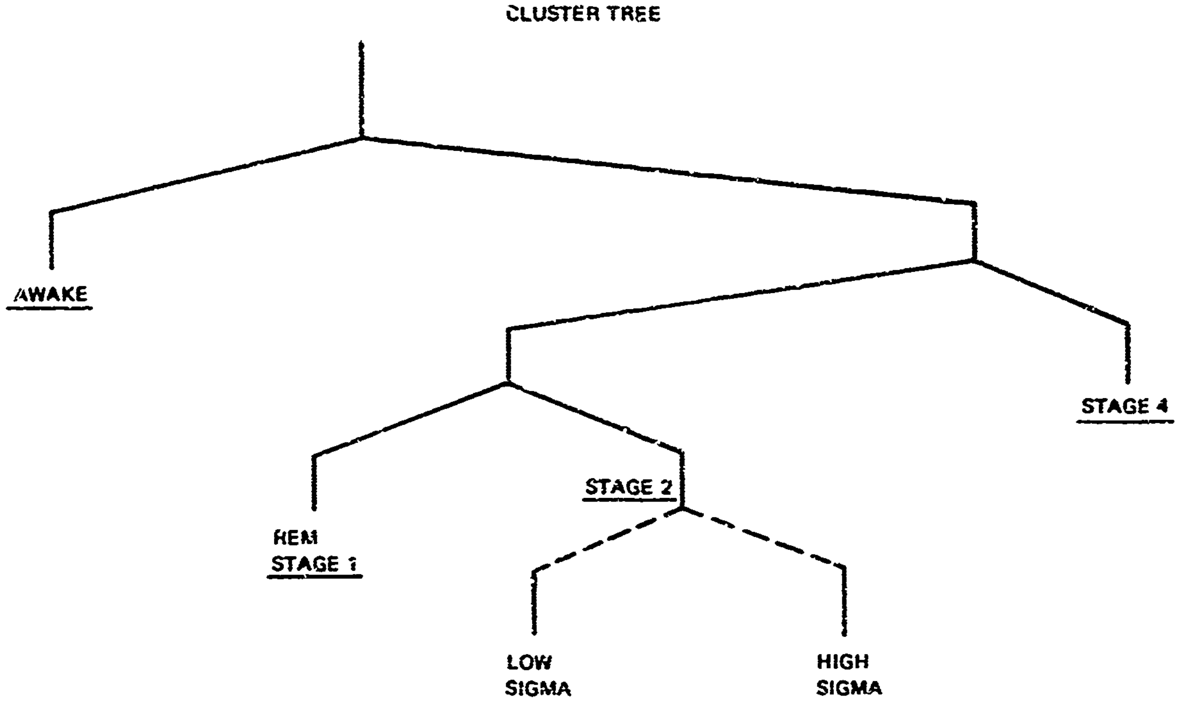
$$\text{Minimum Interpoint Distance} = \overset{\text{min}}{j,\ k} \sum_{n=1}^{N} (x_{jn} - x_{kn})^2$$

where N = number of dimensions,

and j and k run over the set of data points.

The coordinates of the new cluster point are equal to the weighted average of the two old coordinates. Eventually all data points are clumped in a single cluster, terminating the run. By working backwards from this point, the major groupings may be found. These groupings may be entirely independent of the classifications assigned by the human scorer.

In analyzing the cluster development for 158 patterns from subject 02S, five distinct clusters were located. Figure 7 illustrates the manner in which these clusters were clumped together to form the single cluster point at the end of the run. The table below this figure lists the values of the four spectral components of each cluster. Each of the four spectral indicators



UNDERLINED NODES WERE SELECTED FOR CONFUSION MATRIX EVALUATION.

CLASS	PASS	DELTA	THETA	ALPHA	SIGMA
AWAKE	143	108	390	865	233
1, REM	115	174	410	220	213
HI AMP					
2	153	351	625	417	796*
Lo AMP					
2	146	309	552	306	522*
4	152	759	856	367	456

*NOTE THE STRONG DIFFERENCE IN SIGMA AMPLITUDE

Figure 7. Cluster Points Selected from Small Data Base (Subject 02S)

had been scaled to an arbitrary maximum value of 1000. The most interesting features of this table are the absence of a well defined Stage 3 cluster and the formation of two distinct Stage 2 clusters. The prime characteristic distinguishing the two Stage 2 clusters is the strong difference in sigma (sleep spindle) amplitude. This set of five clusters was reapplied to the 158 patterns. Each pattern was assigned the classification of the closest cluster and the resulting confusion matrix is shown in Figure 8. The most notable feature is the almost even split of the stage 3 patterns between the Stage 2 clusters and the Stage 4 cluster.

The clustering program was next applied to a larger data base of 622 patterns from subject 02S. Again the clusters were chosen after the design run independently of the human scoring. The selected clusters were tested on the design base and on a test set of 151 patterns reserved from the same night of sleep. These results shown in Figure 9 clearly validate the integrity of the Awake, Stage 1-REM, Stage 2 and Stage 4 classification. The existence of a separate Stage 3 and the split between Stage 1 and REM were not reflected in the four clinical EEG frequency bands used as input to the clustering program.

A note of caution should be observed in interpreting these results. The analysis presented above was based upon patterns from one subject. Also the program was provided inputs reflecting only the results of frequency analysis of one EEG channel. Information concerning phasic events such as k complexes or rapid eye movements was not used by the clustering routine.

2.4 Tektite Recognition System Design

McDonnell Douglas proposed to process a large batch of overnight recordings from two of the Tektite I aquanauts to evaluate the effectiveness of applying the sleep scoring decision trees to large data bases collected from single individuals. The recognition system designs are to be based upon Fourier analysis of a single channel of EEG.

Recognition systems have been designed for Edward Clifton and John Vanderwalker based on baseline overnight sleep recordings obtained

Visual Scoring	No. of Pat.	Cluster Scoring (Percent)				
		W	1, R	2	3	4
W	4	100.				
1, R	34		97.	3.		
2	92			98.		2.
3	7			43.		57.
4	21					100.

Figure 8. Confusion Matrix - 158 Patterns From Subject 02S

Visual Scoring	No. of Pat.	Cluster Scoring (Percent)				
		W	1, R	2	3	4
W	16	100.0				
1, R	154		89.0	11.0		
2	340		3.5	93.5		2.0
3	28			46.5		53.5
4	84			2.4		97.6

a. Design Pattern Set (622 Patterns)

Visual Scoring	No. of Pat.	Cluster Scoring (Percent)				
		W	1, R	2	3	4
W	3	100.0				
1, R	38		81.6	18.4		
2	84			91.7		8.3
3	6			66.6		33.3
4	20					100.0

b. Test Pattern Set (151 Patterns)

Figure 9. Clustering Results for Overnight Baseline, Subject 02S

at the NMNPRU facility in San Diego. It was necessary to perform four separate decision tree designs in order to produce a satisfactory system for scoring Clifton's baseline records. There were problems with respiration artifacts discovered on one EEG channel and uncoded muscle artifacts. Also Clifton's alpha was quite low, creating difficulties in distinguishing between Awake and Stage 1. A considerable effort has been made to clean up this data base. Examples of decision tree performance on baseline data (used for training and test) are shown in Figure 10.

Tapes recorded from Clifton during the Tektite I project have been received from NMNPRU and will be processed in the immediate future. Some of these records have been hand scored and will provide an excellent test of the system's ability to generalize to other nights of sleep. The bulk of the processing of the Tektite data will be performed during the next reporting period.

2.5 On-Line Sleep Scoring

The sleep scoring systems developed for Ed Clifton were modified for insertion into McDonnell Douglas' on line sleep scoring demonstration program. This program monitors one channel of EEG, either tape recorded or from a live subject; performs analog-to-digital conversion at 62.5 Hz; calculates the Fourier transform; and implements the recognition system and decision tree logic. A sleep stage classification is produced for each 30-second epoch. As an option the spectra and associated classification assigned by the system are written on digital magnetic tape.

Several experiments were performed in order to "tune up" the on line system to produce classifications comparable to those produced by the same decision tree off line. The most significant trial involved redesigning the Clifton decision system to operate with a coarser frequency resolution. Initially the decision trees operated on 130 spectral indicators each with a bandwidth of 0.2 Hz and covering the range from 0.2 to 26 Hz. These systems have been susceptible to slight changes in analog conditions and in the epoch starting time. The Clifton decision system was redesigned using 26 indicators, each covering a 1 Hz bandwidth. This tree appears to

Class	No. of Samples	*	Percent of Samples Classified Into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	9	*	88.9			11.1		
Stage 1	12	*		91.7		8.3		
REM	69	*	2.9	23.2	72.5	1.4		
Stage 2	183	*		4.4	3.3	89.1	2.2	1.1
Stage 3	27	*				14.8	70.4	14.8
Stage 4	67	*					7.5	92.5

Overall Performance = 85.3

a. Vanderwalker System

Class	No. of Samples	*	Percent of Samples Classified Into					
		*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
Awake	16	*	93.8	6.2				
Stage 1	35	*	11.4	74.3	11.4	2.9		
REM	106	*		4.7	91.5	3.8		
Stage 2	164	*	.6	4.9	8.5	84.8	1.2	
Stage 3	18	*				50.0	38.9	11.1
Stage 4	69	*				1.4	14.5	84.1

Overall Performance = 83.8

b. Clifton System

Figure 10. Confusion Matrix (Tektite Decision Trees Tested on Baseline Data)

be less susceptible to variations introduced by the analog electronics. Confusion matrices for both the off line and on line decision trees are shown in Figure 11. A slightly greater tendency to code REM patterns as Stage 2 can be observed for the on line system; otherwise the performance percentages are similar for the pattern classes represented in this particular 4-hour tape. Both the 130 indicator and the 26 indicator systems will be retested to develop run-to-run reliability figures.

		*	Percent of Samples Classified Into					
Class	No. of Samples	*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
REM	68	*	1.5		91.2	7.4		
Stage 2	157	*			4.5	76.4	16.6	2.5
Stage 3	43	*			4.7	16.3	65.1	14.
Stage 4	143	*					5.6	94.4

Overall Performance = 83.9

a. Off Line Performance

		*	Percent of Samples Classified Into					
Class	No. of Samples	*	Awake	Stage 1	REM	Stage 2	Stage 3	Stage 4
		*						
REM	68	*	1.5	13.2	70.6	14.7		
Stage 2	157	*			2.5	83.4	14.0	
Stage 3	43	*				27.9	60.5	11.6
Stage 4	144	*					5.6	94.4

Overall Performance = 82.8

b. On Line Performance

Figure 11. Confusion Matrices Comparing Off-Line and On Line Performance for Clifton 26-Indicator Decision System.

3.0 PROGRAM FOR NEXT REPORTING PERIOD

Analog data from the NMNPRU sleep deprivation study group "A" will be digitized and transformed. Copies will be provided to NMNPRU as requested.

Decision systems will be designed incorporating information derived from two EOG channels as well as the spectral indicators. Reconfiguration of the decision tree will receive continued study.

Techniques for automatically screening movement artifacts from the data will be investigated.

A substantial number of overnight recordings obtained from two Tektite I aquanauts will be scored by computer and summary plots of sleep stages will be generated. These will be compared with the analog scorings provided by NMNPRU.