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APPLICATION OF SOME NEW ARTIFICIAL NEURAL SYSTEM
PROCESSING PRINCIPLES TO (U) TRM RANCHO CARMEL
ARTIFICIAL INTELLIGENCE CENTER SAN DIEGO CA.
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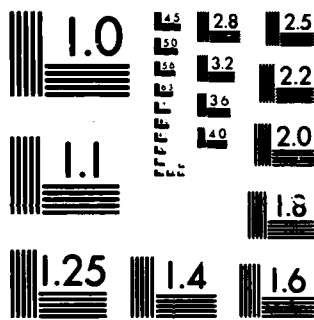
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The overall goal of the (ARO) study is to provide a firm conceptual and theoretical foundation for future work in ANS by exploring the use of three information processing principles. This entails both experimental exploration and theoretical development of "design laws" that can quantitatively predict system behavior and performance. This interim report describes the pattern environment which will support the planned experimentation. The pattern environment is a simple version of spoken english (called Lenglish), (con't)

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where each letter is associated with an arbitrary sound spectrum and there is a continuous transition between the spectra of adjacent letters. The signal input to the ANS will be the English reading of selected source texts.

The planned experimentation will use a model of unsupervised learning to discover feature detectors for spatiotemporal segments of the input language.

ARO 22323.1-MA

**Application Of Some New Artificial Neural System
Information Processing Principles
To Pattern Classification**

Interim Technical Report

**Robert Hecht-Nielsen
Carolyn Smith**

18 November 1985

**US Army Research Office
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1 Introduction

This report documents the progress to date on the Army Research Office/TRW *Application Of Some New Artificial Neural System Information Processing Principles To Pattern Classification* study. An important milestone has been reached in that we have selected the pattern environment and have developed a pre-processing tool which generates that environment for experimentation.

1.1 ARO Study Overview

The overall goal of the ARO study is to provide a firm conceptual and theoretical foundation for future work in ANS. In this effort we are exploring the use of three information processing principles (hierarchical template pattern storage, temporal compression, and simultaneous competitive template matching) and developing concise mathematical formulations of these principles. This will be accomplished with 6 tasks:

- The primary purpose of Task 1 is to select the pattern environment which supports the experimentation and develop the necessary pre-processing. This part of Task 1 has been completed and is documented in this interim report. Additional work on pre-processing techniques such as the Fourier-Mellin transform will be done as the study progresses.
- The work under Task 2 will use the signal environment to carry out experiments with a multi-slab ANS.
- In Task 3, data reduction and analysis will be conducted using the experimental data generated in Task 2.
- In Task 4, theoretical principles of ANS information processing will be developed, using the analysis of Task 3.
- Tasks 5 and 6 will document the work done in final and interim reports.

The schedule for these tasks is given in Figure 1.

1.2 Signal Environment For Experimental Work

The pattern environment which will be the substrate for the experimental work has been selected as a result of our work under task 1. We have decided to use a simple version of spoken English, which we call Letter-English or Lenglish. A description of Lenglish is given in section 2. The initial signal input to the experimentation will be the Lenglish reading of selected source texts, described in section 3. Section 4 of this report outlines our experimental plans for exploring the three processing principles using this pattern environment.



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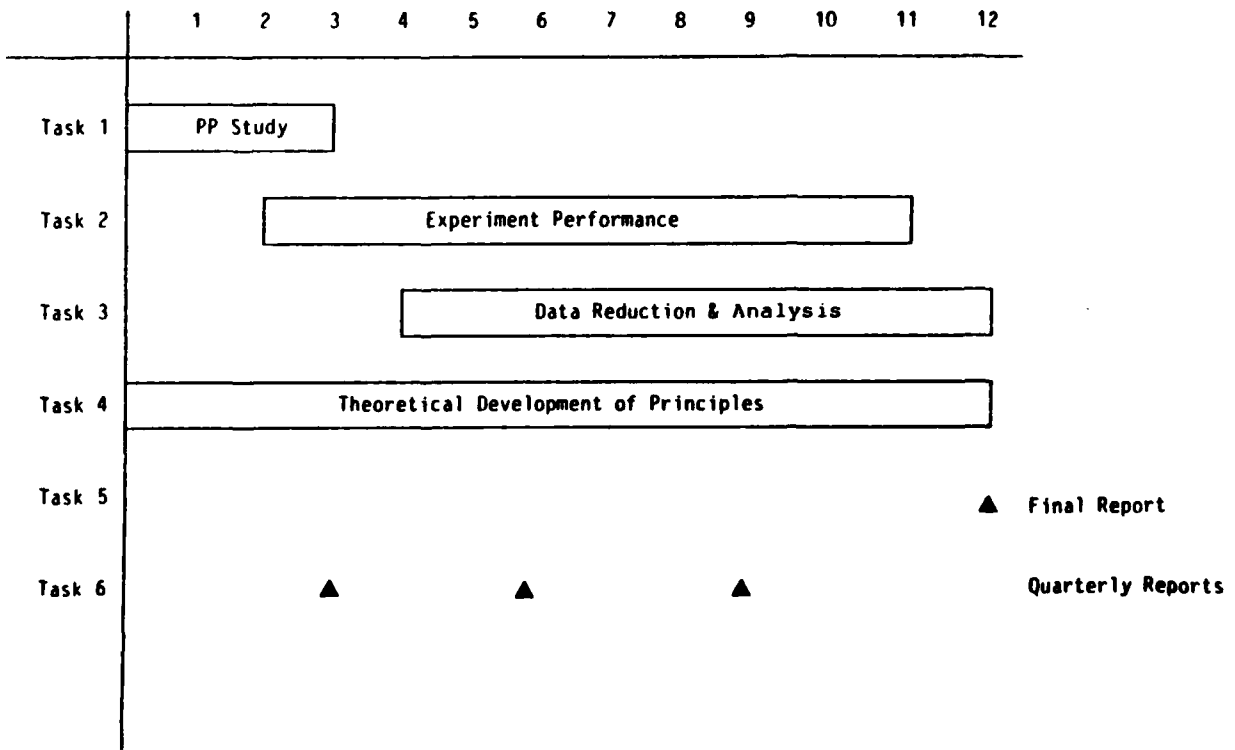


Figure 1: Schedule

2 Lenglish Description

The basic concept of Lenglish is to associate an arbitrary "sound" spectrum with each letter in the English language. Specifically, each letter in the alphabet is assigned one vector from a set of nearly orthogonal 32-dimensional vectors. The zero vector is used to represent pauses in speech between words. Pauses can be removed, if desired, to simulate the effect of word merging. To simulate the continuous nature of spoken language there is a smooth transition between adjacent letters within a word. The transition vectors are generated by convex combination of the adjacent letters' vectors. All of the vectors are normalized to "unit" length except the zero vector and transition vectors to or from the zero vector.

A pre-processing tool generates the signal input to the ANS by translating English text into Lenglish. The tool first finds the spectrum associated with a letter in the text stream. This spectrum is normalized and then repeated or "sampled" a user specified number of times. The tool then generates a user specified number of transition vectors to the spectrum of the next letter in the text. Blanks in the text separating words represent pauses in speech and so are translated into the zero vector.

A movie has been made which shows the input signal generated by the pre-processing tool. Figure 2 shows one frame from the movie. The text rolls across the screen from right to left. A fixed arrow indicates the current letter or transition being processed. The window below the text displays the spectrum for the current letter or transition.

3 Text Sources

In selecting the initial source text to be translated into Lenglish, we wanted a source with a restricted vocabulary, relatively short words, and a lot of repetition. For this reason we decided to use the text of childrens books to define the language. We have chosen the classic "The Little Engine That Could" by Watty Piper and the popular "Frog And Toad Are Friends" by Arnold Lobel. "The Little Engine That Could" contains 1349 words and uses a vocabulary of 302 words. The letter frequencies are given in Table 1. Most of the words are used infrequently, however about 10 percent of the words (24 words) are repeated at least 10 times in the text. The vocabulary set, with associated frequencies, is shown in Table 2. The second book, "Frog And Toad Are Friends", contains 2702 words and uses a vocabulary of 412 words. Over 20 of the words are repeated 20 times or more in the book. The letter and word frequencies are given in Tables 1 and 3.

4 Experimental Plans

The Lenglish signal input derived from the source texts will be divided into training sets and test sets. These sets are the input stimulus to a multi-slab ANS such as the design sketched in figure 3. Our approach to the ANS experimentation with the pattern environment uses a model of unsupervised learning with competition. In this model, a competitive mechanism will be used to discover a set of feature detectors for the input stimulus. This is essentially the competitive learning of Rumelhart [1], with an important extension. Rumelhart's work demonstrated how an

Army Research Office
Artificial Neural Systems
Pattern Environment

TRW

FROG RAN UP THE PA



Figure 2: Input to ANS

Letter	Freq in "Engine"	Freq in "Frog"
A	309	772
B	67	136
C	97	109
D	255	484
E	577	885
F	85	229
G	138	234
H	285	496
I	318	502
J	7	9
K	40	116
L	312	328
M	62	170
N	384	504
O	380	880
P	94	115
Q	1	3
R	221	408
S	265	442
T	447	915
U	165	262
V	39	59
W	100	222
X	0	6
Y	125	182
Z	2	4
.	86	162
.	97	282

Table 1: Frequency Of Letter Use

ANS can organize itself into feature detectors for spatial patterns. Our work under this study will extend these results to the case of time varying (spatio-temporal) patterns. During experimentation the time-varying signal of the simulated speech will be presented to the ANS. When the system reaches equilibrium, slab 1 will have discovered feature detectors for pattern primitives, possibly letters. The output of the slab 1 feature detectors are then the input to slab 2 which uses the same type of mechanism to discover feature detectors for higher level patterns, possibly letter pairs or word fragments. Similarly, each slab in the multi-slab system uses the same basic design to discover features in the input from the lower level slab. Success in self organization is achieved if the system reaches equilibrium. The training sets are used to allow the system to self-organize and the test sets are used to determine if the system has indeed equilibrated on features of the English source.

Note that this application will simultaneously use all three of the information processing principles of interest to this study. Hierarchical pattern storage will be used to code primitive features of the pattern (i.e. letters) in the lowest level, and composite features such as letter sequences at higher levels in the hierarchy. Temporal compression will be used to reduce the time variability of higher level patterns. The recognition of time-varying patterns will occur as the avalanches compete for the privilege of being feature detectors for spatiotemporal segments of the input language.

Results of these experiments, as well as our theoretical results aimed at deriving "design laws" that can quantitatively predict system behavior and performance, will be given in later Interim Technical Reports and in the Final Report.

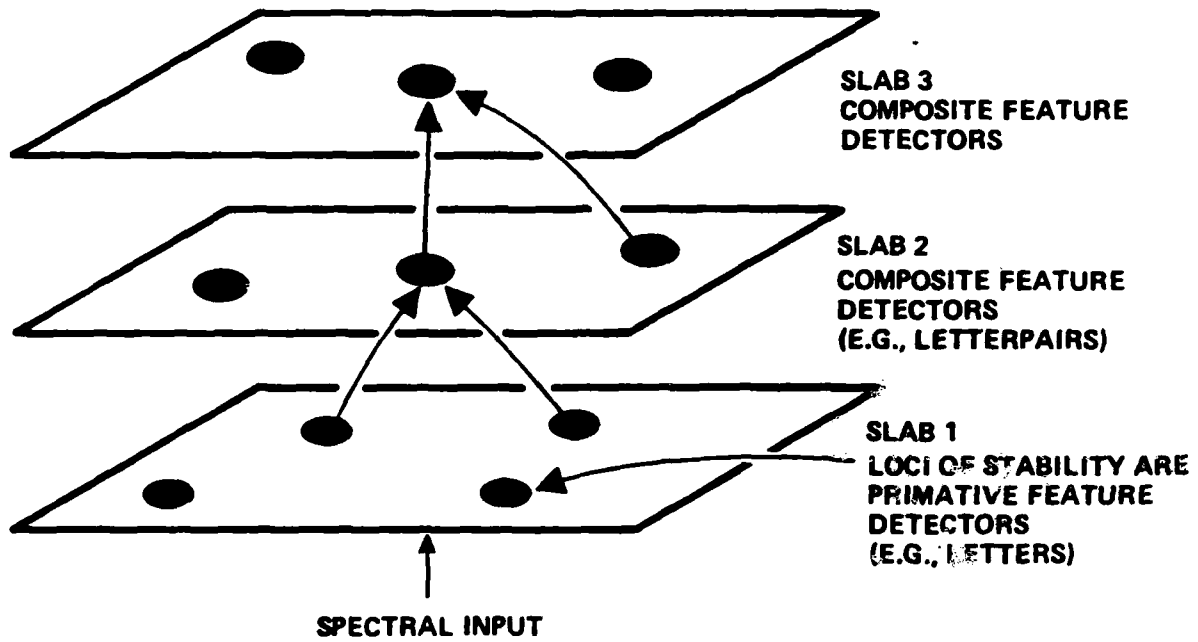


Figure 3: Multi-Slab ANS

86	(comma)	CITY	2	HELPED	2	ON	7	STOPPED	3	WONT	9
97	(period)	CLIMED	1	HER	2	ONE	4	STRONG	2	WORLD	4
16		CLOWN	9	WIFE	4	ONLY	3	SUCH	1	YARD	1
		CLOWNS	1	HERSELF	1	OR	6	SURDEN	1	YELLOW	1
		COMES	2	HIM	2	ORANGES	7	SWITCHING	1	YOUR	14
		COMFORTABLE	1	HIS	2	OTHER	8	TEARS	1	YOURS	1
		COMING	2	HITCHED	1	OUR	4	TENDY	1		
		COULD	8	HOW	1	OUT	9	THAN	1		
		CREAMY	1	HUNGRY	1	OVER	1	THAT	1		
		CRIED	6	HURRAY	2	PARLOR	1	THE	93		
		CRY	1	I	52	PASSENGER	2	THEIR	2		
		CURLS	1	IM	1	PEOPLE	2	THEN	5		
		DING	2	IMPORTANT	1	PERFUMINT	1	THERE	3		
80		DINNY	1	IN	8	PERHAPS	2	THESE	2		
4		DINNERS	1	INCH	1	PICTURE	1	THEY	4		
4		DINNING	1	INDEF	3	PLAY	1	THING	1		
5		ANY	1	INDIGNANTLY	1	PLEASE	6	THINGS	3		
1		APPLES	1	IS	6	PRINT	9	THINK	11		
1		ARE	14	JACK	1	PIFF	1	THOSE	7		
1		ARM	2	JERK	1	PIFFED	3	THOUGHT	1		
1		AS	6	JOLLY	1	PIFFED	3	TIED	2		
2		DREAMED	1	JUMPED	2	PIH	8	TO	27		
2		DROPS	1	JUST	2	PIHLED	3	TOGETHER	3		
1		EAT	7	KIND	3	PIZZELS	1	TOP	1		
2		ELEPHANT	1	KINDLY	1	QUICKLY	1	TOPS	1		
1		ENGINE	33	KNIVES	1	REACHED	1	TOYS	1		
1		ENGINES	2	LAY	1	READ	1	TRACKS	16		
1		EVEN	2	LAY	1	READY	1	TRAIN	9		
1		EVER	2	LIFE	1	RED	1	TREATS	1		
1		EVERY	1	LIKE	2	REF	1	TRIED	16		
1		EYES	3	LITTLE	33	REFST	3	TUGGED	2		
1		FASTER	4	LIVE	1	RIMBELD	1	TURN	2		
1		FELT	1	LOAD	1	RUMBELED	1	UNLESS	5		
1		FILLED	2	LOADED	1	RUSTY	2	UNTIL	1		
1		FINE	1	LOLLOPPS	1	SAD	3	UP	6		
10		FLAG	3	LONG	1	SAID	4	US	13		
1		FOOD	6	LOOK	1	SAW	3	USE	1		
1		FOR	8	LOOKED	1	SAY	1	USE	1		
2		FREIGHT	3	LOOKS	1	SPEMED	1	VALLEY	1		
1		FRESH	1	MACHINES	2	SHE	17	VERY	9		
11		FRIENDS	2	MATTER	1	SHINY	3	WAITERS	1		
1		FULL	2	MAYBE	1	SHIDE	7	WANT	2		
4		FUNNIEST	1	ME	1	SIGHED	1	WAS	4		
2		FUNNY	2	MEAL	1	SIMPLY	1	WAVED	2		
1		GET	1	MERRILY	2	SIT	1	WE	1		
1		GIRAFFES	1	MILK	1	SLEEPING	1	WEARY	1		
11		GIRLS	11	MORE	1	SLOWLY	3	WENT	1		
2		GLASS	1	MOUNTAIN	14	SMILE	1	WERE	8		
2		GO	1	MUST	2	SMILED	1	WHAT	2		
1P		GOING	1	MY	3	SHORTED	1	WHATEVER	1		
1		GOLDEN	1	NECKS	2	SO	6	WHEELS	2		
1		GODD	14	NEVER	2	SOFT	1	WHEN	2		
1		GREAT	1	NEW	3	SORTS	1	WHERE	2		
1		GROWN	1	NEWSPAPERS	1	SORTS	1	WHICH	2		
6		HAD	2	NO	1	SPEINACH	1	WHO	2		
1		HAPPY	2	NOT	1	STARTED	1	WILL	3		
1		HAS	4	OF	15	STEADILY	1	WITH	14		
2		HAVE	8	OFF	16	STONG	1	WITHOUT	1		
1		HE	4	OH	2	STOP	1	WONDERFUL	2		
1		HEADS	1	OLD	3						
2		HELP	9								

Table 2: Word Frequency for "Engine"

References

- [1] Rumelhart, D. E. and D. Zipser, 'Feature Discovery by Competitive Learning' *ICS Report No. 8407*, June 1984.

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