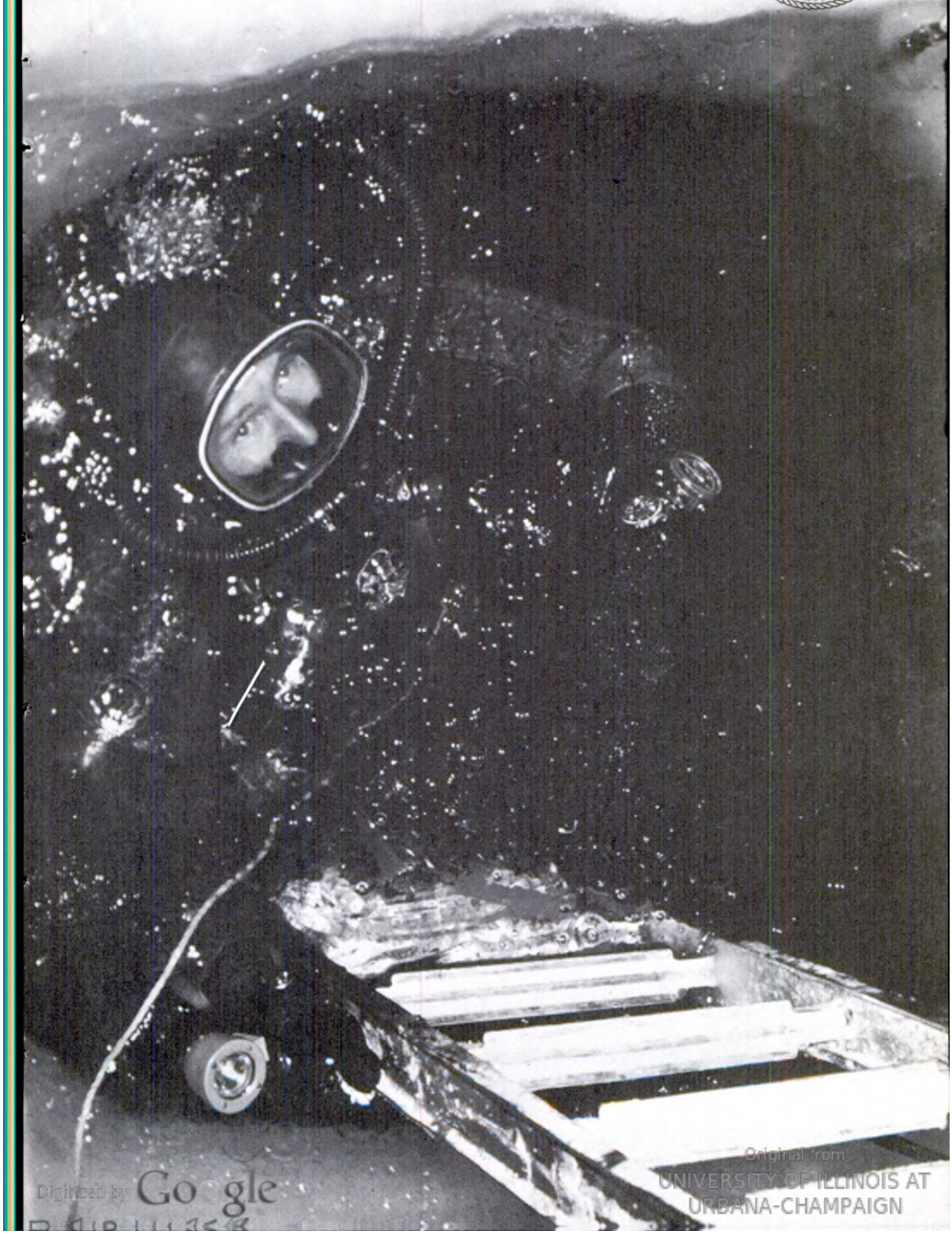
NAVAL RESEARCH

REVIEWS

AUGUST 1972



PROFILES IN SCIENCE

Dr. Leonard Carmichael

Dr. Leonard Carmichael has had many associations with the Navy during his long career as a scientist and administrator. His research in psychology concerns the functioning of sense organs and the nervous system as related to the development of adaptive behavior, efficiency, and fatigue. Along with the late Admiral Louis de Florez, he pioneered the development and testing of synthetic training devices. He also contributed to the development of trophysiological methods for recording eye movements and is an authority on the nature of visual fatigue.

From 1947-1953, Dr. Carmichael was a member of the Naval Research Advisory Committee. From 1952-1963, he was Secretary of the Smithsonian Institution and is now Vice-President for Research and Exploration of the National Geographic Society. A member of the National Academy of Sciences and President of the American Philosophical Society, in 1972 he received the triennially-awarded Hartley gold medal of the National Academy of Sciences "for eminence in the application of science to the public welfare."

Diving in the Arctic

Chester V. Bright*
U.S. Naval Oceanographic Office

In studies of sea ice dynamics it is desirable to obtain information about the geometry of both the top and bottom surfaces of the ice. Since only the top side can be surveyed rapidly at the present time, it would be advantageous to understand the correlation, if there is any, between bottomside and topside. This investigation was designed to determine an expedient means for obtaining various measurements by which the top and bottom sides of sea ice features could be characterized with reasonable precision. The major goal was the evaluation of diving techniques and ice measurement systems.

In November 1970, a group of oceanographer/divers from the Naval Oceanographic Office conducted an investigation on the feasibility of using SCUBA†-equipped divers to characterize the bottom surface of the Arctic sea ice. In 10 diving days four divers accumulated 39 hours and 2 minutes under the ice in 40 separate dives. The longest single dive was 1 hour and 55 minutes, and the shortest was 26 minutes.

Two areas chosen for this initial effort are shown in Figure 1. The first operation was performed in shallow water (15 feet) approximately 100 yards offshore from the Naval Arctic Research Laboratory, Point Barrow, Alaska. The second portion of the investigation was staged from Fletcher's Ice Island (T-3), where the water depths exceeded 6000 feet. T-3 is a floating ice island which has been used as a scientific station for twenty years.

The air temperature averaged 10°F for the three days at Point Barrow with an essentially constant water temperature of 28.9°F. Daylight conditions were minimal—approximately 5 hours of useful light per day. The presence of longshore current with a maximum velocity of approximately 1/4 knot did not cause any problems. Diver visibility in the water decreased from the first day to the third day; however, the loss of visibility did not affect the operation. The average ice thickness was 12 inches.

The situation at Fletcher's Ice Island (T-3) was considerably different with the exception of the water temperature (28.9°F). No currents were detected by the divers at any time during the diving on T-3. Air temperatures ranged from −15°F to −39°F and the continuous darkness made

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†Self Contained Underwater Breathing Apparatus

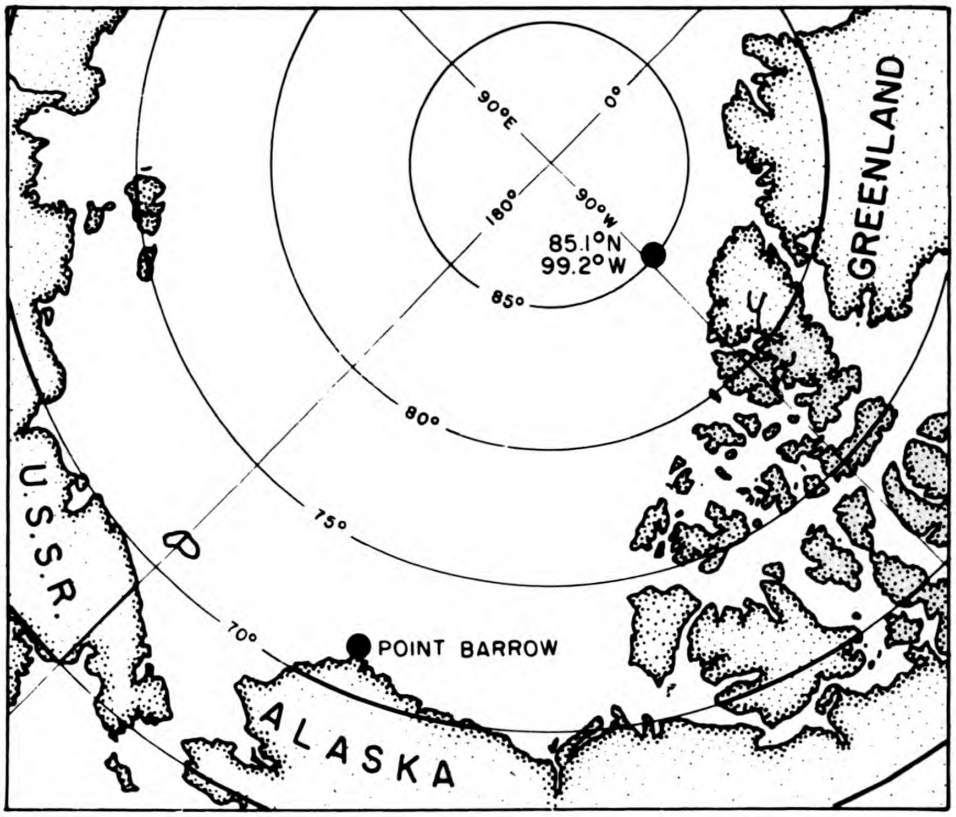

Figure 1 — Location of under-ice diving sites

lights essential. Available lighting equipment provided adequate working lights for under ice navigation. Sea ice thickness was approximately 15 feet.

The investigation was planned throughout with emphasis on simplicity and safety because experience has taught that the fewer the complicated or sophisticated devices and systems, the greater the chances for a successful field operation. The participants were particularly aware of two problems most encountered in the limited previous experience in under-ice Arctic diving; freezing regulators and exposure-limited diving time.

Diving Considerations and Safety

All dives were made using compressed air, open circuit SCUBA. The tanks were charged with a Cornelius air compressor (4 cubic feet per minute). This compressor has two charcoal filters in the hose between the compressor and the tank which eliminated most moisture from the air in the tanks. The compressor performed satisfactorily in temperatures down to −39°F.

The divers carried their air supply in twin 72 cubic foot, galvanized tanks. The two single tanks were not interconnected and each had its

own reserve valve and regulator, one of which was always a Navy-approved regulator. With this arrangement, two divers had four regulators and four reserve air supplies. Since regulator performance under these conditions was unknown, this redundancy provided an important margin of safety by allowing the driver to shift to the second regulator in the event the first one froze up in use. All divers were instructed to return immediately to the entry hole if primary regulator freeze-up occurred. Divers always worked in pairs (the buddy system) and each had a tending line to the surface for safety and for surface-to-diver communications using standard Navy diving signals. The 6 types of regulators* used in these tests were chosed with the following points in mind: (1) to check the performance of both a "piston type" and a "diaphragm type" single hose regulator and (2) to check the performance and reliability of the single hose regulator as compared to the two hose regulator. Three types of exposure suits* were used, including the Swedish Unisuit, which is fitted with inlet and outlet valves to permit diver control of inflation and buoyancy and must be used with the Swedish Cyklon Poseidon regulator. Detailed descriptions of all 3 types can be found in *Evaluation of Swimmer Exposure Suits in Subfreezing Waters,* (Naval Ships Research and Development Laboratory/P.C. 3477), W. T. Jenkins, 1971.

One of the problems associated with the standard, closed cell, neoprene wet suit is the fact that the suit material compresses due to pressure as the diver descends, resulting in a change of buoyancy. This problem of buoyancy decrease was minimized by adjusting the diver's weight for approximately neutral buoyancy at the desired working depth. For example, while diving underneath the ice (about 15 feet thick) at the T-3 diving site, a diver would weigh for neutral buoyancy at approximately 20-25 feet water depth. This allowed routine work from the undersurface of the ice to a considerable depth without an appreciable buoyancy problem.

Although the effects of cold immersion on divers were not part of this study, it should be noted that the divers never got cold enough to involuntarily shiver, that properly fitted hoods and face masks minimized the initial shock to the facial area, and that, while their lips did get numb after awhile, this never presented any problems, even when switching regulators during a dive.

Artificial Lighting

Lights were a necessity in the continuous darkness at the T-3 site and several were used. These included two Birns and Sawyer 1000-watt, and a 120 volt light. The water was so clear there that one of the 1000 watt lights could be seen in excess of 550 feet horizontally underwater

*See Apendix I.

when the beam was aimed in the direction of the viewer. These quartz-iodide lights afforded excellent light for viewing and for still and movie color photography. However, they do require a 110-120-volt power source which adds to the problems of preparing for a remote field operation.

Battery operated lights were also used. Each of the two divers had one small diver helmet-wrist light (Birns and Sawyer) powered by rechargeable alkaline batteries which were used at all times while diving under the ice. The battery-pack was tied between the air tanks and the light was attached to the divers wrist. Being subjected only to the cold water and not to the sub-zero temperature topside, these lights would operate about four hours. It it recommended, though, that they be recharged after about two hours use. Another battery powered light was tested and performed satisfactorily for the hour it was used. This light was buoyant which is a good characteristic of any equipment of importance, especially in water deeper than diver-depth, when a tendency toward being butter-fingered is aggravated by partially numbed fingers and three-fingered mittens. Our battery operated equipment, lights, and movie camera, performed satisfactorily as long as the batteries were maintained in a charged and relatively warm state prior to diving.

Measurement Techniques

Some of the under-ice work required new, untried techniques and equipment. One of the objectives of this study was to determine the feasibility of making a series of measurements of the lateral variation in thickness of the growth layer. The growth layer is a fragile lattice-work of ice crystals that form on the bottom surface of the sea ice and is more saline than the older ice above it.

Two scales were investigated, a 50′-diameter circle and a 100′-diameter circle. The measurements were made along the circumference of the circle that was circumscribed by the divers tending lines as they circled the entry hole, the beginning point being marked by a small buoy placed by the divers. A metal probe marked in 1/10ths of a foot was used for the measurement and the data were recorded with a grease pencil on a plexiglass slate with the aid of wrist light mentioned above. The growth layer thicknesses encountered ranged up to 0.7 of a foot. Figure 2 shows a section of the growth layer being pulled down by a diver and Figure 3 gives a view of the same area from a greater distance.

Another technique developed in the study was a system to measure the under-ice profile of a pressure ridge. This system uses a line weighted at three positions (Figure 4). The line is marked in equal increments, corresponding to the number of points to be measured across the bottom surface profile of the ridge. The optimum sampling interval decided by the divers appears to be one foot increments along the weighted reference

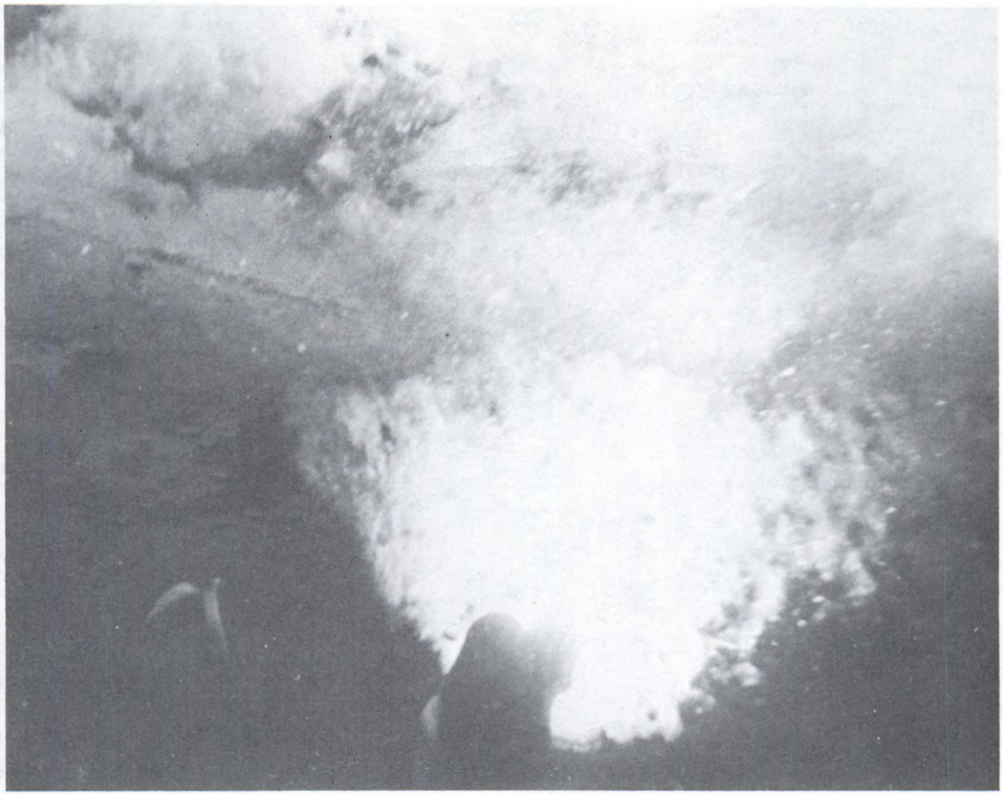

Figure 2 — Section of growth layer being pulled down by diver

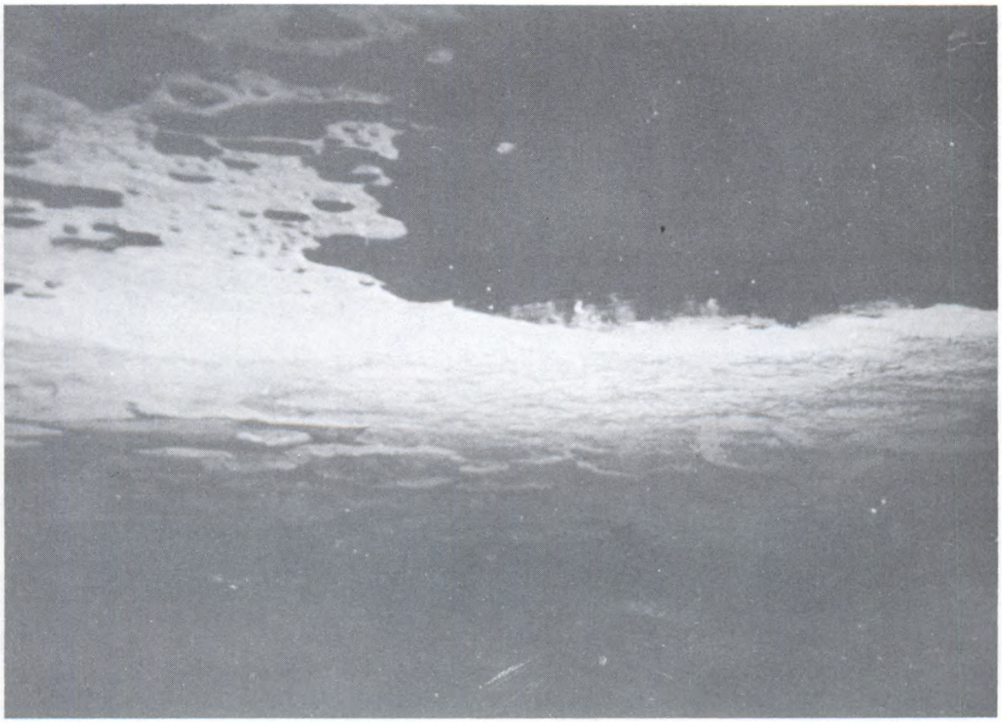

Figure 3 — Same area as Figure 2 from a greater distance

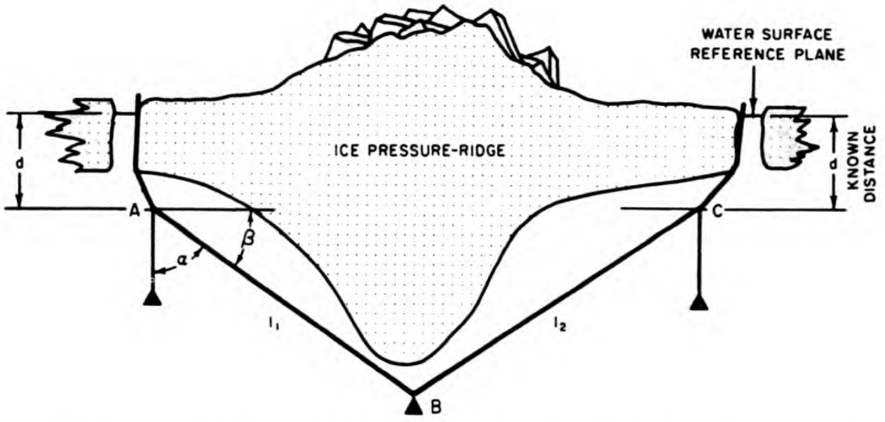

Figure 4 — Geometry of under ice pressure ridge measurement. Angle α is a measurable angle; angle β is easily determined; with angle α and lengths l_1 and l_2 known, triangle A, B, C can be reconstructed.

line. The actual profile data is obtained by a measuring line-buoy probe combination (Figure 5). The buoy probe is a light-weight, fiberglass-covered, styrofoam spar buoy of triangular cross section about two feet in length with a metal rod, about four feet in length, running through it lengthwise, leaving about 1-1/2 feet of the rod extending from the top of the buoy. To the bottom of the buoy (bottom end of the rod) is fastened a length of 1/4 inch line, weighted so the total buoyancy is less than 10 pounds. The divers move along the incremented, weighted line that is secured under the pressure ridge, taking the buoy-line along (Figure 6) from station to station noting the vertical distance between the weighted line and the ice by marking the buoy line at each station. The buoy line markers are small alligator-type electrical wire clips modified by bending the jaws open slightly to accept the 1/4 inch marking line and by securing a one inch metal disc, stamped with a number, to the top surface of the clip (Figure 7). The disc facilitates the opening of the clip by a diver's mitted hand, and divers had no problems with them during a test of this system while under the ice. The clips, consecutively numbered, are carried by a diver on a short line attached to his belt or wrist and are transferred to the hanging buoyline where it intersects the marked line suspended beneath the ridge. The geometric configuration of the suspended line is determined by measuring an angle, and knowing the lengths of the sides. The clip positions on the buoy line are then measured topside and, using the geometry of the suspended line, then reveal the profile of the pressure ridge. Figure 8 illustrates how the various measurements are used to reconstruct the sub-ice profile of the pressure ridge. Figure 9 shows a profile of the edge of T-3 obtained by this method.

Under-Ice Features

"Erosional" features (Figure 10) were observed on the grounded block of multi-year ice off Pt. Barrow and also on the underside of T-3

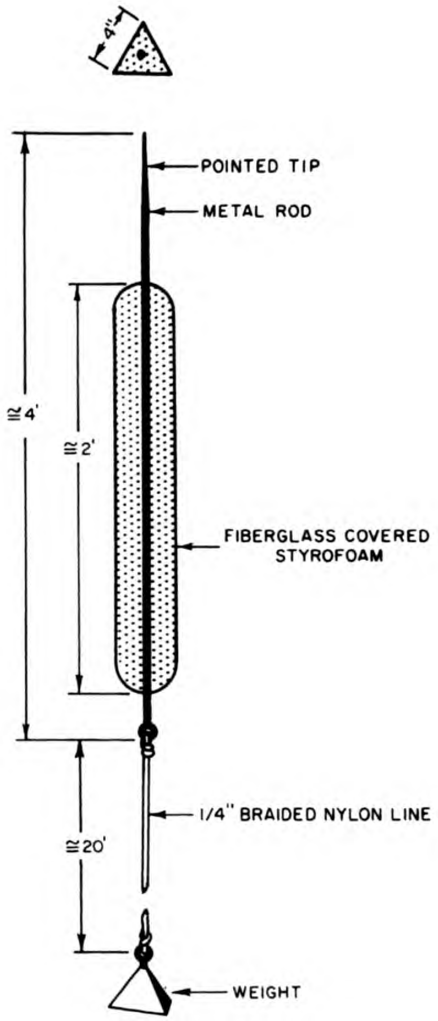

Figure 5 — Buoy-probe and measuring line

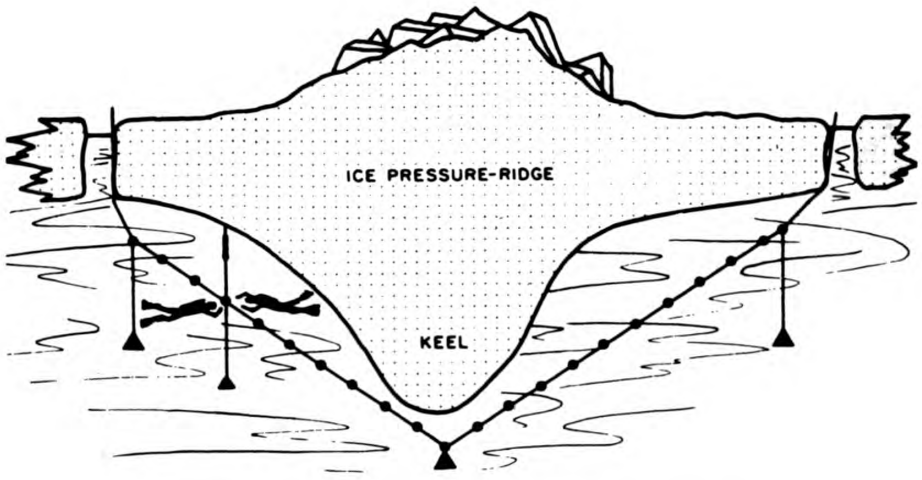

Figure 6 — Employment of buoy line for measuring profile

Figure 7 — Marking clip

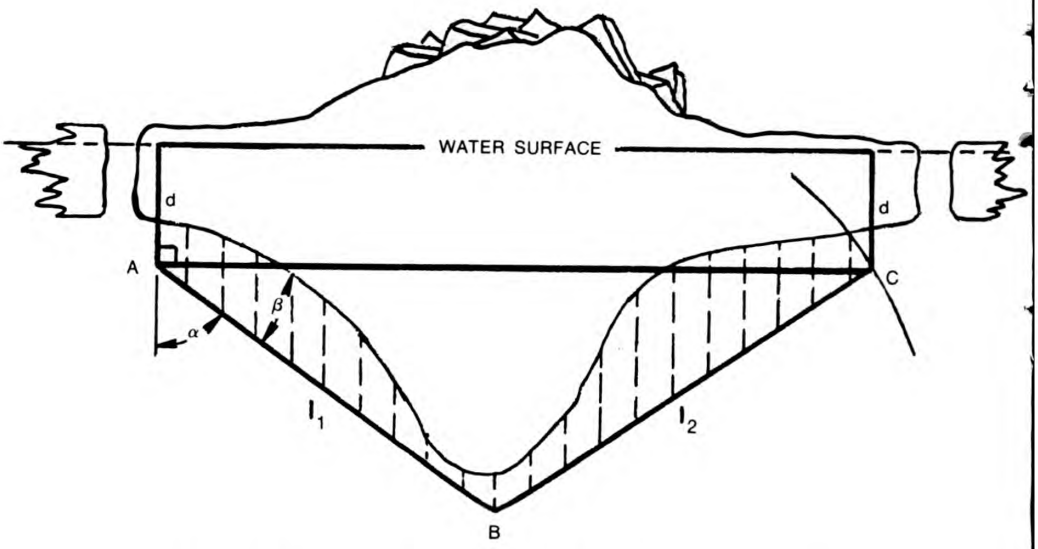

Figure 8 — Typical construction of the sub-ice profile using measurements made by divers

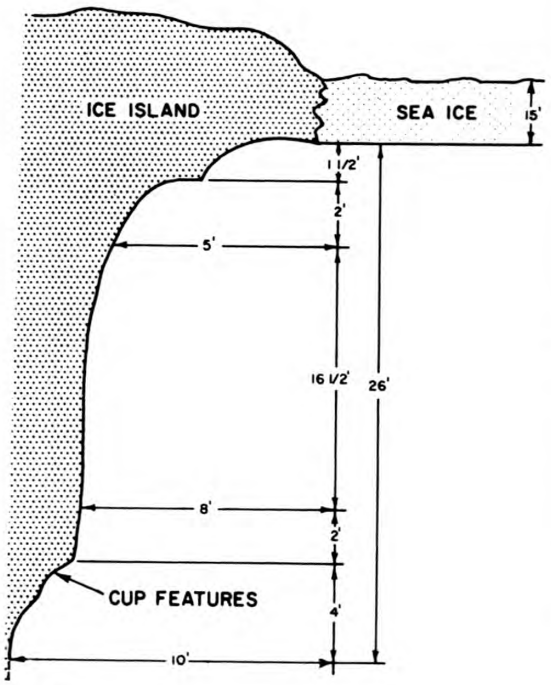

Figure 9 — Profile of edge of T-3

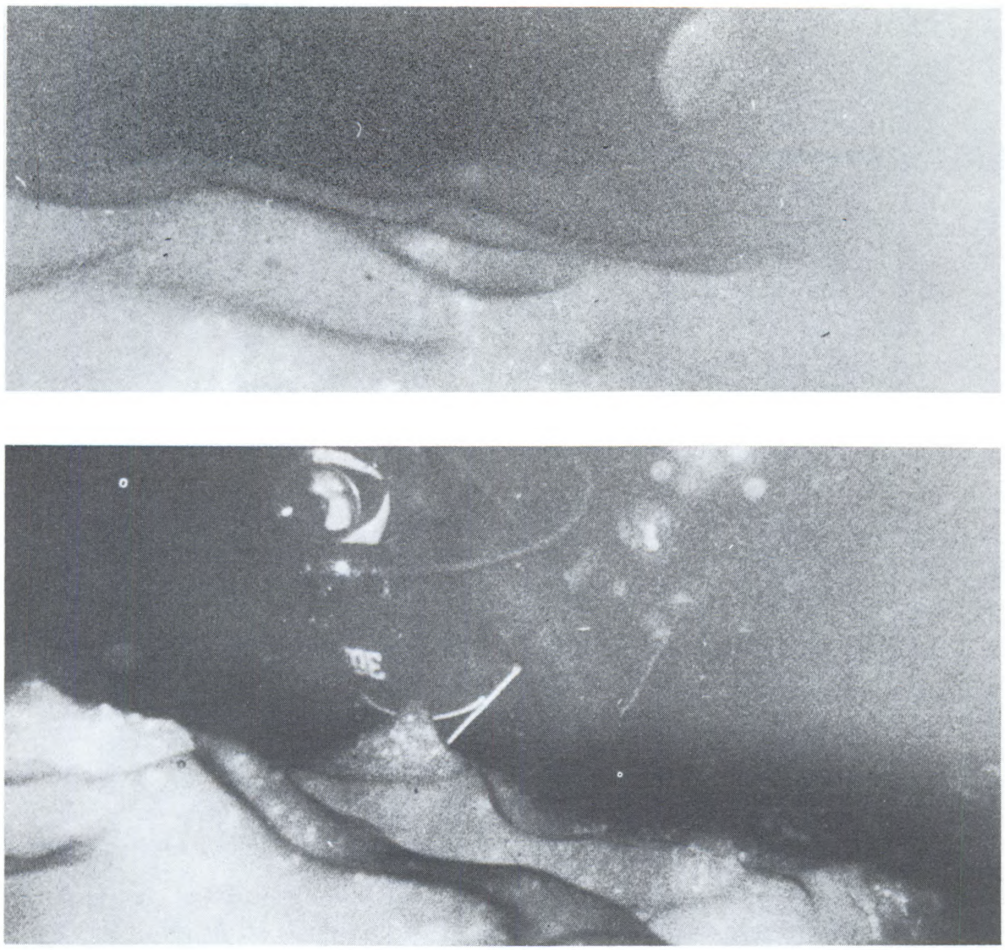

Figure 10 — Erosional features in multi-year ice off Pt. Barrow

(at about 45′ depth). These cup-shaped features look very similar to sun cups which develop in the snow on glaciers in the summer. Their orientation at Pt. Barrow was concave facing upward and at T-3 concave facing downward. Characteristic dimensions indicated a major axis (about 3 feet) and a minor axis (about 2.5 feet) with an amplitude or depth of about 0.5 feet. The major axis of the visible cups seemed to be oriented in the same direction (relative to each other) at both locations. This suggests that their formation or at least their development is a product of a nonrandom energy flux or a function of a directional homogeneity of the pertinent physical properties of the sea ice.

In addition to the erosional features, an icicle or stalactite was observed on the bottom side of the sea ice off Pt. Barrow. This feature (Figure 11) was about one foot long and from 2 to 4 inches in diameter. A small conduit was apparent in the central region running from the top (near the ice cover) to the bottom. The icicle was very fragile; a small amount of diver motion in the immediate vicinity caused disruption as shown by the small portion floating away to the right in Figure 11.

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Figure 11 — Icicle under sea ice (12" thick) off Pt. Barrow

Specimens of invertebrate organisms were collected in the shallow water off Pt. Barrow from the underside of the ice and the bottom. A number of these seemed to reside on or within the sea ice. Samples were also taken during the dives at T-3.

Photography

Both still and motion pictures were taken under the ice. The still pictures were taken with a Nikonos 35mm camera. Flash, strobe, and flood lights all provided satisfactory results. Color movies were taken with a 16mm Milliken DBM-9 camera and 1000 watt underwater lights. Problems with the cameras, as a result of the cold, were few and not considered serious. A 10-minute color movie has been prepared which illustrates both the topside and bottomside aspects of this operation.

Conclusions

With the accumulation of 39 hours and 2 minutes under the ice in 40 separate dives, it has been adequately demonstrated that SCUBA-equipped divers can function efficiently and safely under the ice. Further, it is practical and relatively easy for divers to measure under-ice features, take both still and motion pictures, collect biological samples and perform numerous tasks of varying complexity.

Recommendations

In the interest of greater safety and efficiency of future ice diving operations, the following recommendations are made:

1. Always use a diver safety-line.
2. Always use dual breathing regulators and tanks (this should include a small pressure line between the tanks permitting both tanks to be used with either regulator).
3. Always use a two hose, two-stage regulator for the primary regulator.
4. Attempt to provide a warm dressing area near the diving site.
5. Provide protection for the air compressor in extreme temperatures.
6. Providing a means of heating divers' hands and feet is desirable.
7. Use only experienced divers.

Appendix I

Equipment

The following diving equipment was assembled for use in this project:

A. Regulators
   1. Two Cyklon Poseidon—single hose
   2. Two SCUBA Pro—single hose
   3. Two Con Shelf VI—single hose
   4. One Con Shelf XI—single hose
   5. One Titan II R12J—single hose
   6. Two Aqua Master—two hose

B. Exposure Suits
   1. Three Parkway 3/8″ wet suits (custom made)
   2. Two Unisuits "Super" with Arctic Underwear
   3. One 3M Non-Compressible (experimental)

C. Air Compressor
   1. Cornelius 4 cu. ft. per minute driven by 7 h.p. air cooled gasoline engine

D. Personnel—Listed below is a description of personnel who performed diving during this project.

Name	Weight	Age	Height	Organization
Chester V. Bright	175	45	5′9″	NAVOCEANO
James E. Turcotte	160	32	6′1″	NAVOCEANO
Howard D. Huddell	155	33	5′9″	NAVOCEANO
Wallace T. Jenkins	175	35	5′11″	USNSRDL

Invisible Phonograph Needle in Development by Navy

An invisible phonograph needle is under development by the Navy.

The "needle" is an optical device that makes no contact with the record. This not only virtually eliminates record wear but produces much higher fidelity and also makes it possible to utilize records with greater density of material.

The optical phonograph needle is being developed by Teletron Data Corporation, Kings Park, New York, under a contract with the Office of Naval Research. Teletron, a small, young company, is developing a version of the optical needle as part of an inexpensive system for storing and distributing computer data in multiple copies. The system is called OROS (Optical Read-Only Storage).

The use of records to disseminate many copies of a new data base would be cheaper than magnetic tape. It costs less than ten cents per copy to stamp out a number of records from a master whereas it costs four or five times that amount to make tape copies. Making numerous copies of taped material is also a more complicated process than record production.

The key advantages of magnetic tape are its high fidelity and the fact that it can be erased and rerecorded. The fidelity of tape would be matched or even bettered by the OROS system, and the reuse of tape is no advantage if only playback is desired as in updating a data base. Records, however, could never replace magnetic tape for storing large amounts of data in a computer.

Since there are no moving or mechanical parts in the OROS system, the reading speed is limited only by the associated electronic circuitry. Although the device is capable of playing conventional phonograph records, the inherently greater resolution of the OROS system allows groove size to be greatly reduced. This would permit it to be used with records containing a much greater number of grooves than conventional records, making possible superlong-playing records.

One potential spinoff application of the device is its use for playback of disc-recorded television programs. Such discs with increased grooves could contain programs two or three times the length of video disc-recording systems presently under development by commercial companies. Disc systems would be advantageous for shipboard use since they would be cheaper to provide and easier to use on even small ships.

Machine Recognition of Handprinted Characters

C. L. Coates*
University of Illinois

Philip Noe*
Texas A&M University

The Navy (Office of Naval Research), the Army (Electronics Command) and the Air Force (Office of Scientific Research) have joined together in a Department of Defense program to support a group of nine University Centers of Excellence in the Electronic sciences. The University of Texas is one of these centers.

At Texas, multi-disciplinary research is pursued in electromagnetic wave propagation, physical electronics, pattern recognition and other facets of information theory as well as in control, circuit and antenna theory. The handwriting recognition study is one of these programs, which has applicability to a wide variety of techniques and systems of importance to the military.

In the early 1960's a claim was made that machine recognition of any type font and of some handprinting could be accomplished if enough money were available for research and development (1). The dominant theme of the early workers, regardless of method or cost, was—*build a machine that works*. As a result, there are many recognition machines today which read machine-printed fonts and a few machines which read restricted sets of handprinted characters. However, there is no known machine installation that is capable of recognizing a full set of handprinted characters such as is encountered on programming coding sheets, *etc*. with the exception of certain research oriented systems such as the Stanford Research Institute's context sensitive system (2).

The purpose of this research is to design and build a real-time machine that will recognize, without the aid of context, handprinted characters of the 47 character FORTRAN character set: (ABCDEFGHIJKLMNOP QRSTUVWXYZ0123456789+−*/=()$., and blank). The ground rules require that these handprinted characters be printed within prescribed height and width constraints, and that character separation be maintained. Each character to be recognized must have a unique and unchanging shape corresponding to one of the characters of the standard handprinted character set font shown in Figure 1.

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*Dr. C. L. Coates is associated with the Coordinated Science Laboratory of the University of Illinois. with P. M. Lewis II he co-authored *Threshold Logic*, a major work in that area of science.

Dr. Philip Noe is a professor in the Department of Electrical Engineering. His field of research is pattern recognition and digital systems design.

Figure 1

The final system design is influenced by many additional factors. A simple paper handling system is desirable to eliminate the paper jamming difficulties frequently encountered in high speed systems. A modified standard FORTRAN coding form which is marked to synchronize the beginning of a line is required. Eighty boxes are provided to encourage the user to abide by the height and width constraints. Each line of handprinted data on the coding form is recognized and printed as a single line in the output record with original spacing maintained. The system should have sufficient resolution to provide an unambiguous reproduction of all characters which have a height (or width) greater than half the space height (or width). Normally short or narrow characters, (.,-=1), should be distinguished if the originals are. With the guiding spirit of "*build a system that works*" many variations of character shapes were added to the set of recognizable characters as *de facto* standards. The ultimate goal of the work reported here was recognition of all characters made in a font similar to Figure 1 which can be unambiguously recognized out of context by human observers. Although this goal was not achieved, the work provided the fundamental hypothesis for the system design: namely, that any character shape which is uniquely recognizable out of context by human observers can be recognized by machine. This hypothesis was neither proved not disproved, and it remains as a fundamental standard in handprinted character research.

The nature of the recognition problem implies certain basic features of system organization: the characters must be read, analyzed, and classified; therefore, three subsystems comprise the overall system and are shown in block diagram in Figure 2. An optical scanner reader (OSR) is used to read the characters into a digital computer which provides the measurement–analysis and decision–classification subsystems. Computer programs are used for the measurement and decision processes so that an initially primitive system can be allowed to develop into a complete recognition system as the programs are improved.

The heart of the recognition system design is the measurement system. It is based on the concept that each of the characters in the character-set of Figure 1 has a unique shape. A survey of the methods of feature extraction by Levine (3) describes many of the methods which have been used to define various types of patterns. All methods of feature extraction have a common point that is either stated or inferred throughout the literature: shape is the major determining factor used by man

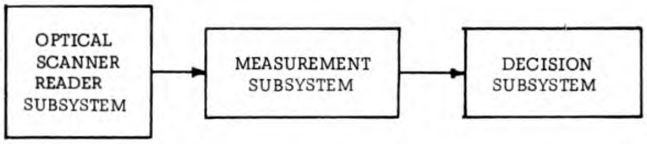


Figure 2 — System Organization

or machine in the analysis of handprinted characters. When analysis of shape fails him the human observer resorts to a variety of methods to reach a decision: he considers possible choices, he verifies by contextual analysis, he asks the author, or he asks someone else to help form a consensus opinion. The human observer has the additional prerogative of consulting a dictionary, and if a syntactically correct variation of the word cannot be found, he can choose to ignore the word and guess at what it means from the remaining sentence or even paragraph content. Machine recognition of handprinting is at a distinct disadvantage when compared with the complexity and versatility of the human observer. Clearly, a measurement system without feedback from the decision system requires unambiguous characters with unique shapes.

Optical Scanner Reader

The design of the data input device, which is known as the Optical Scanner Reader subsystem (OSR), was strongly influenced by the 24-bit work size of the XDS-930 digital computer (henceforth called the 930). The 1/4 inch high character space is scanned by a vertical line of 24 photocells thereby producing a 0.01 inch vertical resolution. These photocells are sequentially sampled at a rate determined by the repetition frequency of an external pulse generator. The output of each photocell of the linear array is connected to one of the 24 parallel input lines of the 930 and is binary quantized: that is during the sampling pulse the photocell output corresponds to a "zero" for the 930 when the photocell is over a white region and to a "one" for the 930 when the photocell is over a dark region. Figure 3 shows the result for the letter B.

Measurement and Decision System

The decision system is a decision tree structure which exists as a software program on the 930. The tree is organized into major branches as a function of the segment count and the extremum conditions. This approach is used because these are the only a-set measurements available in the first descriptor (description which will lead machine to determine specific characters). Furthermore, ideal characters are classified into several major branches by testing. The first test is illustrated in the flow chart of Figure 4.

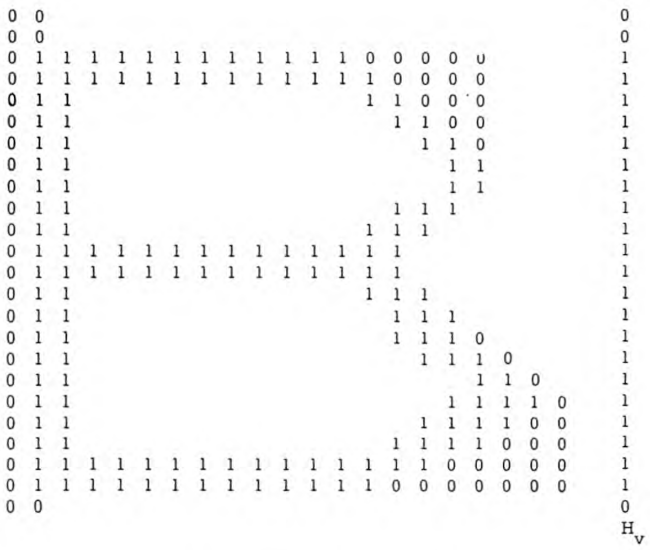


Figure 3 — Digitized B

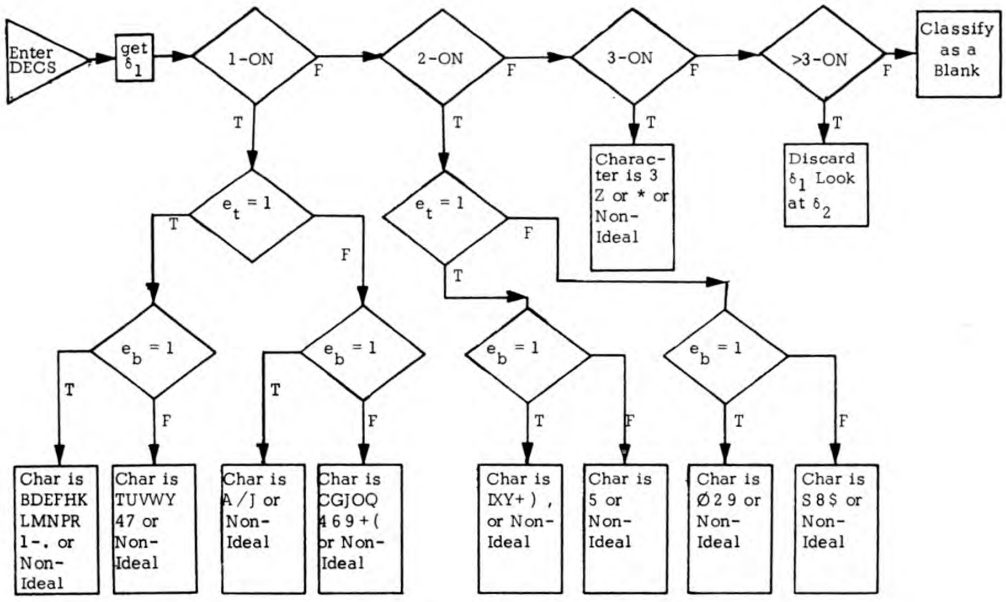


Figure 4 — First level branching (δ_1 test) tree structure

After the first level branching occurs, the subsequent descriptors are wholly or partially tested for *anticipated* characteristics. To illustrate the subsequent levels of testing the descriptor sequence of Table 1 for the B of Figure 3 will be described. The test of the "Left-most scan" of B results in branching in Figure 3 to the decision "Char is BDEFHK LMNPRI-. or Non-Ideal." The second descriptor is obtained from the measurement system and appears to provide no new information other than the fact that the stroke does have a width of two scans. The third

TABLE 1
Measurement Sequence (μ_i) and Descriptor Sequence (δ_j) for Digitized B

Measurement Sequence	α Set																β Set					Descriptor Sequence	Change Causing Descriptor Output
	k-ons	e_t	e_b	D_h	m_t	m_b	c_t	c_b	K_1^1	K_2^1	K_3^1	K_4^1	K_1^2	K_2^2	K_3^2	K_4^2	H_n	w	D_v	ℓ_1	b_1		
μ_1	1	1	1	meaningless on 1st scan													21	19	0	10	0	δ_1	Left most scan
μ_2	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0						δ_2	2nd scan
μ_3	3	1	1	0	0	0	0	0	1	1	0	1	1	1	0	0						δ_3	Segment count, 1-on to 3-on
μ_4	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	1							
μ_5	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	2							
μ_6	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	3							
μ_7	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	4							
μ_8	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	5							
μ_9	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	6							
μ_{10}	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	7							
μ_{11}	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	7							
μ_{12}	3	1	1	0	0	0	0	0	0	0	0	1	1	1	0	7							
μ_{13}	3	1	1	0	–	0	0	0	0	0	0	1	1	1	0	7							
μ_{14}	3	0	1	0	–	+	0	0	0	0	0	1	1	1	0	7						δ_4	Extremum top, e_t, 1 to 0
μ_{15}	4	0	1	0	–	0	0	0	0	1	0	1	1	1	1	0						δ_5	Segment count, 3-on to 4-on; Concavity right, $K_2^r = 1$
μ_{16}	3	0	0	0	–	+	0	0	0	0	0	2	1	1	0	0						δ_6	4-on to 3-on; e_b, 1 to 0; Concavity left, $K_1^\ell = 2$
μ_{17}	2	0	0	0	–	0	0	0	0	0	0	1	2	0	0	0						δ_7	3-on to 2-on, Concavity left, $K_2^\ell = 2$
μ_{18}	1	0	0	1	–	+	2	0	0	0	0	1	0	0	0	0						δ_8	2-on to 1-on; D_h, 0 to 1 implying end of segment; m_b, 0 to + with 1-on; slope magnitude $c_t = 2$
μ_{19}	1	0	0	0	–	+	0	0	0	0	0	1	0	0	0	0						δ_9	D_h, 1 to 0; right most scan
μ_{20}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						δ_{10}	1-on to 0-on; right most scan +1

descriptor is obtained, and Table 1 reveals that the single vertical left edge stroke has become 3 segments, which are all simply connected to a segment in the previous scan. It can be deduced that this is a single segment since two concavities facing right are also indicated. A decision branch covering this test would conclude "Char is a B or E or Non-Ideal." The category of Non-Ideal characters that could satisfy this test are actually any of the characters that can have a left edge vertical. Perturbations nor removed by filtering and smoothing, skewed characters, of just plain wiggly lines can create the shape to satisfy this test. Thus, it is clear that subsequent tests will need to know over what width interval the three segments existed. The next descriptor provides this information along with the reason for the "significant change." This descriptor would produce the decision "Char is a B, a Non-Ideal E, or Non-Ideal." The descriptor of Table 1 shows a scan of four simply connected segments. The figure that can be constructed from this sequence of descriptors is shown in Figure 5. The decision tree branch required to cover this test would be "Char is a B or a reject." Subsequent descriptors need not be tested if it can be assumed that the remaining information is unimportant; however, with handprinted characters this assurance is never possible. Thus, further testing and branching is made on each of the remaining descriptors, which verify that the right side of the B is closed, and the decision is made that the character is a B.

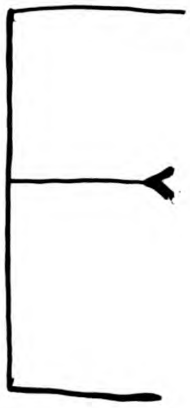


Figure 5

Experimental Development and Results

The measurement and decision subsystems (930 software) were developed by an evolutionary process of shape analysis of actual handprinted characters and anticipated variations on hand-printed characters. The measurements and descriptors described in the previous section represent the end product of many feature choices which were considered.

The first period of software development was based on tests made on data from 27 authors (over 3600 handprinted characters quantized and

stored on magnetic tape (4)). Software modifications were made with respect to this data until the system recognized all of the characters in this set which were not excessively broken, truncated, or ambiguous.

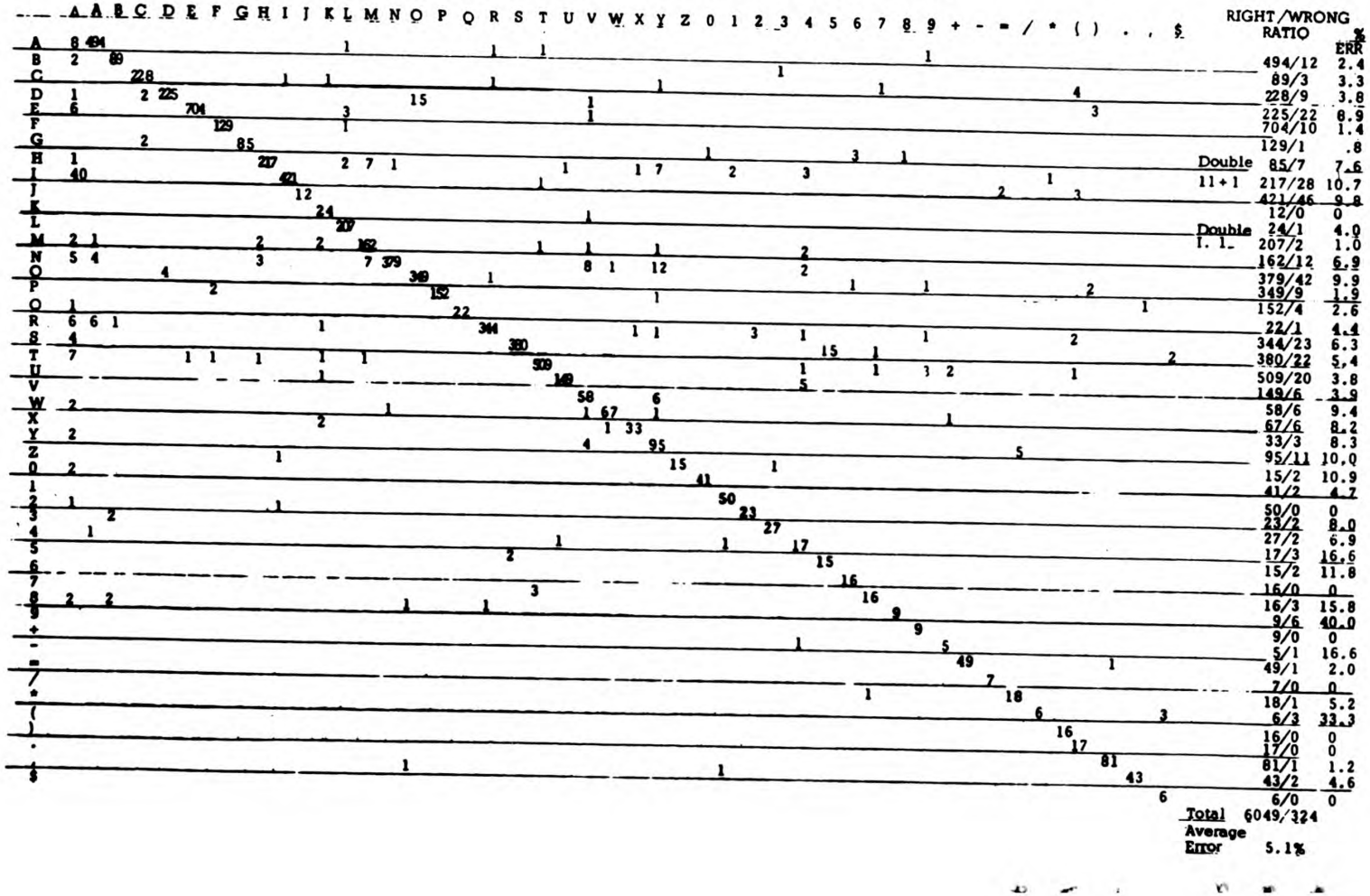
The second period of software development was based on tests made on data from a single author (over 6000 handprinted characters stored in original form on coding sheets). This data was processed by the 930 with the OSR input device described previously. Hardware and coding form development were also required during this period. Initial testing of the online OSR system was conducted with preliminary coding form designs. The data on these early forms were handprinted with India ink or HB grade pencil and both were read satisfactorily by the OSR. However, errors did occur if lines were printed too softly or if horizontal lines are too narrow. In this second period of software development all handprinted characters read by the system on all of the various forms that were considered were used to test and modify the software. The primary purpose of these tests was to determine the effectiveness of an operational online OSR system.

In this second development period the first three pages (about 1300 characters) of the single author data were repeatedly read by the OSR. The software was modified to eliminate all errors which occurred with unambiguous character arrays. This process was continued until the average error rate was reduced to less than 5% on several successive trials. The decision system was further tested to determine that recognition rates for the magnetic tape stored data arrays were unchanged.

There is a major distinction between the two sets of data used in developmental design of the system software; namely, the magnetic tape stored data arrays are invariant, and the OSR data arrays are not invariant. This means that the OSR-decision system can recognize a particular character of the single author data on one reading and reject or misclassify that same character on a second reading. This situation cannot occur with the stored data arrays on magnetic tape. This does not necessarily imply that the magnetic tape input data is better data; it is just invariant while the OSR input device has many variables affecting the quantization of its input data; such as scanning rate, light intensity, initial position, vertical page registration, *etc.*

At the termination of software development the decision system consistently produced an error rate of less than 5% on the first three pages of the single-author data. Due to the complexity of the decision tree program (over 11,000 lines of machine language code) a running error of modifications was maintained to preclude destructive (error increasing) modification of the decision tree. All of the single-author data was processed at this point, and the results are shown in Table 2. The average error rate for the single-author data is 5.1%. Error rates for individual characters run from 0% on the (J169()$) set of characters to 33.3% and

TABLE 2
High Quality Single Author Data Results



40.4% for the * and 8 respectively, and median of 4.4% on the Q. An additional page of data from the same author is included with this data to provide samples of low population characters of the following type: (JKQZ23456789+*()$).

In addition to 3500 characters on magnetic tape and 6000 of the single-author data, over 7000 characters were obtained from 70 different individuals as shown in Figure 6. Each individual was asked for two complete Σ-sets and given brief instructions concerning discrimination techniques. It was emphasized that the width constraining margins of the character spaces could be ignored if separation existed between the characters, but the height constraint could not be ignored or the characters would be truncated. A new form which was used for the multi-author data is printed in red ink and appears with the handprinted samples in Figure 6.

Unfortunately, data obtained from 36 of the individuals is unusable for various reasons: excessive overlapping of the characters, pencil strokes were too light, lower case alphabets, character height too small (less than 1/8 in.), or characters too tall (greater than 1/4 in.). Even in the data which was used a large percentage of the data also had some of these undesirable characteristics. The average error rate on the data from the remaining 34 individuals (multi-author data) is 34.6% and is shown in Table 3. Error rates for individual characters run from 8.3% for the - sign to 67.5% for the $ sign with a median of 33.3% for the (sign. It is quite evident in comparing the result of Tables 2 and 3 that a little training and/or knowledge of the system operations can substantially increase the recognition rate of the system. Also, it is clear from the results of Table 3 that the magnetic tape stored data and the single-author test data did not provide sufficient "training" for the great number of variations which occur in the multi-author data which is typified by Figure 6.

The majority of the errors which occur on the single-author data can be classified as unexpected or unambiguous errors. An unexpected or unambiguous error is defined as a decision made by the machine that would never by made by a human observer. The existence of unexpected errors help to illustrate the complexity of the decision tree. With few exceptions the unexpected errors occur as the result of incomplete testing and branching in the decision tree. Analysis of the descriptor sequence of an unexpected classified character creates a reproduction of the original character in most all cases; therefore, each of the unexpected errors could be eliminated by modifying the decision tree with a *specific* string of tests for the character misclassified. However, experience has shown (during the evolutionary development of the decision tree) that *specific* character correction of this sort rapidly increases the

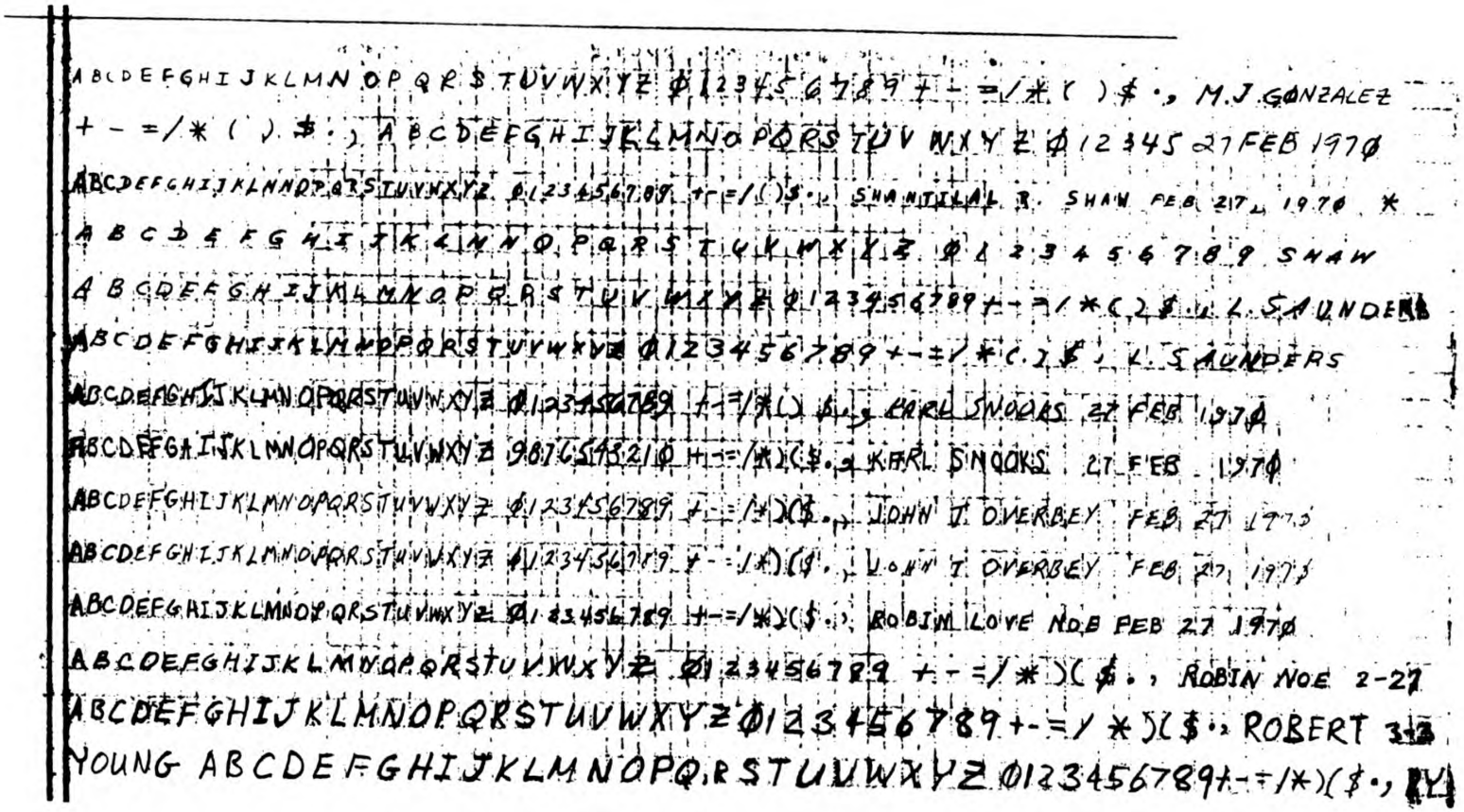
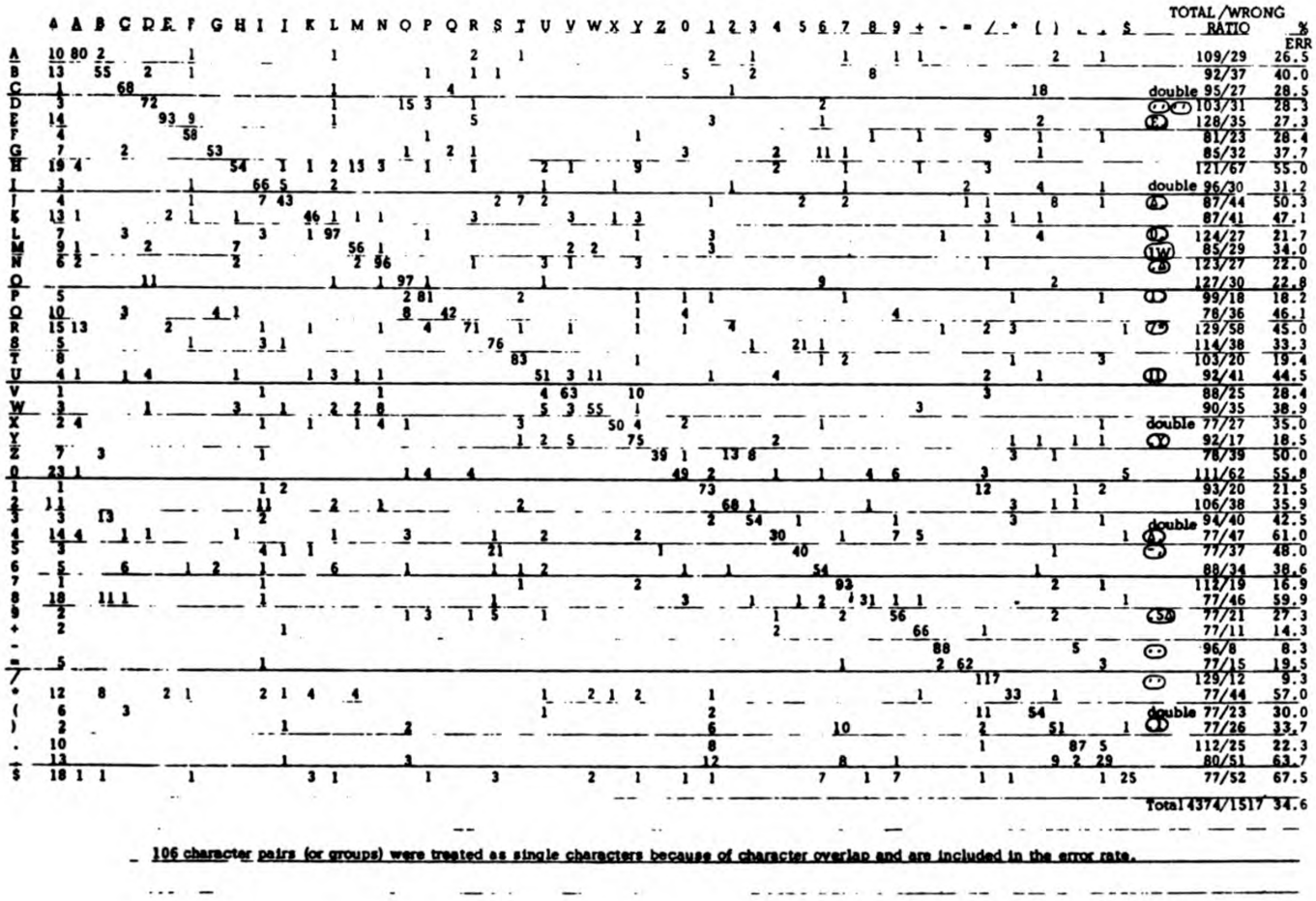


Figure 6 — Multi-author data sample

TABLE 3
Multiple Author Data Results



106 character pairs (or groups) were treated as single characters because of character overlap and are included in the error rate.

computer storage space needed to create all the decision tree paths required to isolate each character. Nearly 300 tests are required to determine the segment count, extremum conditions, slope, and gross connectivity measurements alone. Testing two descriptors in this fashion would require nearly 90,000 tests. Clearly, a decision tree organized to cover all possible descriptor combinations would rapidly saturate any fixed memory computer.

Unexpected errors were eliminated during the development phase by integration of additional testing at the point in the tree where erroneous branching occured. This procedure frequently requires addition of test which were originally thought to be unnecessary under the concept of "expected shape variation." In this framework an A that is called a 9 can result if the A has a short leg on its left hand side. Tests on the bottom slope can be included to eliminate this unexpected error. However, most unexpected errors cannot be eliminated this easily. In most situations a quick fix on the tree to correct a Q called a ϕ will usually create a tree than will call a ϕ a Q on some subsequent test of the system; therefore, modification of the tree is a critical operation requiring careful analysis of every possibility.

In addition to unexpected errors there is a small number of errors which result from measurement ambiguity in the descriptor sequence which defines the character shape. Some examples of measurement ambiguity are shown in Figure 7. To a certain degree these measurement ambiguities would not exist if it were not for the shape ambiguity in the characters shown; that is, the S and 2 are similar to skewed I's, the S is similar to a J, and J similar to a 5. It is felt that ambiguity errors of this type can be eliminated if segment length and interior slope measurements are added to the Σ-set of measurements. In the cases where the 9's are called S it may be necessary to include the length of the open space between segments to eliminate this type of ambiguity. However, testing of these additional measurements must also be included in the decision tree; otherwise, the result would be only to change the category of the error from measurement ambiguity error to unexpected error.

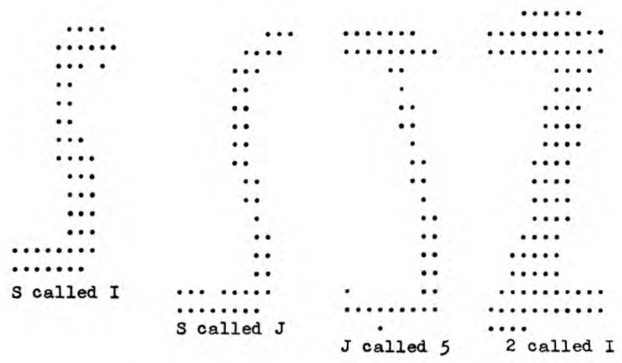


Figure 7 — IJS25 ambiguity

The large percentage difference in errors in the single-author data and the multi-author data can be attributed to the general low quality of the data. To be specific, many of the errors are caused by character overlap, light strokes creating broken characters, excessive skewing, nonstandard character shapes (lower case, *etc.*), blunt pencil strokes filling concavities, and insufficient height or width. Several of these are illustrated in Figure 8. The errors caused by character overlap and by insufficient height or width are in specific violation of constraints established in the specifications for the user. A statistical analysis was run on the two sets of data, and it was determined that an average 23% of the errors occur on characters that are less than 16 cells high. Errors for normally short characters (.,-=) are excluded in this analysis. An additional 12% of the error rate is the result of character overlap, broken characters, and truncation of characters over 1/4 inch tall. Over 60% of the low-quality, multi-author data that was excluded as unusable from the test results are too short, too tall, overlapped and/or broken. The measurement ambiguity error rate is less than 1%; whereas, shape ambiguity (5,S), (8,B), *etc.*, unexpected shape variations, and decision tree failure (unexpected errors) account for the remaining 64% of the error rate. In the multi-author data shape ambiguity is a major factor in the error rate: skewed 1's are indistinguishable from /'s, one author's 5's are nearly identical to another's S's, *etc.*

Conclusions and Recommendations

This research has shown that high-quality handprinted characters of the full set of FORTRAN characters can be recognized out of context if a human observer can also recognize them out of context. However, it is quite clear that the 5% error rate of the system is not satisfactory for most practical applications. On the other hand, the results indicate that the measurement system produces a descriptor set that uniquely identifies over 99% of the shapes seen by the system. Complete elimination of shape measurement ambiguity can be provided by including length and slope of all segments and distance between segments. It is felt that the decision tree structure must be reorganized to fully utilize the inherent accuracy of the measurement system. The need for more resolution is indicated by the error rate associated with short data samples. Furthermore, insufficient resolution places a constraint on filtering and smoothing techniques that can be used. Ideally the characters can be mapped to eliminate the redundancy of information associated with the width of character strokes; however, with insufficient resolution the smoothing and filtering process usually results in a loss of information. This problem is particularly noticeable with ambiguous character pairs such as (B,8), (C,()), (G,6), (S,5), *etc.* It is felt that a substantial increase

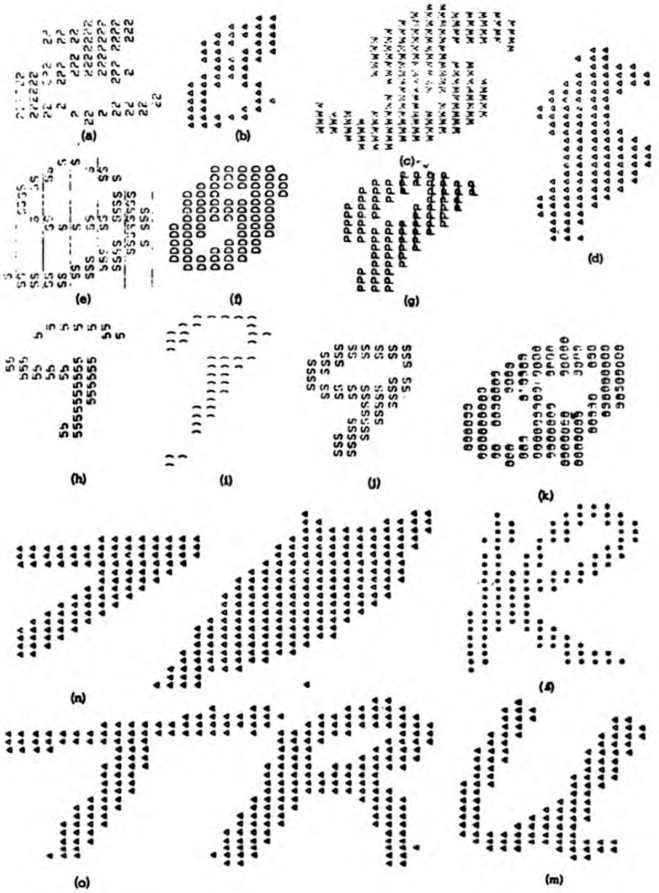


Figure 8 — Quantized Arrays, Multi-author Data. (a) low resolution Z, filling and deletion errors; (b) low resolution 8, filling errors; (c), (d) low resolution $ marks, blunt pencil, light intensity errors; (e) broken 9, filling error; (f) low resolution 8, blunt pencil, filling error; (g) low resolution skewed 9, blunt pencil, skewing, light intensity error; (h), (i), (j) broken 9's, light intensity low gray level broken character errors; (k), (ℓ), (m)non-standard QR and U, unexpected shape errors; (n), (o) overlapped 7ϕ and TR, overlapping produced unexpected shapes, also blunt pencil error on ϕ.

in resolution can produce characters that can have all strokes reduced to single point thickness without a corresponding loss of information. Comparison of the results obtained from the multi-author data with the single author data indicates that the user could be trained to print more carefully and obtain higher recognition rates. An interactive version of this machine could provide the user with the immediate capability of editing each line of decisions before a permanent copy of the decisions is produced.

Other authors have shown that an adaptive decision system can be developed that responds to the individuality of a particular user; that is,

a system in which an individual would establish his own standard set of shapes. With an interactive adaptive machine it becomes quite clear to a user that he cannot expect to make a C and a (exactly alike without producing the same decision with the machine. A final alternative is the addition of a context-sensitive system that can choose between ambiguous pairs or strings of characters. This additional feature adds considerably to processing time and to the cost of the overall system. Nevertheless, humans must often resort to context to correctly classify handprinted characters, and a completely general machine solution may also require a similar capability.

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NRL Scientists Probe Use of Space Signal Sources for Fool-Proof Worldwide Navigational System

Naval Research Laboratory (NRL) scientists are investigating the possible use of celestial radio sources as an indestructible and jam proof navigational aid on a worldwide basis.

The scientists reported the major advantages of using such celestial sources for navigation are: all-weather, 24-hour operation feasibility; no artificial power sources required for the primary source; the source position is relatively fixed for many years, and the primary source is destruct proof and jam proof.

There are presently two types of natural radio sources that could provide worldwide coverage for very-long-baseline-interferometry (VLBI) navigation over distances comparable to the earth's radius. These are the water-vapor spectral line emissions sources which radiate at 22.2 GHz, and the small-diameter components of quasars and radio galaxies.

The theoretical performance of an operational VLBI system for global navigation has been investigated by the NRL scientists. Their particular model system would make use of four natural water-vapor-line radio sources, six master stations, small shipboard antennas, and moderately high-sensitivity receivers.

The basic accuracy limitations of such a system are due to the limited number of very intense radio sources from outer space and the uncertainty of the velocity of the user's moving platform.

The researchers are using their present findings for evaluating higher performance, better coverage, and more accurate navigational systems that may be used in the future.

On the Naval Research Reserve

The Research Reserve program is composed of 66 companies throughout the United States. The Naval Reserve Officers are qualified in the conduct and/or administration of scientific research, or in patent, trade mark, and copyright matters. These officers are available in the event of national emergency to meet the needs of the Office of Naval Research and the Naval Establishment. Through the year the companies report on their activities and training programs.

Mr. D. N. Ivanoff Presented Navy Meritorious Public Service Citation

RADM John B. Johnson, USNR, Asst. Deputy Chief of Naval Operations for Naval Reserve presented the Navy Meritorious Public Service Citation to Mr. Dimitry N. Ivanoff for his personal contribution to NRRC 5-11, Annapolis, Maryland.

During the period 1971-1972, Mr. Ivanoff developed and coordinated an informational program on the USSR for the regular meetings of the reserve company including top speakers in the field. This program covered the economic and international relationships between the U.S. and the USSR, and their impact on R&D efforts.

Mr. Ivanoff's contributions to the reserve unit are especially significant as he is not a reservist and has no administrative assignment to any reserve unit, yet he is a regular attendee.

Mr. Ivanoff was born in Harbin, China of Russian parents and is now a naturalized citizen. He is employed by Westinghouse, Falls Church, Virginia as Director for Applied Systems Development Center for Advanced Studies and Analyses. He has an advanced degree from the University of Southern California in International Relations and Economics.

NRRC 5-4 Member Returns to Active Duty

CDR Craig K. Wallace, MC, USNR, a member of NRRC 5-4, Baltimore, has reported for active duty in Addis Ababa, Ethiopia. Before returning to active duty CDR Wallace was on the staff of Johns Hopkins University School of Medicine.

CDR Wallace is the Officer in Charge of the U.S. Naval Medical Research Unit No. 3 Field Facility at Addis Ababa. The Field Facility is primarily involved in the study of tropical diseases related to military problems. The laboratory is noted for work in relapsing fever and

schistosomiasis. Dr. Wallace will be directly involved with the clinical research in diseases indigenous to the area, and he will also supervise all other research tasks.

NRRC 5-9 Wins Commandant's Trophy

NRRC 5-9, Washington, D.C., received for the second year the Commandant's Trophy for placing first among twenty-five companies in the Fifth Naval District for FY 1972.

Major contributions to the Navy have been made by Company members on Active Duty Training. A recent survey of the past four years showed that 60 percent of the on-the-job training was in a contributory role. Much of this work resulted in written reports or published articles. The Company enjoys a close relation with its host organization, the Naval Research Laboratory. As a contribution to NRL, two Company members recently assisted in updating the Laboratory's Mobilization Plan. The Company has also provided judges for the International Science Fair during the past three years.

NRRC 5-9 provides a lecture program which attracts many visitors. Recent military oriented subjects included "Navy Command and Control," "Army Night Vision Developments," "Recent Developments in the Naval Reserve," "Navy Laboratories in the 1970's" and "Procurement of Research in ONR."

Research by NRRC 5-9 members who are on the staff of NRL were included in the Research Reserve Seminar to be held at the Laboratory in August. The Seminar, which was sponsored jointly by NRRC 5-9 and NRL, covered work in the areas of oceanology, space science and technology, electronics and materials.

Contributory Support Work of NRRC 5-8

This year NRRC 5-8, Washington, D.C. was active in a contributory support role to ONR. Five technical work areas were formed: Program Planning, Computer Sciences, Mathematics, Life Sciences, Physical Sciences Engineering, and Personnel/Training. Each group worked with an ONR manager to set up work-tasks.

In November members of the Company had a four day briefing at Fleet Anti-Air Warfare Training Center, Dam Neck, Virginia.

NRRC 5-10 Tours Dam Neck

Members of NRRC 5-10, Bethesda, Maryland, toured the Fleet Anti-Air Warfare Training Center, Dam Neck, Virginia, as part of their

annual group training program. The visitors were given extensive briefings on hardware and training devices of the Naval Tactical Data System, guided missile systems, fleet ballistic missile systems, and advanced electronic warfare equipment.

Breakthrough for Operational HF Radar Techniques in Mapping Storm Winds at Sea

Scientists at the Naval Research Laboratory (NRL) believe they have developed an operational technique using high frequency (HF) radar to map winds of a storm at long range (500 to 1000 nautical miles) in the North Atlantic from the Laboratory's HF radar research facilities at Chesapeake Beach, Maryland.

NRL radar men say the short time response of the sea surface to local winds may be mapped by the analysis of a matrix of range-azimuth records containing frequency power spectra of HF radar signals backscattered from the sea surface *via* the ionosphere.

Although the potential for the use of HF radar for oceanographic and meteorologic study has been demonstrated over the past decade, the actual implementation of these techniques on an operational basis has not been effected.

Recent test results indicate that HF radar may be a powerful potential as an oceanographic and meteorologic tool as work continues for controlled experiments in this field. These include the measure of backscatter parameters as a function of radar frequency, angle to the wind, and detailed time-dependent sea surface spectral characteristics.

When the HF backscatter spectrum can be confidently related to the spectral characteristics of the sea, the investigators say HF radar will provide a powerful tool for studying the detailed morphology of the sea surface.

Predictive Wind Velocity Model

Dr. Shih-Ang Hsu of the Louisiana State University, Coastal Studies Institute has developed reasonably accurate models for predicting modification of the wind velocity from offshore to onshore in his research under an ONR contract. The input requirements to the models include landwater temperature differentials, initial onshore wind velocity, and land form configurations. The predictions include the mean onshore wind speed, shear stress ratio, and the aerodynamic roughness ratio.

Knowledge of low-level wind velocities in the nearshore area is essential since the wind and temperature control fog, its distribution, and rate of movement. Such a model will assist in predicting cloud cover, fog development, and current conditions in the nearshore zone facilitating planning of aerial reconnaissance and coastal operations.

Research Notes

Improved Communications System for Submarines and Ships

Recent research at Naval Research Laboratory (NRL) promises to be an important advancement in Navy submarine communications and possibly a spinoff benefit to navigational systems for both commercial and Navy ships.

The research effort, sponsored by the Naval Electronics Systems Command, has been directed toward obtaining information on very-low-frequency (VLF) propagation paths, that had not been previously investigated, to determine which frequencies are the most suitable for communication transmissions to Navy submarines.

Since VLF waves penetrate beneath the surface of the earth, they are also useful in prospecting for mineral deposits and orebodies.

During the past few years, NRL scientists have been intensively studying electromagnetic wave propagation at VLF between a newly constructed transmitter at North West Cape, Australia and receiving sites located in Japan, Madagascar, Bahrain Island, Alaska, and the Philippines. The North West Cape VLF transmitter broadcast signals on a schedule which permitted propagation data to be collected on six frequencies in the VLF band at the receiver sites over a 3-month period.

Data collected from the experiments were compared with theoretical predictions. Some effects of multimode propagation were found to be evident in data taken during the nighttime period. In addition the nighttime signals were more variable than daytime signals. Daytime signals appeared to be influenced by the direction that the propagation path made with the earth's magnetic field.

As a result of the investigations, NRL has now been able to give the Navy information on the most suitable transmission site. Information obtained from the study is also applicable to ships using the Omega navigational system.

Progress in Marine Borer Control

Naval Research Laboratory (NRL) scientists have made considerable progress in their search for wood species having a natural resistance toward certain marine boring organisms which attack wooden structures in the sea.

It has been estimated that in the United States the annual cost of replacement or repair of such damaged structures is several millions of dollars. This approach to marine borer control is particular importance today from an ecological standpoint. Borer-resistant marine structures could eliminate the use of timbers treated with various synthetic chemicals which may become implicated as environmental pollutants.

In their search for naturally resistant woods, the principal investigators, J. D. Bultman and C. R. Southwell of the Ocean Sciences Division, have collected and exposed 113 wood species in the marine environment. Of this group 104 species were natural woods of the tropical forests of Panama, and the

remainder were borer-resistant woods gathered from other tropical regions of the world.

The woods were exposed for periods up to 90 months in three different tropical waters, the Caribbean Sea at Coco Solo, C. Z., the Pacific Ocean at Naos Island, C. Z. and in brackish Miraflores Lake, a section of the Panama Canal. All were evaluated for teredo, limnoria and pholad damage.

More than 28 species of marine borers have been identified from these very biologically active waters and their extreme activity provided the scientists a very thorough screening test for these woods.

It was learned from this research that several of the exposed woods were resistant to one or more of these different families of boring organisms. Some of these woods proved to be more durable than other tropical species such as *Ocotea rodiei* (Greenheart) and *Dicorynia paraensis* (Angelique) which have been marked world-wide as borer-resistant woods for marine use.

Highly silicated woods were more resistant to damage by teredoes although some low-silica woods were also very resistant to this borer. All wood species highly resistant to pholads were extremely hard and dense (>0.9 sp gr); however, hard, dense wood were generally more resistant to all borers than the lighter species. There was no correlation between density or silica content and resistance to limnoria damage.

The wood most resistant to all marine borers was *Dalbergia retusa* (Cocobolo). Unfortunately, the physical nature of this tree renders it unsuitable as a source of marine construction timbers. Because of its unusual natural resistance, work is being done to determine the nature of the active material in the wood conferring protection. This natural protectant may prove suitable for treating less resistant conventional marine construction timbers.

LULU on Oceanography Project in Florida

The catamaran R/V LULU, with undersea habitat EDALHAB on board, returned in early May to Woods Hole Oceanographic Institution following a three-month scientific project off the coast of Florida.

The project, sponsored by the National Oceanic and Atmospheric Administration and known as FLARE—"Florida Aquanaut Research Expedition"—included studies of coral reefs, fish behavior, and the chemical composition of sea water.

The versatile 105-foot LULU, which was originally developed as mother ship to Woods Hole's deep-diving submarine ALVIN, served a somewhat different function in combination with the EDALHAB habitat system.

Providing air and electricity through umbilicals, LULU made it possible for EDALHAB to maintain two or three scientist-divers for up to five days at a depth of 45 feet. And while the catmaran had been used previously as life-support to EDALHAB, last spring off the coast of New Hampshire, the completion of the Florida project marked LULU's most extended operation (without ALVIN) since she was built in 1964. The LULU-ALVIN diving system is owned by the Office of Naval Research and operated by Woods Hole.

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The EDALHAB-LULU, a highly mobile combination, was equipped with its own communications system in addition to facilities for surveillance during dives. Telephones and a video camera connected the two, and served to convey the status of the submerged living habitat to LULU at the surface.

The FLARE mission consisted of concentrated exploration of four coral reefs off southeastern Florida and depended on EDALHAB as a temporary home and workshop for marine investigators during the three-month experiment, Evaluations by project scientists on EDALHAB's success as a portable underwater explorin device were uniformly favorable.

The habitat was used during one phase of investigation for studies comparing an artificial reef to an authentic one, to ascertain whether man-made reefs take on the same characteristics as natural structures. Surveillance of the experimental site will continue, although project FLARE has officially ended.

In the course of the project EDALHAB-LULU demonstrated the potential value of a movable habitat supported by a surface carrier, and the combination is regarded by scientists as a step forward in undersea technology. Previous U.S. experiments involving underwater studies of long duration were confined to either fixed habitats or motorized submersibles.

R/V LULU, expected to return to sea later in the month with the submersible ALVIN, is one of five ocean-going research vessels operated by Woods Hole Oceanographic Institution, for scientific investigation of waters around the world. The Institution, with a resident staff of more than 650 scientists and support personnel, conducts a wide range of studies in biology, chemistry, geology and geophysics, ocean engineering, and physical oceanography.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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Diver submerging into the water beneath the Arctic sea ice. See article beginning on page 1.

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OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE, $300

DoD-316