TOWARDS MAKING BRAILLE AS ACCESSIBLE AS PRINT

John K. Dupress
Dwight M. B. Baumann
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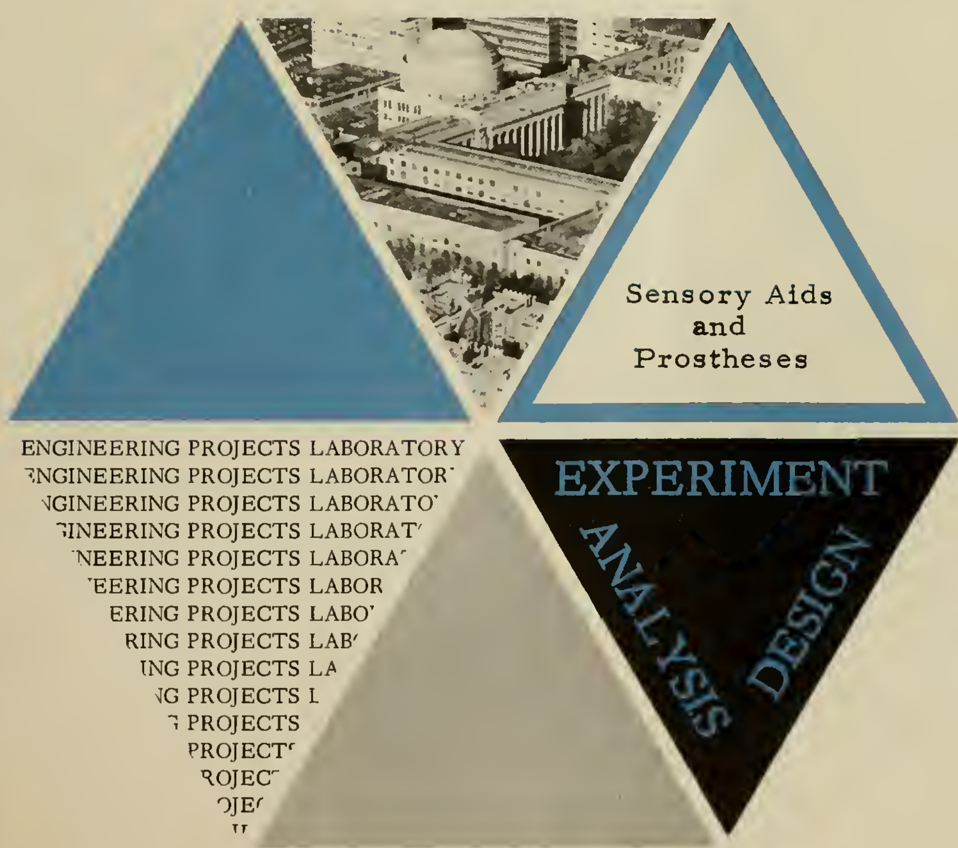
Report No. DSR 70249-1

June 1968

Engineering Projects Laboratory
Department of Mechanical Engineering
Massachusetts Institute of Technology



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PREFACE

John Kenneth Dupress died on the 29th of December 1967 before this report was completed. John was not one to devote much effort to the creation of personal memorials; in his intense, cryptic, single-minded fashion he was concerned only with results and impatient of their accomplishment. We hope that this modest report with John as co-author can stand as another permanent and tangible fragment of the contributions John made to applying technology for the benefit of the blind.

We were first influenced toward work for the blind through the Sensory Research Discussions originated in the fall of 1959 by John and chaired bi-weekly and then monthly by Mr. Dupress until shortly before his death.

In those early days John was Director of Technological Research at the American Foundation for the Blind. His encyclopedic knowledge of world-wide efforts to relate science to blindness, his incisive and critical appraisal of the needs of the blind, his catalog of possible approaches, his enthusiasm and conviction that progress was possible, his willingness to debate with technologists the appropriate courses of action, and the inspiration he himself provided in his ungrudging, sympathy-disdaining adaptation to war blinding and maiming, spurred faculty and students in several M.I.T. departments to sensory aids research.

In 1964, John became the founding Director of the M.I.T. Center for Sensory Aids Evaluation and Development, an organization which formalized the role he had been endeavoring to play, albeit in an ad hoc fashion.

This report coalesces work conducted over the period of John's influence on sensory aids at M.I.T., both in the Mechanical Engineering Department under the supervision of the co-authors, and in the Center for Sensory Aids Evaluation and Development under Mr. Dupress's direct supervision.

We offer the report as a modest memorial to a colleague.

The Sensory Aids and Prostheses Group in the Mechanical Engineering Department and the M.I.T. Center for Sensory Aids Evaluation and Development has had sustained support from the Social and Rehabilitation Services of the Department of Health, Education and Welfare, formerly known as the Vocational Rehabilitation Administration. Private Foundations have provided complementary financing notably the Hartford Foundation, the E. Matilda Zeigler Foundation for the Blind and the American Foundation for the Blind.

D.M. Baumann
R.W. Mann

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1. The Overall Information Processing System

A. Introduction

An article in Vol. 1 of the 1962 Proceedings of the International Congress on Technology and Blindness described the then-several-years-old-state of a program in the Mechanical Engineering Department at M.I.T. directed towards "Enhancing the Availability of Braille".[1] This report is a summary of the present state of that effort. Most of the material referred to here already exists in far more detailed form in theses and in conference and program reports.[2,3] The primary purpose of this document is to provide an index to this source material and to set down in one place a rather succinct overview of the information processing system under development and evaluation. While the report concentrates on the M.I.T. program--in the Center for Sensory Aids Evaluation and Development as well as the Mechanical Engineering Department-- where appropriate, the M.I.T. effort is related to the growing national program of braille production.

The argument for enhanced braille presupposes much about its present availability and use, which in turn raises questions about the blind population in general. Some preliminary treatment of these questions was provided in Ref. 1. Since then the M.I.T. Mechanical Engineering program has produced a thesis[4], subsequently published by the American Foundation for the Blind, which sets out the needs, sources and present production methods and costs of braille, before going on to report on current technological advances in braille production and the implications thereof.

B. The Goals of the System

The goals of the Braille Information Processing System (BIPS) are to increase the volume, scope and ease with which formal and informal communications are made available in braille to persons who are blind (or deaf-blind) while at the same time reducing the time lapse in acquiring braille copy. A subsidiary goal is to reduce the overall economic and social cost of copy interpretable by blind persons.

The system employs the high-speed digital computer as the information handling and braille translating node combined with commercially available and specially designed input and output equipment contiguous to, and remote from the computer. The system is designed to be compatible with future expansions in braille translation services and in supplementary output forms, such as computer generated audible speech.

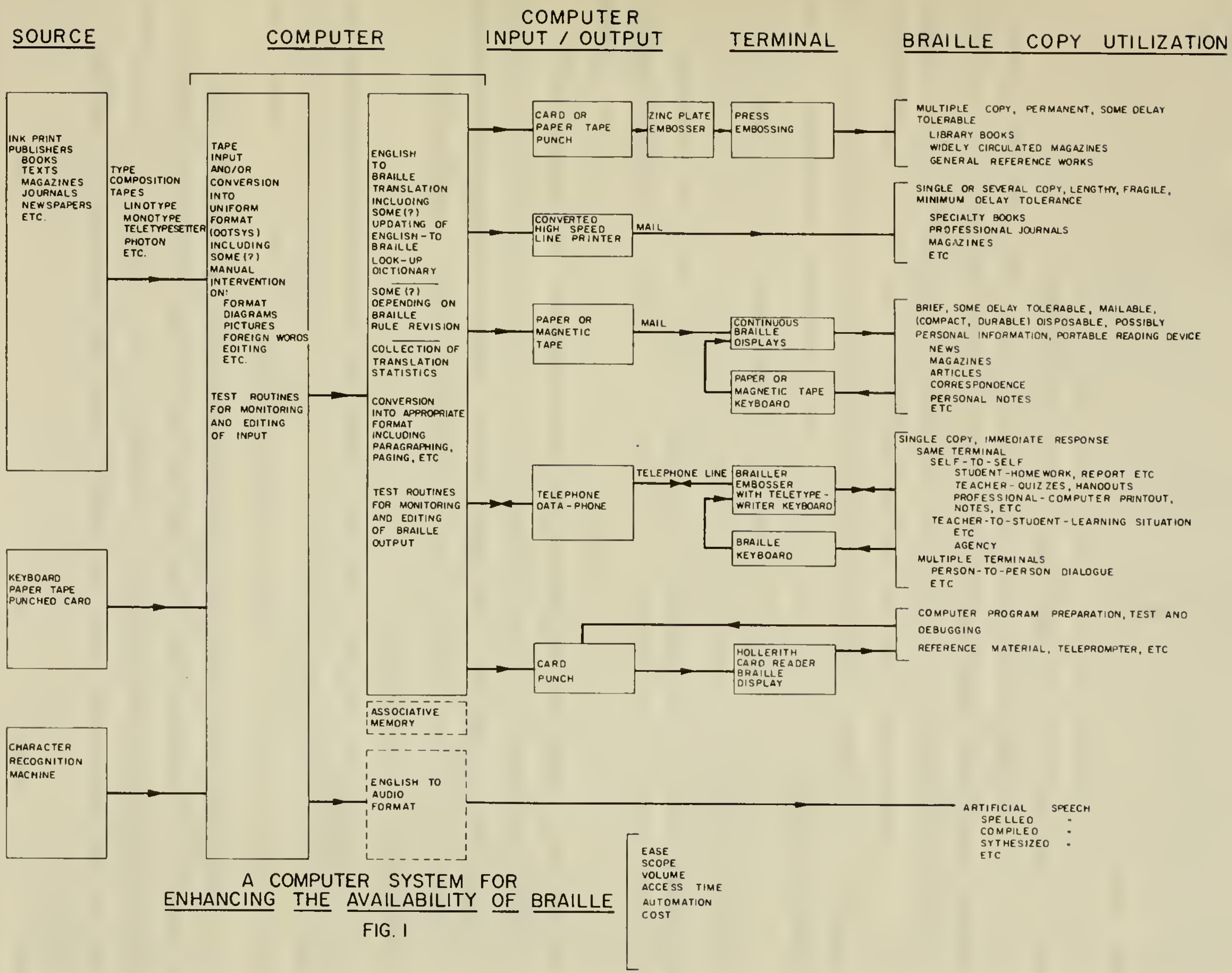
C. Braille Copy Utilization

At the outset one must consider the variety of ways in which blind persons use braille copy. One dimension of utilization is the number of copies required, ranging from some magazine and reference work publication in the thousands of copies through book publishing in the hundred copy range, to educational materials for which 25 or 30 copies might be a maximum, down to the single copy requirements of students, professionals, correspondents, etc. A second primary dimension of utilization is the time lapse between the request for the material and its delivery in braille, or between the origin of the material in ink print and its availability in braille. A third consideration is the relative permanence of the braille copy ranging from durable for library circulation to disposable after one reading. A fourth consideration in utilization is the relative privacy of the information contained in the embossed material.

Combinations of these considerations of quantity, access time, permanence, and privacy define several major functional groupings of braille copy utilization. These are catagorized in the following paragraphs and keyed to the left-hand column of the overall block diagram describing BIPS, Fig. 1.

Category I. Reference works, books, and some magazines are examples of permanent copy, in quantity, where immediate access is not urgent (while always desirable). Permanence here connotes durability and perfection, and therefore calls for press embossing, coating (shellacking) to improve wearability, binding, regional library storage, and mail circulation.

Category II. Some ink print material will never be required in quantity in braille, but certain reference works and books, journal articles, etc., are vital to the effectiveness of students, professionals, and other blind workers. Here immediate access is not essential, and though perhaps lengthy and bulky, the single or few copy braille need not have the longevity or ruggedness expected of library or reference work braille.



A COMPUTER SYSTEM FOR ENHANCING THE AVAILABILITY OF BRAILLE

FIG. I

Category III. Permanent braille copy is not necessary or in fact even desirable for certain materials such as daily news (for the deaf-blind), and news commentary and other current-interest periodicals which might enjoy relatively wide circulation if available in braille. Furthermore, copy intended for restricted and/or personal use might best not be permanently embossed in braille. These uses suggest alternatives to embossed paper for the storing, transporting and reading of information encoded in braille. For storage and delivery reasons the coded format should be durable, compact, inexpensive and compatible with computer input/output equipment to facilitate translation. A personal, portable reading device which read and/or generated this coded format would also provide a blind person with a means for personal, private correspondence, or with a "personal secretary" on which he could take cryptic, personal notes for later reference.

Category IV. In many situations the blind could benefit from the immediate generation of contracted braille in response to typewriter keyboard input with the simultaneous generation of inkprint copy if desired. Such a capability would permit a student to prepare brailled homework or reports, a teacher to braille quizzes or handouts, a professional to generate brailled text, make brailled notes, or check computer results in braille, or a blind person to proofread ink print copy. Immediate braille generation would also make possible a dialogue between teacher and student in learning situations. Deaf-blind persons remote from one another could conduct "conversations" in braille.

Category V. Finally, the blind should be provided with braille displays of formats peculiar and necessary to their employment, such as the Hollerith cards used in computer programming.

BIPS has been designed to facilitate all of the above modes of utilization. It has also been designed so that it can later be expanded to include other means of introducing material to be translated as well as generating other outputs interpretable to blind persons such as audible speech.

D. System Input/Output

Reflection on the various categories of braille copy utilization establishes the origin of material desired in braille. For source material which already exists in ink print, a sighted person operating standard typewriter keyboard prepares the material to be translated as punched cards or punched paper or magnetic tape.

BIPS is also designed to machine read and interpret the type-composition tapes used in book, magazine, journal and newspaper publication for the preparation of masters for ink-print production. In either of these cases information handling and translation in the computer would be performed in the batch-processing mode of operation.

BIPS will also operate in real-time with interactive keyboard input which implies the use of a time-shared, multiple-access computer. Since the typing rates of a human are so incomparably slower than the information processing speed of the computer, one terminal uses but a small fraction of any time interval of computer processing time, permitting simultaneous use of many terminals with each operator's demands on the computer being completely satisfied.

In addition to the conventional embossing of zinc plates for braille press production and the conversion of commercial, high-speed, line-at-a-time chain printers to emboss braille, the generation of palpable braille to meet the utilization categories of Fig. 1 requires new terminal devices. The M.I.T. program has undertaken the development of a typewriter-speed-and-size braille embosser and keyboard, devices to present braille continuously on a belt-like display and a device to provide a braille display of the information content of Hollerith computer cards.

For remote terminal braille translation and embossing, using telephone lines connecting the remote terminal and the central computer, a buffer storage at the computer would permit the off-line storage of input information from the terminal for subsequent efficient batch processing at high computer speeds. At the output of the computer the buffer storage could accept the translated output at computer speed for subsequent retransmission, at lower terminal device speed, to the remote terminal. An incremental, magnetic tape buffer storage unit is under development in the Mechanical Engineering group. The buffer storage can also be used for off-line reading and conversion of type-compositor's tape input into a form suitable for computer input.

Following sections of this report describe in more detail these input and output devices.

II. Computer Aspects

A. Introduction

The feasibility of computer programming of the translation of the English language into contracted Grade II Braille has been demonstrated by a number of workers (Ref. 2, p. 64 - 70). Of these the program originally written for the IBM 704 by Schack and Mertz[5] has seen extensive enough use to establish its adequacy. Over two hundred literary titles have been prepared at the American Printing House for the Blind (Louisville, Kentucky) using this program with supplementary features programmed by APH staff. The process produces acceptable braille and is an economical adjunct to APH's braille production process. However, the system requires copy preparation by manual keypunch of cards which is slow and expensive (estimated to be 2/3 of the total cost of translation). Also the only form of computer output has been punched cards coded to operate APH's stereograph machines which emboss the zinc plates for press embossing of braille copy. The card input and output format has delayed correction of inkprint text input or braille translation output errors until preparation of galley proofs of the zinc embossings.

B. The DOTSYS Program

In 1964 the M.I.T. Center for Sensory Aids Evaluation and Development undertook the systems design of a programming complex adapted to the more ambitious and flexible input media and output braille utilization possibilities of Fig. 1. The system was dubbed DOTSYS (the DOT SYStem) and is described in some detail in Center for Sensory Aids Evaluation and Development Annual Reports[6,7], in the Proceedings of Braille Research Conferences[8,9,10] and elsewhere[4].

Since it is not the purpose of this report to duplicate otherwise available information, suffice it to say here that DOTSYS provides a number of program co-routines or "boxes" each of which manipulates the information being processed in response to computer directed requests from successive elements in the computation chain.

This segmented approach to the programming of DOTSYS was predicated on certain projected advantages. Flexibility is achieved since new "boxes" can be introduced progressively into the system with but minor side effects on the rest of the system. Thus new input media can be assimulated as it becomes available, the translation program can be upgraded, and new braille production techniques can be accommodated. Adaptation to computers of different sizes is facilitated since an overall processing operation can be segmented into blocks which fit the available computer, producing and storing intermediate results for batching operations. Finally from a program writing and testing point-of-view, the "box" approach divides a very big overall job into digestible portions which individuals can program separately while maintaining effective communication with their co-workers, and the individual segments can be independently tested and debugged.

Certain of the "boxes" process different type-compositor's tape information into a common computer coding called UNIVERSAL. Thus the TELCON "box" converts Teletypesetter Tape into UNIVERSAL, or the MONOCON "box" similarly converts Monotype tape input into UNIVERSAL. Provision has been made to accommodate other type-compositor's tape media as they become available by the simple expedient of programming a new "box". INBOX interfaces keyboard input from a teletype machine with the computer in the Compatible Time-Sharing Mode.

UNICON makes UNIVERSAL code compatible with the braille translation program input BRAILL, which then does the actual translation. Since BRAILL is but a "box" in the system, as its internal programming configuration is changed to increase its efficiency, reduce its error rate, simplify the translation code, or accommodate to other than literary braille, i.e., mathematics or music, only that "box" need be changed without altering the rest of the system.

In a similar fashion different "boxes" comply with the coding format and operating requirements of various output devices. Thus FORMAT 2 accommodates the APH stereograph machine, while FORMAT 1 fits the M.I.T. Braille Emobsser. Other "boxes", yet unprogrammed, will be compatible with on-line embossing equipment such as converted chain printers or with punched paper tape formats for continuous, braille-text-reading devices.

OUTBOX interfaces with a terminal device on a time-shared computer system, or produces magnetic disc files which then, off-line, punch the appropriate card or tape format for the particular braille producing scheme.

Auxiliary "boxes" perform highly desirable monitoring or editing functions. Thus UNITYP produces an inkprint version of the type-compositor's tape being machine read, while DOTPR takes the output of BRAILL and produces a printed version of the braille on a typewriter console.

The interconnection of appropriate "boxes" to achieve necessary sequencing from one particular input to one particular form of braille output is itself accomplished by command to the computer. For batch-processing, upon naming of the "box" sequence desired, by card or other input of the "box" acronym titles, a linking program called HOOK automatically assembles the "boxes" in the proper manner, connects them together, transfers control to the proper "box" and then disappears.

C. Applications of DOTSYS

As illustrations of typical configurations of DOTSYS, on August 18, 1966, as part of a M.I.T. summer program exposing students of Special Education from the Columbia University to technological developments of benefit to the blind, Teletypesetter tape produced by United Press International as part of its normal news service embossed Grade II Braille on the M.I.T. Braille Embosser. The boxes used were: INBOX 1, TELCON 1, UNICON, FORMAT 1, OUTBOX 1. On November 18, 1966 a portion of a Teletypesetter tape used by Poole Clarinda Company of Chicago to set type for an ink print book was inputed, translated, outputed, and formated to drive the card-controlled stereograph machines at the American Printing House. The six boxes were: INBOX 2, TELCON 2, UNICON, BRAILL FORMAT 2, OUTBOX 2. On March 9, 1968

M.I.T., Poole Clarinda Co., and Little-Brown Co. announced that a complete book would be brailled from type-compositor's tape, with the braille version available concurrently with the ink print version. The book is the EAST INDIAMAN by E. C. Meachem. APH will press-emboss the work. The Library of Congress is supplementing Rehabilitation Service Administration funding for the demonstration.

Although DOTSYS system programming is attempting to anticipate and automatically provide for the complications inherent in interpretation, translation, formating and coding, as well as the peculiarities which arise in adapting one publication process (ink print) to another (braille), it appears certain that a certain amount of manual intervention will be necessary to accommodate unusual formats, diagrams, illustration, unusual words (foreign, colloquial, etc,), and unusual construction and editorial situations. The character and extent of this manual interaction can only be established on the basis of serious feasibility studies of significantly long runs of different kinds of material. The EAST INDIAMAN project is an example of just such a study.

While it will probably always be true that some minimum intercession will be mandatory, two circumstances auger will for the future of DOTSYS. One is the success of the APH computer braille translation effort in achieving accuracy with acceptible error rates while establishing an economic advantage over human translation. The second is the ever-increasing computer orientation of ink print publication and the concommitant increasing accuracy of type-compositor's tapes as precise descriptions of the ultimate ink print. All of the free-enterprize economic and competitive incentives to automate ink print publication provide bonanza material for machine translation into braille and other blind-interpretable forms.

D. Future Trends for Computer Braille

All current braille translation employs rather elaborate programming on general purpose computers. The nature of the translation rules from English to Braille make necessary the generation in the computer of a "look-up" dictionary in which are stored the allowed contractions of parts-of-a-word and whole words. This dictionary is necessarily open-ended since it grows as new literary situations are encountered. Tabular listings of this sort, while manageable, require much computer memory and operating time due to their serial arrangement. As the dictionary grows, problems arise in accommodating new entries, since on the one hand one cannot afford to leave spaces for unforeseeable future entries, but the insertion of new entries in some logical and addressable order, say alphabetical, may require rewriting of the original table or the starting of new auxiliary tables of smaller size which can be inserted into the main table on a periodic basis.

The M.I.T.-M.E. program has addressed itself to this problem in two ways, by a critical appraisal of the braille translation rules and by researching alternative computer configurations.

E. Braille Code Revision

A thesis[11] in Mechanical Engineering considered the English Grade II Braille contraction rules from an information theory point-of-view, taking into consideration both human comprehension and speed of reading as well as computer translatability. Using available data on word frequency occurrance and error rates in braille interpretation, the study proposed a number of desirable revisions in the Braille Code. The growing use of computer braille translation provides the opportunity to collect more copious and accurate statistics on rule application, contraction usage, extent of space saved, etc., as well as to provide a convenient vehicle by means of which to introduce rule changes on a carefully controlled, experimental basis.

F. Associative Computer Memory

Computer configuration research in Mechanical Engineering has explored an alternative to the tabular storage of look-up information in computer core memory. An associative memory avoids serial-search time by establishing a one-to-one relationship between the description of an entry in memory and the location of that entry in memory, that is to say the associative memory is "content-addressable". The particular forms of associative memory studied[12] stored the tabular information in the form of holograms and used laser illumination to establish the relationships between the input (say a word) and its corresponding output (say the contracted braille equivalent) stored in the table. While the thesis demonstrated the feasibility of the approach, much work remains before practical results will be evident. Although started in the context of the braille translation problem, the technique has many other possible applications.

III. Input Equipment

A. Type Compositor's Tape

The type-compositor's tapes for most commercial type-setting processes are compatible with computer tape reading equipment. An important exception is the MONOTYPE process widely used for school texts, particularly at the elementary levels, and for mathematical and scientific texts and books at all levels as well as most professional journals. The Monotype tape is punched paper, 4-1/4" wide, 31 channels and is read pneumatically at relatively low speed and therefore not compatible with any existing computer input equipment.

A cooperative effort between the Center and the Mechanical Engineering Department has produced a monotype reader which converts the punched paper tape information into a computer compatible magnetic tape record.[6,7] The reader uses some of the frame and drive components common to the commercial pneumatic monotype unit combined with new photo-diode sensing of the holes,[13] electronic logic and an incremental tape recorder, see Fig. 2. A keyboard associated with this information storage unit permits the recording on the tape of appropriate labeling and computer instructions as well as providing a means of editing the magnetic tape record.

B. Remote Keyboard Input and Braille Embossing

The incremental tape recorder and keyboard is intended to serve also as a buffer storage in conjunction with the deployment of keyboard and braille embossing consoles at locations remote from the computer, as for example in schools where there are blind children integrated with classes of sighted children, or in institutions for the blind, or at agencies for the blind who prepare braille copy in response to requests. Such consoles will will be used to transmit, via telephone lines, keyboard generated signals in English, to be translated into braille by the central computer. The braille

Fig. 2. Monotype Reader, Editing Keyboard and Incremental Magnetic Tape Recorder.

signals will then return transit by telephone lines to the source location where they will drive the M.I.T. Braille Embosser and make braille.

When appropriate, this whole process from keyboard operation through braille embossing takes place in real-time. Signal transmission and computer translation occurs so rapidly that for all practical purposes braille generation is simultaneous with keyboard operation. This mode of operation of course requires access to a time-shared, multiple-access computer.

For some material, however, such urgency is not warranted; overnight delivery would be adequate. Computer rental economies result from batch-processing such translation during non-prime shifts. Since keyboard generation of the original information at the remote terminal should be at the convenience of the operator there, a means of storage of the input in a computer compatible form is necessary. The incremental tape recorder serves this function. Located at the computer and connected to the telephone line, it automatically accepts and stores the keyboard information at whatever rate the remote operator provides. It then reads the data into the computer at compatible rates for processing. The recorder can also store the prodigiously fast output of the computer and retransmit this via telephone to the remote brailler at rates compatible with brailler operation. For example, material typed into the computer on one day could be available in braille the next morning.

Using type compositor's tapes (or magnetic tape copies thereof) this same system could generate appropriate text material at the remote location upon the receipt of a telephoned request to a tape library at the computer location. A means for the identification of tapes to be retrieved from publishers and their organization into a tape library would be necessary. Reference 2 describes and compares the merits and economies of different storage media.

C. Character Recognition

Ultimate commercial, industrial and military applications have directed a great deal of research to the problem of machine interpretation of ink print and other graphical symbolism. Currently available reading machines are too limited in capability and too expensive for consideration as a practical source of input to DOTSYS now. However, the "box" structure of DOTSYS can easily accommodate to such devices when they become more flexible and economical.

IV. Output Equipment

A. M.I.T. Braille Embosser

The hardware project which has received the most concerted attention at M.I.T., with origin and application by the M.E. group and development and evaluation at the Center, has been the M.I.T. Braille Embosser. This typewriter-sized unit produces cell-at-a-time embossed braille at up to 16 cells per second in the proper format on standard braille paper. The coded electrical driving signals can be derived from any of several sources including typewriter and braille keyboards, computer output, etc. Preliminary studies[14], the original design[15], its incorporation into a terminal console[16] (Fig. 3), the design of associated braille keyboards[18, 19] (Fig. 4), application in a residential school for the blind[17], Fig. 5, and development, evaluation and the assembly of 6 units at the Center are well documented[6, 7, 8].

Several of the units have been operated extensively and evaluated at the Center. Another has been on loan to a worker for the blind in Illinois. A Braille Embosser is employed in conjunction with a research project in the Electrical Engineering Department at M.I.T. A systems programmer at Project MAC at M.I.T. received computer output in braille for over a year from another prototype. An installation at Perkins School for the Blind with real-time, multiple-access, braille translation via telephone lines to the M.I.T. computer was very well received[20].

A grant from the Hartford Foundation is making possible the production design of the electromechanical and electronic components of the Braille Embosser and the production of 20 units of the improved and final version as well as the preparation of complete manufacturing documentation.

B. Continuous Braille Displays

The section on Braille Copy Utilization argued, by analogy to the world of the sighted, of the need for access in braille to material intermediary between the permanence of press embossed, regional library, braille books and the copy of a personal braille writer such as the Perkins machine. Much of the information that a reader peruses is of a transient

Fig. 3. The M.I.T. Braille Embosser Installed in the Console.

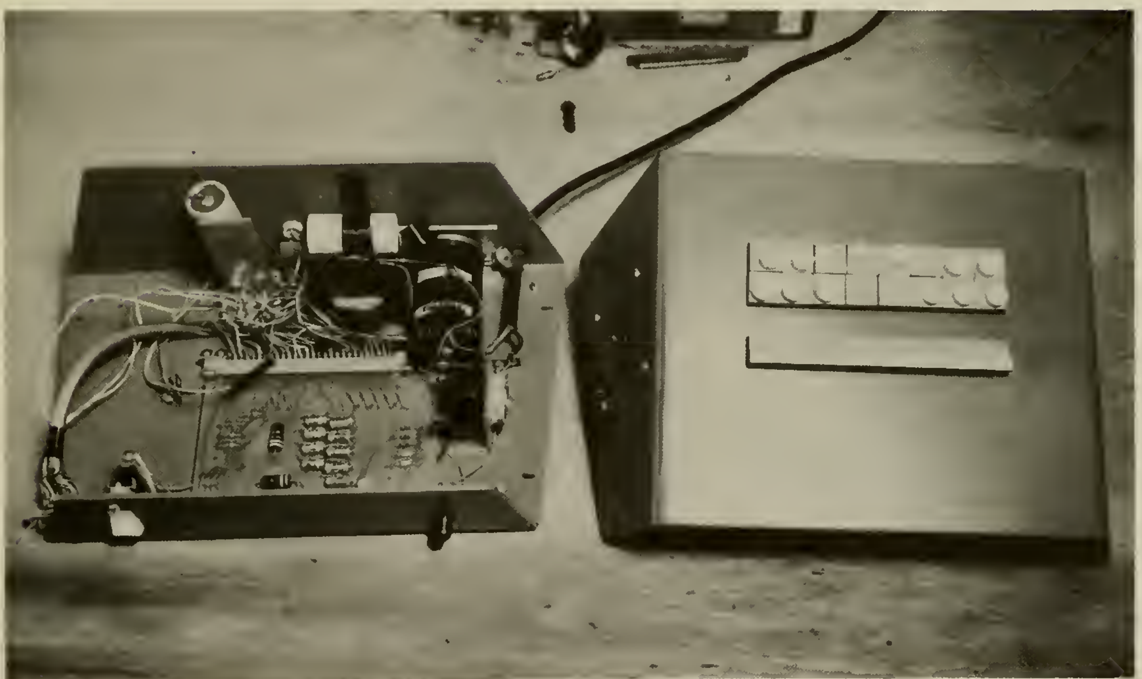


Fig. 4. The M.I.T. Braille Keyboard.

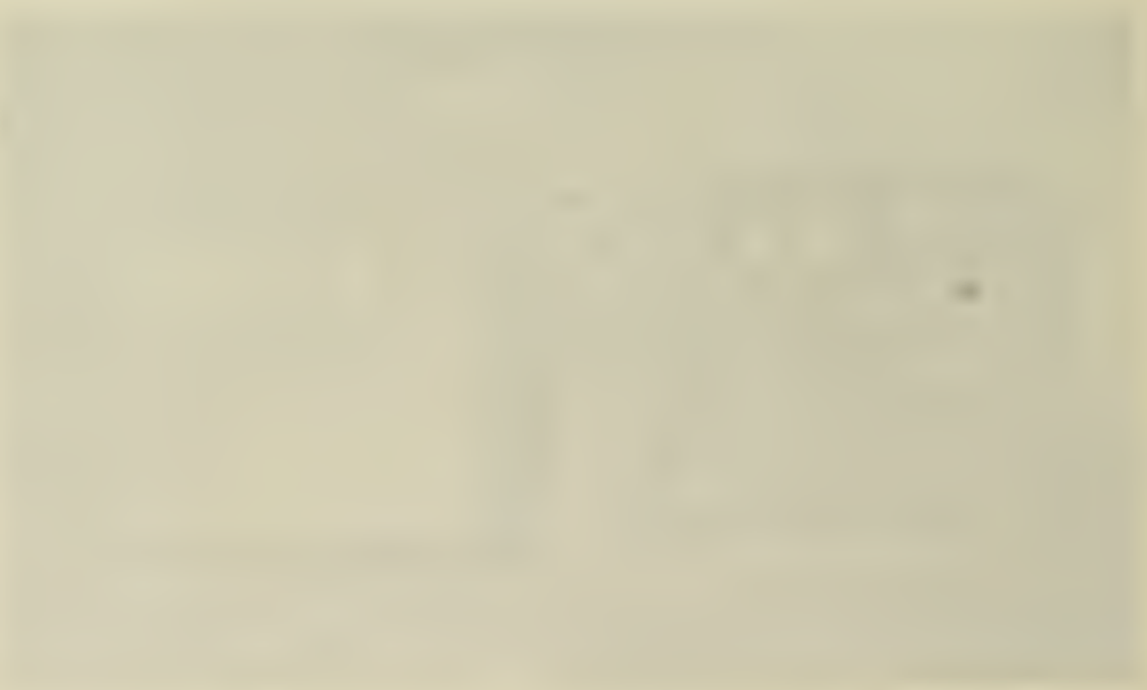


Fig. 5. A Computer Terminal (at Perkins School for the Blind) to Provide Immediate Grade II Braille Translation.

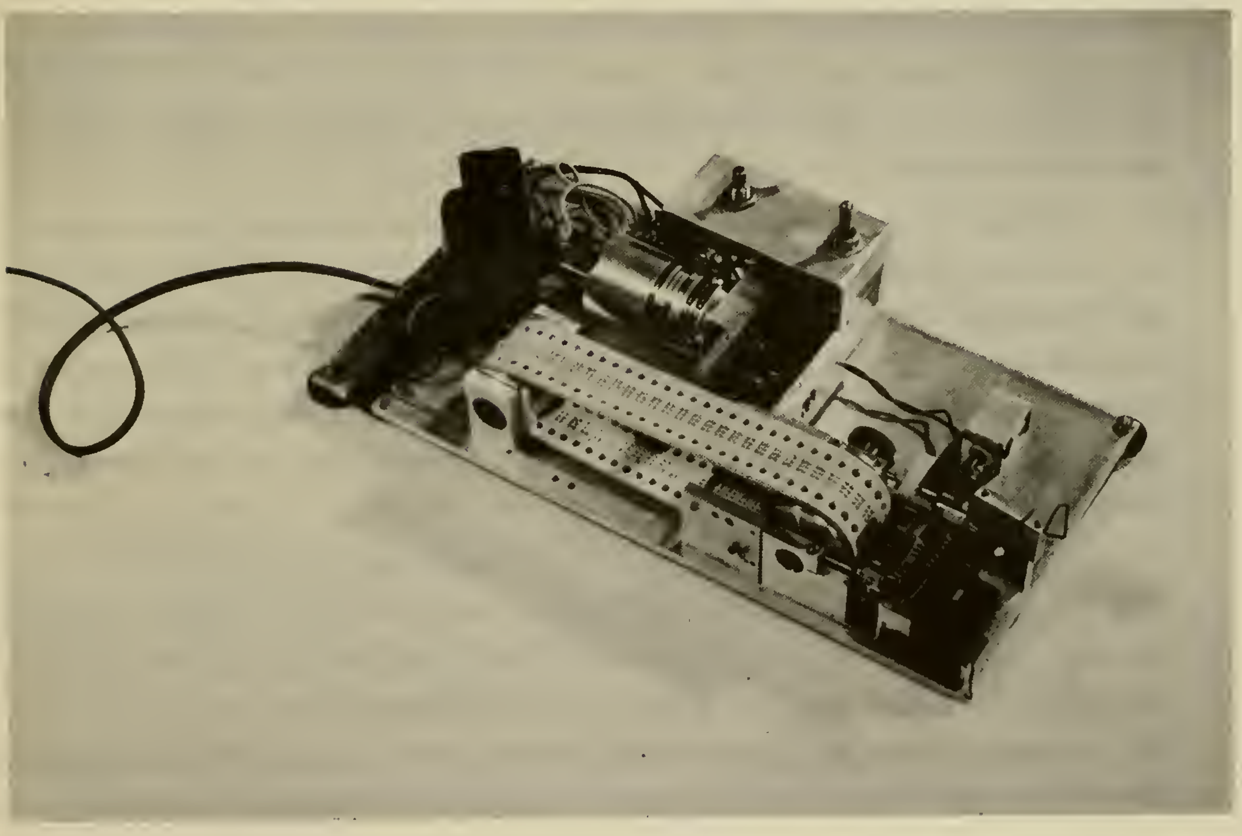


Fig. 6. Portable, Continuous, Braille-Belt Display.

nature --news and commentary-- articles, recipes, personal notes, etc. Frequently this material is brief, of non-standard format and/or unbound. To apply the translating power of the computer to this material while achieving the flexibility and portability of a personal braille reading device requires an information storage medium which is compatible with both the computer and the device, is durable and compact for mailing, storage and handling, and inexpensive enough to discard without regret. Punched paper tape fills many of these criteria admirably.

A number of concepts for transforming the coded perforations in the tape to palpable braille were explored early in the M.E. program[1]. These included the use of pins, whose heads constitute the braille dot, located above or below the reading surface by the direct registration of the pins, arranged in the braille cell array, with the tape perforations or absence thereof. Both line-at-a-time and continuous belt configurations of this type have been built with one belt design subjected to considerable engineering refinement and some evaluation[7,21,22]. The main disadvantage of this "direct" reading of the punched tape is the inefficient use of the potential information content of punched paper tape and the noncompatibility of the tape format used on the reader with tape formats used on computers.

Maximum tape utilization and complete compatibility is achieved if the paper tape adheres to the Braille Paper Tape Standard (8 channel tape with channels 1 - 6 corresponding to braille cell locations 1 - 6, channel 7 machine function, and channel 8 parity check). An ingenious approach which read standard tape and used small ball bearings as the sensed surfaces[23] proved incapable of adequate reading speeds without undue mechanical complication[7].

The current, favored design for a continuous braille display[24], uses a composite flexible belt with holes. The pins are clamped in the up or down position by the physical deformation of the pin holes between the flexed belt (around one of the drive pulleys) where the pin can move and the flat run of the belt in the reading position which clamps the pins. The present design, Fig. 6, also features simplicity of operation and power requirement. The pins are positioned electromechanically from signals that are generated from punched paper tape holes or commerical magnetic tape cartridges.

In its final form the attache-sized case, portable "braille secretary" will include a 6 key braille keyboard and a magnetic or paper tape reader-recorder by means of which the operator can prepare, and concurrently braille proofread, notes for later rereading in braille.

C. Hollerith Card Reader

Computer programming has proven to be a uniquely successful source of professional employment for blind persons. They need the means by which to read information on the punched cards used extensively in computer program writing, test and debugging, and computer operation. Existing devices require hole-by-hole study of the card which is very slow and frustrating. A succession of M.E. undergraduates have been designing and fabricating a unit which will produce a simultaneous display of the total information content of the card arranged as braille cells. The perforations in the card act as valves to port compressed air from a manifold through plastic tubing to erect pins which tactually display the presence of the holes. Since the potential information content of a single Hollerith (IBM) card is 160 braille cells the device may also prove useful as a notebook for the blind, or teleprompter for blind speakers.

V. Nationwide Braille Production-Current and Future

The hardware and software computer programming aspects of the M.I.T. program have been accompanied by a study of overall national braille production, distribution and use. This study[4], a Master's thesis in the M.I.T. Sloan School of Industrial Management, has reviewed data on the blind and visually impaired population in the United States, organized data on braille users and braille translators, and described and documented production and cost information for single copy and multiple copy braille embossing. It then goes beyond presently employed techniques to describe all known and current technological developments related to braille including but not restricted to the M.I.T. program stressed in this report. The features and potential merits of new techniques are reported.

By combination of the known or estimated costs of new machines with present and projected costs of computer usage, and considering possible changes in the demand for braille, estimates are made of the probable costs of new procedures as well as predictions of when they may be operational.

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