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Automated Feature Attribute Accessing From Map Text

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This report documents an investigation into the feasibility of placing machine-readable symbology (bar codes or OCR text) on map products. The approach to this research included a survey of optical-scanning devices, procurement of suitable devices, and interfacing the equipment to a personal computer for the development of a prototype automated feature attribute access system. This report documents the issues that surfaced during the design and testing of this prototype system.

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PREFACE

With the recent advances in bar code and optical character recognition technologies, it seemed appropriate to conduct the ILIR work unit 4A161101A91D1120 to explore applications of these technologies in the mapping field. The purpose of this study was the investigation of potential applications of machine-readable symbology on map products. The study consisted of a product survey, procurement of hardware, and the development of a prototype system for evaluating the possible applications of these technologies.

The author would like to express his sincerest thanks to his associate Douglas Caldwell for his support and technical assistance during this effort. He would also like to thank his other friends and colleagues for their assistance.

The study was done under the supervision of Paul G. Logan, Chief, Data Base Development Branch; Richard A. Clark, Chief, Topographic Data Applications Division; and Eugene P. Griffin, Director, Topographic Developments Laboratory, U.S. Army Engineer Topographic Laboratories.

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INTRODUCTION

The objective of the project summarized in this report was to develop an integrated map/data base system and investigate the feasibility of accessing supplemental data by scanning machine-readable symbols on map products. There are many instances in which a large amount of supplemental feature data exists about particular features on a map. If this data can be stored in a computer data base, it can be accessed rapidly and accurately by optically scanning machine-readable symbology from the map product. The scanned symbology can be used as input to the computer system and provide access to the appropriate supplemental data.

The Federal Aviation Administration (FAA), for example, maintains a data base of airports and radio navigation facilities across the country. Several hundred items of information may be associated with each airport, e.g. elevation, geographic location, facilities available, owner, operator, runways and the latest notices available about the airport. This information is currently available in published airport guides.

To access supplemental information about a particular airport, a pilot must locate the appropriate airport guide, look up the airport in an index, and then search for the pages containing the information needed. The same information could be accessed with much less difficulty by using optical-scanning technology. Each airport is assigned a unique four-digit alphanumeric identifier code by the FAA. If these codes were printed on the aeronautical charts in machine-readable form, the map user could simply scan over the four-letter identifier using an automated access system and within seconds have a soft copy display of all the information on that particular facility. This technology could also be incorporated into an automatic flight planning system. By scanning machine-readable airport identifier symbols from an aeronautical chart, the pilot could enter his intended route into a computer and obtain a proposed flight plan based on stored aircraft and pilot data.

In another context, Army units currently use map overlays to assess the terrain mobility characteristics. The user carries the separate overlay sheets, as well as deciphers the information provided by using a look-up table or map key. This process can be both time-consuming and prone to error because it relies on human interpretation. With bar code or optical character recognition (OCR) data directly on the map, an optical scanner could be used, with a small computer, to decipher the coded data rapidly and accurately. Such a system could be implemented with a small hand-held computer. The savings in operator time and reduced possibility of costly mistakes could prove quite advantageous in the high-stress environment of the battlefield.

APPROACH

The first step in the investigation was to conduct a literature search. The next step was to evaluate available bar code and OCR readers. Concurrently, an evaluation was performed to determine what types of information would be suitable for automated access. Optical readers were purchased and interfaced to an existing personal computer. The developed software demonstrated the feasibility and proof of concept of machine-readable map texts. Several problems associated with using machine-readable text on maps that surfaced during this investigation are discussed in this report.

PRODUCT SURVEY

The product survey identified a wide variety of optical-scanning equipment. Bar code readers ranged from small hand-held units to bench-mounted industrial laser-scanning devices. Most bar code readers were, however, hand-held units. The scanning technologies available are based on light pens, fixed-beam scanners, and moving-beam scanners.

Light pens are the least expensive optical-scanning devices available. Typically, they consist of a light source, detector, and focusing device. When the light pen is scanned across a bar code, the light from the source is reflected from the bar code and focused onto the receptor. The varying reflectivity of the bars and spaces in the bar code produces an analog signal that is passed on to a host processor. This signal is in turn converted into a digital signal and decoded.

Fixed-beam scanners operate in much the same manner as light pens, except that the light source and detector remain fixed and the bar code is passed in front of the scanner. These scanners are generally used in industrial operations where bar codes are affixed to containers or parts passing down an assembly line or other conveyance. As the items pass the scanner, they can be processed automatically. These scanners generally have a fairly wide light source and depend on focusing the receptor on a small area of the bar code. The distance of the bar code from the scanner must be tightly controlled to reduce reading errors.

Moving-beam scanners generally utilize a helium-neon laser light source. The scanner reads a bar code by reflecting the laser light off a moving mirror. Since the light from a laser source is much more focused than that from an incoherent light source, moving-beam scanners can be used over a much larger distance than other types of scanners. In fact, some hand-held scanning guns can scan large bar codes at distances greater than 20 feet. With a moving-beam scanner, the bar code is scanned from 90 to over 400 times per second. Such repetition frequencies result in a read redundancy that greatly reduces the "no read" rate, since a single bad scan can be corrected by the several redundant reads of the symbol.

Light sources for most optical-scanning devices are available in spectral operating regions from visible red to infrared (about 600 to 900 nanometers). In general, the infrared readers use special carbon-based inks, while the visible-red scanners can detect not only carbon-based inks but dye-based black inks and even some colored inks as well. The particular wavelength requirements of the scanner are dictated by the intended application. The wavelength of the light source also dictates the spot size of the reader, which limits its resolution. Resolving power, therefore, puts a lower limit on the size of a bar code, which in practice is usually as small as feasible. As would be expected, coherent optics generally provide a higher scanner resolution.

Other characteristics of bar code readers include the first read rate (FRR). The FRR is the number of valid reads in a given number of tries. If a symbol was scanned 100 times and there were 93 valid reads, the FRR would be 93 percent. Another relevant characteristic is the "system friendliness" of the reader. The quantitative measurement of this characteristic is expressed as the ratio of the number of characters read to the number of substitution errors that occurred. Examples of substitution errors include: "12336" is read as "12363;" "A2398" is read as "A2393;" and "12345" is read as "2345."

The ideal system is one in which the FRR is 100 percent with a substitution error rate of 0 percent. A design based on this ideal would be extremely inflexible in operation and very expensive to build. In order to introduce flexibility in the system as well as lower costs, tradeoffs must be made.

Several OCR readers were also identified in the product survey. These readers were available as page readers and hand-held scanning wands. The major current application for OCR appears to be scanning pages of text into word-processing systems. The hand-held scanner was more appropriate for our intended application. Most scanners use charge-coupled device photodetector arrays to detect light reflected from text symbols, creating an analog signal that is decoded and converted into digital form.

DATA SUITABILITY FOR MACHINE-READABLE TEXT ON MAPS

Data Present on a Map. A map may contain a vast amount of information. It may contain geographic location grids, and may indicate vegetation, buildings, roads, rivers, streams, mountains and many other features, all of which can be depicted by various symbols and colors on the map. In addition, some supplemental information can be printed on a map, although the extent of this supplemental information is limited by spatial constraints and the density of information already printed on the map. An airport symbol on a pilot's sectional chart provides an example of this spatial limitation problem. The name and approximate geographical location of the airport can be determined directly from the sectional chart. Some supplemental information about the airport can also be determined, e.g. communication frequencies, length and direction of the runways, and whether or not lighting is available for night operations. This supplemental information must be determined by interpreting cryptic symbols located near the airport symbol. When several airports appear quite close to one another on a sectional chart, this information becomes very cluttered and greatly increases the chance of misreading the information.

Military units currently use terrain analysis overlays to assist with tactical battlefield planning. These overlays generally are of two distinct types. One type has cells or areas drawn on it--each uniquely identified by a code. Vegetation and surface slope overlays are examples of this type of overlay. The other type has codes for particular features that already exist on the regular charts. River and stream overlays and transportation overlays (bridge and airport) are examples of this type of overlay.

Feature Identifiers vs. Feature Attributes. Bridge and river data are among the various types of supplemental information that can be presented on maps. Bridge data is shown in a table on a map overlay. Each bridge has a unique code number and a unique entry in the bridge table. A particular bridge code would be an example of a feature identifier. Rivers, on the other hand, demonstrate feature attributes. All rivers are encoded by a nine-digit code, with each digit representing a particular attribute about the river. The code is generaland applies to all rivers and streams. For example, the first digit can be 0 through 3. This first digit identifies the feature as:

0 - No drainage feature.
1 - Stream channel - dry or intermittent.
2 - Lake, pond, or reservoir.
3 - Stream channel - wet.

The second digit in the code can be a 0 through 2. It describes the height of the right bank as follows:

0 - No bank or less than one meter high.
1 - Bank is one to five meters high.
2 - Bank is greater than five meters high.

The other seven digits each represent a different attribute and are similarly decoded. Feature attributes can be decoded using the same key; hence, the amount of data in the key remains constant regardless of the number of features that use the key. In other words, the river key remains constant regardless of how many river sections are coded on the map. The bridge data, on the other hand, require an additional entry for each new bridge identifier added to the table.

Data Considerations for an Automated Feature Attribute Access System. By considering some of the various types of supplemental data that relate to maps, one can immediately see that some types of cartographic data are not suitable for automated feature access. There is really little or no value in being able to merely scan a symbol or label from a map unless there is supplemental information available about the feature. A map user would be able to read the symbol from the map faster than he could scan the symbol and read the name from a computer screen or other soft copy device.

This situation indicates the most useful application for an automated feature attribute access system would be to provide the capability of deciphering coded symbols or labels that would otherwise have to be manually decoded by using a key of some sort.

Another application for a system of this type would be to access data, from a supplementary data base, about a particular identifier on the map. Accessing airport facilities information would be an example of this application.

The primary advantages provided by an automated feature attribute access system would include:

1. Very low character substitution error rates.
2. Rapid and accurate access to supplemental feature data.
3. The capability for automatic decoding of cryptic labels.

The first advantage of an automated system is that there are very low character substitution error rates. Machines are capable of reading very accurately; for example, bar codes typically have character substitution rates of only 1 character in about 15,000 to 36 trillion characters read, depending on the type of bar code and the error checking technique used. OCR text has a character substitution rate of less than 1 character in every 10,000. These values compare quite favorably with the error rate of 1 character in every 300 that an experienced key entry operator makes. During the setup and testing of our system, no character substitution errors were noticed.

An automated system can provide a map user rapid and accurate access to supplemental information. When supplemental feature data must be looked up in a table or book associated with the map, it can be a time-consuming process. A pilot, for example, would like to know the manager's phone number at a destination airport. In order to find this information one must locate the Airport Facility Guide for a particular geographic section of the country, and then look up the airport. Although the airport is listed alphabetically, it may be listed under the name of the city in which the airport is located or listed under the name of the airport itself. After locating the appropriate page, a search is made for the manager's phone number in the listing. This process can take several minutes to complete. With an automated system, the pilot could scan the four-letter identifier from a chart, and the associated airport data could be brought up on a terminal device. Using the automated method can save considerable time over the manual method and reduces the chances of getting incorrect information.

The final advantage of an automated system is the capability to decipher coded information rapidly and accurately. Experiments were conducted to demonstrate this capability. The program provided automatic decoding of terrain feature codes. These codes were transferred from a map overlay directly to the associated map using bar codes and OCR text. This provided the operator the capability of scanning the codes and seeing a soft copy of the decoded information. With this system, various types of codes could be decoded, allowing the operator to merely scan the code and read the pertinent data from the computer screen.

An important point is that scanning the data also provides a digital information flow that can be used with any associated software. For example, the terrain specialist is generally concerned with mobility over particular terrain. Software could be developed that utilizes the scanned terrain data and provides mobility information about a particular type of unit or piece of equipment over a certain path on a map.

INTERFACING THE HARDWARE

The bar code and OCR reading units purchased for this project were used merely for concept demonstration evaluation purposes. Therefore, they were bought to interface directly with an IBM PC-AT. The reading units both connected in serial with the PC keyboard. Both readers consisted of (1) a printed circuit board, which plugged into a PC expansion slot, and (2) a hand-held scanning unit. The bar code reader was physically connected with the keyboard, while the optical character reader was interfaced via firmware on the printed circuit board. Both of the readers had firmware that initialized them to their default states when the PC was turned on. After initialization, the readers could be programmed to alter their default characteristics. Programming options on the bar code reader included:

1. The type of bar code to be read.

2. The communication parameters the reader should use when communicating with the PC.

3. The type of error checking used in the bar codes.

A set of bar code data was provided for programming the reader. It was programmed by scanning these bar codes. The first code scanned put the reader in the program mode. The next label represented a major parameter, for example, the type of bar code to be scanned. Then a label was scanned to select options related to the major parameter previously selected. After all the appropriate parameters were selected, a label was scanned to get the reader out of the program mode.

The parameters could be saved in temporary memory or in semi-permanent memory. The reader controller card had random access memory for temporary program storage and electronically erasable programmable read-only memory for semi-permanent parameter storage. The default reading setups could be altered by storing new parameters in the semi-permanent memory.

By scanning various parameters, the reader could be programmed to distinguish automatically between several different types of bar codes, which added to the reader's flexibility. Although the reader could be programmed to read several different fonts, the reading speed decreased when extra code capabilities were added. Since only one type of bar code would be used on a particular product, the programmability of the reader was used only to initialize the reader.

The OCR reader was programmed in a similar fashion, by scanning OCR text labels. The default parameters of the OCR reader could also be altered by storing them in semi-permanent memory. However, the parameters that had to be set in the OCR reader served a different purpose than those in the bar code reader. Since bar codes have inherent data validation, the reader merely needs to know what type of bar code to expect. OCR text also comes in several different fonts, but the OCR reader is only capable of reading one particular font at a time. In order to read different fonts, a programmable read-only memory chip must be replaced on the reader circuit board. The OCR text applications require scanning of fields with distinctive data structures. The user could define these fields by programming the OCR reader. Using only specified data formats reduces errors by validating data.

Data validation is a very important part of an optical-scanning system. There are several techniques used to validate data. Fixed length data fields or start/stop characters enclosing valid data are two simple techniques. Below are some further examples:

Technique	Example
Simple fixed length field	12345 67890
Identification with fixed lengths	M12345 R3987221
Self-defined field lengths	/F5/ABCDE /F4/1234
Variable length with start/stop characters	/12345/ /A1B2/
Monetary protection	>>$1.23

Reading errors can be significantly reduced by utilizing these data validation mechanisms and reduced even further by revalidating the data. For human factors consideration, however, the data validation must be accomplished rapidly. The operator needs immediate feedback when a valid field has been scanned, since hand-scanning often requires the operator to scan the OCR text several times.

The most critical problem associated with OCR data validation is the detection and rejection of a partially scanned data field. The data validation techniques mentioned previously can be employed to constrain the data fields that are to be read. In describing data fields, no field should be defined as a subset of another field. Consider the following fields:

'A'NNNNN	An entry of this sort must be an 'A' followed by five numeric characters.
NNN	This field consists of three numeric characters.

If both of these formats are permitted to exist, the user could scan

ANNNNN
>>> <— motion (right to left).

where the ">" represents the extent of a reverse sweep of the field. In this case, the reverse-scanned data would satisfy the requirements for the second field format and would therefore be erroneously accepted as valid data.

There are techniques available to avoid this problem. If a particular field must be a subset of another field, it could be defined using start and stop characters, thus ensuring a valid read. However, the best solution is not to let any data field format be a subset of another.

THE PROTOTYPE SYSTEM

Once the scanning devices were installed and operating properly, a prototype system was developed to evaluate the feasibility of using machine-readable text on maps. The prototype consisted of a personal computer, the optical-reading devices, software, and a map sheet. Drainage feature attribute codes from a terrain analysis overlay were printed in machine-readable form and transferred to the map sheet.

Normally, the feature code, a nine-character symbol, would have to be manually deciphered using a key at the bottom of the feature overlay. With the prototype automated feature attribute access system, this was no longer the case. The map user merely scanned a feature code and each of the nine characters in the symbol were automatically decoded and their meanings were printed on the computer screen.

During tests, the computer provided the requested information and waited for another code to be scanned. The true value of this system would be better realized if the scanning devices were used for input to more sophisticated software. However, the application program demonstrates the feasibility of the concept. Although the prototype system showed that it is indeed easier, much faster, and more accurate to access supplemental feature data by using machine-readable map symbols, use of the system also identified several weaknesses of the system.

CONSIDERATIONS FOR AN AUTOMATED FEATURE ATTRIBUTE ACCESS SYSTEM

Several problems arose during the design and testing of the prototype automated feature attribute access system. These difficulties, concerning the placement of machine-readable data on map products, must be addressed when considering the design of an automated system. Items to consider include:

1. Spatial requirements of machine-readable data.
2. Symbol placement on the map.
3. Human readability and degradation of symbology.
4. Orientation of the reading device.
5. Orientation of the coded data on the map product.

These issues, as well as others, need investigation before efficient applications of this technology can be developed. There are still other questions that must be answered. What type of bar code should be used? The Department of Defense has standardized Code 39. This code may be suitable since the entire ASCII character set can be represented. Several of the other major codes are only capable of representing the ten digits 0 through 9.

The OCR text can also be printed in several fonts. Some fonts are more easily read than others. Which OCR font should be used? Are the codes that are more illegible to operators more legible to machines, thus providing a more reliable automated system? If so, is it useful to have a system where the symbols are not as clear to the operator?

Spatial Requirements of Machine-Readable Data. The primary drawback of machine-readable data relates to its information density or spatial requirements. Both bar codes and OCR text require a relatively large amount of map space when compared to other text printed on maps. The highest density that can be achieved by bar code data is about 17 characters per inch, using the interleaved 2 of 5 code. This code, however, is only capable of representing the ten digits. Code 39, which can represent the entire ASCII character set, can only be printed with a density of 10 characters per inch. Each bar code should also have at least 0.25 inch of "white space" before and after the coded data to insure accurate scanning. Since standards recommend that bar code height should be about 15 to 25 percent of the overall length of the label, a 10-digit Code 39 bar code would be over 1.5 inches long and more than 0.22 inch tall. This size becomes quite a limiting factor when trying to label several features that are located in close proximity to one another on a map. The OCR text labels also require about 0.25 inch vertically and can only be printed in densities of about 12 characters per inch. The vertical dimension here allows for "white space" above and below the label for accurate pattern isolation. In general, mapping applications of machine-readable data should be limited to large area maps with a low density of information presented on them.

Symbol Placement on the Map. Should the symbols be printed directly on the map or on the map border? Results from this investigation show that the number of bar codes that can be printed on a map product is severely limited due to the amount of space they occupy. There are invisible inks that could be used to print the machine-readable data, which would solve the visible-clutter problem. However, one problem is that symbols still must not be permitted to overlap one another. Another problem with invisible inks is the lack of operator visibility. To ensure accurate scanning, the operator must know where the symbols are placed on the map.

Human Readability and Degradation of the Symbology. Bar codes cannot be interpreted by human operators, which is a problem in an automated map system. One way to overcome this problem is to place readable labels on the map, along with the bar code, although this addition will require more space on the map.

Most OCR fonts are readable, but some are not. Even though there are problems with operator-readable codes, it is advantageous to include them because automated reading devices are severely limited when reading damaged symbols. An operator is capable of filling in the blank if one character is unreadable on a map label. One smeared, or otherwise altered character in an OCR label, on the other hand, can render the label machine-unreadable, which is a serious problem. Thus a supplementary machine-read data base could be rendered totally useless by degraded symbology.

Bar codes have inherent vertical redundancy and therefore remain readable with partial mutilation. Since a single stray ink mark on an OCR label can render it totally illegible to the reading device, a backup method of data input must be provided, such as a keyboard. Even though keying in data is slower and more prone to error, symbols rendered illegible to the scanner could be interpreted by the operator and entered into the system, thus maintaining the system's integrity.

Orientation of the Reading Device. The physical orientation of the scanning device is a critical issue in an automated system design. This problem is not as significant with bar code readers as it is for OCR scanners. Four orientation parameters must be considered: roll, pitch, yaw, and depth of field. Roll and pitch are the angles from vertical of the scanning device in the directions parallel and perpendicular to the motion of the scan. Yaw is the skew or rotation of the scanning device with respect to the motion of the scan. The depth of field is the maximum distance from the label that the scanner can be held and still read the data accurately.

The depth of field on bar code readers is similar to that on OCR scanners, but that is where the similarity ends. Bar code readers are much less sensitive to orientation than OCR readers. They can be operated with pitch and roll of up to 30 degrees. Most hand-held bar code wands are completely insensitive to yaw since they only use a single light detector for reading. This gives the user greater ease in scanning since more attention can be paid to scanning the symbol without concern for wand orientation.

OCR readers generally use a vertical array of optical detectors to sample vertical strips of the scanned text. These scanned strips are converted to digital data and sent to a processor for decoding. Limitations in the pattern isolation and recognition algorithms, require the OCR reader to maintain quite stringent orientation with respect to the scanned symbol. The scanning device tested was effective within the following variations from normal to the media being scanned:

Roll:	+/- 8 degrees
Pitch (tilt):	+/- 6 degrees
Yaw (skew):	+/- 8 degrees

These variations are much more limiting than those for bar code readers, which must be considered when designing an automated system utilizing optical reading devices. Ease of use would dictate the use of bar code devices.

Orientation of the Coded Data on the Map Product. What is the best way to arrange machine-readable data on a map product? Must all symbols be oriented horizontally on the map? Will the orientation be more critical for OCR text than bar code data? The nature of the scanning devices makes the problem of symbol orientation much more critical for OCR text than for bar codes. The problem for OCR readers arises since the reader axis must be oriented perpendicular to the direction of motion while scanning the label. Even if OCR labels are not placed horizontally, they should at least be placed parallel to one another to permit the user to use a consistent scanning technique.

CONCLUSIONS

This study demonstrated the feasibility of placing machine-readable text on map products by developing a prototype automated feature attribute access system. The use of optical-scanning technologies provides a quick and accurate method for accessing supplemental feature data on map products. Although this study showed that this technique is feasible, several limiting factors of such a system were also identified.

This automated feature attribute access system could be most efficiently used where the information density of the map product is quite low and substantial associated data for the features exist. The airport facility information access system cited earlier in this report is an example of the type of system that could utilize this technology most efficiently. The data that must be printed on the map is limited to four-letter identifiers, but each identifier has a vast amount of associated supplemental data that could be accessed automatically.

The spatial requirement of machine-readable data must be considered in the design of this sort of system. Another issue is the durability of the media. Optical readers have fairly stringent requirements for readable symbology. Even though operators can often interpret an illegible symbol, illegibility can render an automated system useless. Operator-readability of the symbology, ease of use, and reliability of the reading devices must all be considered in the design of such a system. Another issue to resolve is what type of bar code or OCR font to use. Despite several considerations that limit the span of possible applications, an automated feature attribute access system could prove beneficial and can be developed.

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