General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)
AN EVALUATION OF CODING METHODOLOGIES FOR POTENTIAL USE IN THE ALABAMA RESOURCE INFORMATION SYSTEM (ARIS) - TRANSPORTATION STUDY FOR THE STATE OF ALABAMA

By Oscar L. Montgomery
Alabama A&M University
School of Agriculture, Environment Science & Home Economics
Department of Natural Resources & Environmental Studies
Normal, Alabama 35762

December 1977

Prepared for
NASA - George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
An Evaluation of Coding Methodologies for Potential Use in the Alabama Resource Information System (ARIS)-Transportation Study for State of Alabama

Dr. Oscar L. Montgomery

AUTHOR(S)

Alabama A&M University
School of Agriculture, Environmental Science & Home Econ.
Dept. of Natural Resources & Environmental Studies
Normal, Alabama 35762

PERFORMING ORGANIZATION NAME AND ADDRESS

National Aeronautics & Space Administration
Washington, D.C. 20542

This work was performed by Alabama A&M University for the Earth Resources Office of the Data Systems Laboratory of the George C. Marshall Space Flight Center. Dr. C. T. Paludan and Dr. S. W. Downs were the MSFC Technical Dirs. of the effort.

This report describes a study of digitizing the transportation arteries, airports, and dock facilities of Alabama and placing them in a computerized format compatible with the Alabama Resource Information System (ARIS). The five county region of the Top of Alabama Regional Council of Governments (TARCOG) was selected as the pilot study area. The research focused on the following objectives: (1) The digitization of the TARCOG area transportation networks consisting of highways, railroads, and waterways; (2) the digitization of airports and dock facilities within the TARCOG area; (3) evaluation of the time required to digitize by the following methods: (a) manual, (b) Telereadex 29 with film reading and digitizing system, and (c) digitizing tablets.

A method for digitizing and storing information from the U. T. Al. grid cell base which was compatible with the ARIS was developed and tested. The transportation arteries, airports, and docks in the study area were digitized and the data stored. The manual method of digitizing was shown to be best for small amounts of data, while the graphic input from the digitizing tablets would be the best approach for entering the large amounts of data required for an entire state.

Editor's Note - Use of trade names or names of manufacturers in this report does not constitute an official endorsement of such products or manufacturers, either expressed or implied, by the National Aeronautics and Space Administration or any other agency of the United States government.
# TABLE OF CONTENTS

## CHAPTER I
**INTRODUCTION**

1

## CHAPTER II
**PROGRAM OBJECTIVES AND PLAN OF WORK**

### OBJECTIVES

2

### PLAN OF WORK

2

A. Data Collection

5

B. Classification Scheme

5

C. Development of Computer Software

8

D. Encoding of Data

8

E. Computer Processing of Data

15

## CHAPTER III
**DIGITIZATION OF TARCOG AREA**

16

## CHAPTER IV
**EVALUATION OF DIGITIZING METHODOLOGIES**

30

## CHAPTER V
**SUMMARY AND CONCLUSION**

32

The preparation of this report was financed in part through Comprehensive Planning Grant from the Department of Housing and Urban Development, HUD P-1004; Administered by the State Planning Division, Alabama Development Office: Office of the Governor.
CHAPTER I
INTRODUCTION

The research activities reported herein are a continuation of the program initiated in 1971 at Alabama A & M University under the sponsorship of the National Aeronautics and Space Administration (NASA), with current research cosponsored by the Alabama Development Office (ADO).

Planet Earth has entered a new era - one marked by a growing awareness that the resources of the planet are limited; this in the face of an ever-increasing demand for their use. Man has begun to appreciate the need for research aimed at making the best use of the limited resources within our ecosphere. With the development of computers comes the ability to obtain, store and retrieve enormous amounts of data for any land, water or atmospheric phenomena of interest.

Many national, state and local organizations have become increasingly aware of the advantages of this technology and have begun using computerized systems to monitor the resources within their regions. The Alabama Development Office is one of the interested users. As the cosponsor of contracts with Auburn University, they have developed a data storage bank of the resources within the State of Alabama, the Alabama Resource Information System (ARIS). The functional components of this system are:

1) Data bases
2) Data gathering
3) Information processing aids and data base manipulation programs
A preponderance of the data presently in the system is in grid cell format. The particular grids used correspond to those of the U. T. M. grid systems. The ARIS system has progressed to the point where the developers are ready to input the transportational arteries of the state into the system.

The Alabama Development Office and NASA have cosponsored a research grant at Alabama A & M University for the development and testing methods of capturing and retrieving transportational information in a format compatible with the ARIS system. The targets of interest were:

1) Highways
2) Railroads
3) Waterways
4) Airports, and
5) Dock facilities.

An acceptable procedure has been developed and tested and a discussion of that system is presented in the subsequent chapters.
CHAPTER II
PROGRAM OBJECTIVES AND PLAN OF WORK

OBJECTIVES

The Department of Natural Resource and Environmental Studies, Alabama A & M University has addressed the problem of digitizing the transportational arteries of Alabama and placing them in a computerized format compatible with the Alabama Resource Information System (ARIS). The five-county area under the auspices of the Top of Alabama Regional Council of Governments (TARCOG) was selected as the study area. The research focused on the following specific objectives:

1) The digitization of TARCOG area transportation networks consisting of highways, railroads and waterways.
2) The digitization of airports and dock facilities within the TARCOG area.
3) Evaluation of time required when digitizing with one of the following methods: a. Manual, b. Telereadex 29 with Film Reading and Digitizing System and c. Digitizing Tablets.

PLAN OF WORK

The plan of work is presented in Fig. 1. The initial step was the acquisition of a suitable data base. Once the desired data had been collected a classification peculiar to the data type was formulated. Concurrent with the encoding of the data was the development of the software that would perform the necessary storage and retrieval manipulations of the test data. Upon completion of those processes the encoded data was processed such that it could be stored, updated and retrieved at any future time. A brief discussion of each stage of development is given here.
FIGURE 1. Plan of work for the digitization of transportational arteries.
A. Data Collection

Current information regarding the location of the transport system within the target area was provided by the local TARCOG office. This data had been color-coded onto State Highway maps (2.5 cm = 4 Km) over which 4-kilometer square grids were superimposed. This scale was used to facilitate encoding of test material. The encoded data was bounded by the following grid coordinates; north/south (3970,000-3785,000) and east/west (630,000-480,000) [Fig. 2]. The U. T. M. grid system is the same grid system used by ARTS.

B. Classification Scheme

From the raw data it was found that all of the data could be represented by ten classes (Table 1).

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Coding System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highways</td>
<td></td>
</tr>
<tr>
<td>Principal Arterial</td>
<td>1</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>2</td>
</tr>
<tr>
<td>Major Collection</td>
<td>3</td>
</tr>
<tr>
<td>Navigable Waterways</td>
<td>4</td>
</tr>
<tr>
<td>Dock Facilities</td>
<td>5</td>
</tr>
<tr>
<td>Airports</td>
<td></td>
</tr>
<tr>
<td>Basic Utility</td>
<td>6</td>
</tr>
<tr>
<td>General Utility</td>
<td>7</td>
</tr>
<tr>
<td>Basic Transport</td>
<td>8</td>
</tr>
<tr>
<td>Air Carrier</td>
<td>9</td>
</tr>
<tr>
<td>Railroads</td>
<td>0</td>
</tr>
</tbody>
</table>

The numbers appearing in the columns labeled "Coding Symbol" are the codes that were used throughout the digitization process. The following are descriptions/examples of the above-mentioned classes.
Highways

**Principal Arterial** - Major streets and roads used for high volume traffic movement to, within and through the region.

**Minor Arterial** - Major streets and roads used for high volume traffic, primarily from the other areas of the region toward urbanized areas rather than serving traffic primarily through the region to other areas.

**Major Collectors** - Major streets and roads used for traffic of moderate-to-fast speeds and relatively high traffic volumes between communities of moderate size and between major local centers of employment, recreation, shopping, residence and rural areas.

Navigable Waterways

Rivers or streams that are of sufficient size to accommodate barge traffic.

Dock Facilities

Facilities for public and private use, primarily oriented to commercial and industrial barge traffic.

Airports

These airports are classified according to the Federal Aviation Administration (FAA) National Airport Plan.


Air Carrier - Huntsville/Madison Airport.

Railroads

All existing rail lines and spur extensions.

C. Development of Computer Software

A simple software system necessary to display the results of the project objectives was developed in cooperation with the Computer Science Department, Alabama A & M University. The program was structured so as to have the following capabilities:

1) Data Storage (Files - 1, 2, 3, ... n)
2) Data Retrieval (Data Sampling Option)
3) Update Capability

The interactive component is such that a user desiring information from this system has only to follow simple steps, e.g.:

Step 1 - Determine desired information.
Step 2 - Determine the grid coordinates of area of interest.
Step 3 - Determine from the file information sheet (Fig. 3) the location of desired data.
Step 4 - Punch the file and grid coordinates on a computer card (Fig. 4).
Step 5 - Place card in the preassemble job deck and read into the computer. In a matter of seconds the output will be printed.

D. Encoding the Data

Concurrent with the development of the computer software was the encoding of the raw data onto computer cards. Three methods of encoding were investigated (Fig. 5) - (1) Manual Encoding, (2) 29E Telereadex with Film Reading and Digitizing and (3) Graphic Tablets. A brief discussion of each method follows and a comparison of these methods is discussed in a later chapter.
FILE INFORMATION SHEET
TRANSPORTATIONAL ARTERIES
FOR THE
TARCOG AREA

TAPE: 203

<table>
<thead>
<tr>
<th>FILE - 1 HIGHWAYS</th>
<th>DISPLAYED AS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRINCIPAL ARTERIAL</td>
<td>1</td>
</tr>
<tr>
<td>MINOR ARTERIAL</td>
<td>2</td>
</tr>
<tr>
<td>MAJOR COLLECTOR</td>
<td>3</td>
</tr>
</tbody>
</table>

| FILE - 2 RAILROADS & WATERWAYS         |               |
| RAILROADS                               | 0             |
| WATERWAYS                               | 4             |

| FILE - 3 AIRPORTS & DOCKS FACILITIES   |               |
| AIRPORTS                                |               |
| BASIC UTILITY                           | 6             |
| GENERAL UTILITY                         | 7             |
| BASIC TRANSPORT                         | 8             |
| AIR CARRIER                             | 9             |
| DOCK FACILITIES                         | 5             |

FIGURE 3. File Information Sheet
DATA BASE

ENCODING

MANUAL

HAND CODING

AUTOMATIC

TELEREADEX 29E

GRAPHICS TABLET

COMPUTER PROCESSING OF CODED DATA

FIGURE 5. Methods of Encoding
Manual Encoding - This method of encoding involved hand coding of the raw data onto coding sheets and the transference of that information to computer cards for processing. The 4-kilometer square U. T. M. grided maps were fastened to the surface of a drafting table and the information was extracted by line and column coordinates. Each data sheet was treated as a "line" and the numbered columns on the sheet corresponded to the east/west columns on the map (Fig. 6). All of the data for the TARCOG area is contained in the first 77 columns of 47 sheets.

29E Telereadex With The Film Reading and Digitizing System - The same raw data used in the manual method was used in every case. Due to the size of the maps on which the raw data was contained, the maps had to be photographed and processed into 35 mm single frame film. Numeric characters were used to represent the different types of information being encoded. The configuration of this sytem was such that only single number characters were recognized.

The film was mounted on a projection plate and simultaneously projected onto the viewing plate. The viewing plate is a 71 cm by 71 cm metal plate with an opaque photowhite finish; providing high contrast images. Two orthogonal wires on the viewing screen, one on the horizontal axis and the other on the vertical axis, were used to locate the information. To determine the coordinate position of information, the horizontal wire was positioned at the base of the grid and the vertical wire was positioned at the center of the grid. The sequential numbers of each grid was determined by the counting system in the Telereadex. The movement of the wires was controlled by the hand-wheels at the base of the screen. The Telereadex unit was the counter, coordinate system and the digits used to locate and represent the type of information on the film. Digits changed as the type of information changed; but the counter and coordinates changed with the punching of cards and the
**FIGURE 6. Coding Sheet**

| Row  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Card Col |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Card Col | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 |
|       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Card Col | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |    |

*ORIGINAL PAGE IS OF POOR QUALITY*
movement of the wires. A key punch machine is connected to the Telereadex.
A card was punched by pressing the foot pedal connected to the Telereadex.
Once the pedal was pressed, all of the information displayed on the Telereadex
is punched onto a card. One card was used for each grid and only one type of
information could be recorded for each grid. Three separate decks of cards
were punched: (1) highways, (2) railroads and waterways and (3) airports and
dock facilities.

Graphics Tablet With Computer Display Terminal - The Graphic Tablet inputs
graphic data into the computer through the computer display terminal. The
Tektronix 4015-1 Graphics Tablet is made up of the writing surface, a pen,
a power module and the tablet control card connected to the terminal display.

The basic function of the Graphics Tablet is to convert the position of
the pen on the tablet surface to a corresponding digital position on the
display terminal. To input data, the tablet is made ready by a three-character
command string and positioning the pen on the tablet. Data input may be
continuous or one point at a time. The Graphics Tablet responds to the pen
when the pen is within 3 mm of the surface of the tablet.

The Tektronix 4015-1 Graphics Tablet was used to capture and store the
transportational information on computer tape by the computer processors.
Each county with its grids were outlined on the tablet and simultaneously
shown on the display terminal. When the desired information was drawn in,
the computer was instructed to store that information on tape. Additional
information could be added to the file by instructing the computer to reprint
the file on the screen and entering more information.
Highways, railroads, waterways, airports and dock facilities were input for each county. A user can obtain the information by instructing the computer to display the information on any class from any county.

E. Computer Processing of Data

In the instance where the manual or Telereadex 29E System is used, the information is punched onto computer cards. Once the data is in card form it was ready to be processed for storage and retrieval. Using the prescribed software the information was processed and stored in three files for later retrieval and updating (Table 2). Additional information over the same area can be stored on the data tape without altering existing programs or files.

Table 2. Information Stored From TARCOD Area

<table>
<thead>
<tr>
<th>File Information Sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Data</strong></td>
</tr>
<tr>
<td>Highways</td>
</tr>
<tr>
<td>Principal Arterials</td>
</tr>
<tr>
<td>Minor Arterials</td>
</tr>
<tr>
<td>Major Collectors</td>
</tr>
<tr>
<td>Railroads</td>
</tr>
<tr>
<td>Waterways</td>
</tr>
<tr>
<td>Dock Facilities</td>
</tr>
<tr>
<td>Airports</td>
</tr>
<tr>
<td>Basic Utility</td>
</tr>
<tr>
<td>General Utility</td>
</tr>
<tr>
<td>Basic Transport Air</td>
</tr>
<tr>
<td>Carrier</td>
</tr>
</tbody>
</table>
CHAPTER III

DIGITIZATION OF TARCOG AREA

Much of the work required in the digitization of the TARCOG area has been discussed in the previous chapters. The discussion here will be limited to the actual output of the system. The output generated as a result of using either the manual or Telereadex 29E System is the same and as such will be discussed without reference to either system. The output from the Digital Tablets is quite different and will be discussed separately at the end of this chapter.

The data appears to be distorted in the north/south direction, this is due solely to the hardware configuration. The alpha-numeric characters for the computer printer have a width-to-length ratio of about 1:1.2. Each character represents a 4-kilometer square surface on the ground. Data from file - 1 of the date tape is presented in Fig. 7, a map of the raw data over the same area appears in Fig. 8. In the instances where two or more highways appeared in a grid cell, the cell was assigned the code of the highway having the largest transport capability. Information with respect to the location of railroads and navigable waterways is found on file - 2 and is displayed in Fig. 9, accompanied by the raw data in Fig. 10. Airports and dock facilities were stored on file - 3 and appears in Fig. 11 with a map of raw data in Fig. 12.
TRANSPORTATIONAL ARTERIES FOR THE TARCOG AREA
TYPE HIGHWAYS 1-2-3
COORDINATE LINES (1-47) COL (1-77)

Fig. 7. File 1. Highways within TARCOG area.
Fig. 9. File 2. Railroads and Waterways in TARCOG area.
FIG. 10. RAILROADS AND WATERWAYS IN TARCOP AREA
Fig. 11. Airport and dock facilities within TARCOG area.
The processing program was structured such that a user would be able to examine a subset of the data anywhere in a file. This is illustrated in Fig. 13, 14 and 15 where the grid cell coordinates of the areas of interest are punched onto computer cards and fed into the computer. The illustrations show only the information from file 1; however, the same options apply to the other files.
TRANSPORTATIONAL ARTERIES FOR THE YARCOG AREA
TYPE HIGHWAYS 1-2-3
COORDINATES LINES (5-25)  COL (20-40)

Fig. 13. Huntsville-Madison County area.
Fig. 14. Athens-Limestone County area.
**TRANSPORTATIONAL ARTERIES FOR THE TUSCALOOSA AREA**

**TYPE HIGHWAYS 1-2-3**

**COORDINATE LINES (25-47)**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>27</td>
<td>28</td>
<td>29</td>
<td>30</td>
<td>31</td>
<td>32</td>
<td>33</td>
<td>34</td>
<td>35</td>
<td>36</td>
<td>37</td>
<td>38</td>
<td>39</td>
</tr>
<tr>
<td>40</td>
<td>41</td>
<td>42</td>
<td>43</td>
<td>44</td>
<td>45</td>
<td>46</td>
<td>47</td>
<td>48</td>
<td>49</td>
<td>50</td>
<td>51</td>
<td>52</td>
</tr>
<tr>
<td>53</td>
<td>54</td>
<td>55</td>
<td>56</td>
<td>57</td>
<td>58</td>
<td>59</td>
<td>60</td>
<td>61</td>
<td>62</td>
<td>63</td>
<td>64</td>
<td>65</td>
</tr>
</tbody>
</table>

**Fig. 15. Guntersville-Marshall County area.**
The output from the Graphics Tablet with the Computer Display Terminal is presented in Figures 16 and 17. Due to the line drawing configuration of this system the symbol for each class was changed. The size of the tablet, 4953 (28 cm x 28 cm), prevented the use of the areawise map. Therefore, the information was input into the system on a county by county basis. It should be noted here that there are larger tablets on the market such as the 4954 Graphic Tablet (100 cm x 75 cm). Specific input commands and processing operations are available in the Tektrenex, 4953/4954 Graphic Table, Instruction Manual.
Fig. 16. Highways within Limestone County
Fig. 17. Railroads and Waterways in Limestone County.
CHAPTER IV

EVALUATION OF DIGITIZING METHODOLOGIES

Once the data has been collected and an acceptable classification has been developed, the investigator is confronted with the problem of which system is most efficient for his use. The answer to that question is not a simple one, for it is dependent on several variables such as: data type; intensity of data; projected use of data; format requirements of digitized output; and most of all, the resource environment in which the investigator is placed.

An effort was made to determine the efficiency of the digitizing methods available for encoding the information on the TARCOG area. The results presented are only applicable to equipment similar to the type of equipment tested with similar types of data. The three methodologies were as follows: (1) Manual Encoding; (2) Telereadex 29E with the Film Reading and Digitizing System and (3) Graphics Tablet with Computer Display Terminal. The time required to encode the various classes using these devices are presented in Table 3.

Table 3. Times Required for Digitization of TARCOG Area

<table>
<thead>
<tr>
<th>Digitized Classes</th>
<th>Methods of Digitizing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual</td>
</tr>
<tr>
<td>Highways</td>
<td>188 min</td>
</tr>
<tr>
<td>Railroads and Waterways</td>
<td>95 min</td>
</tr>
<tr>
<td>Airports and Dock Facilities</td>
<td>37 min</td>
</tr>
</tbody>
</table>
The times appearing are the totals of time when the actual encoding was being done. Constant interruptions by either equipment failures of time-sharing constraints made this approach necessary. The encoding began in the early stages of the research and continued stop-and-go up to the writing of this report. At first glance the manual method appears to be the most efficient. It has a decided advantage over the Telereadex 29E system in both time and the amount of preprocessing of raw data. The differences in the amount of time required are largely due to the type and intensity of the data, with intensity of data being the major factor. Looking at the differences in time required to digitize highways and differences in time required to digitize airports and dock facilities, the former is much less than the latter. There were fewer data points for airports and dock facilities than for highways. The configuration of the Telereadex 29E does not allow for the passing of grid cells that were empty without losing special distribution; whereas the manual method allows the operator to skip over those cells which did not contain pertinent information.

The Digital Tablets required less time than the other methods. Once the operator has access to the program, he simply draws in the information which is transferred directly to the computer tape. These types of digitizing systems have numerous advantages over the aforementioned systems. It may be the best system for this type of encoding. It would certainly be worth the effort and cost if ARIS could purchase this type of system.

The resource environment, more than any other factor, will determine the feasibility of any of the methodologies. The equipment discussed here can be obtained at a cost which is out of reach for those institutions or agencies operating with limited funds.
CHAPTER V

SUMMARY AND CONCLUSIONS

With respect to the previous discussions and illustrations the following statements can be made:

1) A method for digitizing and storing information from a U. T. M. grid cell base has been developed and tested. It is believed that this system is compatible with ARIS data system.

2) The transportational arteries within the TARCOG area have been digitized and processed in a manner the data can be stored, retrieved and updated with minimum program manipulations.

3) A brief examination of three methods indicate that for limited amounts of data the manual method of encoding may be most feasible. The graphics input system would be the best approach to take when one considers the overall goal and objectives of the ARIS system.

4) The accuracy of the computerized maps could be improved by using 1-kilometer square grided maps. This reduction would increase both the accuracy and the amount of data input into the system.